Land Resources of the Vanimo Area, Papua New Guinea

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Land Research Series No. 31

View complete series online

Commonwealth Scientific and Industrial
Research Organization, Australia
1972

ISBN 0 643 00043 7

Printed by CSIRO, Melbourne

72,430-3300

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PART I. INTRODUCTION

By E. Löffler*

I. Location

The Vanimo area is situated in the extreme north-west corner of Papua New Guinea between longitudes 141° and 142° and between the north coast and the watershed of the Bewani Mountains (Fig. 1). The area covers about 2130 sq miles and is

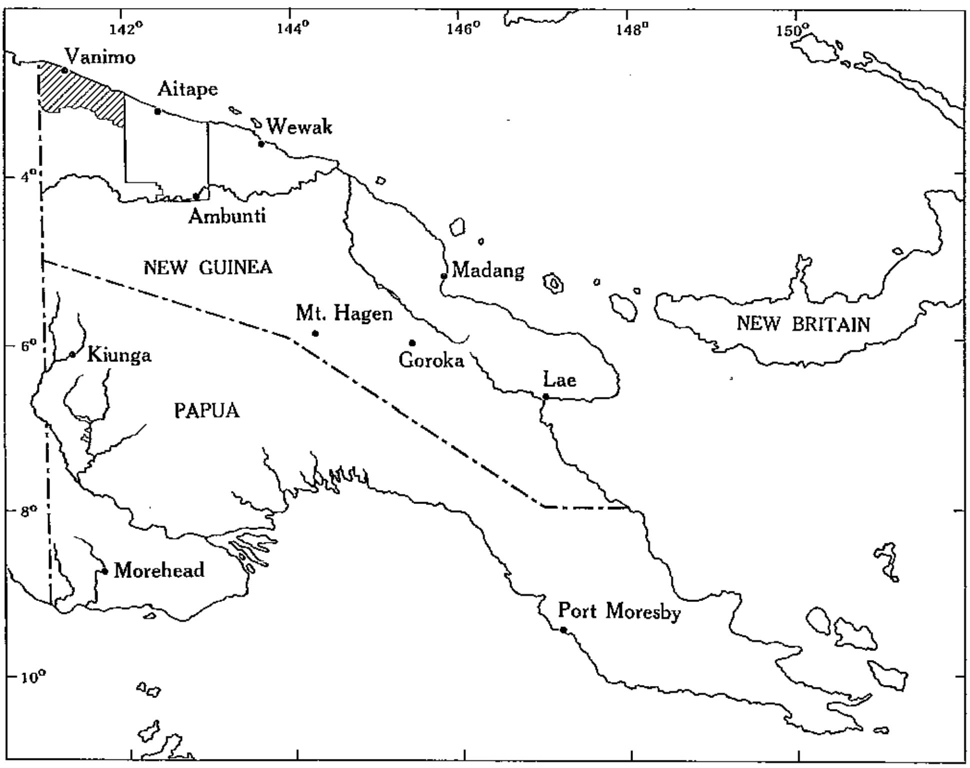

Fig. 1.—Locality map showing Vanimo area (shaded) and adjacent Aitape–Ambunti area.

administratively part of the West Sepik District, with headquarters at Vanimo.

In the east the Vanimo area joins the Aitape–Ambunti area which was surveyed by the Division of Land Research in 1966 (Haantjens *et al.* 1972).

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II. Survey Objective and Procedure

The objective of the survey was to investigate and map the land resources of the area at reconnaissance level. The procedure was the same as on previous surveys by the Division of Land Research. The team consisted of a geomorphologist, a pedologist, a plant ecologist, and a forest botanist. Prior to the field work air-photo interpretation and preliminary mapping were carried out in Canberra. The area is covered by photographs of varying scale and quality. Most is covered by RAF photographs of rather poor quality at a scale of about 1 : 86,000 taken in 1963. The remainder is covered by Adastra Airways photos at a scale of 1 : 50,000 taken in 1964 and by pre-war Australian Petroleum Company photographs at a scale of 1 : 30,000.

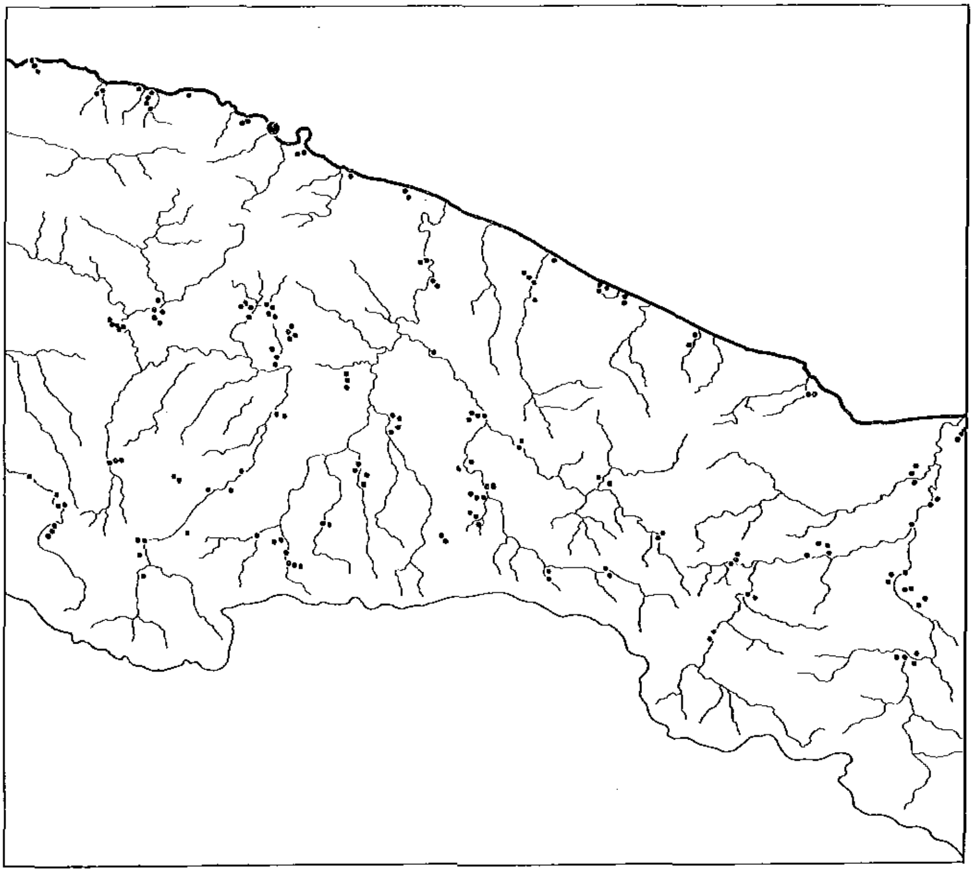

Fig. 2.—Location of sample sites.

Field work was done in July 1968 with the aid of two helicopters from bases at Leitre, Pagei, and Vanimo. As nearly the whole survey area is densely forested, finding suitable landing grounds was a major problem. The river beds of the medium- and larger-sized rivers provided generally the only landing possibilities, and from them field traverses ranging from 20 yards to 3 miles were carried out. The density and spread of sample points were good along the coast and in the intermontane lowlands but generally very poor in the coastal and inland ranges (Fig. 2).

The weather was generally fair. Frequent early morning fogs in the intermontane lowlands caused some delays there and afternoon showers and thunder storms occasionally forced the team to return to the base camp early in the afternoon.

III. History

The pre-European history of the Melanesian inhabitants is unknown. It is likely that the coastal people had trading contact with the Malays and thus became to some extent subject to their influence. According to Thomas (1941) the coastal people show some infiltration of Malay blood which finds its expression in their physiognomy.

In 1827 Dumont d'Urville discovered the well-sheltered harbour of Vanimo (Plate 1, Fig. 1) during a nautical survey along the north coast and named it Anse d'Attaque. However, it was not until the turn of the century that the area was contacted more closely by Europeans with the establishment of the German border post, Germania Hook. In 1910 a joint Dutch–German border survey penetrated inland for the first time along 141° longitude (Schultze-Jena 1914). After Australia took over the German territory a patrol post was set up at Vanimo, mainly to stop smuggling of bird plumage over the border after the passing of the Plumage Bill.

During World War II the area was under Japanese occupation. The Administration was re-established immediately after the war and the area again became part of the Sepik District and was controlled by the District Officer stationed in Wewak. In 1966 the Sepik District was split into the East and West Sepik Districts and Vanimo became the district headquarters of the new West Sepik District.

IV. Communications

The only road suitable for motor vehicles is a short narrow road connecting Vanimo with the coastal villages of Warimo and Yaka. All other land communication is by foot tracks, some of which are well maintained by local villagers. The rivers are not navigable even for small craft except at their tidal outlets. These tidal creeks and the lagoons behind the beach ridges are used by small canoes. There is also some traffic in outriggers along the coast.

Vanimo harbour (Plate 1, Fig. 1) is the only place along the coast which is suitable for anchorage of ocean-going vessels. It can provide good shelter for up to three 10,000-ton vessels.

Airstrips are vital for communication with all inland patrol posts and missions. At Vanimo and Pagei the airstrips are maintained by the Administration, while Leitre, Ossima, and Summumumi airstrips are serviced by the missions. Only Vanimo airstrip is suitable for DC3 and Fokker Friendship aircraft and receives regular service flights.

V. Acknowledgment

Plates 5, 7, 10, 11, 14, 15, and 18 are Crown Copyright and have been made available by courtesy of the Director of National Mapping, Department of National Development, Canberra.

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PART II. GENERAL DESCRIPTION

By E. LÖFFLER,* H. A. HAANTJENS,* P. C. HEYLIGERS,* and J. C. SAUNDERS*

I. LAND FORMS, CLIMATE, VEGETATION, AND SOILS

(a) *Physiographic Regions*

The Vanimo area is subdivided into five major physiographic regions: the coastal plain, the alluvial plains of the major rivers, the coastal ranges, the intermontane lowlands, and the inland ranges (Fig. 3).

(i) *The Coastal Plain.*—The coastal plain forms a narrow belt in front of steeply rising coastal ranges. Either it consists of a sequence of beach ridges and swales with blocked back swamps or it is formed by coral platforms (Plate 1, Fig. 2; Plate 2, Fig. 1). Although the coastal plain occupies only about 1% of the Vanimo area, it is of major importance as it supports about 45% of the population. For this reason little primary vegetation remains; this includes some patches of forest and some permanently inundated back swamps that are covered by herbaceous vegetation or poor sago palm vegetation.

Dark, shallow, alkaline, sandy soils occur on coral. Deep sandy soils are formed on beach ridges, and these become more acid and increasingly develop a darker topsoil from the coast inland. Mainly clayey soils occur on alluvium, and these become increasingly gleyed towards the swampy parts.

(ii) *Alluvial Plains of the Major Rivers.*—The alluvial plains of the Pual and Bliri Rivers cross the coastal plain and extend upstream to the foot of the inland ranges. They consist of widely meandering channels, scroll complexes, low levees, some oxbows, and extensive alluvial plains or back plains. Two to three terraces are developed along the Pual River.

Tall forests cover most of the plains (Plate 2, Fig. 2). Tall forest with a rather open canopy (Fo) occurs on well to imperfectly drained parts not liable to flooding. A similar forest type with scattered light-toned crowns (Fod) is found on lower parts with virtually the same drainage conditions but flooded annually to once every five years. Tall forests with open canopies with sago palms in the undergrowth (FoM, FodM) occur on imperfectly to very poorly drained back plains flooded twice annually to once every three years.

Most soils are undeveloped. They are largely medium to very fine textured, weakly alkaline to weakly acid, and well to poorly drained. Coarser-textured soils occur on lower terraces and scroll plains and are often alkaline and calcareous. On

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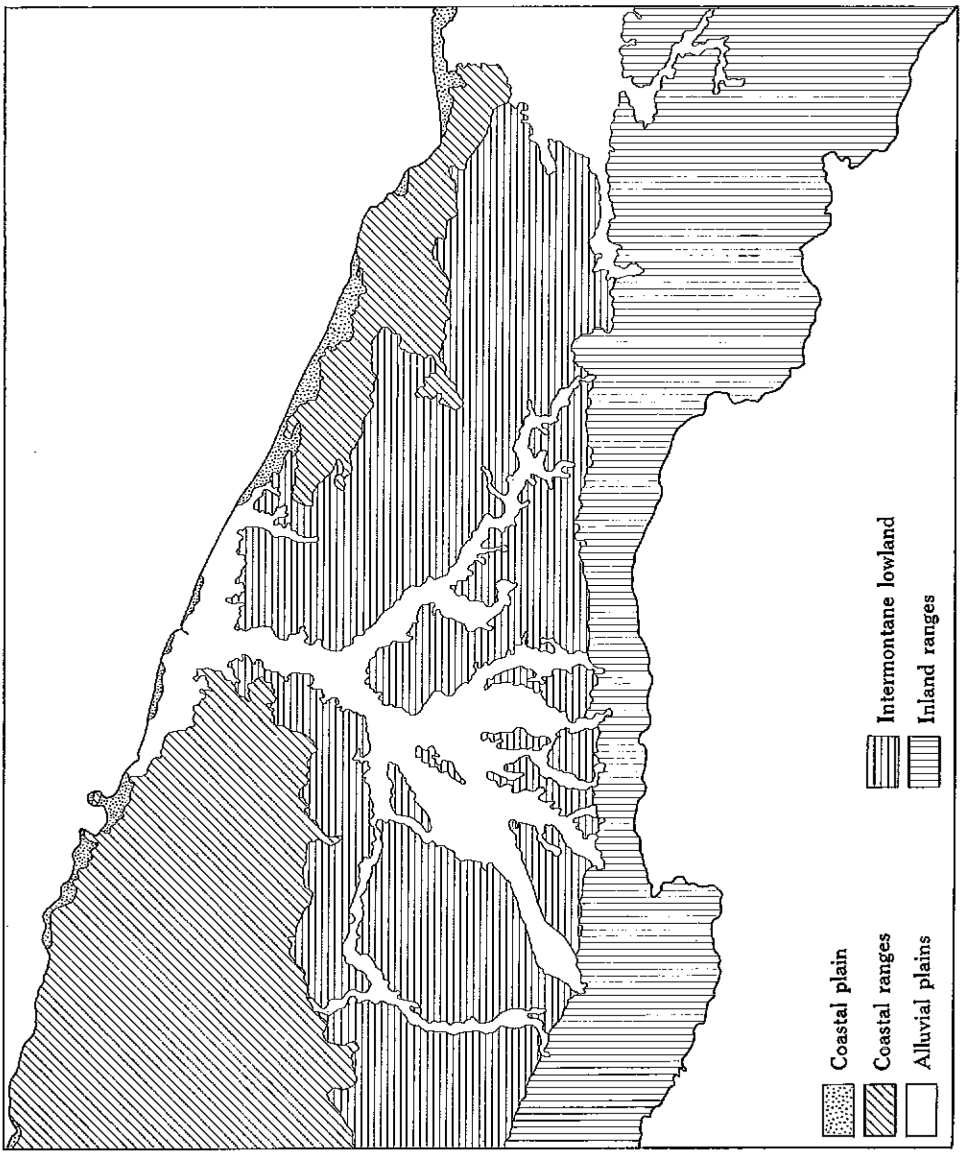

Fig. 3.—Physiographic regions.

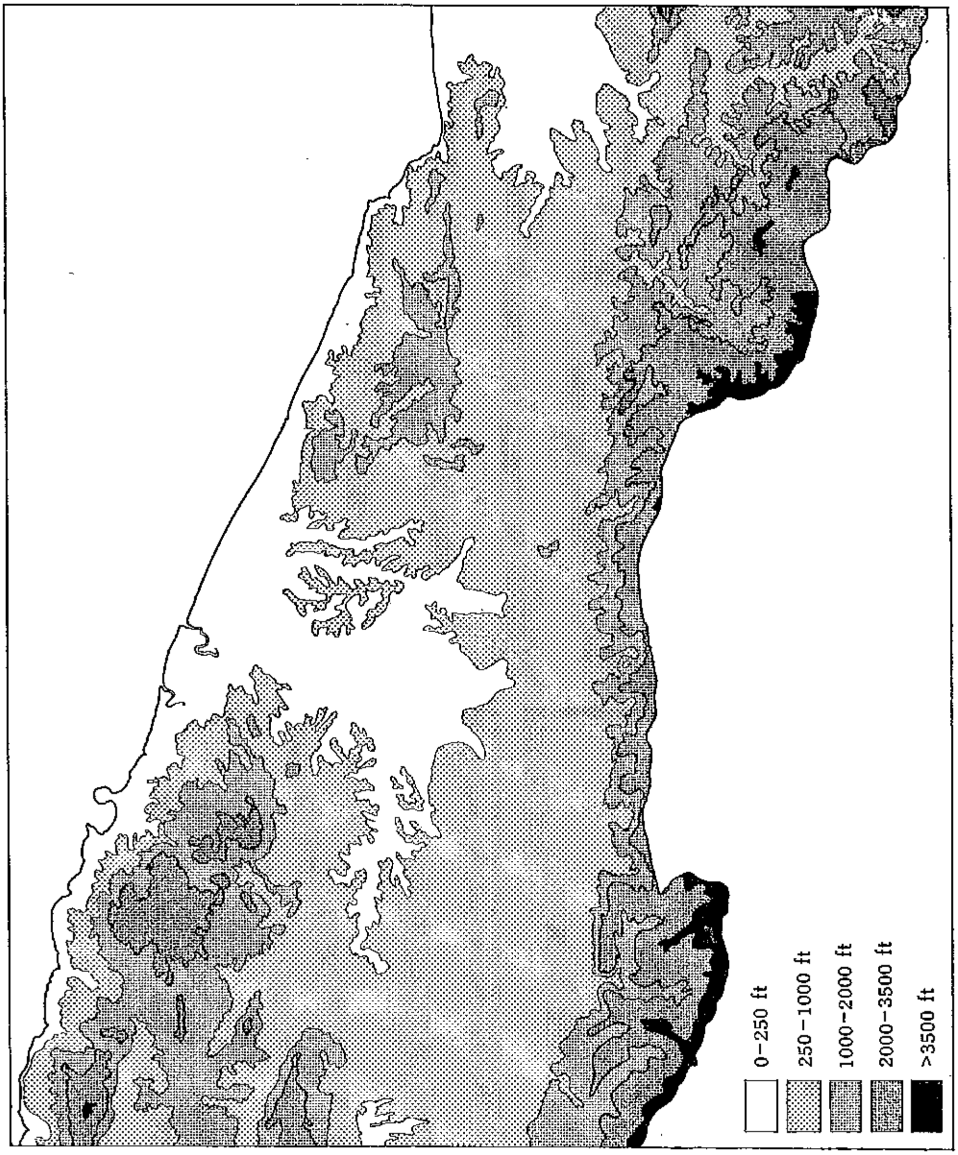

Fig. 4.—Altitudinal zones.

high terraces occur moderately developed soils that are predominantly acid, fine to very fine textured, and imperfectly to poorly drained.

(iii) *The Coastal Ranges.*—The coastal ranges rise abruptly from the coastal plain or directly from the sea to altitudes of 1200 ft or more (Fig. 4; Plate 1, Fig. 2; Plate 2, Fig. 1). They are subdivided by the lower Pual River into a smaller eastern and a larger western part. They consist of plateaux and plateau-like areas with steep escarpments to the north. The dominant rock type is limestone with a varying degree of impurity. Where limestone occurs in pure facies the plateau surfaces are formed by karst hills and dolines.

The vegetation is tall forest with a more or less open canopy with scattered light-toned crowns (Foid, Fid). Tall forest with an irregular, small-crowned canopy with light-toned crowns (Fisd) occurs in the west in limestone-dominated areas. Here, at higher altitudes, mid-height forest types are found, usually with dense canopies and emergent *Araucaria* (Fmc, Fmci, Fmis).

Typical limestone soils are very shallow, very dark, neutral to alkaline in reaction, and fine textured. Deeper, very fine-textured soils occur on intercalated sedimentary rocks and are basically similar to those in the next region.

(iv) *The Intermontane Lowlands.*—The intermontane lowlands separate the coastal ranges from the inland ranges and form the major structural feature of the area. There are two parts, a heterogeneous pattern of subparallel to dendritic ridges in the east (Plate 3, Fig. 1), and flat to gently undulating alluvial fans in the west (Plate 3, Fig. 2). The ridges and hills to the east are built up of marl and mudstone of Pliocene age. These soft sediments form unstable slopes and slumping is a common feature throughout this area. In the west most of the lowlands are occupied by a system of coalescing fans that extend from the inland ranges and by low to very low ridges rising above the alluvial plain of the middle Pual River.

Hills and ridges are largely covered by tall forest with a rather open irregular canopy with scattered lighter-toned crowns (Foid) (Plate 3, Fig. 1), with areas of secondary forest (FR, FoiA). The fans carry tall forests with open canopies and dense understoreys (Plate 3, Fig. 2). The type with light-toned crowns (FodD) occurs in less ill-drained areas than the type with a small-crowned canopy (FosD). Sago palm vegetation (M, Me) is found on depressions in the fans (Plate 3, Fig. 2) and in blocked valleys.

The typical soils on soft sedimentary rocks are rather shallow, slightly to moderately developed, fine- to very fine-textured soils of weakly alkaline to weakly acid reaction. Deeper soils occur where the bed-rock is covered by colluvium. Slight gleying is rather common. More developed acid soils, commonly with a somewhat coarser-textured surface soil, occur on more stable sites, mostly upper slopes and crests, and dip slopes.

On the fan surfaces occur mainly moderately to very strongly developed acid to strongly acid soils of fine to very fine texture, but usually with coarser-textured surface soils. They are partly slowly permeable and more or less gleyed, and partly friable and well drained.

(v) *The Inland Ranges.*—The inland ranges are part of the mountain chain which separates the Sepik drainage system from the coastal one. They comprise the Bewani Mountains and in the east an outlier of the Torricelli Mountains. They rise along a series of fault scarps from the intermontane lowlands and consist mostly of three belts: a zone of foothills 0·5–2 miles wide built up of soft sediments with moderate relief (Plate 3, Fig. 1); a zone of high broad ridges up to 3 miles wide consisting of more consolidated sediments including some limestone blocks; and a third zone of massive mountain ridges formed by basement rocks (Plate 3, Fig. 1; Plate 4, Fig. 1).

The foothills are covered with tall forests with more or less open irregular canopies and normally with scattered lighter-toned crowns (Foi, Foid, Fid). Mid-height forests form the vegetation of the two other zones. Mid-height forest with a rather dark-toned, rather even canopy (Fm) occurs on higher crests and slopes where clouds gather in the daily atmospheric rhythm. Mid-height forest with a very dense canopy of irregular height (Fmci) is found on the limestone blocks. Mid-height forests with less dense canopies (Fmi, Fmi′, Fmoi) cover most of the other land forms. The degree of canopy closure seems to be at least partly influenced by slope stability.

The soils are mostly slightly to moderately developed, weakly acid to acid, and medium to fine textured; they range from shallow to rather deep. Locally, mainly on crests and upper slopes, occur strongly developed, strongly acid, friable deeper soils.

(*b*) *Climate*

The Vanimo area has a wet tropical climate with little seasonal variation in rainfall and temperature. The mean annual rainfall on the coast is 105 in. and decreases to 80–90 in. inland. The months May–October generally have less rainfall than the remainder of the year. This coast–inland rainfall gradient is interrupted at Ossima in the intermontane lowlands where the rainfall is slightly lower than further inland. This interruption is probably caused by the rain shadow effects of the coastal ranges. The annual temperature ranges are minimal. The mean annual temperature is about 80°F with virtually no seasonal variation and the diurnal range is about 14 degF.

II. Forest Resources

(*a*) *General*

The Vanimo area is relatively rich in forest resources, approximately 90% of the land carrying commercial forests. This is mainly due to the low population density, both past and present, over much of the area and also to the relative scarcity of permanent swamps. The most productive and accessible forests occur on the fans (FodD) and on the better-drained parts of the alluvial plains (Fo, F, Fod). Areally, however, by far the most important forest (Foid) occurs on a variety of upland land systems with variable access.

At the time of the survey, vehicular access within the area was limited to a few miles of road centred on Vanimo, the remainder being serviced by aircraft. However, most of the area would be accessible by roads following the better-drained parts of the alluvial plains and the adjacent foothills and fans. Although it is unsubstantiated by evidence, it is considered that the major rivers are generally not suitable for floating logs, except perhaps in their lower reaches.

The external outlet for timber and timber products is obviously by sea, and although there is a dearth of potential harbours along the coastline, particularly in the east, Vanimo provides an excellent all-weather anchorage and existing port facilities.

(b) Regional Assessment

(i) *The Coastal Plain.*—This region is very low in forest resources and any exploitation of the small remaining areas of timber might well be achieved when logging adjacent regions. Access is generally good, more so in the western than in the eastern parts where a higher proportion of back swamps occur.

(ii) *Alluvial Plains of the Major Rivers.*—Forests cover 90% of the alluvial plains. The forest resources are high, particularly on the better-drained terraces. Access is generally good throughout except for seasonal flooding, and the continuous network formed by this region allows easy access to inland parts of adjacent regions.

(iii) *The Coastal Ranges.*—The forest resources of this region are high with a forest cover of 98%. Access is variable. The coastal escarpment severely limits access from the north and elsewhere scattered occurrences of karst topography impose severe restrictions. However, from the south-east, access to the plateaux appears to be more feasible.

(iv) *The Intermontane Lowlands.*—This is the largest of the regions and is high to very high in forest resources. Forests cover 96% of the region. Access could be gained to the region via the alluvial plains of the Pual and Bliri Rivers. Access within the region is good to very good in the west, where most of the forests occur on fans and alluvial plains, and moderate to poor in the east on sedimentary ridges and hills.

(v) *The Inland Ranges.*—The forest resources of this region are classed as moderate to low generally, but locally high in the foothills zone where access is moderate. Elsewhere, access is considered poor to very poor, and nil on the massive mountain ridges. However, in much of this region the forests, both commercial and non-commercial, are invaluable for watershed protection.

III. Population and Land Use

(a) Population

The Vanimo area has a total indigenous population of 6400. This figure has been derived from the quasi-annual census of villages listed in the Village Directory* and located within the survey area. There are 50 villages unevenly clustered over the area (Fig. 5); hence the population density of 3 persons per square mile is not very meaningful except to show that this is well below the average for Papua New Guinea.

There are three areas of population concentration: the coastal plain; the middle course of the Pual River and its tributaries; and the alluvial fans near Pagei. About 45% of the whole population lives on the coastal plain which occupies only 1% of the survey area. The villages are situated on the beach ridges and are generally inhabited by 80–130 persons. However, Vanimo and Warimo villages are much larger, with 400–500 inhabitants. Some of the coastal villages have been established only recently by people moving from the inland to the coast. This is indicated by the relatively large number of abandoned inland villages and also by the report of Marshall (1937), who in

* Village Directory, 1968, Department of Native Affairs, Port Moresby.

1936 walked along the coast from Aitape to Vanimo and noted that the area between Serra and Vanimo was *virtually uninhabited*.

Another 25% of the population is centred around the middle course of the Pual River and its tributaries. The villages are perched on narrow ridge crests and surrounded by numerous coconut palms (Plate 4, Fig. 2). The population concentration here seems to be due mainly to the abundance of sago which grows in the blocked tributary valleys of the Pual.

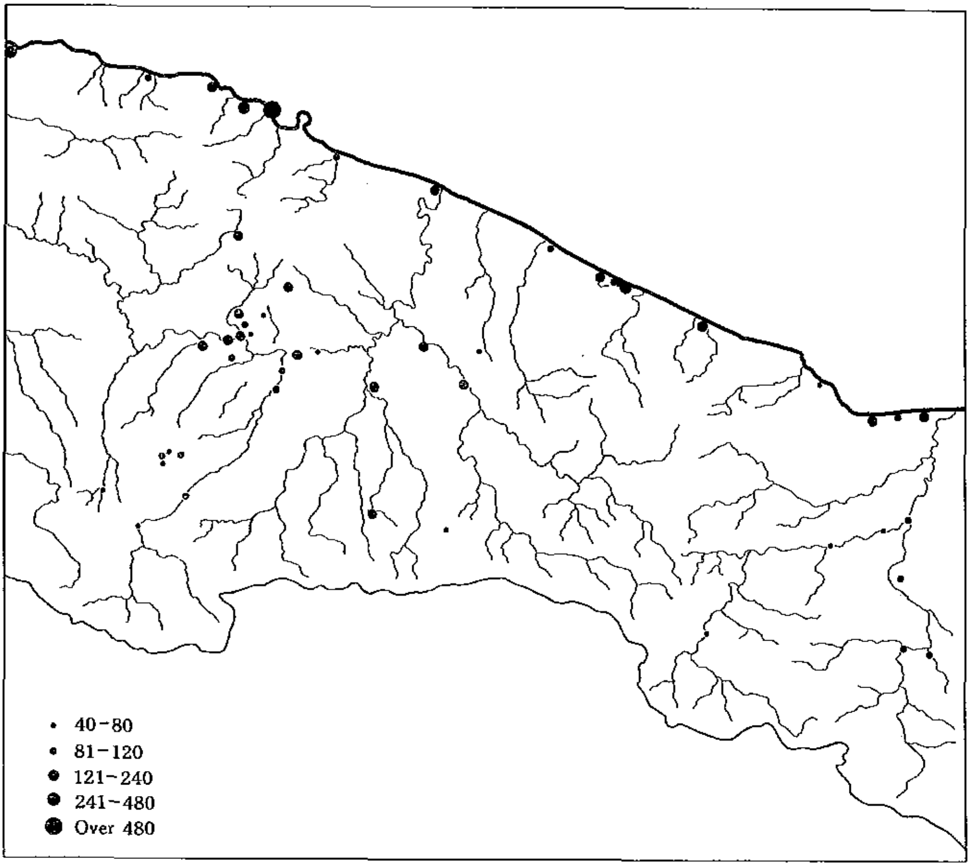

Fig. 5.—Distribution of indigenous population.

A minor concentration of population can be found around the Pagei Patrol Post. The people left their original villages which were situated in the mountains and settled in the vicinity of the patrol post. The rest of the population is scattered over the area, mainly along the reaches of the major rivers and their tributaries.

The non-indigenous population amounts to about 60 Europeans, most of whom are living in Vanimo. They are engaged in governmental and mission activities and also in the timber industry.

(*b*) *Land Use for Subsistence*

The present land use pattern in the Vanimo area is virtually the same as the one described by Fagan and McAlpine (1972) for the Aitape–Ambunti area, except that because of the low population density there is little pressure on land. The present land use is restricted to subsistence agriculture which in general terms may be described as shifting cultivation. As in the Aitape–Ambunti area there is a preference for a cyclic rotation of clearing and cultivation within relatively well-defined areas of secondary vegetation (Fagan and McAlpine 1972). In the coastal plain there seem to be some gardens that are more or less permanently used. The main crops cultivated are yam (*Dioscorea* spp.), taro (*Colocasia esculenta*), sweet potato (*Ipomoea batatas*), bananas (*Musa* spp.), cassava (*Manihot esculenta*), and papaw (*Carica papaya*). Some European crops like maize, tomatoes, and pineapples are also grown in small amounts. Coconuts are abundant in all the villages especially on the beach ridges.

Everywhere sago is an important part of the diet and in some places it seems to be the most important staple of all. It grows abundantly in the vicinity of most villages.

IV. Agricultural Land Use Capability

(*a*) *General*

The approximate areas of land with different levels of suitability for arable crops (permanent cultivation), tree crops, improved pastures, and irrigated rice are shown in Table 1. It should be kept in mind that these figures are based on the overall suitabilities of land systems. Some land systems have a relatively uniform level of suitability throughout, but in many the suitabilities vary (often greatly) for different types of land within the land system.

Table 1

Areas* (sq miles) with different levels of suitability for four types of agricultural activity

Type of activity	Level of suitability: Very high	High	Moderate	Low	Very low	Nil
Arable crops	Nil	Nil	435	169	505	1032
Tree crops	Nil	Nil	354	745	449	593
Improved pastures	Nil	435	736	561	216	193
Irrigated rice	Nil	286	119	25	Nil	1711

* The total in each row equals 2141 sq miles, the size of the survey area.

Probably the most striking feature of the area is the absence of land systems with a very high to high capability for arable and tree crops and a very high capability for improved pastures. This is due to the unfavourable physical conditions of the soils on the topographically most suitable land which comprises the well-drained alluvial plains and undissected fan surfaces. On the fan surfaces it is also due to very low chemical soil fertility. The land use capability of this area is generally lower than that of the adjoining Aitape–Ambunti area (Haantjens *et al.* 1972) which, apart from the soil factors outlined above, is caused mainly by the presence of large limestone areas that have serious topographic limitations and little soil. Contrary to the general trend, however, the proportion of land with a high to low capability for improved pastures is larger, and that with a very low to nil capability is lower, in the Vanimo area than in the Aitape–Ambunti area. This is due to the lower proportion of very rugged mountainous and hilly terrain and because the adverse soil conditions are judged to influence pastoral potential less than that of other types of agriculture.

(b) *Regional Land Use Capability*

An agricultural assessment of each land system is presented in Part III. The methods used were essentially the same as described for the Aitape–Ambunti area (Haantjens 1972) except that the land systems were placed into somewhat broader land use capability groups, the distribution of which is shown on the map of agricultural land use capability. The capability levels are shown on the map reference and a very brief indication of the nature of the land in each group is given here.

Group 1.—This includes the undissected fan surfaces, the best-drained valley floors and terraces, and the beach ridge–swale complexes. Poor drainage is the most common limitation but low soil fertility is important on fan surfaces.

Group 2.—Comprising mainly larger alluvial plains and terraces, this group also includes the small coral platforms and associated coastal plains. Poor drainage is generally the main limitation but alkaline droughty soils limit the suitability of the coral plains.

Group 3.—The largest part consists of irregular generally moderately steep hill slopes on sedimentary rocks. The remainder is partly dissected alluvial fans with surface remnants and steep slopes. Topographic conditions are the main limitation.

Group 4.—This includes hilly plateau-like areas on limestone and sedimentary rocks and uplifted dissected coral platforms with flattish surface remnants and steep slopes. While there are fairly serious topographic limitations, shallowness and alkalinity of the soils are probably equally serious problems.

Group 5.—Most land in this group is low hilly with irregular moderately steep to steep slopes on mudstone, the major limitations being in the physically poor, commonly shallow, and locally alkaline soils. Also included are some irregular mountain slopes with better soils. Unstable slopes pose risks throughout this group.

Group 6.—This comprises low-lying poorly drained plains with probably very fine-textured slowly permeable soils.

Group 7.—Comprising steep hilly country on variable sedimentary rocks; limitations are mostly of a topographical nature but also lie in rather shallow and slowly permeable soils that in some cases are alkaline.

Group 8.—This consists of very steep hilly land on sedimentary rocks and fanglomerate (strongly dissected alluvial fans). Steep irregular topography is the main limitation.

Group 9.—This comprises mainly high steep hill ridges on clastic sedimentary rock, limestone, and, locally, igneous rock. Some lower ridges with unstable slopes are also included in this group. Soil limitations occur particularly on limestone and mudstone.

Group 10.—Consisting of various kinds of freshwater swamps, this land could be made more productive by reclamation, but in most cases this would be costly and the heavy clay soils might remain an unfavourable factor.

Group 11.—Part of this group consists of generally high hill ridges on clastic sedimentary rocks, with either very steep or very unstable and slumped slopes. The greater proportion of the group comprises rugged limestone country of variable relief and with shallow soils.

Group 12.—This comprises mainly very rugged mountainous and some high hilly land on igneous and sedimentary rocks. Also included are small, highly unstable, swampy flood-out plains.

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PART III. LAND SYSTEMS OF THE VANIMO AREA

By E. LÖFFLER,* P. C. HEYLIGERS,* H. A. HAANTJENS,* and J. C. SAUNDERS*

I. INTRODUCTION

In the Vanimo area 39 land systems ranging in size from 3 to 229 sq miles have been distinguished and described. A land system is defined as "an area or group of areas throughout which there is a recurring pattern of topography, soils, and vegetation" (Christian and Stewart 1953). Land systems show characteristic recurring patterns on air photographs and their boundaries are basically determined by photo interpretation of land form and vegetation (Mabbutt and Stewart 1963). The method of describing the land system is essentially the same as that used by Haantjens *et al.* (1972) in the adjacent Aitape–Ambunti area. It replaces the tabular description of the land systems in terms of land units previously used by the Division of Land Research by a more detailed description without the formalization of land units. A detailed account of this method is given in Haantjens (1968) and Haantjens *et al.* (1972).

Each description gives information on land forms, terrain parameters, streams and drainage, geology, vegetation, soils, population and land use, forest resources, and agricultural and engineering assessments. The descriptive terms used are defined and explained in Appendix I.

The land systems are arranged in eight groups representing the major geomorphic categories. The order of the groups and the land systems within each group is mainly based on geomorphic criteria (Table 2).

The Vanimo report is to be regarded as a continuation of the Aitape–Ambunti report; the land system boundaries between the two areas have been linked up (discrepancies occur because of differences in the available base maps) and mapping has been made as consistent as possible. Eighteen land systems of the Aitape–Ambunti area also occur in the Vanimo area.

To illustrate the land systems stereo pairs have been selected. Because of the small scale of most of the air photographs a stereo pair generally covers several land systems and therefore only 16 plates are used to show examples of 39 land systems. Some land systems are shown on more than one plate; if the occurrence is only of minor importance the land system is not mentioned in the description of the plate. North is always to the right of the photograph.

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TABLE 2

DIAGNOSTIC FEATURES OF THE LAND SYSTEMS

Geomorphic category	Main land-form type	Relief	Rock type	Age	Dominant vegetation	Land system
Littoral plains	Coral platform	Nil	Coral limestone	Recent	R–Fr	1, Madang*
	Beach ridges and swales		Beach sand			2, Nubia*
Freshwater swamps and unstable flood-plains	Coastal back swamps		Alluvial clay and sand		FmPM, N/M	3, Leitre
	Blocked valley swamps		Alluvial clay and peat		M	4, Kabuk*
	Flood-plain swamps		Alluvium		FmoM	5, Pandago*
	Frequently flooded unstable plains				Seral	6, Nigia*
Alluvial plains	Valley floors along small streams		Alluvium (clay, silt, and sand)		Fosd	7, Basu
	Narrow flood-plains				F, Fo, Fod	8, Papul*
	Flood-plains and terraces				FoM, FodM	9, Po*
					Fo, Fod	10, Pual
Alluvial fans	Undissected fans		Fanglomerate (silt, sand, and gravel)	Pleistocene	FodD, FosD	11, Pagei
	Slightly dissected fans	Very low			FodD	12, Luap
	Strongly dissected fans				Foid	13, Punwep
	Swampy depressions on fans	Nil			M, MR	14, Nabes
Hills and mountains on soft sedimentary rock	Very low hills and ridges	Ultra-low–very low	Marl and mudstone	Pliocene	Foid	15, Isi
	Low ridges with very short spurs	Low	Marl, mudstone, and siltstone			16, Fivuma
	Asymmetric ridges		Marl, mudstone, and sandstone		Foid, Fid	17, Muru
	Irregularly branching ridges		Siltstone, mudstone, and sandstone			18, Yassip*
	Short ridges	Moderate			Foid, Fmoi	19, Morumu*
	Irregular ridges with short spurs		Marl and mudstone		Foid, FoiA	20, Puari

	Broad ridges with moderate side slopes		Marl, mudstone, and siltstone		Foid	21, Puive
	Very steep hills		Siltstone and sandstone	Miocene–Pliocene	Fmi, Foid	22, Numoiken*
	Strike ridges and hogbacks	Moderate–high	Siltstone, sandstone, and conglomerate		Foid, Fmi	23, Musak*
	Broad mountain ridges	High	Siltstone, mudstone, and sandstone	Miocene	R–FR/MR	24, Flobum*
	Slumped mountain ridges			Eocene–Miocene	Fmi, Fmoi	25, Piore
	Asymmetric mountain ridges		Siltstone, sandstone, and conglomerate	Miocene		26, Wuro*
	Slumped and gullied mountain ridges		Siltstone and sandstone	Eocene–Miocene	Fmi, Fmi′	27, Sulen*
Hills, plateaux, and mountains on mixed sediments with limestone dominant	Fine-grained pattern of ridges	Low	Limestone, mudstone, and volcanics		Fisd	28, Ijapo
	Irregular ridges with short spurs		Limestone, sandstone, siltstone, and mudstone	Miocene–Pliocene	Foid	29, Punan
	Dissected plateaux	Low–moderate	Limestone, siltstone, and mudstone			30, Limio
	Plateaux with hilly surface		Limestone, siltstone, mudstone, and volcanics	Eocene		31, Jassi
	Coarse-grained ridges	Moderate	Limestone, marl, mudstone, and siltstone	Eocene–Miocene	Foid, Fid	32, Oenake
	Ridges with broad crests		Limestone and sandstone	Miocene	Fmoi, Foid	33, Barida*
Hills and plateaux on limestone	Uplifted coral reef platforms	Low	Limestone	Pleistocene	Foid, Fisd	34, Musu
	Karst hills			Pliocene	Fisd, Foid	35, Kohari
	Plateaux and plateau remnants	High			Foid, Fmci	36, Serra
Hills and mountains on igneous rocks	Finely spurred steep ridges		Granodiorite, gabbro, and diorite	Basement	Fmoi, Fmi	37, Kum
	Isolated hills and ridges		Gabbro and volcanics		Fmi	38, Mup*
	Massive mountain ridges	Very high	Granodiorite, gabbro, and diorite		Fmi, Fmoi	39, Somoro*

* Also occurs in the Aitape–Ambunti area.

III. Land System Descriptions

(1) Madang Land System (8 sq miles)

Land Forms (Plate 5).—Flat to gently undulating raised coral platforms and coastal plains on coral limestone, generally rising very gently from the sea except east of Vanimo where a 6-ft-high cliff is developed. On the seaward side a belt of coral reef *c.* 300 ft wide slightly raised above high tide separates coastal plain from open sea.

Terrain Parameters.—Altitude: 0–45 ft. Relief: nil (1·5 ft). Characteristic slope: very gentle (1°). Grain: —.

Streams and Drainage.—No surface drainage except where larger streams cross coastal plain as allochtonous streams. Well drained by subterranean drainage.

Geology.—Recent coral-derived beach sand and alluvium overlying coral limestone.

Vegetation.—Original vegetation of tall forest (Fo) now covers only 17% of land system and has been largely replaced by secondary vegetation, ranging from gardens to old secondary forest (R–FR). Locally, on exposed coral limestone shores, *Pemphis acidula* may form scrubs up to 15 ft tall.

Soils (4 obs.).—On coral platforms, very slightly developed, dark, strongly alkaline, moderately shallow, very rapidly permeable, coarse-textured soils. Nitrogen contents high to moderate, phosphate very high, potash low.

On the coastal plain near Vanimo that is covered with beach sand and alluvium, occur undeveloped, weakly acid, very deep soils. They are imperfectly drained, moderately permeable, and fine- over coarse-textured near the coast and poorly drained, slowly permeable, and fine-textured further inland. Nitrogen contents moderate to low, phosphate contents low, and potash contents moderate.

Population and Land Use.—Population of 1344 distributed over 4 villages. Large parts of the land system under present use.

Forest Resources.—Very low. Very high stocking rate forest (Fo) covers 17%, mainly in the north-eastern part. Access very good throughout.

Agricultural Assessment.—Overall capability moderate for arable crops and low for irrigated rice. Coral platforms have only low suitability for arable crops and tree crops and moderate capability for improved pastures because of droughty and alkaline soils. Moderate suitability for tree crops only on better-drained parts of coastal plains. Depending on degree of drainage deficiencies, these plains have high to moderate capability for arable crops and very high to high capability for pastures.

Engineering Assessment.—Generally suitable for road construction. Coral platforms in particular would be very suitable for airfield construction.

Soils on coral SP to SM and GM; shallow. Soils on alluvium CH to CL with local SM in the subsoil; very deep to deep.

(2) Nubia Land System (8 sq miles)

Land Forms (Plates 6, 19).—A sequence, up to 1500 ft wide, of very low gently undulating beach ridges and swales. Narrow, gently to moderately sloping beach backed by a short steep slope to the youngest beach ridge which is about 6–9 ft a.s.l. Single beach ridges are 60–180 ft wide, swales 15–60 ft wide. Swales permanently or seasonally inundated in places.

Terrain Parameters.—Altitude: 0–12 ft. Relief: nil (6 ft). Characteristic slope: gentle (2°). Grain: —.

Streams and Drainage.—Some swales serve as drainage lines but have virtually no gradient. They are fed by ground water as run-off is nil. Beach ridges cut through in places by streams draining back swamps and plains behind them. Streams run frequently parallel to coast for some distance before breaking through beach ridges to reach the sea in 60–90-ft-wide brackish to salt-water tidal creeks.

Geology.—Recent beach sand.

Vegetation.—Original vegetation of beach ridges was forest dominated by *Calophyllum*, *Barringtonia*, *Cerbera*, *Artocarpus*, and others (so-called "*Barringtonia* formation"), but is now replaced by secondary vegetation, ranging from gardens and coconut plantations to old secondary forests (R–FR), and including some mid-height grasslands, usually dominated by *Imperata*, often with scattered shrubs and low trees (V).

Near mouth of Bliri River a large stand of tall open *Casuarina equisetifolia* forest (Cq) occurs. *Ipomoea pes-caprae* and its ecological allies (so-called "*pes-caprae* formation") form patches of sand-binding vegetation on youngest beach ridges. Tall or mid-height forest with open canopy and with sago palms in understorey (FoM, FmoM), sago palm vegetation with emergent trees (Me), or mid-height forest with an open irregular canopy with pandans and sago palms common (FmPM) occurs in swales.

Soils (5 obs.).—On frontal beach ridges undeveloped, weakly alkaline to neutral, deep, rapidly permeable sandy soils, which are well drained except for some very low ridges with *Casuarina* that are poorly to imperfectly drained. Further inland occur similar soils, neutral to weakly acid in reaction, showing very slight profile development in form of thick dark topsoil. On oldest ridges soil reaction becomes acid and topsoil becomes medium-textured. No drainage deficiencies observed in any of these inland soils.

In swales deep swampy soils, which may range from undeveloped, alkaline, rapidly permeable sands in youngest outer swales to weakly acid soils with dark peaty or loamy surface soils in older swales further inland.

Soil nitrogen contents range from very low in least-developed to moderate in most-developed soils. Phosphate shows similar trend, from very low to low. Potash data show reverse trend, from moderate in youngest to low in older soils. Some marked and unexplained differences in phosphate and potash contents compared with Nubia land system in Aitape–Ambunti area.

Population and Land Use.—Population 1145 distributed over 9 villages. Present land use covers nearly entire land system.

Beach ridges planted with coconut palms close to the sea and gardened further inland. Swales used for exploitation of sago.

Forest Resources.—Very low. A pure stand of low stocking rate *Casuarina equisetifolia* forest (Cq) covering 12% occurs near mouth of Bliri River. Elsewhere, scattered stands of moderate stocking rate forest (FoM) covering 8% are found in swales. Access generally good, particularly along beach ridges, but seasonally limited in swales.

Agricultural Assessment.—Probably moderate capability for arable and tree crops, and high capability for improved pastures. Drainage deficiencies in some swales and drought risks and low soil fertility on beach ridges are main limitations for arable crops, poor drainage and high pH for tree crops. Moderate capability for irrigated rice in swales.

Engineering Assessment.—Very suitable for construction of roads parallel to coast and also for airfield construction, except lowest ridges near Bliri River. Bridging river would be major obstacle in coastal road linking Vanimo with Aitape.

Soils mainly SP, but with thin OL surface soils on inland ridges and in swales; very deep.

(3) Leitre Land System (7 sq miles)

Land Forms (Plates 6, 19).—Coastal back swamps located in front of steeply rising coastal ranges. Swamps 3000–4500 ft wide and up to 9000 ft long, blocked by belt of beach ridges generally 1200–1500 ft and in one case 3000 ft wide. Transition zone between beach ridges and swamps is periodically dry. In areas where beach ridges too narrow to map they are included in this land system.

Terrain Parameters.—Altitude: 0–6 ft. Relief: —. Characteristic slope: nil. Grain: —.

Streams and Drainage.—Swamps connected with open sea through narrow overflow channels. Owing to strong sand transport along coast these channels often are only temporarily open. During periods of intensive rainfall back swamps drain through these channels, during drier periods sea water flows into swamps.

Geology.—Sticky clay merging into beach sand at seaward side.

Vegetation.—More than half covered by mid-height forest, mostly with open irregular canopy, with pandans and sago palms common (FmPM), and some with open canopy in which pandans are dominant (FmoP). Aquatic herbaceous vegetation (H) and mixtures of *Nypa* and sago palms (N/M) in permanently inundated situations, and sedge vegetation with scattered pandans (V) in fringing periodically dry areas, form the other components.

Soils (2 obs.).—Very poorly drained to swampy, and weakly acid mostly undeveloped, moderately deep, very slowly permeable, very fine-textured; in wettest parts permanently submerged and covered with organic muck. Low in nitrogen, moderate in phosphate, but high to very high in potash.

In transition zone to beach ridges occur slightly developed, moderately permeable, medium- over coarse-textured soils with thick dark topsoil, which have moderate nitrogen content, are low in phosphate, low to very low in potash.

Population and Land Use.—One village, 110 people, situated on narrow beach ridge blocking the back swamp. Sago palms in Leitre exploited by population living on Nubia (2).

Forest Resources.—Nil. Access nil.

Agricultural Assessment.—In natural state only very low capability for improved pastures and moderate capability for irrigated rice. Drainage improvement by land reclamation would be very difficult and costly.

Engineering Assessment.—Should be avoided as much as possible for road construction. Any roads should be built up above inundation and flood level and provided with culverts.

Soils mostly CH, with some SM and SP, and locally OM surface soils; very deep.

(4) Kabuk Land System (9 sq miles)

Land Forms (Plate 11).—Flood-plain swamps occurring in valley floors, the drainage of which has been blocked by strongly aggrading main river.

Terrain Parameters.—Altitude: 15–300 ft. Relief: —. Characteristic slope: nil. Grain: —.

Streams and Drainage.—Swamps partly drained by creeks meandering in valley floor. Creeks 6–12 ft wide, 3–6 ft deep contain clear, nearly stagnant water showing that they do not erode but are merely drainage lines. Swamps inundated to at least 0·75–1·5 ft for probably all year.

Geology.—Recent clay and peat.

Vegetation.—Mostly sago palm vegetation (M), locally with emergent trees (Me) and *Hanguana*-dominated herbaceous vegetation (H) where inundation is deep.

Soils (2 obs.).—Probably similar to those in Pandago (5). In valleys with herbaceous vegetation occur permanently inundated neutral peat soils, partly poorly, partly well decomposed, covered by or alternating with layers of soft clay.

Population and Land Use.—No population, but area extensively used for exploitation of sago, supplying most of population near Ossima.

Forest Resources.—Nil. Access very poor to nil.

Agricultural Assessment.—In natural state only very low capability for improved pastures, low capability for wet rice. Some valleys totally unsuitable for agriculture but could possibly be used for construction of fish ponds. Land reclamation difficult and costly, and would not result in high-quality land because of very clayey soils.

Engineering Assessment.—Should and can be avoided for road construction. Soils CH and some Pt; very deep.

(5) Pandago Land System (11 sq miles)

Land Forms (Plate 6).—Flood-plain swamps developed in alluvial plains of major rivers.

Terrain Parameters.—Altitude: 10–150 ft. Relief: —. Characteristic slope: —. Grain: —.

Streams and Drainage.—No organized stream network but some shallow channels drain swamps mainly at times of high water supply.

Geology.—Recent alluvium.

Vegetation.—About two-thirds covered with mid-height forest with open canopy with sago palms in understorey (FmoM), remainder sago palm vegetation with emergent trees (Me).

Soils (1 obs.).—Undeveloped, neutral, moderately deep, very poorly drained, very slowly permeable, and fine-textured. Although inundated during wet season, water-tables can fall to depth of 4–7 ft during drier season. Soil nitrogen contents moderate, phosphate moderate to high, potash high to very high.

Population and Land Use.—No population, but area important supplier of sago to nearby villages.

Forest Resources.—Very low. Low stocking rate forest (FmoM) covers 64%. Access poor but may be possible during part of dry season.

Agricultural Assessment.—Low capability for improved pastures, moderate capability for wet rice. Land reclamation difficult and costly, and would not result in high-quality land because of very clayey soils.

Engineering Assessment.—Should and can be avoided for road construction. Soils CH; very deep.

(6) Nigia Land System (3 sq miles)

Land Forms (Plate 7).—Unstable flood-out plains and flood-plains near Bewani Mountains front; pronounced microrelief up to 3 ft.

Terrain Parameters.—Altitude: 150–270 ft. Relief: nil (3 ft). Characteristic slope: low gradient (0 : 1000). Grain: —.

Streams and Drainage.—Highly unstable drainage with changing channels, one area with no organized drainage. Subject to frequent flooding.

Geology.—Recent alluvium almost wholly calcareous indicating very recent deposition.

Vegetation.—Original forest largely destroyed by recent severe flooding and deposition of sandy sediments. Commonness of (? survived) sago palms could lead to establishment of sago palm vegetation (M) when frequency of flooding diminishes.

Soils (1 obs.).—Completely undeveloped, alkaline and calcareous, very deep, swampy to very poorly drained, but moderately permeable and medium-textured; very low in nitrogen, low in phosphate, but high in potash.

Population and Land Use.—Nil.

Forest Resources.—Nil. Access very poor owing to unstable drainage and frequent flooding.

Agricultural Assessment.—No agricultural capability in natural state; land reclamation very difficult and costly.

Engineering Assessment.—Should and can be avoided for road construction. Soils stratified, mainly CL and ML; very deep.

(7) Basu Land System (36 sq miles)

Land Forms (Plates 8, 9).—Valley floors, 300–1800 ft wide, along smaller and medium-sized streams; consisting generally of 150–900-ft-wide flood-plain, and one to three terraces of variable width. Flood-plain includes small scroll plains and flood-plain terraces. Lowest and generally most extensive terrace is 15–30 ft above flood-plain, middle and upper terraces 30–60 ft above flood-plain. Terraces discontinuous.

Terrain Parameters.—Altitude: 30–600 ft. Relief: nil (3 ft). Characteristic slope: very gentle (2°). Grain: —.

Streams and Drainage.—Flood-plains regularly flooded during main rainy season, terraces are well above high-water mark. Terraces dissected by widely spaced steep-sided gullies, 5–15 ft deep, 9–12 ft wide. Gradients of rivers between 1 : 30 and 1 : 200.

Geology.—Alluvium overlying mudstone.

Vegetation.—Tall forest with an open, rather small-crowned canopy with scattered light-toned crowns (Fosd).

Soils (7 obs.).—On terraces above flood level mainly undeveloped, deep to very deep, well-drained, moderately permeable and medium- to fine-textured, or slowly permeable and fine-textured soils, neutral to weakly acid on middle terraces, acid to weakly acid on higher terraces. Nitrogen contents low, phosphate low to moderate, potash moderate to high, with highest values in least acid soils.

On scroll plains and flood-plain terraces soils probably similar to those in Pual (10).

Population and Land Use.—Nil.

Forest Resources.—High. High stocking rate forest (Fosd) covers 93%, minor areas of high (Fod) and moderate stocking rate forest (FoM) cover 2%. Access good throughout except during periods of limited flooding and on minor areas of poorly drained soils.

Agricultural Assessment.—High capability for improved pastures, moderate capability for arable crops, tree crops, irrigated rice, Very good-quality land on many terraces; on flood-plains capability reduced to moderate or nil, depending on severity of flood hazards. Rather high soil pH and local poor drainage reduce capability for tree crops. Flooding and rather broken nature of terraces restrict suitability for wet rice.

Engineering Assessment.—Only minor topographic obstacles to road-building; location of some areas favourable for regional road connections. Only small to medium-sized bridges required; construction of low-level flood-way crossings would be possible. Soil materials generally of low suitability for road construction; sand and gravel do not appear to be available in large quantities.

Soils mainly CH to MH, some CL, locally ML and SM in subsoils; very deep.

(8) Papul Land System (61 sq miles)

Land Forms (Plates 13, 14).—Flood-plains and river terraces up to 1 mile wide developed along larger rivers. Flood-plains consisting of meandering channels, scroll plains, and flood-plain terraces are generally 900–1500 ft wide and bounded by well-developed terraces. In most areas only one terrace observed rising 6–15 ft above flood-plain. Where lowest terrace is extensive it is also referred to as alluvial plain. In places a second terrace 30–45 ft above flood-plain occurs. Terrace surfaces have irregular micro-relief up to 1·5 ft and are crossed by shallow channels.

Terrain Parameters.—Altitude: 120–500 ft. Relief: nil (1·5 ft). Characteristic slope: very gentle (0·5°). Grain: —.

Streams and Drainage.—Flood-plains regularly flooded during rainy season but terraces are above high-water level. Flood-plains and terraces drained by shallow creeks. Edges of terraces dissected by steep-sided gullies.

Geology.—Recent alluvium.

Vegetation.—Differs in three major occurrences. In the east along the Piore River, tall forest with rather open canopy (Fo), and on scroll plains, seral stages developing from cane-grass vegetation (Gt/Fmo).

In the central part along Sereri and Bilia Creeks, tall forest with open canopy with scattered light-toned crowns (Fod) is the major forest type, with smaller-crowned forests in upper reaches (Fosd) and on some ill-drained terraces of Sereri Creek (Fos), and mid-height forest with rather open canopy (Fmo) in upper reaches of Bilia Creek.

In the west along the Pulan River, tall forest with rather closed canopy (F) covers most of land system; tall forest with rather open canopy with light-toned crowns (Fod) and seral stages (Gt/Fmo) occurs further downstream.

Soils (8 obs.).—On scroll plains and flood-plain terraces probably similar to those of Pual (10). Soils on lower terraces alkaline, can be calcareous; on upper terraces usually neutral to weakly acid or weakly acid to acid. This trend of increasing acidity is due to increased leaching, first of carbonates, then of exchangeable cations, with increasing age. Nearly all soils are undeveloped.

Soils are moderately deep to very deep, moderately to slowly permeable, and generally imperfectly drained. Few soils are poorly drained, while youngest soils tend to be well drained. Soil texture generally fine, but some medium-textured soils and coarse-textured subsoils also occur. Consistently fine-textured soils on wider, plain-like terraces.

Nitrogen contents low to moderate; phosphate contents vary greatly, but appear to be low in acid soils, moderate in neutral to weakly acid soils, very variable in alkaline soils; potash moderate to very high in weakly acid to alkaline soils, low in acid soils.

Population and Land Use.—Population 737 distributed over 7 villages. Land use negligible.

Forest Resources.—High. Very high stocking rate forests (F and Fo) cover 34% (24% and 10% respectively), high stocking rate forests (Fod, Fos, and Fosd) cover 43% (30%, 9%, and 4%), and low stocking rate forest (Fmo) covers 4%. Distribution of forest described under Vegetation. Access generally good but may be hampered on flood-plains by flooding and in minor areas by poor drainage.

Agricultural Assessment.—High capability for improved pastures, moderate for arable crops and irrigated rice, low for tree crops. Flooding renders narrow stretches along major streams almost useless for development and drainage deficiencies are major limitation. Rather high to very high soil pH is common additional hazard for tree crops. Gullies and surface unevenness on terraces reduce capability for arable crops and irrigated rice.

Engineering Assessment.—Only slight topographical limitations for road construction and favourably located for regional road connection inland between Vanimo and Aitape and/or Lumi. Bridge construction would be a major cost item but cheaper low-level flood-way crossings appear suitable. Soil materials generally of low suitability for road construction. Only limited amounts of sand and hard gravel in river beds.

Soils CH, MH, CL, with some ML and SM in subsoils and near streams; nearly always very deep.

(9) Po Land System (57 sq miles)

Land Forms (Plates 8, 9).—Poorly drained alluvial plains between slightly higher alluvial plains along major rivers and low mudstone hills (mainly in Isi (15)).

Terrain Parameters.—Altitude: 15–450 ft. Relief: nil. Characteristic slope: nil. Grain: —.

Streams and Drainage.—Probably ill-defined pattern of small shallow wash-courses with intermittent flow. Large parts seem subject to flooding.

Geology.—Alluvium.

Vegetation.—Tall forest with open canopy with sago palms in understorey (FoM) covers about 50%. About one-third carries tall forest with open canopy with scattered light-toned crowns and sago palms in understorey (FodM) and the remainder, east of the lower course of the Pual River, has tall forest with rather open small-crowned canopy and dense understorey (FosD).

Soils (0 obs.).—Probably intermediate in character between poorly drained soils of alluvial plains of Pual (10) and very poorly drained clay soils of Pandago (5).

Population and Land Use.—Nil.

Forest Resources.—Moderate. Moderate stocking rate forests (FoM and FodM) cover 87% (52% and 35%) and high stocking rate forest (FosD) covers 13%. Access only moderate, most of land system having poorly to very poorly drained soils and being subject to regular flooding.

Agricultural Assessment.—Probably very low capability for arable crops, moderate for improved pastures and for irrigated rice. Impeded drainage and seasonal inundation are major limitations. Land reclamation probably difficult and costly, but could lead to moderate to high capability for arable crops and very high capability for improved pastures. High pH and high clay content may make even reclaimed land not very attractive for tree crops.

Engineering Assessment.—Roads will generally have to be raised to prevent inundation and much attention needs to be given to road-side drainage.

Soils mainly CH, probably some MH and CL; very deep.

(10) PUAL LAND SYSTEM (229 SQ MILES)

Land Forms (Plates 6, 7, 9, 14, 19).—Extensive alluvial plains developed along major rivers, consisting of a recent flood-plain, a wide alluvial plain (also called lower terrace, if it is lowest of a sequence of terraces), and one or two terraces. Flood-plain includes meandering rivers, cut-off meander tracts, numerous scroll plains, sand bars, and flood-plain terraces. Main river tracts mostly 250–400 ft wide, flood-plains 300–2000 ft wide. Flood-plains 4·5–8 ft above low-water level. Alluvial plains or terraces are between 150 and 2000 ft wide, lie 5–8 ft above flood-plains, and seem to be slightly above normal flood level. Middle terraces, 3–6 ft above lower terrace, are 600–900 ft wide and are not covered by floods. Upper terrace, 18 ft above middle terrace, was observed at one locality only, and it is not known if it occurs regularly.

Terrain Parameters.—Altitude: 12–540 ft. Relief: nil. Characteristic slope: low gradient (1 : 000). Grain: —.

Streams and Drainage.—Two main streams traverse alluvial plains in widely spaced meanders. Beds are 240–360 ft wide and contain great amount of gravel and sand. Plains drained by widely spaced shallow streams and small channels, about 6–9 ft wide and 3 ft deep. Channels are mostly intermittent in flow and are probably largely fed by run-off from slowly permeable soils. Flooding occasional and of restricted occurrence.

Geology.—Alluvium, stratified clay, silt, sand, and gravel, either derived directly from igneous and sedimentary rocks in the present catchment area or representing re-transported fan material originating from extensive fans that once covered most of the intermontane lowlands.

Vegetation.—Cane grass, often with scattered trees, and seral stages leading to and including mid-height forest with rather open canopy (Gt/Fmo, Fmo) cover bars, banks, and flood-plain terraces. In upper reaches of Puwani and Bewani Rivers this is replaced by *Casuarina cunninghamiana–Eucalyptus deglupta* forest (CE) or its seral stages in which *Casuarina* is predominant.

The main type covering more than half is tall forest with rather open canopy (Fo); flooding occurs very rarely if at all. Next in importance is tall forest with open canopy with scattered light-toned crowns (Fod), indicating some degree of flooding. Tall forest with rather open small-crowned canopy (Fos) occurs in some areas partly enclosed by ridges.

Soils (32 obs.).—The great majority of soils are undeveloped. Scroll flood-plains have alkaline and calcareous, deep to very deep, mainly well-drained but locally poorly drained, moderately permeable soils of medium to fine texture, sometimes with coarse-textured subsoils. On alluvial plains and lower terraces soils are mostly neutral, sometimes weakly alkaline to alkaline or weakly acid, deep to very deep, well to imperfectly drained, and moderately to slowly permeable with medium to fine, rarely very fine textures, but fairly commonly with coarse-textured subsoils. Poorly to very poorly drained soils, often very fine-textured and slowly to very slowly permeable, are locally common.

On small lower terraces are neutral well-drained soils of variable depth, mainly coarse-textured and rapidly permeable, partly medium-textured and moderately permeable. Middle terraces have weakly acid or even acid, deep to very deep, well-drained, moderately or even rapidly permeable, mostly medium- but also fine-textured soils with coarse-textured subsoils. Soils on high terraces are moderately developed, acid (sometimes weakly acid), moderately deep, imperfectly to very poorly drained, very slowly permeable, very fine- to fine-textured. Greater acidity and soil development indicate long period without aggradation.

Isolated occurrences of Pual along coast have weakly acid, or alkaline and calcareous, moderately deep to deep, imperfectly drained, slowly permeable fine-textured soils, many subject to flooding.

Nitrogen contents low on middle and high terraces, moderate to low on alluvial plains and lower terraces, low or even very low on scroll plains. Phosphate contents low to high on alluvial plains, low on scroll plains and middle terraces, moderate to low on upper terraces. Potash contents mostly high.

Population and Land Use.—Population 1567 distributed over 15 villages. About 2–3% of area is used for gardening. Population also uses Pandago (5), if it is adjacent, for sago collecting.

Forest Resources.—High. Very high stocking rate forest (Fo) covers 56%, high stocking rate forests (Fod, Fos) 31% (28%, 3%), and low stocking rate forest (Fmo) 4%.

Areas of *Casuarina cunninghamiana–Eucalyptus deglupta* forest, although not now classed as commercial (trees <5 ft girth), may well be soon because of rapid growth of eucalypts. Access considered good throughout except for minor limitations imposed by small areas of poor soil drainage and variable frequency of flooding.

Agricultural Assessment.—Overall capability probably high for improved pastures and irrigated rice, moderate for arable crops, low for tree crops. Flooding is serious limitation in only small areas along major rivers and near coast. Drainage deficiencies are main limitation, particularly for tree crops and least for pastures. Rather high pH and locally limited soil depth are added limitations for tree crops. Best land is on well-drained, less clayey but commonly rather infertile soils on lower and middle terraces and parts of flood-plain. Drainage improvement by land reclamation might be rather difficult and costly, or be rather ineffective because of slow soil permeability.

Engineering Assessment.—Topographically very suitable for road construction. By virtue of its distribution Pual deserves special attention in planning of regional road connections. Bridging larger rivers would be costly and could involve foundation problems. Low-level floodway crossings would be suitable for many streams. Adequate roadside drainage needs to be provided, and roadways might have to be slightly raised in places to reduce or prevent flooding. Most soils are not very suitable or unsuitable as road-building material but subsurface supplies of sandy and gravelly soils are likely to be common. Except for lowermost stretches, river beds are rich in hard gravel.

Soils mainly CH, MH, and CL, with ML, SP, SM, and GS common in subsoils on lower and middle terraces and in scroll plains; very deep.

(11) Pagei Land System (93 sq miles)

Land Forms (Plates 7, 10, 14).—Extensive flat to very gently sloping alluvial fans and fan remnants mainly along north front of Bewani Mountains. Some smaller intermontane fan remnants also occur in mountainous areas. Gradient of fans in most cases is less steep than gradients of present rivers. Thus relative height of fans decreases from fan front where it is *c.* 100 ft to mountain front where it is 15 ft or less. In some areas fans merge with recent flood-plains. At least two distinct levels of fans can be recognized on photos. Ground observations show that there are more levels but as they differ by only a few feet they cannot be traced on air photos. Closed depressions are frequent where fans are extensive. The fans are bound by very steep short marginal slopes.

Terrain Parameters.—Altitude: 300–600 ft. Relief: nil (3 ft). Characteristic slope: very gentle (1°). Grain: —.

Streams and Drainage.—Fans mostly ill drained; large areas with no drainage have resulted in numerous swamps, the larger ones of which have been mapped as Nabes (14). Only main rivers draining mountains have cut into the fans and cross them. These main streams have very few short tributaries from the fan areas. Some gullies occur at the margins but have nowhere cut back significantly. Gradients of through-going rivers are Pulan 1 : 250, Puwani 1 : 130, and Bewani 1 : 125.

Geology.—Stratified partly cross-bedded silt and sand layers with some gravel beds unconformably overlie blue-grey marl and mudstone of Pliocene age.

Vegetation.—Largely tall forest with open canopy with scattered light-toned crowns and dense understorey (FodD); similar but smaller-crowned forest (FosD) in very badly drained areas comprises about 30% of land system.

Tall forest with irregular canopy with or without scattered light-toned crowns (Fid, Fi) and mid-height forest with irregular canopy (Fmi) occur on intermontane fan remnants.

Soils (12 obs.).—On fan surfaces soils tend to become more developed from south to north, away from the mountain front, although this is by no means precisely related to distance. Further from the mountains soils are very strongly developed, strongly acid, deep to very deep, well drained, fine-textured, moderately permeable, and have in some cases a coarser-textured surface layer. On middle fan sectors soils are less strongly developed, commonly less acid, and generally slowly permeable and imperfectly drained, tending to have more pronounced coarser-textured surface soil. In an example of two different fan levels, with only a few feet difference in height, soil on higher surface was much more developed than on lower surface.

Close to mountain front three different soils were observed: firstly, an undeveloped, weakly acid, rapidly permeable, moderately deep soil with medium- over coarse-textured layers indicating that some fan deposits near mountain front are very young indeed; secondly, and probably most representative, a moderately developed acid soil in which texture changes from fine to coarse with depth; thirdly, a poorly drained, slowly permeable, very fine-textured soil with coarser-textured surface soil which is probably typical for intercalated clayey sediments. This soil appears to be transitional to soils on Nabes (14).

Soils on very steep marginal slopes are likely to be similar to those in Punwep (13), although slightly developed and undeveloped soils are probably more common.

Nitrogen contents generally low, ranging from very low to moderate. Phosphate and potash very low on fan surfaces, although some higher potash contents were found nearer to mountain front. Both nutrients are low to moderate on very steep marginal slopes.

Population and Land Use.—Population of 315 distributed over 4 villages, all close to Pagei Patrol Post. About 4–5% of the area is used for gardening; sago collected from Nabes (14).

Forest Resources.—Very high. Very high stocking rate forest (FodD) covers 62%, high stocking rate forests (FosD, Fi, Fid) cover 34% (29%, 3%, 2%), moderate stocking rate forest (Fmi) covers 1%. Access is generally good except in more poorly drained parts which usually carry FosD forest. Intermontane fans generally encircled by less accessible land systems with steep slopes.

Agricultural Assessment.—Apart from a few short marginal slopes there are no topographic limitations. Strong acidity and very low fertility of most fan-surface soils are main limitations for arable crops and improved pastures. Fertility is somewhat higher on upper fan sectors near mountain front, but here stoniness is a common slight to moderate limitation. Possibly there are slight erosion hazards for arable crops. Many soils have poor physical condition and drainage deficiencies, particularly important limitations for tree crops. Thus overall capability is estimated to be moderate for arable crops and tree crops, high for improved pastures. Possibly there are problems in providing water for cattle. Land is generally too uneven and too high above river levels for irrigated rice.

Engineering Assessment.—No topographic problems in road-building, apart from difficulties in negotiating very steep short marginal slopes. Roadside drainage is generally necessary. Road cuts are easily made in very deep soils and are likely to be fairly stable. Soil materials are moderately to poorly suitable as subgrade; road-surfacing materials probably restricted to some gravel and boulders in upper fan sectors. Much suitable gravel, however, occurs in wide stream beds in nearby Papul (8) and Pual (10).

Soils are mainly CH (MH for friable red soils in northern sectors), commonly with a thin veneer of MH to CL; some MH, CL, and subsurface SP and GC on fan surfaces near mountain front; very deep.

(12) Luap Land System (59 sq miles)

Land Forms (Plates 7, 10, 14).—Slightly dissected fans and undulating intermontane alluvial plains. Fans and plains have very gentle to gentle slopes; steep frequently slumped slopes only at the margins.

Terrain Parameters.—Altitude: 240–540 ft. Relief: very low (90 ft). Characteristic slope: very gentle (1°30′). Grain: fine (650 ft).

Streams and Drainage.—Drainage rather poor to good. Branching system of first- and second-order streams has cut back into fan front causing backward erosion and retreat of front. No ground observations made along streams.

Geology.—Stratified partly cross-bedded silt and sand layers with some gravel beds unconformably overlie blue-grey Pliocene marl and mudstone.

Vegetation.—Tall forest with an open canopy with scattered light-toned crowns and dense understorey (FodD) covers about two-thirds and probably indicates rather poor drainage. A number of tall forest types with irregular canopies (Fid, Fisd, Foid) cover remaining better-drained parts.

Soils (3 obs.).—Probably include most of those described for Pagei (11) and Punwep (13) except for the slightly developed soils near mountain front.

Population and Land Use.—Nil.

Forest Resources.—Very high. Very high stocking rate forest (FodD) covers 64%, high stocking rate forests (Foid, Fisd, Fid) 35% (22%, 8%, 5%), moderate stocking rate forest (Fmi) 1% and confined to steeper margins. Access is generally good except in minor areas of poor soil drainage and on margins where, although slopes are steep, relief is very low.

Agricultural Assessment.—Mainly because of greater proportion of steep slopes than in Pagei (11), capability is low for arable crops, moderate for improved pastures. Since this factor is a lesser limitation for tree crops and soil drainage is generally better than in Pagei (11), capability for tree crops is still assessed as moderate.

Engineering Assessment.—Intermediate in road construction problems and soil conditions between Pagei (11) and Punwep (13).

(13) Punwep Land System (34 sq miles)

Land Forms (Plate 10).—Strongly dissected fan remnants form very fine-grained pattern of very low hills and short ridges. Ridge crests and hill tops are very narrow and frequently flat topped. Summit level is even, indicating a former continuous fan surface. Slopes are very steep and straight to slightly convex. Gullies have cut back into lower slopes often exposing underlying Pliocene marl–mudstone beds.

Terrain Parameters.—Altitude: 240–540 ft. Relief: very low (90 ft). Characteristic slope: very steep (35°). Grain: very fine (400 ft).

Streams and Drainage.—Well drained by a dense branching system of first- and second-order streams draining into Pual River.

Geology.—Stratified partly cross-bedded silt and sand layers with some gravel beds unconformably overlie blue-grey marl and mudstone of Pliocene age. Marl and mudstone frequently crop out at lower to middle slopes.

Vegetation.—Tall forest with a rather open irregular canopy with scattered light-toned crowns (Foid) covers northern extremity of fans. Mid-height forest with an irregular canopy (Fmi) occurs at foot of Bewani Mountains.

Soils (4 obs.).—On steep slopes of fans are weakly acid, moderately deep to deep, well-drained soils, partly very slightly developed, moderately permeable and fine textured, partly moderately developed, slowly permeable and fine to very fine textured with somewhat coarser-textured surface soils; on marl poorly drained, shallow, very slowly permeable, very fine textured.

On flat-topped crests soils are reminiscent of but less developed than on intact fan surfaces—weakly acid to acid, moderately deep to deep, slowly to very slowly permeable, very fine textured with somewhat coarser-textured surface soils.

Nitrogen contents are low, but moderate in a few poorly drained soils; phosphate is low to moderate on steep slopes, very low on fan-surface remnants; potash is moderate to low.

Population and Land Use.—Nil.

Forest Resources.—High. High stocking rate forest (Foid) on 60% and moderate (Fmi) on 40%. Access is generally poor due to very steep slopes; however, this is alleviated by very low relief.

Agricultural Assessment.—Because of topographic limitations, only low capability for tree crops and improved pastures.

Engineering Assessment.—Although road construction will be severely hampered by strong dissection and steep slopes, no great height differences need be negotiated. North–south roads can often follow even crests for rather long distances, but east–west roads would be much more difficult. Road cuts can be made with little effort and are probably fairly stable, except when made in underlying marl. Useful gravel is probably rare but can sometimes be found in nearby rivers. Fan deposits may be moderately suitable for fill, and in some cases for subgrade.

Soils are nearly all CH near surface, but probably CL to SC subsoils on steep dissection slopes; very deep to moderately deep.

(14) Nabbs Land System (4 sq miles)

Land Forms (Plate 10).—Permanent swamps in closed depressions on fan surfaces.

Terrain Parameters.—Altitude: 390–540 ft. Relief: nil. Characteristic slope: nil. Grain: —.

Streams and Drainage.—Swamps are local drainage basins for parts of fans but have no outlet streams. Most land is probably permanently inundated up to one foot.

Geology.—Recent clay overlying fan deposits.

Vegetation.—Sago palm vegetation (M), commonly exploited (MR), covers the whole area.

Soils (1 obs.).—Moderately developed, acid to strongly acid, moderately shallow, very poorly drained, very slowly permeable, very fine-textured soils. Nitrogen contents are probably high to moderate, phosphate and potash are moderate to low.

Population and Land Use.—Unpopulated. Extensively used for sago exploitation.

Forest Resources.—Nil. Access is poor due to combined factors of poor soil drainage and in parts long inundation.

Agricultural Assessment.—Poor drainage, inundation, and poor physical soil conditions mean low capability for improved pastures only. With some improvement in water control, capability for (mainly rain-fed) wet rice appears high. Land reclamation by drainage improvement likely to be rather difficult and would increase capability for arable crops to moderate, for improved pastures to high.

Engineering Assessment.—Should and can be avoided for road and other construction purposes. Land reclamation may involve construction of run-on intercepting ditches along margins, and larger drainage channels to gullies or streams in surrounding Pagei (11).

Soils are CH; very deep.

(15) Isi Land System (229 sq miles)

Land Forms (Plates 6, 8, 9, 11).—Very low and in places ultra-low hills and ridges mostly rising from alluvial plains. Ridges generally form irregularly branching pattern, slopes moderately steep to steep and frequently slumped causing locally great differences in slope steepness. Slumps are mainly on lower and middle slopes; some also on upper slopes causing knife-edged steep-sided ridge crests. Slumps have commonly 15–24-ft high back walls and 18–24-ft wide slump benches. Upper slopes are generally convex, middle and lower slopes concave. Ridge crests are very narrow, locally narrow, some flat topped. Crestal slopes are uneven but summit level of ridge crests and hill tops is rather even. Gullies cut back into middle slopes and are 6–18 ft wide, 3–18 ft deep, 75–90 ft apart. Size of gullies increases downslope.

Terrain Parameters.—Altitude: 15–300 ft. Relief: ultra-low and very low (30–120 ft). Characteristic slope: moderately steep (14–17°). Grain: very fine (360 ft).

Streams and Drainage.—Dense irregular pattern of small streams mostly of first and second order. Larger streams are mapped out separately as Basu (7). Most stream gradients are 2–3°.

Geology.—Pliocene marl and mudstone.

Vegetation.—Tall forest with a rather open irregular canopy with scattered light-toned crowns (Foid) covers about three-quarters; on the remainder is less open forest (Fid).

Soils (14 obs.).—Very fine- to fine-textured and nearly always slowly to very slowly permeable soils. Most are moderately shallow, locally moderately deep. Shallow soils are confined to some very steep slopes. Soils are generally well drained, locally imperfectly drained, and on slump benches poorly drained. Soil reaction varies with weathering from alkaline to strongly acid. More acid, moderately to strongly developed soils tend to occur on crests, upper slopes, and slumped slopes. More alkaline, slightly to moderately developed soils tend to dominate on lower and steepest slopes.

Low to moderate soil nitrogen contents that tend to be highest on moderate slopes; phosphate is low to very low; potash is high to very high and tends to be highest on lower and steeper slopes, lowest on upper slopes.

Population and Land Use.—Population of 285 distributed over 3 villages. These are situated near Ossima on narrow ridges near sago-supplying valley floors of Kabuk (4). About 3% of land system used for gardening.

Forest Resources.—High. High stocking rate forests (Foid, Fid) cover 92% (77%, 15%), remainder is stocked by small areas of various forest types including secondary forest. Access is moderate, main limitations being moderately steep slopes and minor areas of imperfect to poor drainage on slump floors.

Agricultural Assessment.—Very low capability for arable crops and moderate capability for improved pastures, topography being main limitation. Pasture establishment may be difficult on very clayey soils, but would probably provide best possible protection against slumping and soil creep. Control of gullying requires special attention. Slow permeability and local drainage deficiencies and soil alkalinity reduce capability for tree crops to low.

Engineering Assessment.—Instability of slopes, particularly when cut by roads along contour and absence of suitable road-building materials are major problems in road construction. Much culverting needed but rarely substantial bridges.

Soils are mainly CH, rarely MH; generally moderately deep to shallow, with deep to very deep soils only on slump and valley floors.

(16) Fivuma Land System (160 sq miles)

Land Forms (Plates 11, 13, 17).—Long subparallel to dendritic hill ridges with very short fine-grained spurs. Ridge crests are very narrow, locally knife edged and undulating, occasionally stepped; some are flat topped. Summit level of ridge crests in tectonically little-disturbed areas is relatively even, indicating that ridges are remnants of rather flat surface, in some areas related to high fan surfaces. Side slopes are mostly steep to very steep. Frequent slumping causes locally great variety in slopes ranging from gentle slopes at slump benches to very steep slopes (up to 50°) at slump backs. Gullying is very common: gullies mostly cut back into middle slopes and regularly occur in connection with slumps. Gullies are 90–150 ft apart, 5–15 ft deep, in extremes up to 30 ft.

Terrain Parameters.—Altitude: 60–900 ft. Relief: low (240 ft). Characteristic slope: very steep (35°). Grain: fine (720 ft).

Streams and Drainage.—Subparallel to branching streams up to third order mostly flowing in beds cut into soft bed-rock.

Surprisingly high amount of coarse basement gravel in beds of larger streams, although there is no basement known to occur in catchment areas. Hardly any basement gravel in Pliocene beds which occupy the whole land system. It probably derived from former fans which in early and middle Pleistocene covered most of intermontane lowlands. First-order streams have gradients between 1 : 20 and 1 : 60, second- and third-order streams have high and low gradients respectively. Widths of stream beds vary between 9–15 ft (first order) and 60–90 ft (third order).

Geology.—Pliocene marl, mudstone, and siltstone (calcareous and non-calcareous); locally some reef limestone is intercalated. Beds are generally little disturbed.

Vegetation.—Tall forest with a rather open irregular canopy with light-toned crowns (Foid) and related type with a less open canopy (Fid) cover 87%; remainder is mainly secondary vegetation (R–FR).

Soils (9 obs.).—Fine to very fine-textured and mainly slightly to moderately developed and moderately deep soils, shallow to moderately shallow near crests and on steeper slopes. Some almost undeveloped deep soils are on slumped slopes. Soil permeability is slow to moderate but soils are well drained except on some imperfectly to poorly drained slump benches and floors. Soil reaction is predominantly alkaline to neutral but moderately to strongly developed, weakly acid to acid soils are common on upper slopes, probably due to increased weathering.

Nitrogen contents are generally moderate, locally low; phosphate is generally low but moderate on some slumped slopes; potash is high and even very high on some slumped slopes.

Population and Land Use.—Population of 407 distributed over 3 villages, all near Ossima and in similar locations to villages in Isi (15). Present land use is restricted to close environment of villages and amounts to about 9%; sago is collected from nearby Kabuk (4).

Forest Resources.—High. High stocking rate forests (Foid, Fid) cover 87% (83%, 4%), remainder carries secondary forest and minor areas of various forest types. Access is poor with limitations imposed by steep or occasionally very steep slopes and minor areas of imperfect to poor drainage on slump floors.

Agricultural Assessment.—Only low capability for improved pastures because of very steep slopes. Common neutral to alkaline soil reaction, local shallow soil depth and slow permeability, and risks of superficial slumping reduce capability for tree crops to very low.

Engineering Assessment.—Apart from minor limestone cobbles south of coastal range there are no suitable road-building materials. Very steep and commonly unstable slopes, fine grain and dense stream net, and relief of 240 ft are considerable obstacles to road-building. Most streams, however, are small enough to be negotiated with culverts.

Soils are mainly CH, locally MH or CL; mainly moderately *deep to shallow, but can be deep on colluvium.*

(17) Muru Land System (41 sq miles)

Land Forms (Plate 12).—Asymmetric (homoclinal) ridges with mostly steeper north-facing slopes (outcrop slopes) and gentler south-facing slopes (dip slopes). Outcrop slopes are very steep, straight to concave, and short. Dip slopes are moderately steep and relatively straight and long. Ridge crests are straight and very narrow to knife edged. Slumps are less frequent on outcrop slopes than on dip slopes. Creeks have cut back into lower slopes of outcrop slopes and into middle or upper slopes of dip slopes, causing extremely irregular secondary relief (up to 30 ft). Gullies are between 15 and 30 ft deep, 12–15 ft wide, 60 ft apart.

Terrain Parameters.—Altitude: 90–900 ft. Relief: low (250 ft). Characteristic slope: outcrop slope, very steep (42°); dip slope moderately steep (16°). Grain: medium (1700 ft).

Streams and Drainage.—Frequently pattern of short streams draining outcrop slopes and longer streams draining dip slopes. Much basement gravel found in beds of larger rivers probably deriving from former fans (see Fivuma (16)).

Geology.—Pliocene marl and mudstone forming dip slopes, hard *sandstone beds forming outcrop slopes.*

Vegetation.—Tall forest with a rather open irregular canopy with scattered light-toned crowns (Foid) covers more than half, forest with a less open canopy (Fid) covers most of remainder. Mid-height forest with a rather open irregular canopy (Fmoi) occurs on highest crests and upper slopes.

Soils (5 obs.).—Mostly acid soils, weakly acid on irregular slumped slopes, and moderately developed, with greatest soil *development on dip slopes. Soils also moderately shallow to* moderately deep, mostly slowly to very slowly permeable, and very fine to fine textured. On relatively undissected dip slopes are poorly to imperfectly drained, on slumped irregular dip slopes imperfectly to well-drained soils. Moderately permeable well-drained soils of medium texture occur on outcrop slopes.

Nitrogen contents are low, in cases moderate on dip slopes; phosphate ranges from very low to moderate, but mostly low; potash is high in soils on marl, moderate to low in soils on sandstone.

Population and Land Use.—No population and land use insignificant.

Forest Resources.—High. High stocking rate forests (Foid, Fid) cover 95% (56%, 39%), moderate stocking rate forests (Fmoi, FR) the remainder (2%, 3%). Access is moderate, main limitations are very steep outcrop slopes and imperfect to poor drainage on dip slopes.

Agricultural Assessment.—Because of topographical limitations, poor physical soil conditions, commonly including impeded drainage, area is virtually useless for arable cropping and has low capability for tree crops. Capability for improved pastures is *probably moderate.*

Engineering Assessment.—Road construction is difficult due to steep slopes, irregular microrelief of gullies and slumps, instability of road cuts, and scarcity of road-building materials. Limited amounts of suitable gravel occur only in a few larger streams. Interbedded sandstone could be moderately suitable as fill and subgrade. However, low to moderate relief and rather regular alignment of ridges would facilitate construction of roads in a north-west to south-west direction.

Soils are CH, rarely MH, CL; generally moderately deep, rarely shallow.

(18) Yassip Land System (5 sq miles)

Land Forms (Plate 13).—Very low irregularly branching ridges with very narrow to narrow gently sloping crests and moderately steep to steep side slopes, with local slumps and slump benches.

Terrain Parameters.—Altitude: 150–600 ft. Relief: low (120–240 ft). Characteristic slope: steep (30°). Grain: medium (1200 ft).

Streams and Drainage.—Dense dendritic to subparallel patterns of small streams, of which first and second order probably have intermittent flow. Gradient is low except for first-order streams. Most streams flow in rock-cut beds. The land system is well drained.

Geology.—Interbedded Pliocene siltstone, mudstone, and sandstone.

Vegetation.—Tall forest with a rather open irregular canopy (Foi) and tall forest with a rather open irregular canopy with light-toned crowns (Foid) cover equal areas.

Soils (0 obs.).—Probably slightly to moderately developed, neutral to weakly acid, moderately shallow to moderately deep, moderately to slowly permeable, fine to very fine-textured soils. Some strongly developed, strongly acid, but otherwise similar soils with somewhat coarser-textured surface soils may occur on some crests.

Nitrogen contents are probably low to moderate, phosphate low to very low, potash high to moderate.

Population and Land Use.—Nil.

Forest Resources.—Very high. Very high stocking rate forest (Foi) and high stocking rate forest (Foid) each cover 50%. Access is moderate with limitations due to steep and rarely very steep slopes.

Agricultural Assessment.—Because of steep slopes capability is very low for arable crops, low for tree crops, moderate for improved pastures. Since terrain is not very rugged and of low relief, some development for mixed farming or grazing could be justified.

Engineering Assessment.—Topographic problems for road construction are relatively small. particularly since road cuts can be made rather easily in the soft rocks and are likely to be rather stable. No road-building materials but they could be obtained from adjoining Barida (33). Only local access roads would ever be required.

Soils are mainly CH, mostly moderately deep to shallow, but very deep soils also common.

(19) Morumu Land System (35 sq miles)

Land Forms (Plate 14).—Dendritic to subparallel pattern of moderately high short ridges. Summit level is relatively even; crests narrow, but some flat-topped older surface remnants probably represent a former fan surface. Side slopes are irregular, ranging from moderate to very steep, due to frequent slumping. Slump floors are 100–4000 sq ft; back walls 10–50 ft high.

Terrain Parameters.—Altitude: 150–750 ft. Relief: moderate (350 ft). Characteristic slope: very steep (35°). Grain: very fine (480 ft).

Streams and Drainage.—Dense angular pattern of small streams with low to high gradients. Streams flow in narrow valleys with no flood-plains. Stream beds contain little gravel. Well drained, but imperfectly drained pockets occur in slumps due to the slow permeability of rocks.

Geology.—Interbedded Pliocene siltstone, mudstone, sandstone, locally some limestone, generally steeply dipping. Sediments are the youngest that have been strongly faulted during orogenesis of Bewani Mountains.

Vegetation.—Tall forests, mainly with a rather open irregular canopy with scattered light-toned crowns (Foid), cover about two-thirds. Remainder is covered with mid-height forests with irregular canopies, mainly of more open type (Fmoi).

Soils (9 obs.).—On predominating very steep slopes mainly moderately developed, acid to weakly acid, moderately deep to shallow, well-drained, fine-textured, and moderately permeable soils. On slump floors soils tend to be somewhat less developed, neutral to alkaline in reaction, slowly permeable, somewhat deeper, and commonly poorly drained; can have coarser-textured surface soils.

On crests and moderate upper slopes soils are partly similar to those on steep slopes, partly more strongly developed, acid, moderately deep, slowly permeable, fine textured with coarser-textured surface soils; can be imperfectly drained. On a few old surface remnants soils are very strongly developed, strongly acid, very deep, well drained, fine textured, but moderately permeable.

On limestone, very locally interbedded with clastic sedimentary rocks, occur shallow dark soils that are typical for this rock (see Musu (34), Kohari (35), Serra (36).

Nitrogen contents are low to moderate, but high on limestone; phosphate is very low to low, but moderate on limestone; potash is mostly moderate to high, but high to very high on slump floors and very low in the chemically very infertile soils of old surface remnants.

Population and Land Use.—Nil.

Forest Resources.—High. Very high stocking rate forest (Foi) covers 4%, high stocking rate forest (Foid) 64%, moderate stocking rate forests (Fmoi, Fmi) 32% (27%, 5%). Access is generally poor due to steep to very steep slopes and poor drainage on slump floors.

Agricultural Assessment.—Mainly because of topographic limitations capability is virtually nil for arable crops, low for improved pastures. Because of local soil alkalinity, poor drainage, limited soil depth, and steep slopes capability is low for tree crops.

Engineering Assessment.—Because of difficult topography and instability of slopes and road cuts Morumu difficult for road construction, but can generally be avoided. Road-building materials are restricted to rare conglomerate and limestone beds. Some fresher sandstone at depth may be moderately suitable as sub-grade.

Soils are mainly CH, but also MH and CL; shallow to moderately deep.

(20) Puari Land System (56 sq miles)

Land Forms (Plate 12).—Irregular pattern of moderately high to high ridges with short spurs. Ridge crests are broad and often flat-topped. Prominent slumps are characteristic feature throughout. Slump back walls are 10–100 ft high, slump floors range from a few square feet to several thousand square feet. Side slopes are concave and very steep, and slump back walls precipitous. Surface of crests is undulating to stepped; summit level, however, is rather even. Lower slopes are densely dissected by gullies.

Terrain Parameters.—Altitude: 150–900 ft. Relief: moderate (300–600 ft). Characteristic slope: very steep (37°). Grain: medium (1400 ft).

Streams and Drainage.—Wide pattern of larger streams cut into broad alluvium-filled valleys. Tributaries mostly short and of second and first order. Considerable amount of coarse gravel in river beds as well as in terraces. Two terrace niveaux observed: higher terrace 7·5–9 ft above present low-water level, lower terrace 3–4·5 ft above present low-water level. Larger streams have low to high gradients (Basu River 1 : 400).

Geology.—Pliocene marl and mudstone throughout.

Vegetation.—Originally tall forest with rather open irregular canopy with scattered light-toned crowns (Foid). Now over about 40%, comprising nearly whole of western occurrence, secondary forest (FR) is frequent. In eastern occurrence some tracts of tall forest with rather open irregular canopy with scattered *Albizia* (FoiA) are also old secondary forest.

Soils (1 obs.).—Fine- to very fine-textured and mainly slowly permeable. Undeveloped to slightly developed, moderately deep, neutral to weakly acid soils likely to occur on colluvial material of slumps, with very shallow weakly alkaline soils on slump walls and imperfectly to poorly drained soils common on slump floors. On slopes with rock *in situ*, soils probably slightly to moderately developed, moderately shallow to moderately deep, and weakly alkaline to weakly acid; commonly imperfectly drained. Soils on terraces probably similar to those described for flood-plain and low terrace in Basu (7).

Nitrogen and phosphate contents are likely to be low, potash mostly high.

Population and Land Use.—One village with 41 people. Land use is negligible, but was rather intensive in the past judging by widespread occurrence of secondary forest.

Forest Resources.—High. High stocking rate forests (Foid, FoiA) cover 60% (38%, 22%), moderate stocking rate forest (Foid/FR) 36%. Access, however, is very poor due to very steep slopes and to a minor extent poor soil drainage on slump floors.

Agricultural Assessment.—Due to topographic limitations, unstable slopes, and rather unfavourable soil conditions there is only low capability for improved pastures.

Engineering Assessment.—Very difficult terrain for road construction, but can easily be avoided. Any roads would be best located on lower slopes and terraces along larger streams which contain some useful gravel.

Soils probably nearly all CH; probably shallow to moderately deep on rock *in situ*, moderately deep to deep on colluvium.

(21) Puive Land System (21 sq miles)

Land Forms (Plate 15).—Irregular pattern of broad ridges with moderate to moderately steep side slopes and moderately steep to steep crestal slopes. Side slopes generally long, often with superimposed hummocky to ridgy secondary relief. Ridge crests narrow to broad. Slumps frequent, slump benches up to 150 ft wide. Gullies often occur near upper slopes 4·5–6 ft deep, 6–12 ft wide, 150–180 ft apart, often connected with slumps. On low and middle slopes are gullies 90–120 ft apart, 10–18 ft deep. Limestone boulders scattered over slopes originate from limestone areas (Jassi (31), Musu (34), Serra (36)) which rise steeply at northern margin of land system.

Terrain Parameters.—Altitude: 300–900 ft. Relief: moderate (400 ft). Characteristic slope: moderate (15°). Grain: coarse (2400 ft).

Streams and Drainage.—Larger meandering streams with beds 60–90 ft wide, cut into soft bed-rock. Stream beds have great amount of coarse limestone gravel (up to 10 in. diam.). Tributaries are short and of first to second order; mostly they flow perpendicularly into main streams and are more or less parallel to each other; very gentle to gentle slopes. Main streams have very high gradients (Piore River 1 : 75). First- and second-order streams have beds up to 15 ft wide, also cut into the bed-rock; they do not transport much limestone gravel.

Geology.—Pliocene marl, mudstone, and siltstone in places overlain by limestone detritus. As these beds are at transition from Pliocene limestone facies to Pliocene marl facies the lithology varies greatly from place to place.

Vegetation.—Tall forest with rather open irregular canopy with light-toned crowns (Foid) in some areas mixed with secondary vegetation, mainly forest (FR), covers about 80%; remainder occupied by less open forest (Fid).

Soils (5 obs.).—Slightly developed, neutral to weakly alkaline, shallow, well-drained, slowly permeable, and very fine-textured. Moderately deep, but otherwise similar soils associated with mass movement on slopes.

Nitrogen contents moderate, phosphate low, potash high to very high but moderate in some colluvial soils.

Population and Land Use.—One village with 153 people. Gardening along river where village is situated and swampy patches used for sago exploitation.

Forest Resources.—High. High stocking rate forests (Foid, Fid) cover 87% (66%, 21%), moderate stocking rate forest (Foid/FR) covers 8%. Access good and only limited by minor occurrences of steep slopes.

Agricultural Assessment.—Because of adverse topography and very clayey soils capability is nil for arable crops. Although topographically somewhat more suitable for tree crops, capability very low because of rather alkaline, shallow, slowly permeable soils. Moderate capability for improved pastures.

Engineering Assessment.—Although serious, topographic problems in road-building are alleviated by presence of long moderately steep slopes which are, however, irregular in detail.

Although slopes appear rather stable, road cuts in soft marl and mudstone may prove liable to landslides. Soils and rocks are unsuitable as road-construction materials but there is useful gravel in larger streams. Road-building material plentiful in limestone areas adjoining the land system in west, north, and east.

Soils CH; shallow to moderately deep, but can be deep on colluvium.

(22) Numoiken Land System (119 sq miles)

Land Forms (Plates 6, 13–15, 18).—Short to very short commonly spurred or grooved ridges with knife-edged to narrow crests; side slopes generally very steep but frequent slumping causes locally great variations. Microrelief very irregular, up to 6 ft.

Terrain Parameters.—Altitude: 300–1200 ft. Relief: moderate (400 ft). Characteristic slope: very steep (37°). Grain: fine (900 ft).

Streams and Drainage.—Dendritic pattern of mainly small to medium-sized streams with high gradients. Streams flow in narrow valleys in rock-cut beds. Generally well drained.

Geology.—Pliocene to Miocene interbedded siltstone and sandstone, calcareous in places, with minor intercalations of conglomerate.

Vegetation.—Areas at foot of the Torricelli and Bewani Mountains, comprising about two-thirds, are covered with mid-height forests, usually with irregular and often rather open canopy (Fmi, Fmoi), in some areas replaced by secondary forests (FR, FmA). Other occurrences are tall forest, usually with rather open irregular canopy with light-toned crowns (Foid), occasionally with less open canopy (Fid, Fisd), and locally of secondary status (FR).

Soils (3 obs.).—Well-drained, moderately permeable; probably mostly very slightly to moderately developed, neutral to weakly acid, fine- to medium-textured. Generally deep to very deep in colluvial material on slumped slopes, but moderately shallow on rock *in situ*. Moderately developed, moderately shallow to deep, acid, fine-textured soils common on upper slopes and crests, in places strongly developed with a somewhat coarser-textured surface soil.

Nitrogen contents low, phosphate very low to low, potash high and in some cases very high, but lower figures also likely.

Population and Land Use.—Nil.

Forest Resources.—Moderate. High stocking rate forests (Foid, Fid, Fisd) cover 33% (26%, 4%, 3%), moderate stocking rate forests (Fmi, Fmoi, Fmv) cover 58% (32%, 24%, 2%), moderate stocking rate secondary forest (FR) covers 5%. Access poor due to large proportion of steep to very steep slopes.

Agricultural Assessment.—Because of rugged topography capability is nil for arable crops, very low for tree crops and improved pastures.

Engineering Assessment.—Because of steep, often unstable slopes, high relief, and irregular ridge pattern road construction would be very difficult. Can generally be avoided in road traverse planning but a road link between Lumi and Vanimo might have to traverse small sectors in south-east of area. Weathered rock is very easy to remove in road cuts, and even fresh rock on lower slopes would generally not require ripping. Coarser-grained rocks may be suitable for subgrade, but there is little or no road-surfacing material.

Soils MH, CH, less CL; mostly moderately deep, less commonly shallow or deep.

(23) Musak Land System (7 sq miles)

Land Forms (Plate 13).—Strike ridges and hogbacks with straight steep dip slopes and short very steep to precipitous outcrop slopes. Crests knife-edged to very narrow, slumping common.

Terrain Parameters.—Altitude: 450–1200 ft. Relief: moderate to high (240–750 ft). Characteristic slope: very steep (30°). Grain: medium (1100 ft).

Streams and Drainage.—Dense but rather disorganized pattern of small streams partly parallel to the strike. Few through-going streams and gradients are mostly high, streams flow in rock-cut beds. Well to excessively drained.

Geology.—Miocene to Pliocene interbedded siltstone, sandstone, conglomerate with moderate to steep dips.

Vegetation.—Two-thirds carries tall forest with rather open irregular canopy with scattered light-toned crowns (Foid); remainder, at higher altitudes, mid-height forest with irregular canopy (Fmi).

Soils (0 obs.).—On dip slopes probably moderately developed acid, moderately shallow, fine-textured, with somewhat coarser-textured surface layers; on outcrop slopes slightly to moderately developed, neutral to weakly acid, shallow to moderately shallow, fine- to medium-textured. Permeability generally moderate but may be slow on dip slopes, where some soils are also imperfectly drained. Probably some moderately deep to deep soils occur on slumped lower slopes.

Nitrogen contents probably low to moderate, phosphate very low on dip slopes, variable on outcrop and other slopes, potash probably mostly high to moderate.

Population and Land Use.—Nil.

Forest Resources.—High. High stocking rate forest (Foid) covers 66% and moderate stocking rate forest (Fmi) covers 34%. Access very poor due to steep to very steep slopes.

Agricultural Assessment.—Due to its ruggedness and generally poor soils only very low capability for improved pastures.

Engineering Assessment.—Should and can be avoided in road planning. Could be minor source of gravel and subgrade materials for road construction in adjacent land systems.

Soils CH, MH, CL, with some ML and SC; shallow to deep.

(24) Flobum Land System (31 sq miles)

Land Forms (Plates 13, 16).—Massive low mountain ridges and mountain slopes with generally moderately steep densely spurred slopes. Strong mass movement has produced highly irregular secondary relief of 45–150 ft with an array of hummocks, slump alcoves, gullies, and ridges with local slopes varying from gentle to very steep.

Terrain Parameters.—Altitude: 600–3000 ft. Relief: high (900 ft). Characteristic slope: moderately steep (15°). Grain: fine (720 ft).

Streams and Drainage.—Fine- to coarse-textured pattern of usually subparallel main streams with subparallel to dendritic tributaries. All streams perennial, fast flowing, shallow. Gravel and boulders abundant, originating from basement mountains. Well drained.

Geology.—Miocene siltstone, mudstone, and sandstone, some conglomerate, locally intercalated limestone.

Vegetation.—Original vegetation probably largely mid-height forests with more or less open irregular canopies (Fmi, Fmoi), with mid-height forest with even canopy (Fmv) in higher parts. In south-eastern occurrence in the Torricelli Mountains, original vegetation replaced over large areas by secondary vegetation, and sago has been planted in suitable localities (R–FR/MR).

Soils (1 obs.).—Probably mostly undeveloped, acid to weakly acid, moderately deep to deep, moderately permeable, fine- to medium-textured. On small slump floors soils are imperfectly to poorly drained, elsewhere well drained. Probably very shallow soils on steepest slopes near crests, streams, and on slump walls. More developed, acid to strongly acid, moderately shallow to deep, fine-textured soils, partly with somewhat coarser-textured surface soils are likely to occur locally, mainly on upper slopes.

Nitrogen contents moderate to low, phosphate low to moderate in undeveloped soils, very low in more developed soils, potash mostly high to moderate.

Population and Land Use.—Population nil. Secondary forest and planted sago indicate former land use in the SE. corner.

Forest Resources.—Low. Moderate stocking rate forests (Fmi Fmv, Fmoi, FR) cover only 55% (29%, 15%, 9%, 2%). Access is moderate with limitations imposed by steep slopes and poor soil drainage on slump floors. However, much is isolated by less accessible country.

Agricultural Assessment.—Very low capability for arable crops because possibilities restricted to small patches of gentle to moderate slopes associated with slumps. Low capability for tree crops because of climatic limitations above 2000 ft, locally unfavourable soils, and unstable slopes, and general ruggedness and irregularity of terrain. These factors are less limiting for grazing, therefore moderate capability for improved pastures.

Engineering Assessment.—Because of moderately steep, long, overall slopes and widely spaced major streams, more suitable for road construction than any other mountainous and several high hilly land systems. Nevertheless, high relief, irregular and often unstable slopes, and scarcity of road-building materials (essentially confined to igneous gravel in stream beds) pose considerable problems. Construction materials likely to be available in adjoining Somoro (39).

Soils MH, CH, and also ML; moderately deep to deep, locally shallow.

(25) *Piore Land System* (158 *sq miles*)

Land Forms (Plates 16, 20).—Coarse-grained high dendritic ridges with broad rounded crests. Side slopes moderately steep and steep but very steep near main river courses. Upper slopes mostly convex, middle and lower slopes straight to concave. Ridge crests irregularly sloping with slopes between 5° and 50°. Due to frequent slumping connected with gullying, slopes are extremely irregular in detail. Gullies, 15–30 ft deep and wide, extend up to middle slopes. Microrelief can be as high as 30–45 ft. Terraces observed in several places, 15–30 ft above present stream beds, up to 90 ft wide, flat to very gently sloping.

Terrain Parameters.—Altitude 300–1500 ft. Relief: high (900 ft). Characteristic slope: steep (25°). Grain: coarse to very coarse (4000 ft).

Streams and Drainage.—Large rivers, including some main rivers of area, with subparallel to branching system of long tributaries with rather short tributaries of third to second order. Many river courses are fault controlled. Gradients of main streams high (Piore River 1 : 225), of larger tributaries very high (Mili River 1 : 80), of smaller tributaries probably gentle. Large amount of coarse to very coarse gravel in stream beds and on terraces. Dominant rocks limestone, basement, and volcanics.

Geology.—Mainly consolidated Eocene to Miocene siltstone, sandstone, and mudstone; some limestone and volcanics. Basement rocks occasionally form parts of lower slopes. Beds strongly faulted.

Vegetation.—Mid-height forest with even canopy (Fmv) has its major occurrences in this land system, on gentler topography at mid altitudes. Mid-height forests with irregular canopy (Fmi) and with rather open, irregular canopy (Fmoi) are the other more important types, at mid and higher altitudes. Secondary vegetation in extreme SE. corner of area. In Mili River region tall forest with irregular canopy with scattered light-toned crowns (Fid), sometimes with more open canopy (Foid) and mixed with secondary forest (FR) at lower altitude.

Soils (7 obs.).—All observations made in colluvial material or pre-weathered rock debris. In slightly weathered material soils are slightly developed, acid (sometimes weakly acid to neutral), deep to very deep, fine- to medium-textured, moderately permeable, commonly with much rock gravel in subsoil; in strongly weathered material soils are strongly to moderately developed, acid, deep to moderately deep, fine-textured and moderately but locally slowly permeable. All are well drained. Colluvium may consist of coarse limestone debris mixed with only a small amount of weakly alkaline clay.

Nitrogen contents moderate, phosphate low to moderate in little-developed soils, very low to low in well-developed soils; potash, varying from moderate to very high, is higher in less-developed soils and lower in more-developed soils.

Population and Land Use.—One village with 41 people at middle course of Piore River. Land use is on narrow terraces along river. In extreme SE. corner occurrence of secondary forest indicates former land use.

Forest Resources.—Moderate. High stocking rate forests (Foid, Fid) cover 9% (7%, 2%) in Mili River region; elsewhere, moderate stocking rate forests (Fmi, Fmoi, Fmv, Fm) cover 84% (41%, 23%, 19%, 1%). Moderate stocking rate secondary forest (FR) covers 3% in association with both occurrences. Access poor due to steep or, rarely, very steep slopes.

Agricultural Assessment.—Very low capability for arable crops because of topographic limitations, particularly very irregular microrelief. Moderate capability for tree crops and improved pastures.

Engineering Assessment.—Major problems for road-building are steep overall slopes, high relief, and apparent instability of many slopes. Microrelief will require almost continuous cut-and-fill operations and construction of many culverts. Although road-building material is limited to limestone outcrops and rubble, there is suitable igneous gravel in larger river beds which may present rather large problems in bridge construction. Despite this, road construction may be simpler than in surrounding land systems.

Soils mainly moderately deep MH and CH, but very shallow GC on limestone debris slopes.

(26) Wuro Land System (10 sq miles)

Land Forms (Plate 16).—Hogback mountain ridges with long steep dip slopes and short very steep outcrop slopes; slumps and gullies cause very irregular microrelief.

Terrain Parameters.—Altitude: 600–3000 ft. Relief: very high (1500 ft). Characteristic slope: very steep (37°). Grain: fine (600 ft).

Streams and Drainage.—Widely spaced parallel streams of second and third order, perpendicular to strike, up to 30 ft wide, cut into bed-rock. Small first-order tributaries mostly subparallel or parallel to strike. Well drained.

Geology.—Slightly consolidated Miocene siltstone, sandstone, and conglomerate. Beds dip steeply. Underlying basement locally exposed at lower slopes.

Vegetation.—Mid-height forests with irregular canopy (Fmi), with rather open irregular canopy (Fmoi), and with even canopy (Fmv) cover most. Mid-height forest with irregular canopy with scattered *Albizia* (FmA) on watershed of Torricelli Mountains.

Soils (1 obs.).—On dip slopes probably moderately developed, acid, moderately shallow, slowly permeable, and fine-textured with somewhat coarser-textured surface soils; on outcrop slopes probably less acid, very shallow to shallow, medium- to fine-textured; on irregular lower slopes moderately developed, acid, moderately deep, moderately permeable, fine-textured. All probably well drained except on slump floors.

Nitrogen contents likely to be moderate to low, phosphate low, but very low on dip slopes, potash high to moderate.

Population and Land Use.—Nil.

Forest Resources.—Low. Moderate stocking rate forests (Fmi, Fmoi, Fmv) cover 75% (33%, 24%, 18%). Access very poor, limited mainly by steep dip slopes, very steep outcrop slopes, and to a minor extent poor drainage on slump floors.

Agricultural Assessment.—Because of ruggedness and physically poor soils there is no significant land use capability.

Engineering Assessment.—Should and can be avoided for road construction. May contain some useful road-building materials; igneous rock on lowest slopes, some sandstone and conglomerate throughout.

Soils CH, MH, CL, with some ML and SC; very shallow to moderately deep.

(27) Sulen Land System (18 sq miles)

Land Forms (Plate 13).—Slumped and gullied mountain ridges with narrow crests and very steep side slopes.

Terrain Parameters.—Altitude: 600–3000 ft. Relief: high (900 ft). Characteristic slope: very steep (35°). Grain: medium to coarse (2000 ft).

Streams and Drainage.—Subparallel pattern of first-order streams flowing at right angles into frequently fault-controlled second-order streams which flow in rock-cut beds. Well drained.

Geology.—Eocene to Miocene sedimentary rocks. Some basement rocks probably also occur near the transition to Somoro (39).

Vegetation.—Occurrences at higher altitudes are covered with mid-height forests. Most prominent is mid-height forest with irregular canopy (Fmi), often mixed with seral stages (Fmi′), pointing to instability of the slopes as probably does mid-height forest with rather open irregular canopy (Fmoi). On crests forests have more even canopy (Fm, Fmv). Tall forest with rather open irregular canopy with scattered light-toned crowns (Foid) at lower altitudes.

Soils (0 obs.).—Likely to be slightly to moderately developed, acid, moderately shallow to moderately deep, and medium- to fine-textured, but probably shallow on steepest slopes. Permeability generally moderate, locally slow or rapid.

Nitrogen contents low, phosphate very low to low, potash mostly high.

Population and Land Use.—Nil.

Forest Resources.—Moderate. High stocking rate forest (Foid) covers 16%, remainder carries moderate stocking rate forests (Fmi, Fmoi, Fmv, Fm) over 42% (20%, 12%, 5%, 5%) and low stocking rate forest (Fmi/Fmi′) over 42%. Access very poor due to high proportion of very steep to steep slopes and, in many cases, topographic position.

Agricultural Assessment.—Too rugged and too wet for agricultural development.

Engineering Assessment.—Should and can be avoided in road planning. Could be source of road-building materials for a road between Lumi and the coast, to Vanimo and/or Aitape.

Soils CH, MH, CL; moderately deep to shallow, locally very shallow or deep.

(28) Ijapo Land System (43 sq miles)

Land Forms (Plate 18).—Very fine-grained pattern of dendritic low to moderate ridges, ridge crests being knife-edged to very narrow and irregularly sloping. Short, slightly concave to straight, in detail often stepped side slopes moderately steep to steep. However, local slumping causes variations and slopes between 3° (slump benches) and up to 40° can occur. Middle and upper slopes undissected, lower slopes dissected by some gullies.

Terrain Parameters.—Altitude: 300–1000 ft. Relief: low (250 ft). Characteristic slope: very steep (32°). Grain: very fine (350 ft).

Streams and Drainage.—Very fine-grained pattern of small streams of first to third order; some subterranean drainage through dolines. However, drainage system is mostly integrated. No field observations about stream beds.

Geology.—Eocene to Miocene sediments of very mixed lithology. Limestone seems to be dominant in most of the areas, volcanics and mudstone subdominant.

Vegetation.—Tall forest with irregular small-crowned canopy with scattered light-toned crowns (Fisd) covers 70%, remainder covered by larger-crowned forests (Fid, Foid).

Soils (3 obs.).—On volcanics and mudstone slowly permeable and very fine-textured, generally shallow, neutral, but in places weakly alkaline on lower slopes. Soil development moderate, or on lower slopes slight. On crests and upper slopes there can be somewhat coarser-textured surface soil and slightly impeded drainage. On slump benches on lower slopes a slightly to moderately developed, neutral to weakly alkaline, moderately deep, imperfectly drained soil was observed.

No soils on limestone were observed, but they would be similar to those described for Serra (36).

Nitrogen contents tend to be moderate to low, phosphate low, potash appears to be high to very high in slightly developed, low in moderately developed soils.

Population and Land Use.—Nil.

Forest Resources.—High. High stocking rate forests (Fisd, Foid, Fid) cover 100% (79%, 14%, 7%). Access poor due to very steep slopes.

Agricultural Assessment.—Because of very steep slopes, close dissection, and physically rather poor and/or shallow soils capability is only low for improved pastures.

Engineering Assessment.—Unlikely to be a demand for roads in foreseeable future. Road construction would demand great deal of cut-and-fill work, which may require ripping, and even blasting of fresh rock in deeper cuts. Weathered rock may be suitable for fill and subgrade, while limestone and fresh volcanic rock suitable for pavement may also be available in sufficient amounts.

Soils CH and probably GC; mainly shallow, locally moderately deep on slumped slopes, or very shallow on limestone.

(29) Punan Land System (45 sq miles)

Land Forms (Plate 17).—Low ridges with fine-grained short spurs forming very irregular pattern. Ridge crests narrow and generally steeply sloping. Side slopes moderately steep to steep but very steep along deeply incised gorges. Slumps common.

Terrain Parameters.—Altitude: 600–1200 ft. Relief: low (220 ft), except along river gorges where it is moderate (500 ft). Characteristic slope: moderately steep (12°). Grain: medium (1200 ft).

Streams and Drainage.—Branching pattern of first- and second-order streams flowing into few larger streams, the courses of which seem in some cases to be fault controlled.

Geology.—Miocene and Pliocene sediments of very mixed lithology. Probably mainly impure limestone with frequent intercalations of sandstone, siltstone, and mudstone.

Vegetation.—Tall forest, mainly with rather open, irregular canopy with scattered light-toned crowns (Foid), occasionally with less open canopy (Fid).

Soils (0 obs.).—Probably similar to those described for Isi (15) except on limestone where they are likely to be similar to those of Serra (36). Plant nutrient contents also similar to those of Isi (15) and Serra (36).

Population and Land Use.—Nil.

Forest Resources.—Very high. High stocking rate forests (Foid and Fid) cover 91% and 9%. Access is moderate because most slopes are moderately steep.

Agricultural Assessment.—Capability probably similar to that of Isi (15) but slightly lower because of presence of stony shallow soils on limestone, and deeply incised rivers; access also considerably more difficult.

Engineering Assessment.—Unsuitable for regional road connections because of unstable slopes and some deeply incised streams.

Soils mainly CH, some GC on limestone; probably moderately deep to deep, but shallow on very steep slopes, very shallow on limestone.

(30) Limio Land System (21 sq miles)

Land Forms (Plate 6).—High dissected plateau with steep north-facing scarp. Surface very irregular, consisting mainly of short low ridges. Slopes on plateau generally moderately steep but gentle slopes also occur. Near the scarps and along steeply incised rivers slopes are very steep. Slumps occur only on the very steep slopes.

Terrain Parameters.—Altitude: 30–900 ft. Relief: low (200 ft) on plateau, moderate (600 ft) at margins and along gorges. Characteristic slope: moderately steep (10°) on plateau, very steep (40°) along gorges and on scarps. Grain: medium (1300 ft).

Streams and Drainage.—Mainly consequent subparallel second- and third-order streams. The latter with only a few tributaries flow directly into the sea, crossing coastal plain in confined valleys. Most second-order streams drain into coastal back swamps extending in front of north-facing scarp. Beds of third-order streams contain coarse well-rounded gravel, mainly limestone, up to 20 in. diam.

Geology.—Limestone of Miocene to Pliocene age locally interbedded with siltstone and mudstone.

Vegetation.—Tall forest with rather open irregular canopy with scattered light-toned crowns (Foid).

Soils (1 obs.).—On sedimentary rock soils are likely to be similar to those described for Fivuma (16) and Jassi (31), on limestone and mixed lithology to those for Serra (36). On some colluvial lower slopes moderately developed, weakly acid, moderately deep, imperfectly drained, slowly permeable, fine-textured soils.

Plant nutrient contents likely to be similar to those of land systems mentioned above.

Population and Land Use.—Nil.

Forest Resources.—High. High stocking rate forest (Foid) covers 96%. Access poor overall, but on plateau could be considered moderate, and along scarps and incised rivers very poor to nil.

Agricultural Assessment.—Because of topographic problems and rather unfavourable soil conditions, overall capability very low for tree crops, low for improved pastures. Best land is on plateau surface, where it would even be possible to use small areas for arable cropping. The plateau, however, is very inaccessible and probably wet and cloudy.

Engineering Assessment.—Should and can be avoided in regional road planning. An access road to plateau surface would probably be best located in west where ascent is most gradual.

Soils CH to MH on soft sedimentary rocks, CH to GC on limestone; on sedimentary rocks probably shallow on steep slopes, moderately deep to deep on gentle slopes; very shallow on limestone.

(31) Jassi Land System (88 sq miles)

Land Forms (Plate 18).—Plateau and plateau-like areas with irregular strongly undulating to even, low hilly or ridgy surfaces with steeply incised narrow valleys; local flat surfaces (Krisa Plateau). Ridge crests narrow and strongly undulating. Slopes short or very short, straight, and moderate to moderately steep but locally gentle. Steep to very steep slopes bound plateau or are developed along major rivers. Larger rivers transport large quantities of coarse limestone gravel. In places along rivers two terrace levels have developed, lower *c.* 9–15 ft above low water level, and older 45–75 ft.

Terrain Parameters.—Altitude: 300–1000 ft. Relief: low (200 ft), moderate at margins and along gorges (500 ft). Characteristic slope: moderate (10°). Grain: medium (1500 ft).

Streams and Drainage.—Subparallel to branching system of streams. Larger streams, mainly third- and fourth-order, have beds 30 ft wide bounded by steeply rising slopes; tributaries are little incised. Some subterranean drainage through dolines. Gradients of main streams 1 : 100–1 : 250.

Geology.—Eocene sediments of very mixed lithology; limestone seems dominant but mudstone, siltstone, sandstone, and volcanics are also important.

Vegetation.—Tall forest with rather open irregular canopy with scattered light-toned crowns (Foid) covers 73%; tall forest with irregular canopy with scattered light-toned crowns (Fid), but mostly small crowned (Fisd), on remainder. Secondary vegetation (R–FR) around Krisa village.

Soils (3 obs.).—On sedimentary rocks slightly to moderately developed, neutral to weakly alkaline, and mostly fine-textured and moderately permeable on sandstone, very fine-textured and slowly permeable on mudstone. Mainly moderately shallow, but deep on colluvial material on some steep slopes. Some moderately to strongly developed, weakly acid to acid soils may also be present on upper plateau slopes.

On limestone and mixed lithology soils are probably very similar to those described for Serra (36).

Nitrogen contents tend to be low to moderate on soft sedimentary rocks, moderate to high on limestone; phosphate generally low to very low; potash high to moderate.

Population and Land Use.—One village (Krisa) with 153 people situated at edge of plateau where gardening is extensive; land use for whole land system is minor.

Forest Resources.—High. High stocking rate forests (Foid, Fisd, Fid) cover 98% (73%, 18%, 7%), remaining 2% carries moderate stocking rate secondary forest (FR). Access good to moderate with occasional limitations imposed by steep to very steep slopes along margins and gorges.

Agricultural Assessment.—Low capability for arable crops which could be grown with moderate to serious erosion hazards on plateau surfaces and gentler slopes on soft sedimentary rocks. Capability moderate for improved pastures, low for tree crops due to physically rather poor soils with commonly rather high to high pH. Access generally difficult because of steep marginal slopes.

Engineering Assessment.—Would, together with Kohari (35), provide best location for road across coastal range between Vanimo and Pagei as topographic obstacles are only moderate. Major problems would be negotiating long steep marginal slopes. Natural slopes and road cuts probably fairly stable, except in mudstone. Ripping may be required in limestone and some harder sandstone. There are adequate supplies of road-construction materials in the form of limestone, weathered and fresh sandstone, and volcanic rock.

Soils CH (some CL on sandstone) on clastic sedimentary rocks, CH or GC on limestone; shallow to moderately deep on sedimentary rocks, very shallow on limestone.

(32) Oenake Land System (58 sq miles)

Land Forms (Plates 5, 18).—Ridges and spurs mainly forming north side of Oenake Mountains, with moderately steep to steep slopes and very steep slopes along major rivers. Because of mixed lithology slopes are in detail extremely irregular, often showing hummocky secondary relief up to 60 ft. Huge limestone blocks common on surface add to irregularity. Crests of ridges and spurs broad to narrow and generally moderately steep to steeply sloping. Slumps and deep gullies rare. Therefore, slopes in general are relatively little dissected. In areas of pure limestone dolines (sink holes) occur.

Terrain Parameters.—Altitude: 150–1000 ft. Relief: moderate (600 ft). Characteristic slope: steep (24–30°). Grain: coarse to very coarse (4000 ft).

Streams and Drainage.—Mainly subparallel third-order streams flowing in narrow gorges directly into sea or into Mossu River. There is a branching system of tributaries, most of which are short and have gradients up to 3°. Stream beds of larger streams are up to 75 ft wide and filled with sand and coarse gravel, dominantly limestone. Some volcanics and basement gravel occur but their source is unknown. In some areas there is also subterranean drainage through dolines. Gradients of larger rivers are between 1 : 20 and 1 : 60.

Geology.—Dominantly limestone but intercalations of marl, mudstone, and siltstone frequent. Beds probably of Eocene to Miocene age.

Vegetation.—Tall forest with rather open irregular canopy with scattered light-toned crowns (Foid) covers about half, tall forests with less open canopies (Fid, Fisd) cover most of remainder.

SE. of Mt. Bougainville small area bears mid-height forest with irregular small-crowned canopy (Fmis).

Soils (3 obs.).—Slightly developed, well drained, ranging in reaction from neutral to strongly alkaline. On limestone dark, shallow to very shallow, rapidly to very rapidly permeable, fine-textured, and variably stony and rocky. On soft sedimentary rocks moderately shallow to moderately deep, fine- to very fine-textured, slowly permeable.

Nitrogen and potash contents high to moderate, phosphate moderate to low.

Population and Land Use.—Nil.

Forest Resources.—High. High stocking rate forests (Foid, Fid, Fisd) cover 92% (48%, 24%, 20%), moderate stocking rate forest (Fmis) covers the remainder. Access moderate, limited by steep or rarely very steep slopes.

Agricultural Assessment.—Because of steep slopes, high relief, common stony or bouldery surfaces, and shallow rather alkaline soils, capability is very low for tree crops, low for improved pastures.

Engineering Assessment.—Forms main obstacle to any road inland from Vanimo that would utilize the easier terrain of Jassi (31) and Kohari (35). Should be avoided as much as possible. Switchbacks are likely to be required to negotiate high relief. Road-building materials plentiful. Road cuts stable in limestone but rather unstable in soft sedimentary rocks.

Soils GC on limestone, CH on soft sedimentary rocks; very shallow on limestone, shallow to moderately deep on sedimentary rocks.

(33) Barida Land System (26 sq miles)

Land Forms (Plate 14).—High ridges with broad crests (120–150 ft) and very steep straight side slopes; smooth crestal slopes. Gullies 100–120 ft apart dissect the lower and middle slopes and small terracettes form irregular microrelief (3–5 ft).

Terrain Parameters.—Altitude: 300–1000 ft. Relief: moderate (600 ft). Characteristic slope: very steep (35°–38°). Grain: medium (1800 ft).

Streams and Drainage.—Mostly drained by small first-order streams flowing in ravines with intermittent flow. Second- or third-order streams are subparallel and courses mostly fault controlled. Abundant limestone gravel in beds of larger rivers.

Geology.—Upper Miocene massive limestone and sandstone. Sandstone probably forms upper parts of ridges.

Vegetation.—Crests mainly covered with mid-height forests; canopy structure varies between even (Fmv), rather even (Fm), and irregular (Fmi). Tall forest with rather open irregular canopy with scattered light-toned crowns (Foid) and mid-height forest with similar canopy (Fmoi) occur on the slopes.

Soils (2 obs.).—Slightly developed, dark, shallow, neutral to weakly alkaline, and well-drained ranging from rapidly permeable, gravelly or stony, medium-textured on pure limestone to slightly deeper, moderately permeable, fine- to very fine-textured on sandstone and argillaceous limestone.

Nitrogen contents moderate, phosphate and potash low to moderate.

Population and Land Use.—Nil.

Forest Resources.—Moderate. High stocking rate forest (Foid) covers 30% and moderate stocking rate forests (Fmoi, Fmi, Fmv, Fm) cover 70% (43%, 17%, 5%, 5%). Access is poor due to common occurrence of steep to very steep slopes.

Agricultural Assessment.—Because of very steep slopes and shallow rather alkaline soils there is only low capability for improved pastures.

Engineering Assessment.—Should and can be avoided for road construction. Valuable source of road-building materials if road connection is contemplated through SE. part of area between Lumi and coastal towns of Vanimo and/or Aitape.

Soils CH and GC; shallow to very shallow.

(34) Musu Land System (22 sq miles)

Land Forms (Plate 5).—Uplifted and dissected remnants of coral reef platforms forming terraces or ridges 60–300 ft above sea level. Terrace surfaces flat to gently sloping or undulating, bounding scarps very steep and locally steep. No continuous terrace levels, indicating that tectonic movements differ greatly from place to place. Particularly in front of Mt. Bougainville uplift seems to be much stronger than further east. On higher platforms some karst features in form of dolines.

Terrain Parameters.—Altitude: 60–300 ft. Relief: low (150 ft). Characteristic slope: very steep (38°). Grain: coarse (2400 ft).

Streams and Drainage.—As it is only a narrow strip along coast, little can be said about drainage conditions. In front of Mt. Bougainville no surface drainage, further east some permanent streams from Oenake Mountains have cut into platforms. Streams receive only few tributaries from land system and contain large amount of coarse gravel, dominantly limestone but also some crystalline rocks of unknown source.

Geology.—Very young coral limestone of Pleistocene age.

Vegetation.—Tall forest with rather open irregular canopy with scattered light-toned crowns (Foid) covers 60%, tall forests with less open canopies (Fisd, Fid) 25%; remainder gardened or bears secondary forest (R–FR).

Soils (8 obs.).—On platform remnants and rather gentle upper slopes with rare rock outcrop only slightly stony soils that are either slightly developed, dark coloured, weakly to strongly alkaline, shallow to very shallow, fine- to very fine-textured with high to moderate nitrogen contents, moderate to very high phosphate, high to low potash; or moderately to almost strongly developed, neutral, moderately shallow, very fine-textured with somewhat coarser-textured surface soils, and with moderate nitrogen contents, low to very low phosphate, low potash.

On very steep slopes with much rock outcrop, stony and gravelly soils that are mostly similar in nature to the first soils described above, but in places consist of peculiar dark red very friable clay.

A moderately strongly developed, weakly acid, moderately deep, very fine-textured soil, low in all three major nutrients, was observed on one of rare filled-in dolines. Except for this imperfectly drained, slowly permeable soil, all soils well drained and moderately to very rapidly permeable.

Population and Land Use.—One village with 99 people is situated on very narrow coastal platform in front of steeply rising coastal ranges. About 15% of land is or was used for gardening.

Forest Resources.—High. High stocking rate forests (Foid, Fisd, Fid) cover 85% (60%, 20%, 5%). Access very poor due to dominance of very steep to steep slopes and boundary scarps.

Agricultural Assessment.—Steep side slopes unsuitable for agricultural development, but on platform remnants capability moderate for arable crops, high for improved pastures, low for tree crops because of shallow alkaline soils. Soils likely to dry out rapidly during rainless periods of few weeks. Overall capability assessed as low for arable crops, very low for tree crops, moderate for improved pastures.

Engineering Assessment.—Problems in road construction very similar to those in Serra (36) but with fewer scarps and generally lower relief.

Soils GC and CH; very shallow, locally shallow.

(35) Kohari Land System (67 sq miles)

Land Forms (Plate 18).—Ultra-fine- to very fine-grained pattern of low to very low hills; between mostly conical-shaped hills steep sink holes lead to depths. Area is good example of tropical karst. Some structural lineations in form of low ridges. Slopes of hills convex and very steep.

Terrain Parameters.—Altitude: 300–900 ft. Relief: low (150 ft). Characteristic slope: very steep (30°). Grain: ultra-fine (200 ft).

Streams and Drainage.—No integrated drainage network developed; most drainage seems to be subterranean. Only some allochtonous streams cross limestone country, probably most subterranean water flows into these streams. Rivers transport large amount of coarse limestone gravel.

Geology.—Reef limestone dominantly from Pliocene Hollandia formation.

Vegetation.—Tall forest with irregular small-crowned canopy with scattered light-toned crowns (Fisd) covers about two-thirds; most of remainder covered by tall forest with more open, less small-crowned canopy (Foid).

Occurrence in Bewani Mountains bears mid-height forest with very dense canopy of irregular height (Fmci).

Soils (0 obs.).—Probably similar to those on pure limestone in Musu (34) and Serra (36). Some sink-hole floors may be filled in and have more developed, deeper, very fine-textured soils as in similar situation in Musu (34).

Population and Land Use.—Nil.

Forest Resources.—High. High stocking rate forests (Fisd, Foid) cover 94% (66%, 28%) and in the Bewani Mountains low stocking rate forest (Fmci) covers 6%. Access nil because of very steep to steep slopes of this karst topography.

Agricultural Assessment.—Due to topographic and soil limitations only very low capability for improved pastures. Provision of water for cattle may cause problems because of scarcity of streams and difficulty of collecting water in dams or tanks.

Engineering Assessment.—Although topography very broken in detail there are no major relief elements to be negotiated by roads. Hardly any need for roadside drainage, little or no need for bridges, road-building material is plentiful, and road cuts would be stable. In any road link across coastal range between Vanimo and Pagei this would probably be most suitable land from engineering point of view.

Soils probably GC and CH; probably very shallow.

(36) Serra Land System (113 sq miles)

Land Forms (Plates 14, 19).—High to very high limestone plateaux, plateau remnants, and ridges with undulating to hilly surfaces. Scarps generally very steep to precipitous, 300–600 ft high, in extreme cases up to 1800 ft high, occurring either at margins of plateaux or forming side slopes of gorges. Frequent structural lineation in form of long narrow ridges and scarps.

Prominent karst features such as conical hills and sink holes (dolines) on some plateaux but not throughout land system. Slopes of conical hills convex and very steep.

Terrain Parameters.—Altitude: 120–3600 ft. Relief: high (1000 ft), on plateau surfaces low (250 ft). Characteristic slope: very steep (37°). Grain: very fine (280 ft).

Streams and Drainage.—Large areas without integrated surface drainage. Some larger allochtonous streams flow through limestone areas in steep-sided gorges receiving little surface water from the limestone areas as most of their tributaries are situated beyond limestone country. Mainly subterranean drainage. River beds up to 90 ft wide and contain mainly coarse limestone gravel (up to 10 in. diam.).

Geology.—Reef limestone, dominantly Pliocene. Locally, thin lenses of mudstone interbedded with limestone.

Vegetation.—At lower altitudes tall forest, predominantly with rather open irregular canopy with scattered light-toned crowns (Foid). Tall forest with rather open even canopy (Fov) on part of Serra Hills, other tall forests have less open canopies (Fid, Fisd).

At higher altitudes, on Mt. Bougainville and in Bewani Mountains, mid-height forests with dense canopy (Fmc) and usually of an irregular height (Fmci).

Soils (8 obs.).—On pure limestone slopes slightly developed, shallow to very shallow, alkaline to weakly alkaline, dark, rapidly to moderately permeable, medium- to fine-textured, usually containing stones and gravel. On crestal flats soils are similar but neutral in reaction. On argillaceous limestone similar but lighter-coloured, shallow to moderately shallow, slowly to very slowly permeable, very fine-textured. Nitrogen contents mostly high to moderate, phosphate moderate to low, potash low to moderate. On clastic sedimentary rocks interbedded with limestone, or on colluvium, moderately developed, neutral to weakly acid, moderately shallow to moderately deep, slowly permeable, fine- to very fine-textured soils, commonly with somewhat coarser-textured surface layers. Nitrogen contents moderate to low, phosphate low to very low, potash moderate to high.

All soils well drained, except for a swampy but moderately permeable, acid, moderately deep, fine-textured soil with peaty horizons, observed on a filled-in doline which is very high in nitrogen and phosphate, moderate in potash.

Population and Land Use.—Nil.

Forest Resources.—High. High stocking rate forests (Foid, Fid, Fisd, Fov) cover 80% (50%, 15%, 11%, 4%), low stocking rate forests (Fmci, Fmc) 20% (17%, 3%). Access nil due to high incidence of very steep to steep slopes, karst features, and marginal scarps.

Agricultural Assessment.—Because of rugged topography and shallow stony soils of high pH there is only low capability for improved pastures. Some plateau surfaces reasonably suitable for development, but access difficult because of surrounding scarps and long steep slopes.

Engineering Assessment.—Terrain difficult for road construction because of steep slopes, high relief, and probable need for blasting in making road cuts in hard limestone. However, possibilities exist of selecting less difficult routes along ridge crests and plateau surfaces, and of avoiding scarps and very steep slopes. Limestone probably very suitable for many kinds of road-construction material, and natural slopes and road cuts likely to be very stable. Thus, Serra is in places preferable to adjoining hilly land systems on soft sedimentary rocks.

Soils mainly GC and CH, with some CL; mainly very shallow to shallow, locally moderately deep.

(37) Kum Land System (10 sq miles)

Land Forms (Plate 20).—Sharply and densely spurred, branching ridges with very narrow gently sloping to steep crests, and very steep straight slopes.

Terrain Parameters.—Altitude: 900–3000 ft. Relief: high (500–900 ft). Characteristic slope: very steep (38°). Grain: fine (600 ft).

Streams and Drainage.—Fine-grained pattern of small streams up to fourth order, flowing in narrow rock-cut valleys with pebbly to bouldery and rocky beds.

Geology.—Igneous basement rocks, mainly gabbro and diorite.

Vegetation.—Mid-height forests, predominantly with rather open irregular canopy (Fmoi), otherwise with less open canopy and sometimes mixed with seral stages (Fmi, Fmi′).

Soils (1 obs.).—Soils friable, moderately permeable, and well drained. On very steep slopes probably slightly to moderately developed, neutral to acid, moderately shallow to moderately deep, moderately to rapidly permeable, medium-textured (and in the subsoil gravelly). On some less steep upper slopes moderately to strongly developed, strongly acid, deep to very deep, fine-textured, with medium-textured subsoils. Nitrogen contents moderate; phosphate very low in well-developed soils, low in least-developed soils; potash ranges from moderate to very high but low in most-developed soils.

Population and Land Use.—Nil.

Forest Resources.—Moderate. Moderate stocking rate forests (Fmoi, Fmi) cover 94% (60%, 34%), remaining 6% low stocking rate forest (Fmi/Fmi′). Access very poor due to co-dominance of steep and very steep slopes.

Agricultural Assessment.—Nil capability.

Engineering Assessment.—Should and can be avoided in road planning. Isolated occurrences associated with large areas of sedimentary rocks could be valuable as sources of igneous and volcanic rock.

Soils probably mainly very shallow to moderately deep CL on steep slopes; locally moderately deep MH on upper slopes and crests.

(38) Mup Land System (7 sq miles)

Land Forms (Plate 16).—Isolated hills and ridges on basement rocks or volcanics rising 300–1000 ft above surrounding sedimentary areas. Ridge crests knife-edged to very narrow or flat-topped, side slopes very steep and in places precipitous; small slumps common.

Terrain Parameters.—Altitude: 300–1500 ft. Relief: high (750 ft). Characteristic slope: very steep (40°). Grain: fine (840 ft).

Streams and Drainage.—Apart from gullies, no streams; well drained.

Geology.—Igneous basement rocks (gabbro) and volcanics forming windows in areas of sedimentary rocks.

Vegetation.—Mainly mid-height forests with irregular canopies (Fmi, Fmoi), occasionally with *Albizia* (FmA).

Soils (4 obs.).—Probably moderately developed, acid, moderately shallow to deep, moderately permeable, fine- to medium-textured. Probably very shallow on steepest slopes and strongly developed, strongly acid, deep, and fine-textured on wider crests and less steep upper slopes. All soils probably well drained.

Nitrogen contents probably low to moderate, phosphate very low to low, potash low to very high.

Population and Land Use.—Nil.

Forest Resources.—Moderate. Moderate stocking rate forests (Fmi, Fmoi) cover 74% (58%, 16%) and low stocking rate forest (Fmi/Fmi′) a further 9%. Access very poor to nil due to dominance of very steep slopes and topographic isolation.

Agricultural Assessment.—Largely because of rugged topography, but also because of moderate soil depth and low soil fertility, very low capability for tree crops and improved pastures.

Engineering Assessment.—Should and can be avoided for regional road construction. Could serve as source of road-building materials for road between Lumi and Vanimo and/or Aitape.

Soils probably MH, CH, and CL; probably mainly moderately deep to deep, but shallow on steepest slopes.

(39) Somoro Land System (152 sq miles)

Land Forms (Plate 20).—Dendritic pattern of massive mountain ridges with knife-edged to very narrow crests. Slopes very steep and straight but commonly steepening at base. Landslide scars common.

Terrain Parameters.—Altitude: 900–6000 ft. Relief: very high (2000 ft). Characteristic slope: very steep (35–40°). Grain: coarse (2000 ft).

Streams and Drainage.—Coarse-textured angular strongly fault- and joint-controlled pattern of first-, second-, and third-order streams flowing with rapids in shallow rocky or bouldery channels in very narrow rock-cut valleys. Larger streams have discontinuous boulder and gravel terraces. Well drained.

Geology.—Basic igneous rocks, probably mainly granodiorite, gabbro, and diorite.

Vegetation.—Mid-height forest with rather dark-toned, rather even canopy (Fm) on crests and upper slopes, mid-height forests with irregular canopies (Fmi, Fmoi) on middle and lower slopes, and *Casuarina papuana* stands (Ca) on landslides forming characteristic vegetation pattern.

Soils (2 obs.).—Likely to be slightly to moderately developed, acid to weakly acid, shallow to moderately deep, moderately to rapidly permeable, and medium-textured. Probably very shallow soils and rock outcrop on steepest slopes, strongly developed, strongly acid, deep to very deep, moderately permeable, fine-textured soils on wider crests. All soils well drained.

Nitrogen contents probably generally low, phosphate very low, potash mostly high.

Population and Land Use.—Nil.

Forest Resources.—Low. Moderate stocking rate forests (Fmi, Fmoi, Fm) cover 37% (19%, 15%, 3%) and low stocking rate forest (Fmi/Fmi′) covers 7%. Access nil due to dominance of very steep slopes and topographic isolation.

Agricultural Assessment.—Nil capability.

Engineering Assessment.—Somoro forms biggest single obstacle for establishment of road connections between coast and Sepik basin, and should be avoided in road planning. If any such roads were located in the vicinity, it could be major source of suitable road-building materials.

Soils mainly CL, although possibly some SC on coarser-grained rocks, some GC subsoils, and some MH on upper slopes and crests; very shallow to moderately deep, locally deep on crests.

PART IV. CLIMATE OF THE VANIMO AREA

By KAREN SHORT*

I. INTRODUCTION

(a) *Principal Climatic Features*

The climate of the area falls within Köppen's (1931) tropical rain forest (*Af*) classification or Thornthwaite's (1931) wet tropical type (*AA′r*).

Mean annual rainfall is 105 in. on the coast at Vanimo and tends to decrease to 80–90 in. inland, and exhibits a seasonal pattern in that May–October is generally drier than the remainder of the year. This apparent coastal–inland gradient is slightly more marked in the dry than in the wet season but, as seen below, appears to be interrupted on the southern fall of the coastal range.

Temperature ranges are minimal. Mean annual temperature is about 80°F with virtually no seasonal variation and the diurnal range is about 14 degF.

(b) *Climatic Controls*

The broad climatic controls operating in this region are similar to those described by McAlpine (1972) for the area directly adjoining to the east, except that the east–west rainfall gradient anomaly found in that area may not hold here.

The major variations from these broad-scale controls are caused by the influence of local circulations which result mainly from the orographic effect of the coastal ranges and the Bewani Mountains.

(c) *Climatic Records*

Temporally climatic data for the area, apart from those for Vanimo, consist of only short and frequently interrupted periods of daily rainfall data (Table 3), hence the erection of standard periods for analyses is not possible. Vanimo is the only station within the area for which data other than rainfall are available. Spatially all stations are situated in the west along the West Irian border (Fig. 6). Data for Amanab and Imonda, lying slightly to the south of the survey area, have also been included as they consist of a somewhat longer record than other inland stations.

This situation makes climatic interpretation difficult and possibly unreliable in detail. For this reason detailed data for Vanimo only are presented in tabular form in this report. Other stations have been subjected to the same analysis as Vanimo but comment is made only when a clear difference from the tabulated data is apparent.

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II. General Climatic Characteristics

(a) Rainfall

Mean monthly and annual rainfall data for the various stations in the area are given for the full length of record in Table 3. Their spatial distribution is indicated by means of histograms in Figure 6. Mean annual rainfall is highest on the coast at

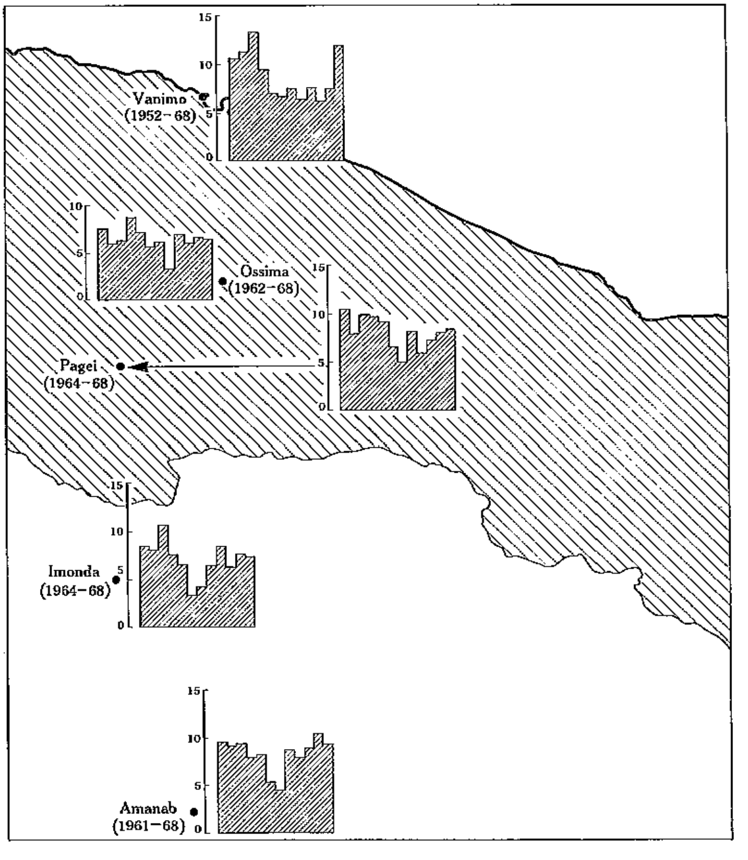

Fig. 6.—Location of rainfall recording stations, with years of records and annual distribution of rainfall (in.) (January–December).

Vanimo, where it is 105 in., decreases inland to 80–90 in. at Ossima and Imonda, but rises again to 100 in. further south at Amanab. Thus, within the area surveyed there seems to be a coast–inland rainfall gradient. However, this gradient appears to be interrupted at Ossima where a somewhat lower annual rainfall is experienced. The effects of this interruption are mainly confined to the "wet" season (i.e. November–April). Vegetation evidence (Part VII) indicates that this effect is even greater west of Ossima. The explanation for this interruption may lie in the orographic effects of the Coastal Range. This range rises to about 2500 ft just north of Ossima, but reaches 4000 ft to the west.

TABLE 3

MEAN MONTHLY AND ANNUAL RAINFALL (IN.) WITH HIGHEST AND LOWEST ANNUAL RAINFALL ON RECORD

Station	Elevation (ft)	Length of record (yr)	Jan.	Feb.	Mar.	Apr.	May	June	July	Aug.	Sept.	Oct.	Nov.	Dec.	Annual	Highest	Lowest
Amanab	1200	8*	9·48	9·08	9·25	7·91	8·28	5·37	4·78	8·87	8·01	8·96	10·35	9·34	99·68	124·20	87·58
Imonda	1100	6†	8·52	8·06	10·83	7·51	6·55	3·26	4·17	6·66	8·68	6·27	8·71	8·42	87·64	96·90	77·79
Ossima	275	7	7·56	5·98	6·32	8·76	7·06	5·53	6·04	5·83	6·95	6·04	6·68	6·63	79·38	96·90	68·24
Pagei	575	5†	10·48	7·97	10·04	9·96	9·36	6·78	4·99	8·32	6·00	7·37	8·23	8·52	98·02	103·05	87·19
Vanimo	10	17	10·67	11·25	13·40	9·54	6·98	6·61	7·30	6·12	7·66	6·05	7·55	11·93	105·06	126·40	82·16

* Only 7 years complete. † Only 4 years complete.

TABLE 4

VARIABILITY OF MONTHLY RAINFALL (IN.) AT VANIMO (1952–68)

	Jan.	Feb.	Mar.	Apr.	May	June	July	Aug.	Sept.	Oct.	Nov.	Dec.	Annual
Highest rainfall	17·22	23·61	34·63	17·07	11·24	14·80	15·37	11·09	16·15	10·93	12·66	26·64	146·52
Upper quartile	14·14	13·24	18·42	12·70	8·41	7·43	9·09	7·66	8·98	7·06	9·63	13·53	110·37
Median	11·61	10·34	9·90	10·08	7·56	6·21	7·45	6·12	7·03	6·23	6·93	11·79	109·05
Lower quartile	6·77	8·17	8·03	6·82	4·66	4·30	4·82	4·39	5·32	4·71	5·60	7·41	95·08
Lowest rainfall	3·72	3·77	6·19	2·56	3·10	1·92	1·22	2·66	2·83	1·69	3·62	4·43	73·51

The monthly rainfall data in Table 3 also indicate the seasonal pattern of rainfall referred to earlier. At Vanimo the wet season falls are approximately twice those of the dry season. Elsewhere, especially at Ossima, seasonality is less marked.

The variability of annual rainfall (expressed by the standard deviation as a percentage of the mean) is 17% at Vanimo. Further measures of monthly and annual variability are presented in Table 4 which indicates a greater interquartile and total variability in the wet season. Records are too short at other stations for the derivation of reliable measures of variability.

No direct measure of rainfall intensity is available. Table 5 presents the percentage frequency of rain days per quarter with rainfall within specified classes for Vanimo. Falls of over 2 in. are more common in the wet season than in the dry season and the highest daily rainfall on record at Vanimo is 12·16 in. recorded in September 1955. Similar analyses for other inland stations indicate a similar seasonal pattern but generally daily falls tend to be lighter. Apart from Vanimo, Pagei is the only station to record a fall of over 6 in. for the period considered.

TABLE 5

PERCENTAGE FREQUENCY OF RAIN DAYS PER QUARTER WITH RAINFALL WITHIN SPECIFIED CLASSES FOR VANIMO

Amount (in.)	Jan.–Mar.	Apr.–June	July–Sept.	Oct.–Dec.
0·01–0·24	45	53	52	49
0·25–0·99	33	31	35	37
1·00–1·99	14	12	10	9
2·00–3·99	6	4	3	4
4·00–5·99	0·9	0·4	0·4	0·6
≥6·00	0·1	0·1	0·1	0·1

While Table 5 already gives some impression of the relatively rainy nature of the climate this aspect is shown more clearly in Table 6. This table gives the average and longest lengths of rainy and rainless periods per quarter, as well as the percentage of rain days for Vanimo. Again the seasonal difference in these measures is apparent, especially in terms of longest occurrences of rainy and rainless periods on record.

TABLE 6

LENGTHS OF RAINY AND RAINLESS PERIODS PER QUARTER FOR VANIMO

	Jan.–Mar.	Apr.–June	July–Sept.	Oct.–Dec.
Mean length of rainy periods (days)	2·9	2·4	2·2	2·4
Longest rainy period (days)	32	14	9	23
Percentage of rain days	59·0	50·3	48·0	52·6
Mean length of rainless periods (days)	2·0	2·4	2·4	2·2
Longest rainless period (days)	9	19	11	12
Percentage of rainless days	41·0	49·7	52·0	47·4

A comparison of Vanimo with similar analyses for the short records of the other stations indicates that inland a greater number of rainy days is experienced in every quarter of the year and lengths of rainless periods tend to be slightly greater, but from Table 5 they are associated with generally lighter falls.

(*b*) *Temperature*

Table 7 indicates the restricted range of mean monthly and other temperature characteristics for Vanimo. Here mean annual temperature is 79°F, mean annual maximum temperature is 86°F, and mean minimum annual temperature is 72°F, giving an average diurnal temperature range of 14 degF. This diurnal temperature range is considerably greater than the seasonal range of only 2 degF. The highest daily maximum temperature on record is 95°F and the lowest daily minimum temperature on record is 51°F.

No other temperature data are available for the area but the greatest variations from the Vanimo situation would result from increasing altitudinal position, where an approximate overall lapse rate decrease in mean temperature of 3 degF per 1000 ft would apply.

(*c*) *Other Climatic Characteristics*

The monthly average indexes of relative humidity together with estimates of evaporation for Vanimo are given in Table 8. Humidity is high throughout the year and shows little seasonal variation. Early morning atmospheric conditions on the foothills and inland plains are frequently saturated or near saturated. Morning fogs are frequent and occasionally persist until mid morning along valley floors. Inland, mean monthly dew-point temperatures range from only 2–3 degF above mean monthly minimum temperatures (McAlpine 1972). Estimates of evaporation as related to pan evaporation have been derived from mean monthly maximum and minimum temperatures, vapour pressure, and day length (Fitzpatrick 1963). Mean annual evaporation is 54 in. per annum and shows only slight seasonal variation.

No sunshine and radiation data are available but Table 8 shows mean daily total possible sunshine hours and times of sunset and sunrise at Vanimo. Additionally, mean monthly total and low cloud cover are shown for 0900 and 1500 hr expressed as a percentage of sky covered. The total amount of cloud cover tends to be slightly greater in the wet season than in the dry season, but does not vary greatly from 0900 to 1500 hr. By contrast the low cloud cover, while not exhibiting the seasonal effect, does increase from 0900 to 1500 hr.

III. Soil Moisture

Estimates of soil moisture regimes presented here have been derived from a computer simulation of a simple water balance model.* Essentially the model is designed to give estimates of week to week changes in available soil moisture using estimated evapotranspiration as withdrawals and weekly rainfall inputs. The assumed maximum soil moisture storage (field capacity) is 4 in.

* Keig, Gael, and McAlpine, J. R.—WATBAL—A computer system for the estimation and analysis of soil moisture regimes from simple climatic data. CSIRO Aust. Div. Land Res. tech. Memo. No. 69/9 (unpublished).

TABLE 7

MEAN MONTHLY TEMPERATURE CHARACTERISTICS (°F) FOR VANIMO (1952–68)

	Jan.	Feb.	Mar.	Apr.	May	June	July	Aug.	Sept.	Oct.	Nov.	Dec.	Annual
Highest daily maximum	90·0	89·5	91·3	95·0	92·0	91·0	90·4	92·0	91·0	93·1	90·6	90·6	95·0
Mean maximum	85·9	85·9	86·0	86·6	87·3	86·2	85·5	86·1	86·2	86·6	86·8	86·4	86·3
Mean	78·9	78·6	79·4	79·8	80·4	79·4	78·8	79·4	79·3	79·6	79·8	79·0	79·4
Mean minimum	71·9	71·3	72·7	73·0	73·5	72·5	72·2	72·7	72·4	72·7	72·7	71·5	72·4
Lowest daily minimum	58·5	59·0	57·7	59·0	59·0	50·5	58·1	59·0	59·0	58·0	58·5	55·0	50·5

TABLE 8

RELATIVE HUMIDITY, EVAPORATION, CLOUD, AND SUNSHINE DATA FOR VANIMO

	Jan.	Feb.	Mar.	Apr.	May	June	July	Aug.	Sept.	Oct.	Nov.	Dec.	Annual
Av. index of relative humidity (%)*	88	89	87	87	88	88	87	86	87	87	86	88	87
Evaporation (in.)†	4·7	4·2	4·6	4·4	4·5	4·1	4·3	4·6	4·4	4·8	4·8	4·9	54·3
Mean cloudiness (%)													
Total 9 a.m.	84	82	86	76	72	62	69	69	69	72	78	81	75
Low 9 a.m.	35	38	42	35	31	32	34	30	38	38	35	28	35
Total 3 p.m.	85	80	84	82	78	68	71	79	74	75	80	79	78
Low 3 p.m.	41	44	49	45	45	42	42	40	39	45	45	38	42
Sunshine													
Length (hr/day)‡	12·2	12·1	12·0	12·0	11·9	11·8	11·8	11·9	12·0	12·1	12·1	12·2	
Sunrise (hr)	0636	0642	0642	0630	0630	0636	0642	0642	0624	0612	0612	0618	
Sunset (hr)	1848	1848	1842	1830	1824	1824	1830	1836	1824	1818	1818	1830	

* Ratio of average 9 a.m. vapour pressure to saturation vapour pressure at average mean temperature.

† Estimated by method of Fitzpatrick (1963).

‡ Mean daily possible sunshine hours.

The results of the application of the model are presented for Vanimo only. The same model has been applied to the other stations in the area but their rainfall records are too short to produce reliable summary statistics. Nevertheless, where differences from the Vanimo regime are marked these are indicated.

Figure 7 presents a smoothed mean weekly soil moisture storage curve for three stations. The plot for Imonda indicates that this station may tend to have a somewhat lower level of soil moisture storage during the dry season than Vanimo. On the other hand, the station with the lowest annual rainfall, Ossima, varies most from Vanimo in the first quarter of the year.

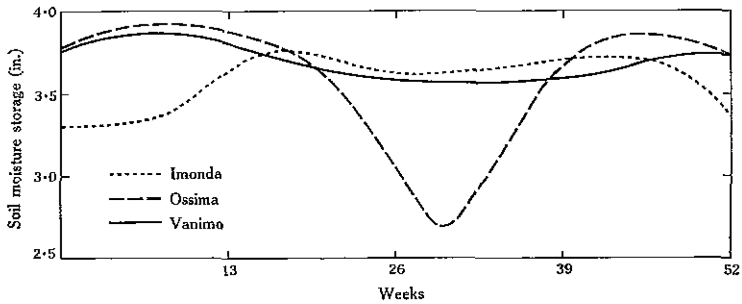

Fig. 7.—Mean weekly soil moisture storage.

These curves represent only mean weekly conditions and do not in themselves portray the risk of serious soil water deficits that might influence plant growth and

TABLE 9

MEAN NUMBER OF WEEKS AT VANIMO WITH SOIL MOISTURE STORAGE AT SPECIFIED LEVELS TOGETHER WITH MAXIMUM AND MINIMUM QUARTERLY LEVELS ON RECORD*

	Storage levels			
	Full	*1–49%* Depleted	*50–99%* Depleted	*Empty*
Jan.–Mar. mean	9·9	2·8	0·2	0
Max. (1959)	13·0	0	0	0
Min. (1967)	8·0	2·0	3·0	0
Apr.–June mean	7·9	4·6	0·4	0
Max. (1962)	13·0	0	0	0
Min. (1952)	4·0	6·0	3·0	0
July–Sept. mean	6·5	6·1	0·4	0
Max. (1963)	9·0	4·0	0	0
Min. (1952)	5·0	4·0	4·0	0
Oct.–Dec. mean	8·0	4·8	0·2	0
Max. (1964)	12·0	1·0	0	0
Min. (1956)	4·0	6·0	3·0	0

* Year of occurrence in parenthesis.

production. An indication of this facet is given in Table 9, where a frequency distribution of mean soil moisture storages for Vanimo is presented. As can be seen, complete depletion has not occurred at Vanimo for the length of record considered and depletion below 50% is rare in all quarters. There is only a slight increase in depletion in the dry season. The maximum and minimum variations from the mean values at Vanimo can also be seen in Table 9.

The situation for the other stations indicates that inland the seasonal contrast is a little more apparent than at Vanimo. Depletions of 1–49% are more common at Ossima in the first quarter of the year and in the third quarter at Imonda, where, additionally, depletions of 50–99% occur in about 15% of the weeks in the record.

The residual term in the water balance model, after evapotranspirational and soil moisture storage requirements have been met from weekly rainfall, is water surplus. This may be regarded as an estimate of a combination of surface run-off and deep percolation. The mean annual water surplus for Vanimo is 60 in. per annum and inland, for the record considered, it varies from 37 in. per annum at Ossima to 54 in. per annum at Amanab.

IV. Acknowledgment

Climatic data were provided by the Commonwealth Meteorological Bureau.

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PART V. GEOLOGY AND GEOMORPHOLOGY OF THE VANIMO AREA

By E. LÖFFLER*

I. INTRODUCTION

The Vanimo area is situated in the north-west corner of Papua New Guinea and extends from the north coast to the watershed between the Sepik River system and the coastal drainage system. The area contains a narrow coastal plain, two extensive alluvial plains, a roughly east–west-directed belt of coastal ranges rising up to 3950 ft, an intermontane zone of hills and fans, the intermontane lowlands, forming a tectonic and topographic low south of the coastal ranges, and the inland ranges (Fig. 3) which are a part of the "northern ranges" (Carey 1938) of New Guinea and which rise to 6280 ft. These main physiographic regions include a variety of land forms and rock types (Fig. 8).

Geologically the area is part of the "northern sedimentary basin" of New Guinea (Osborne 1956) and is dominated by Tertiary and younger sediments.

II. LAND FORMS AND PHYSIOGRAPHIC REGIONS

(a) The Coastal Plain

The coastal plain forms a belt up to two miles wide in front of the steeply rising coastal ranges. In the east, between the Bliri and the Pual Rivers, it consists mainly of a sequence of beach ridges and swales, behind which are brackish back swamps connected to the sea by narrow overflow channels (Nubia (2) and Leitre (3) land systems; Plate 1, Fig. 2, Plate 6). The sequence of beach ridges is generally 1300–1600 ft wide; the back swamps have an average width of 3000–4500 ft. Only the four largest streams draining the eastern coastal ranges cross the coastal plain in confined meandering channels. All the other streams drain into the swamps.

In the west the coastal plain consists of narrow raised coral platforms (Madang (1)) which generally slope gently up from the sea to about 8 ft, although near Vanimo airstrip a 6·5-ft-high cliff has been formed. West of Vanimo a 300-ft-wide belt of coral reef which rises slightly above the high-tide level separates the coastal plain from the open sea (Plate 2, Fig. 1).

(b) The Alluvial Plains of the Major Rivers

The alluvial plains of the two main rivers of the area, the Pual and Bliri, cross the coastal plain and extend upstream to the foot of the Bewani Mountains (Pual (10)). The alluvial plains consist of the present flood-plains and wide alluvial plains which may be subdivided into up to three terraces. The rivers are mostly 250–400 ft wide, locally they reach 800 ft and their flood-plains are 300–2000 ft wide. The flood-plains are 5–8 ft above the low-water level and are periodically flooded during the rainy season. The lowest terrace or alluvial plain is 150–2000 ft wide, lies 5–8 ft above the

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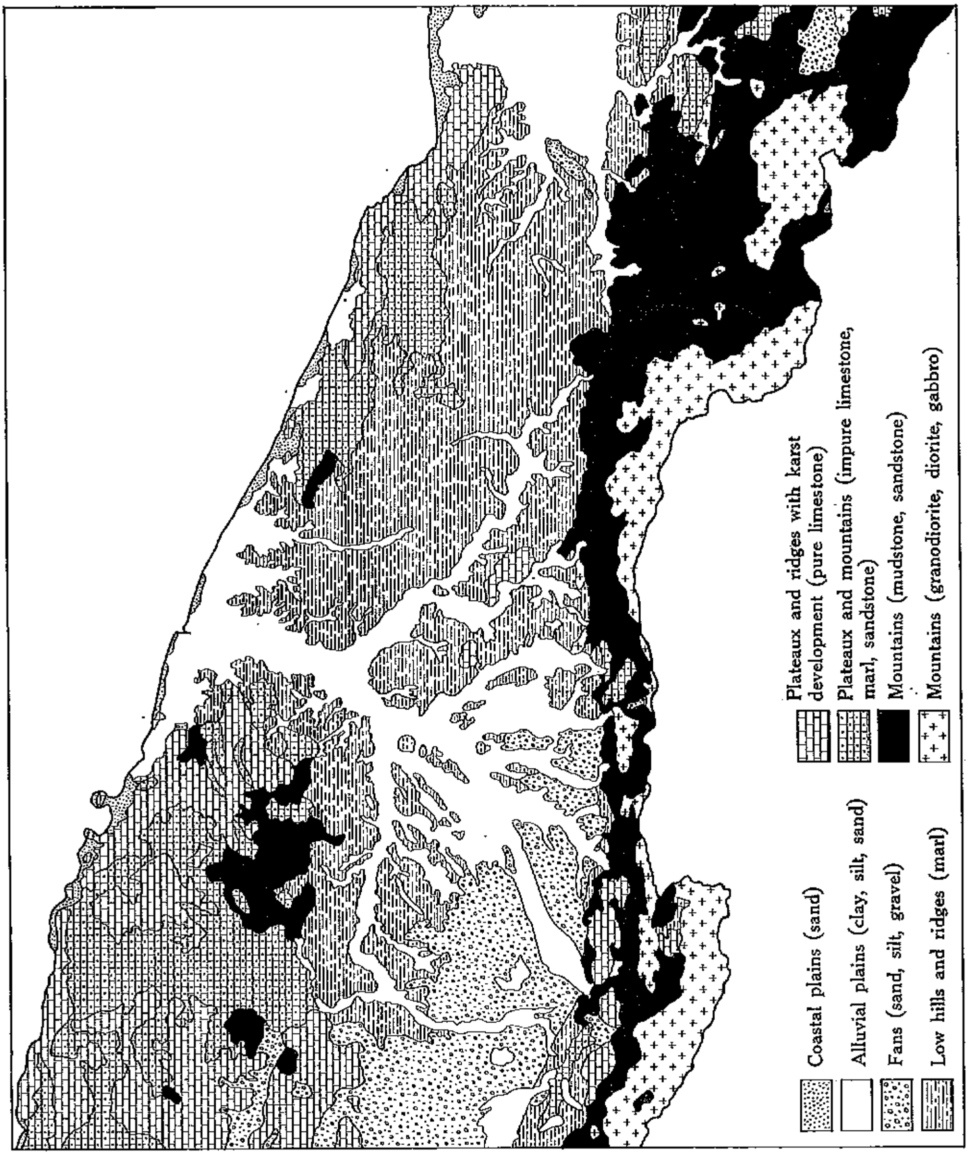

Fig. 8.—Land forms and rock types.

flood-plain, and seems to be slightly above the normal flood level. If a second terrace is developed it lies 3–6 ft above the lowest and is 650–1000 ft wide. This terrace does not appear to be covered by present-day floods. A third terrace, 20 ft above the second, was observed at one locality. The edge of this terrace is densely dissected by gullies that have cut back 100–200 ft into the terrace.

(*c*) *The Coastal Ranges*

The coastal ranges consist of a WNW.-directed zone of mountains and plateaux rising steeply from the coastal plain or from the sea (Plates 6 and 19). They are subdivided by the alluvial plain of the Pual River, which forms a topographic and structural low, into a smaller eastern part called the Serra Hills and a larger western part comprising the Oenake Mountains, the Ijapo Hills, and the Kohari Hills.

The Serra Hills form a belt 1·8–3 miles wide of rugged country lying between the Bliri and Basu Rivers. To the north they are generally bounded by steep escarpments, while to the south the transition to the lower country of the intermontane trough is gradual, except at the eastern end. The altitude of the range lies between 600 and 1300 ft, except south of Leitre where it rises to a maximum of 1600 ft (Fig. 4).

The eastern part of the Serra Hills constitutes a plateau with steep margins to the north, east, and south (Serra (36); Plate 19). The plateau surface is characterized by a pattern of conical to hemispherical low hills surrounding deep sink holes. The plateau is further subdivided by some prominent scarps which are fault-controlled. Towards the west the karst features gradually disappear and the plateau surface changes to an irregular pattern of mainly short low ridges and undulating areas (Limio (30)). Structural lineations are still present but are less prominent than further east. The transition to the intermontane trough in the south is here gradual and consists of a heterogeneous belt of low broad ridges with short closely spaced spurs.

The coastal ranges west of the Pual plain consist of a heterogeneous group of mountains, plateaux, and hills extending up to 18 miles inland. The alluvial plains and fans of the upper Pual and Bewani river systems form the well-marked southern boundary of these coastal ranges.

The Oenake Mountains rise steeply from the sea or narrow coral platforms and extend as a 5–9-mile-wide range from the lower Pual plain in the east to the lower Tami plain in the west. Some of the coral platforms have been uplifted up to 300 ft above sea level (Musu (34)). However, there are no continuous levels which indicate that the tectonic movements differ considerably from place to place. The eastern part of the Oenake Mountains comprises limestone plateaux with few karst features and rather flat to undulating surfaces. They are bound by low scarps. Towards the west follows an area where karst hills and dolines, as in the eastern part of the Serra Hills, are the dominant land forms. The western part of the Oenake Mountains consists of a single ridge with steep slopes to the coast in the north and the Mossu valley in the south. The range culminates in Mt. Bougainville at 4000 ft. West of the international border the range slopes down rapidly to the Tami plain.

The western part of the Oenake Mountains is separated from the Ijapo Hills by the steeply incised Mossu valley which drains into the Tami plain. The Ijapo Hills comprise a fine-grained pattern of low to moderately high hills (Ijapo (28); Plate 18); they are bounded by the Jassi River, a tributary of the Pual River, to the east and the

Jabir River which drains into the Jassi River to the south. To the west they plunge into the Tami plain (outside the area).

The Kohari Hills are situated south of the Ijapo Hills and consist of a plateau remnant with steep margins to all sides. The plateau surface shows well-developed karst features (Kohari (35); Plate 18).

(*d*) *The Intermontane Lowland*

The intermontane lowland or trough, 9–16 miles wide, lies between and parallel to the coastal ranges and the Bewani Mountains. It consists of two parts, a heterogeneous pattern of subparallel to dendritic ridges in the east (Isi (15) and Fivuma (16); Plate 3, Fig. 1; Plates 8 and 11) and a mainly flat to gently undulating plain in the west (Po (9), Pual (10), and Pagei (11); Plate 3, Fig. 1; Plates 7 and 10).

The ridges in the east have a local relief up to 300 ft that decreases gradually towards the Bliri and Pual plains. The highest area is represented by the Fivuma River–Sereri River watershed which reaches a minimum of 600 ft and forms a broad saddle between the Serra Hills and the Bewani Mountains (Fig. 4).

The flat to gently undulating section of the trough further west forms a strong contrast to these ridges. Here most of the trough is occupied by a system of coalescing fans (Pagei (11); Plates 7 and 10) which extend from the foothills of the Bewani Mountains. Near the West Irian border the fans form a continuous, nearly undissected plain connecting the Bewani Mountains and the Kohari Hills. Further east along the middle course of the Pual River the fans are dissected and end with a 100–115-ft-high scarp above the flood-plain of the Pual River. The fans range in altitude from 600 ft near the mountain front to 300 ft near their dissected frontal part.

(*e*) *The Inland Ranges*

The inland ranges, comprising the Bewani Mountains and an outlier of the Torricelli Mountains, are part of the "northern chain" (Carey 1938) of Australian New Guinea. They form the watershed between the north coast and the Sepik River system and trend generally east–west. The Bewani Mountains are separated by a topographic and structural low, the southern continuation of the Pual plain low, into the western and eastern Bewani Mountains. At their eastern end they bend south-eastwards and join up with the Torricelli Mountains.

Along a series of prominent fault scarps the Bewani Mountains rise sharply from the intermontane trough. North of the watershed they consist generally of three belts, a 0·6–2-mile-wide belt of foothills with a moderate relief and a fine-grained topography, an up to 35-mile-wide belt of high broad ridges with a coarse-grained topography (mainly Piore (25); Plate 16), and the core of the Bewani Mountains which consists of massive, very high, and coarse- to very coarse-grained mountain ridges (Somoro (39); Plate 20). The maximum elevation of the range is 6280 ft.

III. Geology

(*a*) *Previous Investigation*

The earliest geological work in the area was done in 1910, when a team of German scientists surveyed the border area between what were then the Dutch and German territories (Schultze-Jena 1914). Schultze-Jena described the main features of the area, with the coastal ranges of Quaternary to Tertiary reef limestone in the north, the main mountain ranges which he called Bewani Mountains to the south, consisting of a basement core and flanking Tertiary sediments, and the extensive alluvial plain in between consisting of Recent sediments.

In 1928–29 Nason-Jones carried out a geological survey around Vanimo and set up an initial stratigraphical classification (Nason-Jones 1930). However, not until 1940 was the whole area systematically explored, when Osborne* and his team surveyed the Aitape–Vanimo area using air photos for the first time. Osborne founded a sound stratigraphical classification on which most of the later work has been based. Recently Marchant (1969) carried out a "photogeological assessment" of the northern New Guinea basin north of the Sepik River.

(*b*) *Stratigraphy*

The Vanimo area forms part of the "Northern Sedimentary Basin of New Guinea" (Osborne 1956) and consists mainly of upper Tertiary sediments unconformably overlying uppermost Cretaceous and lower Tertiary sediments or crystalline basement (Fig. 9).

(i) *Basement.*—Basement rocks are exposed in the highest part of the Bewani Mountains where they form a distinct topography of massive mountain ridges. Some small outcrops of basement have also been reported from the Serra Hills and the Oenake Mountains (Schultze-Jena 1914; Osborne, unpublished data*). The most common rock types are diorite, granodiorite, and gabbro. Some schist and serpentine have been found in the Mossu valley (Schultze-Jena 1914) and in the Serra Hills.* The basement rocks are considered by Osborne to be at least upper Cretaceous and are everywhere separated from the overlying sediments by basaltic lava flows.

(ii) *Eocene to Lower Miocene.*—The basement complex is overlain by a varied succession consisting of basalt lavas, limestone, mudstone, agglomerate, conglomerate, and greywacke overlain by carbonaceous siltstone, mudstone, sandstone, and some thick reef limestone. This sequence of sediments was called Bliri River beds and ranges from Eocene to lower Miocene.* Their total thickness amounts to 10,000–18,000 ft.

These Bliri River beds crop out in the Bewani Mountains where they form a belt of mountain ridges next to the basement core. They also form parts of the Oenake Mountains and the Ijapo Hills where reef limestone is the dominant rock type. They do not occur in the Serra Hills.

The Bliri River beds are strongly faulted and folded in the Bewani Mountains, while in the coastal ranges they are only little disturbed.

(iii) *Middle Miocene to Upper Miocene.*—The Bliri River beds are overlain by the rocks of the Barida formation in the east and by the Puwani formation in the west. The transition is gradual. The 3000-ft-thick Barida formation consists mainly of white globigerina limestone with local pockets of calcite and tuff, marl, sand, and volcanic agglomerate, while the 1200-ft-thick Puwani formation consists mainly of reef limestone and foraminiferal marl.

* Osborne, N. (1942).—The geology of the Aitape area, Permits Nos. 1 and 3, Territory of New Guinea. Report for Australasian Petroleum Company Pty. Ltd. (unpublished).

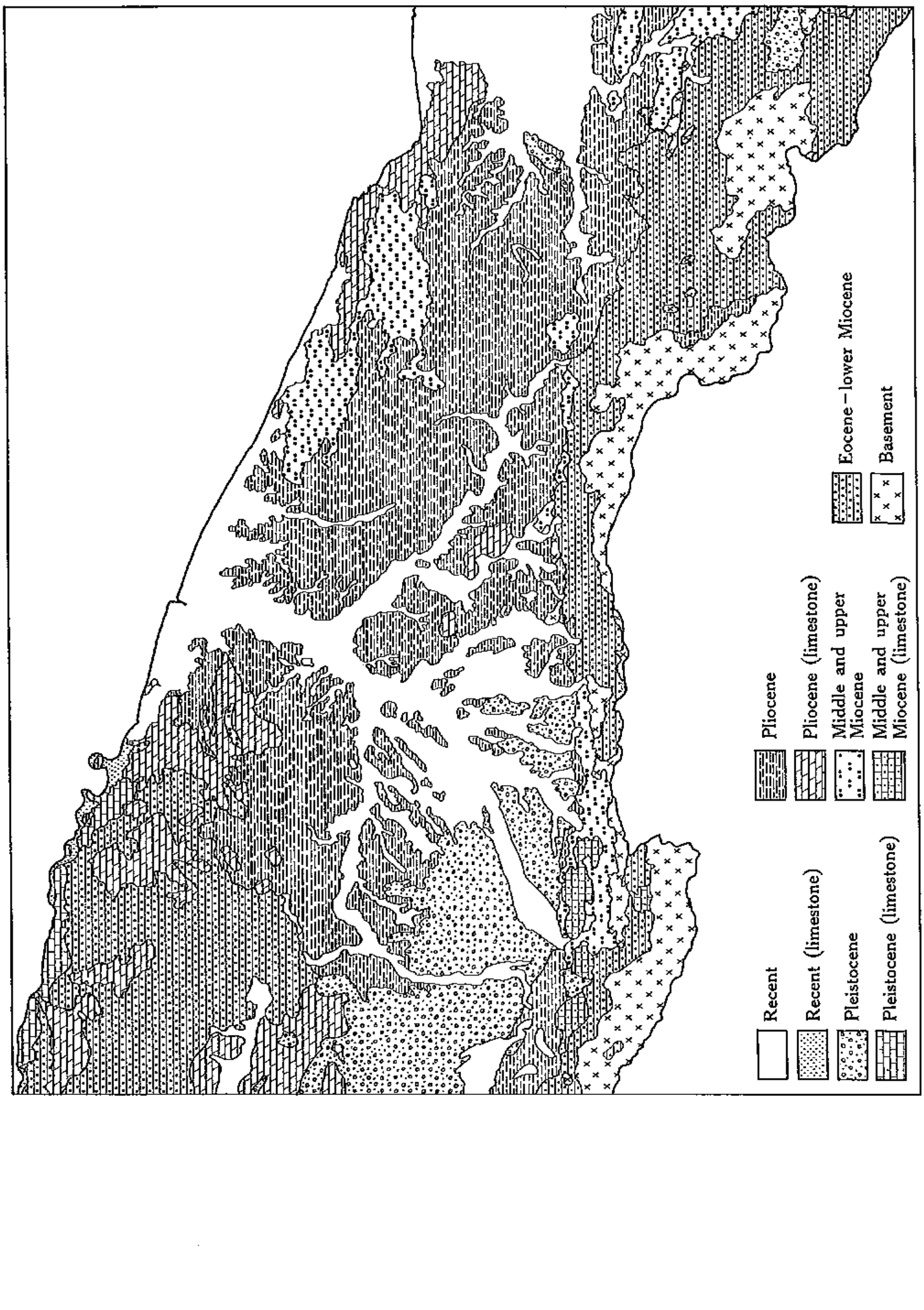

Fig. 9.—Generalized geology.

The two formations crop out along the Bewani Mountain front generally north of the Bliri River beds. A large area in the Serra Hills south of Leitre is also part of this sequence although they cannot be separated from the surrounding Pliocene sediments on the air photos.

(iv) *Pliocene.*—The Pliocene is represented by a 12,000–15,000-ft-thick sequence of alternating marine and non-marine sediments. The lower Pliocene rocks (Neni Group, Smoky Mudstone Group after Osborne) overlie the upper Miocene sediments conformably but with a well-defined boundary. They consist dominantly of foraminiferal marl interbedded with thin layers of sandstone, siltstone, and mudstone. These beds crop out in a narrow belt along the Bewani Mountains front. The overlying middle Pliocene sediments (Romi formation after Osborne*) are also mainly marine, the most common rock type being soft blue-grey marl. Mudstone and siltstone occur as local facies particularly close to the coastal ranges. These middle Pliocene beds cover a large proportion of the survey area forming the eastern part of the intermontane trough as well as most of the southern slopes of the coastal ranges.

The limestone of the Serra Hills and of the eastern half of the Oenake Mountains and the Kohari Hills is thought to be a lateral facies of the Romi formation;* the transition from limestone to mudstone and marl is gradational and it is sometimes difficult to determine the boundary between the two rock types on the air photos.

The Romi formation is overlain by a sequence of terrestrial sediments consisting of thick beds of conglomerate, some grit, sandstone, and non-calcareous mudstone and siltstone. These sediments are the youngest which took part in the orogenesis of the Bewani Mountains. They crop out in small areas in the foothill zone of the Bewani Mountains.

(v) *Quaternary.*—Pleistocene beds, 100–150 ft thick, overlie the Pliocene sediments with an unconformity. They consist of flat-lying gravel, sand, and silt and cover large areas in front of the mountains. The most extensive outcrop is in the western part of the intermontane trough where Pleistocene fan sediments extend from the Bewani Mountains to the Kohari Hills forming a nearly undissected plain.

Some of the raised coral of the Serra Hills and particularly of the Oenake Mountains appears to be very young and therefore is thought to be of Pleistocene age. Pleistocene coral limestone was also recorded by Schultze-Jena (1914) and Zwierzycki (1927) from the former Dutch part of the Oenake Mountains.

(c) *Structure*

The main structural element of the area is the roughly west–east-directed Bewani–Torricelli fault system. The faulting and uplift of the Bewani and Torricelli Mountains which started in the upper Pliocene were especially strong along the north-facing front of the present mountains and produced a system of strike faults which are thought to be high-angled thrusts. These generally WNW.–W.-striking faults are crossed by transcurrent faults mostly having a NE.–E. and a NW.–W. trend. A significant feature in the fault system is the offset of the Bewani system northward from the Torricelli system which finds a clear topographic expression.

* Osborne, N. (1942).—The geology of the Aitape area, Permits Nos. 1 and 3, Territory of New Guinea. Report for Australasian Petroleum Company Pty. Ltd. (unpublished).

The coastal ranges which probably formed "stable areas or shelf during the evolution and folding of the geosyncline"* are thought to represent uplifted antiforms. The trend of the major strike faults and cross faults in the coastal ranges is generally parallel to that of the Bewani Mountains.

IV. Geological and Geomorphological History

The geological history of the area can be traced back to the early Tertiary or possibly late Cretaceous when the "Bewani Geosyncline"* which extended from the present north coast to the present main cordillera started to develop. Osborne considers that most of the area was dry land and possibly part of a continental mass during most of the Mesozoic. Intensive volcanic activity took place from the beginning of the geosyncline to the lower Miocene, covering large areas with lava flows. The volcanic eruptions alternated with deposition of limestone and other sediments. According to Osborne* there probably is a major break in the Oligocene, but as the stratigraphy has not yet been fully established the existence of such a break must remain doubtful (Marchant 1969). The volcanism decreased during the early or middle Miocene.

Subsidence of the geosyncline continued during most of the Miocene and reef limestone developed in favourable areas and terrigenous material was deposited in other places. Periods of emergence and subsidence of the geosyncline resulting in deposition of an alternating sequence of marine and non-marine sediments characterize most of the Pliocene.

At the upper Pliocene the framework of the present landscape became visible. In the north, parts of the coastal ranges formed positive areas during most of the Pliocene and contributed sediments to the geosyncline. In the south, the basement area was also elevated relative to the geosyncline.

At the end of the Pliocene the main uplift of the Bewani Mountains and the coastal ranges began and the geosyncline in between, the remnant of which is the present intermontane trough, rose above sea level, receiving a large amount of terrestrial sediments from its rising margins. Most of the intermontane trough became covered by fan material and so a continuous system of coalescing fans extended all over the intermontane trough.

In the Bewani Mountains the uplift and faulting were particularly strong as shown by the occurrence of nearly vertically dipping sediments, large-scale offsets, and numerous prominent fault scarps.

In the coastal ranges the uplift was less rapid than in the Bewani Mountains and took place mainly along broad anticlinal axes. Along with the uplift went the exposure of the limestone to the atmosphere and the start of the karst development.

In the intermontane trough later uplift and faulting in the eastern part accompanied by increased erosion destroyed the alluvial fans and created the heterogeneous pattern of subparallel to dendritic ridges. Some fan remnants have been preserved mostly as flat-topped ridge crests, but the largest remnant of approximately 2 sq miles forms a low plateau between the Piore River and its tributary the Fivuma River. This plateau has probably been preserved because it is situated in a tectonic graben.

* Osborne, N. (1942).—The geology of the Aitape area, Permits Nos. 1 and 3, Territory of New Guinea. Report for Australasian Petroleum Company Pty. Ltd. (unpublished).

The western part of the intermontane trough was little affected by later tectonic events and most of the fan system is still present. In recent times the fans have been dissected by headward erosion from the tributaries of the Pual and Puwani Rivers. Thus the fans which once formed a continuous piedmont plain between the southern slopes of the coastal ranges and the northern slopes of the Bewani Mountains—as they still do in the watershed area of the Pual–Bewani River systems—have gradually receded to the south. They end at present with a marked, generally 115-ft-high front against the alluvial plain of the Pual River on the undulating country formed by the exposed Pliocene marls. This indicates that the fans are fossil.

V. Geomorphic Processes

(a) *Earthquakes*

Earthquakes are common in the area. Brooks (1965) has concluded that the Torricelli Mountains and the eastern Bewani Mountains are likely to be affected by 10–20 shocks of magnitude 6 or greater per square degree per century. The geomorphic effects of the earthquakes that occurred in this century in the Torricelli Mountains and the Bewani Mountains have been recently discussed in detail by Simonett (1967).

The strongest earthquake recorded was in 1935 with the epicentre north of Lumi. The immediate results of this earthquake were rapid mass movements in the form of landslides. These caused local damming of valleys and subsequent catastrophic flooding. According to Simonett (1967) landsliding was more frequent in basement areas than in sedimentary areas. In the Vanimo area only the eastern Bewani Mountains were noticeably affected by the earthquake, in particular the Bewani–Torricelli saddle. Simonett (1967) calculated that a volume of about $1 \cdot 7 \times 10^5$ cu yd of earth was removed as a result of the earthquake in the basement area of the eastern Bewani Mountains.

(b) *Denudation Processes*

(i) *Landslides*.—The most effective and rapid denudation process in the area is landsliding. Soil, subsoil, and weathered rock as well as the forest cover are stripped off the very steep slopes leaving behind avalanche trails that show up clearly on the air photos. Landslides are most common in the basement area. Many landslides are caused by earthquakes (see above); but they are also common in areas that have recently been little affected by earthquakes such as the headwaters of the Bewani and Puwani Rivers. Here the major cause seems to be rapid headward erosion of the streams and consequent undercutting of slopes. Heavy rain storms and falling trees may also be responsible for initiating some landslides.

(ii) *Slumps*.—While the above-described mass movements of the debris avalanche type are most common in the basement area, slumps with a marked backward rotation are very frequent in the areas of sedimentary rocks, except limestone. In the marl and mudstone country of the intermontane trough slumps often cause a chaotic macro and microrelief. Vertical displacements can range from a few feet to 150 ft. The size of the slump benches varies similarly between a few square feet and 54,000 sq ft. However, sizes in the order of 200–2000 sq ft can be regarded as the norm. The main cause for slumping is, as for landsliding, undercutting of slopes by gullies and streams.

(iii) *Gullies.*—Gullies are narrow channels with very steep to nearly vertical side slopes. They are mostly deeper than wide or at least as deep as wide and have in general no permanent water flow. They normally start on the middle slopes, rarely on the upper slopes, and join up on the lower slopes where they frequently form small streams. Gullies were observed in all land systems but they are most frequent in the marl and mudstone areas, where they are mostly 60–150 ft apart and up to 30 ft deep. Gully heads often join up with slumps and seem to cause most of the slumping.

(iv) *Soil Creep.*—The importance of soil creep as a denudation process in mountainous areas of the humid tropics was recognized by early explorers (Behrmann 1924; Freise 1935–36; Sapper 1935). In the Vanimo area soil creep indicated by curving tree trunks and terracettes is widespread. It was observed on nearly all slopes that exceeded 30°, regardless of the rock type. On slopes under 30° a certain relation between the occurrence of soil creep and type of rock was observed. On limestone and basement no indications of soil creep were found below 30°, on sandstone and siltstone the lower limit for soil creep was on slopes of about 20°, while on marl and mudstone slopes of 10° form the lower limit.

(v) *Slope Wash.*—It has been widely believed that slope wash directly caused by rainfall is of minor importance for slope processes under primary forest in the humid tropics. Recent investigations in north-east Papua, however, showed that slope wash can be an important process of erosion on slopes of over 5° (Ruxton 1967). In the Vanimo area, evidence of slope wash such as exposed roots, stow of leaf litter behind larger tree trunks, and hollows at the downhill-facing side at the tree base has been observed on slopes of over 10°. However, there are also a significant number of observations where no signs of slope wash have been observed in spite of great slope steepness. Therefore it is difficult to assess the significance of slope wash in this area.

(vi) *Fluvial Erosion.*—As Behrmann (1924) has already pointed out, the typical valley form in mountainous areas of New Guinea is a V-shaped valley with straight and steep to very steep side slopes. Basal concavities at the valley slopes are absent. This applies to all valleys in the mountains of the Vanimo area. The valley forms indicate rapid fluvial erosion and down-cutting. Only the largest streams (Piore and Bliri Rivers) erode laterally and have wide flood-plains.

A dam in the upper course of the Puwani River which was formed in the last 30 years gives a rough estimate of the amount of sediment transported in a river. A volume of at least $3 \cdot 3 \times 10^6$ cu yd of sand and gravel was deposited within this period from a catchment of 30 sq miles (Löffler 1970). Most of the material eroded from the mountains has been deposited in front of the mountains either as alluvial fans in the intermontane trough or as alluvium on the coastal plain.

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PART VI. SOILS OF THE VANIMO AREA

By H. A. Haantjens*

I. Soil Classification and Description

(a) Soil Classification

The 167 soil profiles, observed entirely in auger borings, have been classified into subgroups according to the 7th Approximation (United States Soil Conservation Service 1960), except for the oxisols which have been classified and separated from the dystrochrepts and ultisols according to the writer's own system.† Because of the superficial nature of the observations and the lack of relevant analytical data, it was necessary in some cases to deviate from the literal application of the differentiae used in the 7th Approximation. The problems encountered and the manner in which they were dealt with are the same as those described in earlier reports (Haantjens 1967, 1972).

The subgroups have been labelled with four capital letters (Haantjens 1972). Many of them have been subdivided into what are called lowest (category) soil classes, which have been indicated by a suffix numeral, usually in order of increasing acidity and profile development within a group. The lowest soil classes have, as nearly as feasible, been made uniform in properties affecting their use for practical purposes.

A tentative correlation of the lowest soil classes of the Vanimo area with those of the adjoining Aitape–Ambunti area is presented in Table 10. It should be kept in mind that a number of Aitape–Ambunti soil classes, particularly amongst those occurring south of the main mountain range, have no equivalents in the Vanimo area. In comparison with work done in the Aitape–Ambunti area (Haantjens 1972), slightly more acid soils have been included in the eutric dystrochrepts (IODE) rather than in the orthic dystrochrepts (IODO), because this appeared to conform more precisely to the 7th Approximation concepts.

(b) Soil Description

(i) *Pedological Description of Soil Classes*.—A brief description, necessarily limited in scope by the superficial nature of the observations, of the lowest soil classes, grouped according to great group and subgroup, is presented in tabulated form (Table 11). In considering this table the following points should be kept in mind:

The single number in column 1 represents the number of observations of the soil class. The number(s) preceded by T refers to later tables containing information on the occurrence of the soil class as observed in the field.

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† Haantjens, H. A. (1965).—The classification of oxisols (latosols). CSIRO Aust. Div. Land Res. Reg. Surv. tech. Memo. 65/5 (unpublished).

TABLE 10

CORRELATION BETWEEN LOWEST SOIL CLASSES OF VANIMO AND AITAPE–AMBUNTI AREAS

Vanimo area	Aitape–Ambunti area*	Vanimo area	Aitape–Ambunti area*
EAPO	=EAPO	IAUO	IAUP
EPOA	=EPOA	IUHO	=IUHO2
EPOO1	EPOO	IOER	—
EPOO2	(EPOO)	IOEO1	IOEL
EPOU	(EUHO2)	IOEO2	—
EAYS1	EAY3	IOED	—
EAYS2	EAHY1, (EAY5)	IODE1	IODE1
EAYO1	EAY1	IODE2	IODE2
EAYO2	EAY3	IODE3	(=)IODE4
EAYO3	EAY3	IODE4	IODE3
EAHY	(EAHY1)	IODE5	—
EAHO1	—	IODE6	IODE3, IODE5
EAHO2	=EAHO	IODE7	—
EAHU	EAHU2	IODO1	(=)IODO2
EAHS	=EAHS2	IODO2	IODO1
EUHL	EUHL	IODO3	=IODO1
EUHA1	(EUHA1)	IODO4	IODO4
EUHA2	EUHA1	IODO5	IODO5
EUHA3	EUHA2	IODX	IODX
EUHA4	=EUHA3	AAOO1	(AAOO)
EUHA5	EUHA4	AAOO2	(AAOO)
EUHA6	—	AAOO3	(AAOO)
EUHO1	=EUHO1	AUTA1	—
EUHO2	EUHO1	AUTA2	=AUTA1
EUHO3	(EUHO1, EUHO3)	AUTA3	AUTA3
EUHO4	EUHO2–3	AUTA4	AUTA2
EUHO5	=EUHO3	AUTA5	AUTA2
EUHO6	EUHO3–4	AUTO1	AUTO1
EUHO7	EUHO5	AUTO2	(AUTO2)
EUHO8	=EUHO5	AUTO3	AUTO2
EUHO9	—	AUTO4	AUTO2
EUHO10	—	AUTO5	AUTO2
EUHO11	=EUHO7	AUTO6	—
EUHO12	EUHO9	AUTO7	(=)AUTO3
MUHP	=MUHP	AUTU	—
MUHE	—	UAOO	(UAOU)
MUHO	(MUHO1)	UOTA1	(UOTA1)
MR–P	MR–O1	UOTA2	UOTA2
MR–O1	=MR–O1	UOTA3	(UOTA2)
MR–O2	(MR–O2)	UOTO1	=UOTO1
MR–O3	(MR–O2)	UOTO2	UOTO2
MR–O4	MR–O2	UOTO3	(UOTO3)
MR–E	MR–E	UOPA	UOPA1–2
MR–X	—	OHNT	(OANT2)
IAOO1	—	OANT	OANT1, OANT2
IAOO2	—		UOTO5

* The = sign indicates virtual identity. A class by itself indicates similarity, a class in parenthesis indicates some similarity, no class indicates there is no soil class even slightly similar at the lowest categorical level.

The statements on profile development represent a rather subjective assessment based partly on the degree of weathering of the soil material, partly on the degree of horizon differentiation, soil acidity, and solum thickness.

All features in columns 4–11 refer to the solum (A + B horizons) alone, except when the solum thickness is nil or very thin (entisol, psammentic and entic hapludoll) and for orthic haplumbrept and orthic umbraquept. In these cases the descriptions also refer to any unconsolidated C or D horizons.

The term dark topsoil refers to any surface A_1 horizon with a Munsell value of 3 or less and an organic carbon content of $0\cdot6\%$ or more. It includes any peaty surface horizon (histic epipedon).

The matrix colour refers to the B horizon, or to the unconsolidated C or D horizon in soils without significant solum development, as specified above. In MR-O and MR-X soils it refers to the lower part of the dark topsoil.

The gleying description refers firstly to the depth at which gleying occurs, secondly to the degree of gleying.

The primary purpose of column 8 (coarser-textured upper horizon) is to signal the possibility that the soil class has a texture B horizon (argillic horizon). Column 8 is only used when the field texture of the surface horizon is at least one class coarser than that of the underlying horizon. The figures in brackets indicate the thickness of this coarser horizon.

The texture in column 9 is excluding anything that may have been written in column 8. An arrow indicates a trend with depth.

The usual consistence is the typical consistence during the drier season of the soil material, based on field evaluations. It refers to the texture classes listed in column 9. The coarser-textured upper horizon (column 8) always has a softer, more friable or less plastic consistence.

Special features include many properties that appear to have pedological significance but are not covered in the previous columns. They are mostly self-explanatory. The mentioning of reddish and other bright mottles indicates the possibility of the presence of plinthite in varying degrees of development.

Most descriptive and quantifying terms used in Table 11 have been more precisely defined in Appendix I. Depth-of-gleying classes are the same as thickness-of-solum classes. Colour names are based on a grouping of hue/value/chroma combinations in a Japanese version of the Munsell colour chart (details available upon request). The degree of gleying is based on matrix colour and mottling.*

Parentheses in column 2 and following are used essentially to record variability with the greatest economy in words. For example, (very) thin means thin *or* very thin; (neutral →) alkaline means wholly alkaline *or* neutral merging into alkaline with depth; dark (grey) (brown) means dark grey *or* dark brown *or* dark grey-brown; (sandy) clay (loam) means clay *or* sandy clay *or* clay loam *or* sandy clay loam. When a whole entry is in parentheses the property was observed only in part of the observations of the soil class. Parentheses round a soil class name indicate that this name does not occur in the 7th Approximation.

* Haantjens, H. A. (1969).—Agricultural land classification for New Guinea land resources surveys, second revised edition. CSIRO Aust. Div. Land Res. tech. Memo. 69/4 (unpublished).

Table 11

SUMMARIZED PEDOLOGICAL DESCRIPTION OF LOWEST SOIL CLASSES

(Refer also to Part VI, Section I(*b*)(i))

1 Soil class, No. of obs., Occurrence	2 Profile development	3 Solum thickness	4 Soil reaction	5 Dark topsoil	6 Matrix colour	7 Gleying	8 Coarser-textured upper horizon	9 Texture	10 Usual consistence	11 Special features
Orthopsamments, aquic										
EPOA 1, T13	Very slight	(Very) thin	Neutral→ strongly alkaline	Thin	Very dark olive (brown)	Moderately shallow, moderate	—	Sand	Loose, non-plastic	—
Orthopsamments, orthic										
EPOO1 1, T13	Very slight	Very thin	Neutral	Moderately thick	(Very) dark olive-brown	—	—	Sand	Loose	—
EPOO2 1, T15	Nil	Nil	Neutral	Thin	Olive-grey	—	—	Loamy sand→ gravelly coarse sand	Loose	—
Orthopsamments, udic										
EPOU 1, T15	Nil	Nil	Neutral	—	Very dark olive-brown	—	—	Loamy→ gravelly sand	Very friable →loose	—
Psammaquents, orthic										
EAPO 1, T13	Very slight	Very thin	Neutral→ strongly alkaline	Thin	Very dark grey	Shallow, strong	—	Sand	Non-plastic, non-sticky	—
Hydraquents, (histic)										
EAYS1 1, T14	Nil	Nil	Neutral	—	Green-grey	Very shallow, strong	—	Clay	Slightly plastic, extremely sticky	Very dark peaty subsoil
EAYS2 1, T20	Nil	Nil	Acid→ weakly acid	Thick, peaty	(Very) dark olive (brown)	Moderately deep, strong	—	Clay	Slightly plastic, extremely sticky	Peaty clay deep subsoil
Hydraquents, (orthic)										
EAYO1 1, T14	Nil	Nil	Alkaline	—	Very dark green-grey	Very shallow, strong	—	Stratified: clay to loamy sand	Slightly plastic, variably sticky	Calcareous
EAYO2 1, T15	Nil	Nil	Neutral	—	Grey-green	Very shallow, strong	—	Heavy clay	Slightly plastic, extremely sticky	Peaty clay layer
EAYO3 1, T15	Slight	Nil	Acid→ weakly alkaline	—	Olive-grey, (very) dark green-grey	Shallow, strong	—	(Heavy) clay	Plastic, very sticky	—

Haplaquents, hydric										
EAHY 2, T15	Nil	Nil	Weakly acid to neutral	—	Variable grey and brown	Very shallow, strong	—	Stratified: (heavy) clay to sandy (clay) loam	Variably plastic and sticky	—
Haplaquents, orthic										
EAHO1 1, T15	Nil	Nil	Alkaline	—	Dark brown-grey→dark green-grey	Moderately shallow, strong	—	Clay loam to sandy loam →clay	Variably plastic and sticky	Slightly calcareous
EAHO2 3, T14	Nil	Nil	Neutral	—	Dark olive-grey to blue-grey	Very shallow, strong	—	Heavy clay	Very plastic, (very) sticky	—
Haplaquents, udic										
EAHU 3, T13, 15	Nil	Nil	Neutral to weakly acid	—	Variable grey and brown	Very to moderately shallow, strong	—	Mainly clay to clay loam	Variable	—
Haplaquents, spodic										
EAHS 1, T15	Nil	Nil	Neutral	—	Brown-grey→ green-grey	Moderately deep, strong	—	Silty heavy clay	Mainly plastic	—
Haplaquents, aquic										
EUHA1 1, T15	Nil	Nil	Alkaline	—	Dark olive-brown→ olive-grey	Moderately deep, strong	—	Clay→heavy clay	Firm to plastic →very plastic, sticky	Calcareous
EUHA2 1, T15	Nil	Nil	Alkaline	—	Dark olive-brown→ olive-grey	Shallow, moderate	—	Silty clay (loam)	Friable, firm	—
EUHA3 2, T15	Nil	Nil	Neutral	—	Mostly brownish, some grey	Shallow, moderate; moderately shallow, strong	—	Mainly (silty) clay	Firm to friable →variably plastic, sticky	—
EUHA4 2, T15	Nil	Nil	Weakly acid	—	Brownish→ greyish	Moderately shallow, strong	—	Mainly silty heavy clay	(Very) firm→ (very) plastic, variably sticky	—
EUHA5 2, T13,15	Nil	Nil	(Weakly) acid	(Thin)	(Dark) brownish and greyish	Shallow, moderate	—	Clay merging into coarse sand	Firm→loose, non-plastic, slightly sticky	—
EUHA6 1, T17	?Nil	?Nil	Strongly acid →alkaline	—	Grey-brown → grey	Moderately deep, strong	—	Silt loam→ clay→heavy clay	(Very) friable, →very plastic, slightly sticky	?Two unrelated sediments
Hapludents, orthic										
EUHO1 2, T15	Nil	Nil	(Strongly) alkaline	—	Dark olive (brown)	—	—	Stratified fine sand to silty clay loam	Loose to friable	Calcareous
EUHO2 1, T15	Nil	Nil	Alkaline	—	Dark brown-grey→dark olive-brown	—	—	Silty clay→ sand	Firm→loose	Calcareous

TABLE 11 (*Continued*)

1 Soil class, No. of obs., Occurrence	2 Profile development	3 Solum thickness	4 Soil reaction	5 Dark topsoil	6 Matrix colour	7 Gleying	8 Coarser- textured upper horizon	9 Texture	10 Usual consistence	11 Special features
Hapludents, orthic (*Continued*)										
EUHO3 1, T15	Nil	Nil	(Strongly) alkaline	Thin	(Dark) olive-brown	—	—	Clay	(Very) firm	Calcareous
EUHO4 3, T15	Nil	Nil	Weakly alkaline	(Thin)	Dark olive-brown, dark grey-brown	(Moderately shallow, weak)	—	Silty clay (loam)(→ sand)	Friable→ non-plastic, slightly sticky	—
EUHO5 4, T15	Nil	Nil	Neutral	(Thin)	Dark olive-brown to brown-grey	Shallow to moderately deep, weak	—	Mainly (silty) clay	Mainly firm to plastic	—
EUHO6 6, T15	Very slight	Nil	Weakly acid → neutral	(Thin)	Variably brownish, mostly dark	(Moderately deep, weak)	—	Stratified: clay to sand	Variable	—
EUHO7 3, T15,16	Very slight	Nil	Weakly acid (→ neutral)	Thin	(Dark) grey-brown	—	—	(Sandy clay) loam to silty clay→ sand	(Very) friable → loose	(Gravelly subsoil)
EUHO8 2, T15	Very slight	Nil	(Weakly) acid	Thin	Olive-brown, yellow-brown	—	—	(Sandy) clay (loam)→ coarse sandy (clay) loam to sand	(Very) friable → loose, non-plastic, non-sticky	(Gravelly subsoil)
EUHO9 2, T15	Very slight	Nil	Acid	—	Olive-brown, grey-brown	(Moderately) shallow, weak	—	Clay	Firm (to plastic)	Scattered gravel, stones
EUHO10 3, T17	Nil	Nil	(Neutral→) alkaline	(Moderately) thin	Olive-brown, grey-brown	(Deep, weak)	—	(Silty) (heavy) clay	(Very) firm to (very) plastic	Calcareous subsoil and substratum
EUHO11 2, T16,17	Very slight	Nil	Weakly acid to neutral (irregular)	—	Grey-brown, olive-brown	Deep, weak to moderate	—	Clay	Very firm to plastic	Weathered rock fragments; weathered sedimentary rock at depth
EUHO12 3, T18	Very slight	Nil	Acid	Thin	(Dark) yellow-brown, grey-brown	—	—	(Silty) clay, silty clay loam	Firm or friable to plastic	Many weathered rock fragments below 15–30 in. depth
Hapludolls, (psammentic)										
MUHP 1, T13	Very slight	Very thin	Neutral→ alkaline	Moderate	Very dark olive	—	—	Sand, loamy in topsoil	Loose	—

Hapludolls, entic										
MUHE 1, T18	Very slight	Very thin	Neutral→ alkaline	Moderate	Dark brown-grey	—	Loam (7)	Sandy clay→ sandy loam	(Very) friable	Many but variable rock fragments
Hapludolls, orthic										
MUHO 1, T19	Slight	Moderately thin	Neutral→ weakly acid	Moderate	Dark brown	—	—	Clay	Friable to plastic	Increasing rock fragments
Rendolls, psammentic										
MR–P 2, T13	Very slight	Thin	Strongly alkaline	Moderate	Mainly dark brown	—	—	Sandy loam→ (loamy) (coarse) sand	Loose	Much gravel
Rendolls, orthic										
MR–O1 1, T19	Slight	Very thin	Weakly alkaline	Moderate	Very dark brown	—	—	Loam	Very friable	Very much gravel
MR–O2 5, T19,20	Slight	Thin	(Strongly) alkaline	Thick to moderate	Very dark (grey) (brown)	—	Clay (loam) (3–5)	(Heavy) clay	(Very) friable →(very) firm to plastic	(Very) many rock fragments
MR–O3 3, T17,20	Slight	Very thin	Weakly alkaline (→alkaline)	Moderate	Dark (olive) brown, very dark grey-brown	—	—	Clay	(Very) friable	Variable rock fragments
MR–O4 3, T19,20,21	Slight	(Very) thin	Neutral	Moderate	Very dark (grey) brown	—	—	(Clay) (loam)	Very friable to firm	Much gravel and stones
Rendolls, eutrochreptic										
MR–E 2, T19,20	Moderate	(Very) thin	(Weakly) alkaline	Thin to moderate	Dark grey/ olive brown	—	—	Mainly heavy clay	Very firm to very plastic	—
Rendolls, (lithoxic)										
MR–X 1, T20	Strong	Very thin	Alkaline	Thin	Very dark red	—	—	Clay	Very friable	Strong fine blocky to granu-ular structure; very stony
IAOO1 2, T16,17	Moderate	(Moderately) thick	Acid→neutral	—	Olive-brown to dark blue-grey	Shallow, strong to moderate	Clay to silty clay loam (2–4)	(Silty) heavy clay	Firm to very plastic, vari-ably sticky	—
IAOO2 2, T16,17	Moderate	Thick	(Strongly) acid	—	Yellow-brown to light green-grey	Very shallow, strong to moderate	Clay (4)	Heavy clay	Very plastic, variably sticky	Red-brown mottles upper part
Umbraquepts, orthic										
IAUO 1, T14	Slight	Thin	Acid→ weakly acid	Thick	Dark olive-brown	Very shallow, weak	—	(Sandy clay) loam→sand	Slightly to non-plastic, (slightly) sticky	—
Haplumbrepts, orthic										
IUHO 1, T13	Slight	Moderately thin	Acid→ weakly acid	Thick	Dark (olive) brown	—	—	Loam→sand	Very friable →loose	—

TABLE 11 (*Continued*)

1 Soil class, No. of obs., Occurrence	2 Profile development	3 Solum thickness	4 Soil reaction	5 Dark topsoil	6 Matrix colour	7 Gleying	8 Coarser-textured upper horizon	9 Texture	10 Usual consistence	11 Special features
Eutrochrepts, rendollic										
IOER 1, T20	Slight	Moderately thin	Alkaline	—	Grey-brown	—	Clay (2)	Heavy clay	Very plastic	—
Eutrochrepts, orthic										
IOEO1 2, T17,19	Slight	Moderately thin	Alkaline	—	(Dark) olive-brown	—	—	(Heavy) clay	(Very) firm	(Slightly) calcareous
IOEO2 2, T17,20	Slight	Thick	Alkaline	(Thin)	(Dark) olive-brown, (dark) grey-brown	—	—	(Heavy) clay	Plastic to very firm	Limestone fragments; calcareous at depth
Eutrochrepts, dystric										
IOED 6, T17,19	Slight	Moderately thin (to moderately thick)	Neutral→ (weakly alkaline)	—	(Dark) olive-brown, (dark) grey-brown	(Moderately deep, weak)	Clay (1–3)	(Silty) heavy clay, rarely clay	Very firm (to very hard, to very plastic)	Calcareous in and just above C horizon
Dystrochrepts, eutric										
IODE1 2, T17,20	Slight	Thin	Neutral to weakly acid	Thin	Dark (grey) brown	—	Clay (2–3)	Heavy clay	Extremely plastic to very firm	—
IODE2 3, T17,19	Slight to moderate	Moderately thin to moderately thick	Neutral (→ weakly acid)	—	Dark brownish → (yellow) brown	—	—	(Sandy) clay	Firm to plastic	(Some gravel)
IODE3 2, T17	Slight to moderate	Thin	Weakly acid	Thin	(Dark) grey-brown, olive-brown	—	—	Sandy or silty clay	Firm to friable	—
IODE4 4, T17,20	Slight to moderate	Moderately thin to moderately thick	Weakly acid, rarely neutral	(Thin)	Olive-brown, grey-brown	—	(Silty) clay (0–2)	(Silty) heavy clay	Very firm	—
IODE5 3, T17,19	Moderate	Moderately thick	Acid (→ weakly acid)	—	Olive-brown, grey-brown	Moderately deep, moderate	(Silty) clay loam (0–3)	Silty clay	(Very) firm to plastic	—
IODE6 2, T17	Moderate	Moderately thin	Acid	—	Grey-brown	—	Clay loam (0–2)	(Silty) clay, sandy clay	Friable, slightly hard	Few→many rock fragments
IODE7 2, T17,18	Moderate	Moderately thin to thick	Acid	—	(Dark) yellow-brown, grey-brown	—	Clay loam (0–3)	(Silty) clay	Firm, plastic and sticky	—
Dystrochrepts, orthic										
IODO1 1, T21	Slight	Thin	(Strongly) acid	Thin	Dark brown	—	—	Silt loam to clay loam	Very friable, slightly sticky	Many rock fragments
IODO2 2, T16,21	Moderate	(Moderately) thin	Acid	Thin	Dark (yellow) brown	—	—	Clay	Friable to firm to (slightly) plastic	—

IODO3 2, T17	Moderate	Moderately thick	Acid	—	Variably brownish	Shallow, weak	Clay loam (3–4)	(Silty) clay	(Very) firm to plastic	—
IODO4 1, T17	Moderate	Thick	Acid	—	Grey-brown, yellow-brown	—	—	Stratified clay loam, (sandy) clay	Friable to slightly plastic	Rock fragments, increasing with depth
IODO5 1, T21	Moderate	(Moderately) thin	Strongly acid	—	Dark yellow-brown	—	Loam (2)	Silty clay	(Very) friable	—
Dystrochrepts, oxic										
IODX 2, T21	Strong	(Moderately) thick	Strongly acid	A_0(1–9) of roots and litter	(Dark) red-brown, dark brown-red	—	—	Silty clay→ clay loam	(Very) friable to slightly plastic and slightly sticky	(Many rock fragments)
Ochraqualfs, orthic										
AAOO1 1, T17	Slight to moderate	Moderately thin	Weakly acid →neutral	—	Dark olive-brown to dark grey	Very shallow, moderate	Clay loam (8)	Clay	Plastic, variably sticky	—
AAOO2 4, T15,16	Moderate	Moderately thin to moderately thick	(Weakly) acid	—	Dark brown to light grey	Very shallow, strong	Clay (loam) (6–10)	(Silty) heavy clay to clay	Very plastic to slightly plastic and very sticky	Vague boundary between solum and underlying weakly acid to neutral materials
AAOO3 1, T17	Strong to moderate	Moderately thick	Acid	Thin	Grey-brown to olive-grey	Very shallow, moderate	Clay loam, silty clay (5)	(Silty) heavy clay	Very plastic	—
Typudalfs, aquic										
AUTA1 2, T17,20	Slight to moderate	Moderately thick	Neutral to weakly acid	(Thin)	Variable grey and brown	Shallow, moderate	Clay (9–10)	Silty heavy clay	Very firm to very plastic	—
AUTA2 1, T15	Moderate	Moderately thick	Weakly acid →neutral	—	Grey-brown	Shallow, moderate	(Clay) loam (9)	(Silty) clay	Firm	Vague boundary between solum and alkaline underlying materials
AUTA3 1, T17	Moderate	Thick	Acid→ weakly acid	—	Variable grey and brown	Moderately shallow, strong	Clay (8)	Heavy clay	Very firm to extremely plastic	Vague boundary between solum and weakly alkaline softened rock
AUTA4 2, T15,16	Moderate	(Moderately) thick	Acid→ weakly acid	—	Yellow-brown to grey-brown	(Moderately) shallow, moderate	Clay (loam) (6–7)	Heavy clay, silty (heavy) clay	Very plastic, firm to plastic	Vague boundary between solum and underlying neutral materials
AUTA5 2, T16	Moderate	Moderately thick	Acid	—	Grey-brown to olive-brown→ olive-grey	Shallow, moderate	Loam, (fine sandy) clay loam (14–16)	(Silty) clay	Firm to plastic	—

TABLE 11 (*Continued*)

1 Soil class, No. of obs., Occurrence	2 Profile development	3 Solum thickness	4 Soil reaction	5 Dark topsoil	6 Matrix colour	7 Gleying	8 Coarser-textured upper horizon	9 Texture	10 Usual consistence	11 Special features
Typudalfs, orthic										
AUTO1 3, T17,20	Moderate	Moderately thick	Neutral→ weakly acid (→alkaline)	(Thin to moderately thick)	(Dark) olive-brown, (dark) grey-brown	—	Clay loam, (silty) clay (5–8)	Clay, (silty) heavy clay	(Very) firm to (very) plastic	—
AUTO2 2, T20	Moderate	Moderately thin	Neutral to weakly acid	Thin	Dark (yellow) brown	—	Clay (5–6)	Silty heavy clay	Very hard, very firm	—
AUTO3 1, T20	Moderate	Moderately thin	Weakly acid	Thin	Grey-brown, (dark) yellow-brown	Shallow, weak	Sandy clay (loam) (8)	(Sandy) heavy clay to clay	Very hard, very firm	—
AUTO4 2, T16	Moderate	Moderately thin	(Weakly) acid	—	(Dark) yellow-brown	Shallow, weak	Clay (loam) (11–12)	Silty heavy clay to clay	(Very) firm to very plastic	Vague boundary between solum and underlying neutral materials
AUTO5 2, T17,20	Moderate	Moderately thick	(Weakly) acid	Thin	(Dark) grey-brown, yellow-brown	—	Clay (loam), silty clay (7–12)	(Silty) heavy clay	Very to extremely firm, very plastic	—
AUTO6 2, T17,20	Moderate	Moderately thin to moderately thick	(Weakly) acid	—	Grey-brown, dark yellow-brown	—	Sandy loam, clay loam (5–8)	Sandy clay loam, silty clay	Very friable to firm	Vague lower boundary of solum
AUTO7 1, T20	Moderate to strong	Moderately thick	Acid	—	Grey-brown	Shallow, weak	Clay loam →clay (16)	Silty heavy clay	Very firm to very plastic	Low black concretions and dark red (brown) mottles; vague lower solum boundary
Typudalfs, ochrultic										
AUTU 1, T20	Moderate to strong	Moderately thin	Neutral→acid	—	Dark (yellow) brown	—	Clay (9)	Heavy clay	Hard, friable	Strong sub-angular blocky structure
Ochraquults, orthic										
UAOO 1, T15	Moderate to strong	Moderately thick	Acid	—	Dark (brown) grey	Very shallow, moderate; moderately deep, strong	Silty clay loam (14)	Silty clay	(Slightly) plastic and (very) sticky	Dark red-brown mottles
Typochrults, aquic										
UOTA1 2, T17	Moderate to strong	Moderately thin	Acid	—	Dark brown to yellow-brown	Very shallow, moderate to weak	(Silty) clay loam (6–7)	(Sandy) clay to sandy heavy clay	(Very) firm to (very) plastic	—

UOTA2 3, T15	Strong to moderate	(Moderately) thick	(Strongly) acid	—	Brown to olive-brown	Very shallow, moderate to weak	(Silty) clay loam (6–13)	(Silty) clay	Firm to plastic	Vague lower boundary of solum
UOTA3 1, T17	Strong	(Moderately) thick	Strongly acid	—	Yellow-brown → brown-grey	Shallow, moderate	Clay (5)	Heavy clay	Very to extremely plastic	—
Typochrults, orthic										
UOTO1 4, T17,18	Strong to moderate	Moderately thick	Acid	—	(Dark) yellow-brown, grey-brown	(Weak)	(Silty) clay (loam) (6–9)	(Silty) heavy clay→ (silty) clay	Very firm to very plastic→ firm to plastic	—
UOTO2 1, T18	Strong	Moderately thick	Strongly acid	—	Dark brown→ yellow-brown	Moderately shallow, weak	Clay loam (5)	Clay	Plastic	Vague lower boundary of solum
UOTO3 2, T16	Strong to very strong	(Moderately) thick	Strongly acid	—	(Dark) grey-brown→ (yellow) brown	—	(Sandy) clay loam (7–18)	Clay	Firm to plastic	Reddish mottles in subsoil, variable hard gravel
Plintochrults, aquic										
UPOA 2, T16	Very strong	(Moderately) thick	(Strongly) acid	—	Grey-brown to yellow brown → grey-brown to olive-grey	Moderately shallow, moderate	(Fine sandy) clay loam→ (fine sandy) clay (11–26)	(Clay→) (silty) heavy clay→ clay	Very firm to very plastic	Prominent red, brown, light grey mottling in B
(Normaplox, typic)										
OHNT 1, T21	Very strong	Thick	Strongly acid	—	Dark red-brown→ dark brown-red	—	Silty clay loam (4)	Silty clay	Friable to slightly plastic	Vague lower boundary of solum
(Normargox, typic)										
OANT 4, T16.17	Very strong	(Very) thick	Strongly acid (to acid)	(Thin)	Dark brown to yellow-brown → brown to (dark) red-brown	—	(Sandy or silty) clay loam to (sandy or silty) clay (6–14)	(Silty or sandy heavy clay→) (silty) clay	Friable to (slightly) plastic, (firm)	Vague lower boundary of solum

(ii) *Description of Soil Classes for Land Use Purposes.*—In Table 12 the lowest soil classes are rated for a number of properties that are important for land use. Many ratings depend on assessment rather than measurement of the properties. Soil reaction ratings, however, are based on colorimetric pH measurements in the field. Nitrogen, phosphate, and potash ratings are derived from analyses of surface and subsurface samples carried out in the chemical laboratory at the Division of Land Research under the supervision of Mrs. I. M. Serjeant. Unified Soil Classification and linear shrinkage ratings are based on actual measurements made on 101 samples, and on extrapolation of these data to soils not analysed. The determinations were carried out by the soil mechanics laboratory of the Department of Public Works, Port Moresby.

Definitions of the rating terms used can be found in Appendix I. Soil reaction ratings in Table 12 can differ slightly from those in Table 11, because the former are based on pH data corresponding to the agricultural depth value, while the latter are based on pH data from the solum. Three ratings are given for available soil water storage capacity. The first applies to the top 20 in. of soil, the second to the top 45 in., and the third to 72 in. of soil. L^- equals 2–2·9 in. of water, L^+ equals 3–3·9 in. of water.

Parentheses are used in Table 12 in the same manner as described for Table 11.

(iii) *Description of Soils in Land Systems.*—In order to increase the usefulness of the descriptions for practical purposes, they are couched primarily in terms of practically important soil properties. Another reason for this is that many land systems appear to be more homogeneous with respect to such soil properties than with respect to their pedological lowest soil class composition. The lowest soil classes observed in each land system are listed in Tables 13–21.

Soil texture is mentioned in the land system descriptions in a simplified form: *coarse texture* includes sand, loamy (fine) sand, clayey sand, and gravelly loam; *medium texture* includes sandy loam, silt loam, loam, and sandy clay loam; *fine texture* includes silty clay loam, clay loam, sandy clay, silty clay, and clay; *very fine texture* includes sandy heavy clay, silty heavy clay, and heavy clay.

II. Soil Distribution and Formation

(a) *Soil Distribution*

Because of the great variability in detail of land forms and sedimentary rock types in much of the area, the number of soil observations has proved too small to establish precise correlations in many cases. Therefore no areal extrapolation could be made of sufficient reliability to produce a separate soil map. It is only possible to discuss some general trends in the distribution of the soils over the land system.

The distribution of the lowest soil classes over the land systems as observed in the field is shown in Tables 13–21, from which land systems without field observations have been excluded. The tables basically follow the grouping of the land systems on the land system map. For pedological reasons, however, freshwater swamp land systems and the unstable flood-plain land system (land systems 3–6) have been taken out of the littoral plains and alluvial plains groups and placed together in Table 14. It should also be noted that land system 9, although excluded for lack of field data, is likely to fit better in Table 14 than in Table 15 from the pedological point of view. The large group of land systems on soft sedimentary rocks has been broken up into two tables for convenience.

Where a lowest soil class occurs in more than one group of land systems a reference to the other relevant table(s) has been added. The type of land form on which each soil was observed is mentioned in the tables to provide some extra information. Lithology has been mentioned in the tables only when it differs from what would normally be expected in each group.

(i) *Note on Table 13.*—The two land systems of the "dry" littoral plains are pedologically distinct, as is to be expected. The group as a whole is characterized by generally having its own distinct lowest soil classes. Two classes from a coastal alluvial plain, however, were also observed on inland alluvial plains (Table 15).

(ii) *Note on Table 14.*—The freshwater swamps have their own specific and quite expected lowest soil classes, but very similar soils are also common on the alluvial plains of Table 15.

(iii) *Note on Table 15.*—The alluvial plains have mostly soil classes unique to this type of terrain. Some coarse-textured soils on low terraces are very similar to sandy soils on frontal beach ridges (Table 13). The commonness of poorly to very poorly drained soils, similar to the normal soils of freshwater swamps, is noteworthy. These soils occur mostly under tall forest on apparently normal alluvial plains, which is in contrast to normal experience in New Guinea. No explanation can be offered, but it appears that the actual drainage status of the soil as evaluated from matrix colour and mottling may be of lesser significance in relation to the vegetation than other hydrological factors such as flooding, inundation, and water-table fluctuations, and possibly also climatic factors and even human interference with the vegetation. Imperfect relationships between soil drainage status and vegetation were already noticed in the adjoining Aitape–Ambunti area (Table 12 of Heyligers 1972).

Some more acid undeveloped soils (such as EUHO7) and more developed soils occur also in the land systems of the alluvial fans (Table 16) and indicate a basic pedological similarity between the fan surfaces and the high terraces in the alluvial plains.

(iv) *Note on Table 16.*—Although many of the lowest soil classes on the alluvial fans also occur in other groups of land systems, the most common soils on fans are unique or nearly unique for this group. The overlap with the alluvial plains is discussed above. The smaller overlap with hilly land systems in other groups is probably caused by basic similarities in soil formation on steep slopes in the hills and in dissected fans, and in one case by lithological similarity.

(v) *Note on Tables 17–20.*—There is considerable overlap in the lowest soil class composition of the land system groups on soft sedimentary rocks, on mixed sedimentary rocks dominated by limestone, and on limestone. The strong overlap of Table 19 with both Tables 17 and 20 is according to expectations and confirms the intermediate position of the group of land systems on mixed lithology. The overlap between Tables 17 and 20, however, is somewhat surprising. There is evidence that only vestiges of clastic sedimentary rocks are necessary in land systems on limestone

TABLE 12

RATING OF LOWEST CATEGORY SOIL CLASSES FOR PROPERTIES IMPORTANT TO LAND USE

(Refer also to Part VI, Section I(*b*)(ii))

1 Soil class	2 Agricultural depth	3 Avail. soil water storage capacity*	4 Drainage status	5 Permeability	6 Soil reaction	7 Nitrogen	8 Phosphate	9 Potash	10 Unified Soil Classification	11 Linear shrinkage	12 Engineering depth
Orthopsamments, aquic											
EPOA	Deep	VL, L, M	Poor	Very rapid	Weakly alkaline	Low	Very low	Moderate	SP	Nil	Very deep
Orthopsamments, orthic											
EPOO1	Deep	VL, L, M	Good	Very rapid	Neutral	Very low	Very low	Moderate	SP	Nil	Very deep
EPOO2	Moderately shallow	VL, L, L	Good	Rapid	Neutral	Low	Very low	Moderate	SM over SG	Very low over nil	Very deep
Orthopsamments, udic											
EPOU	Deep	VL, L, M	Good	(Very) rapid	Neutral	Low	Low	High	Thin ML over SG	Very low over nil	Very deep
Psammaquents, orthic											
EAPO	Deep	VL, L, M	Swampy	Very rapid	Alkaline	N.d.	Very low	Moderate	SP	Nil	Very deep
Hydraquents, (histic)											
EAYS1	?Deep	L^-, MH, H	Swampy	?Moderate	Neutral	N.d.	N.d.	N.d.	CH over Pt	Extremely high	Very deep
EAYS2	Moderately deep	M, H, H	Swampy	Moderate	Acid	Very high	Very high	Moderate	CH over OH	High	(Very) deep
Hydraquents, (orthic)											
EAYO1	Very deep	L^+, MH, VH	Swampy	Moderate	Alkaline	Very low	Low	High	CL	Moderate	Very deep
EAYO2	Deep	L^-, M, M	Very poor	Very slow	Neutral	Moderate	High	High	CH	Very high	Very deep
EAYO3	Very deep	L^-, M, H	Very poor	Slow	Weakly acid	Moderate	Moderate	Moderate	CH	High	Very deep
Haplaquents, hydric											
EAHY	Deep	L^-, M, MH	Very poor	(Very) slow	Neutral to weakly acid	Moderate	Moderate	High	CL	Moderate	Very deep
Haplaquents, orthic											
EAHO1	Deep	L^+, MH, H	Poor	Rapid over slow	Alkaline	Very low	Moderate	High	CL	Moderate	Very deep
EAHO2	Moderately deep to moderately shallow	L^-, M, M	Very poor to swampy	Very slow	Neutral	Moderate	High to moderate	Very high to high	CH	High	Very deep
Haplaquents, udic											
EAHU	(Very) deep	L, MH, (V)H	Poor	Moderate	Neutral to weakly acid	Low to moderate	Low to high	High to moderate	CL to CH	Moderate to high	Very deep
Haplaquents, spodic											
EAHS	Moderately deep	L^-, M, M	Poor	Slow	Neutral	Moderate	Moderate	High	CH	High	Very deep
Hapludents, aquic											
EUHA1	Moderately deep	L^-, M, M	Imperfect	Slow	Alkaline	Moderate	Moderate	High	CH	High	Very deep

EUHA2	Very deep	L^+, MH, VH	Imperfect	Moderate	Alkaline	Low	Very high	Very high	MH	Moderate	Very deep
EUHA3	Deep	L, M(H), MH	Imperfect	Moderate	Neutral	Low to moderate	Moderate	High	CL to MH	Moderate to high	Very deep
EUHA4	Moderately deep	L, M, M	Imperfect	(Very) slow	Neutral to weakly acid	Low to moderate	Low to moderate	High	CH	High	Very deep
EUHA5	(Very) deep	L, M(H), M(H)	Imperfect	Moderate	(Weakly) acid	Moderate	Low	Low to moderate	CH over SM	(Very) high over very low	Very deep
EUHA6	Deep	L^+, MH, MH	Imperfect	Moderate over very slow	Strongly acid over alkaline	Low	Low	Moderate	ML over CH	Low over high	Very deep
Hapludents, lithic											
EUHL	Very shallow	(V)L^-, L, L	Good	Moderate to rapid	Weakly alkaline to neutral	N.d.	N.d.	N.d.	CL, GC	Moderate	Very shallow
Hapludents, orthic											
EUHO1	Very deep	L^-, MH, VH	Good	Moderate	(Strongly) alkaline	Low	Low	(Very) high	ML to MH	Moderate to high	Very deep
EUHO2	Deep	L^+, M, M	Good	Moderate to rapid	Alkaline	Low	Low	(Very) high	ML over SM	(Very) low	Very deep
EUHO3	Deep	L^-, M, MH	Good	Moderate	Alkaline	Moderate	High	Very high	CH	Very high	Very deep
EUHO4	(Very) deep	L^+, MH, H	Good	Moderate	Weakly alkaline	Moderate	Low	Very high to low	MH	High	Very deep
EUHO5	Deep to moderately deep	L^+, M(H), MH	Good to imperfect	Slow	Neutral	Low to moderate	High to moderate	(Very) high	CH (to CL)	High (to very high)	Very deep
EUHO6	(Very) deep	L, MH, H	Good	Moderate	Neutral to weakly acid	Low	Low to moderate	High to moderate	CH to CL, rarely ML	High, rarely low	Very deep
EUHO7	(Moderately) deep	L, M, M	Good	Rapid to moderate	Weakly acid	Low to moderate	Low	Low to high	MH to CH over SP to CL	(Very) high over nil to low	Very deep
EUHO8	(Very) deep	L^+, M(H), (M)H	Good	Moderate	(Weakly) acid	Low	Low	Low to moderate	MH over ML to SM	High to moderate	Very deep
EUHO9	(Moderately) deep	L^-, M, M	Good (to imperfect)	Slow	Acid	Low	Low	Very low to moderate	CH	High	Very deep
EUHO10	(Moderately) deep	L^-, M, M(H)	Good	Slow to moderate	(Weakly) alkaline	Moderate	Low	High to moderate	CH	(Very) high	(Moderately) deep
EUHO11	(Moderately) deep	L^-, M, M	Good	Moderate	Neutral	Low to moderate	Moderate	Very high to low	CH to CL	High	Moderately deep
EUHO12	Very deep to moderately deep	L, M(H), MH	Good	Moderate	Acid	Low to moderate	Low to moderate	High	MH	(Extremely) high	Moderately deep
Hapludolls, (psammentic)											
MUHP	Deep	VL, L, M	Good	Very rapid	Neutral	N.d.	Low	Low	SP	Nil	Very deep
Hapludolls, entic											
MUHE	Very deep	L^-, M, MH	Good	Moderate	Weakly alkaline	Low	Low	Very high	CL	Moderate	Moderately deep
Hapludolls, orthic											
MUHO	Shallow	L^-, L, L	Good	Moderate	Neutral	Moderate	Moderate	Low	CH	High	Shallow
Rendolls, (psammentic)											
MR–P	Moderately shallow	VL, L, L	Good	Very rapid	Strongly alkaline	Moderate to high	Very high	(Very) low	?SM over SP	Very low	Very shallow

TABLE 12 (*Continued*)

1 Soil class	2 Agricultural depth	3 Avail. soil water storage capacity*	4 Drainage status	5 Permeability	6 Soil reaction	7 Nitrogen	8 Phosphate	9 Potash	10 Unified Soil Classification	11 Linear shrinkage	12 Engineering depth
Rendolls, (orthic)											
MR–O1	Shallow	VL, VL, VL	Good	Rapid	Alkaline	Moderate	Low	Moderate	CL	Moderate	Very shallow
MR–O2	Shallow	(V)L, L, L	Good	Moderate to rapid	Alkaline	(Very) high	Moderate, rarely high	Moderate to high	CL to CH	High	Very shallow
MR–O3	Shallow	L, L, L	Good	Moderate to very rapid	(Weakly) alkaline	Moderate to high	Moderate to very high	Moderate to low	CL	Moderate	Very shallow
MR–O4	(Very) shallow	L⁻, L, L	Good	Moderate to rapid	Neutral	High to moderate	Moderate to low	Very high to low	CL	Moderate	Very shallow
Rendolls, (eutrochreptic)											
MR–E	(Very) shallow	VL, (V)L, (V)L	Good	Moderate to slow	(Weakly) alkaline	Moderate	Low	High	CH	Very high	Very shallow
Rendolls, (lithoxic)											
MR–X	Shallow	VL, (V)L, (V)L	Good	Very rapid	Alkaline	High	Moderate	Very low	CL	Moderate	Very shallow
Ochraquepts, orthic											
IAOO1	(Moderately) shallow	L⁻, L, L	Poor	Very slow	(Weakly) acid	Low to moderate	Low	(Very) high	CH	Very high	Moderately deep
IAOO2	Moderately shallow	L⁻, L, L	(Very) poor	Very slow	(Strongly) acid	Moderate to high	(Very) low	Very low to high	CH	Very high	Moderately deep to very deep
Umbraquepts, orthic											
IAUO	Deep	L⁺, M, MH	Very poor	Moderate to rapid	(Weakly) acid	Moderate	Low	Very low	OL and ML over SP	Low over nil	Very deep
Haplumbrepts, orthic											
IUHO	Deep	L⁻, M, M	Good	Rapid	Acid	Moderate	Low	Very low	ML to SM over SP	Low over nil	Very deep
Eutrochrepts, rendollic											
IOER	Shallow	L⁻, L, L	Good	Very slow	Alkaline	Moderate	Low	Low	CH	Very high	Shallow
Eutrochrepts, orthic											
IOEO1	(Moderately) shallow	L⁻, L, L	Good	Slow	(Strongly) alkaline	Low to moderate	Low to moderate	(Very) high	CH	Very high	Shallow
IOEO2	Moderately shallow to moderately deep	L⁻, M, M	Good	Slow	Alkaline	Moderate	(Very) low	Very high to moderate	CH	High	Shallow to moderately deep
Eutrochrepts, dystric											
IOED	(Moderately) shallow	L⁻, L–M, L–M	Good	Slow	Weakly alkaline to neutral	Moderate	Low, rarely very low	High, rarely very high	CH	High	Shallow to moderately deep

Dystrochrepts, eutric												
IODE1	Shallow	L^-, L, L	Good	Slow	Neutral	Moderate	Low	Very high	CH	Extremely high	Shallow
IODE2	(Moderately) deep	L^-, M(H), M(H)	Good	Moderate	Neutral	Moderate to low	Low to moderate	Moderate to very high	CH to CL	High	Moderately deep to shallow
IODE3	Shallow	L^+, L, L	Good	Moderate	Weakly acid	Moderate to low	Low	Moderate to high	MH to CL	High	Shallow
IODE4	*Moderately shallow*	L^-, M, M	Good	Slow	Neutral to weakly acid	Moderate	Low	(Very) high	CH	Very high	Shallow to moderately deep
IODE5	Moderately deep	L, M, M	Imperfect	Slow	Weakly acid	Low	(Very) low	High to moderate	CH to MM	High	Shallow to moderately deep
IODE6	Moderately deep	L^+, M, M	Good	Moderate	Acid	Low	(Very) low	Low to high	CH to MH	High	Shallow to moderately deep
IODE7	Moderately deep	L^-, M(H), M(H)	Good	Moderate	Acid	Moderate to low	Low	High	CH	High	Moderately deep
Dystrochrepts, orthic												
IODO1	Moderately shallow	L^-, L, L	Good	Moderate	Acid	Low	Very low	High	[illegible]	Moderate	Moderately deep
IODO2	(Very) deep	L^+, MH, H	Good	Moderate	Acid	Low	(Very) low	(Very) high	CH to CL	Moderate to very high	(Very) deep
IODO3	Moderately shallow	L^-, M, M	Good	Moderate	Acid	Low	Very low	Moderate to high	MH to CH	High	Moderately deep
IODO4	Deep	L^+, MH, H	Good	Moderate	Acid	Low	Low	High	MH	Very high	Moderately deep
IODO5	Deep	L^+, MH, MH	Good	Moderate	Strongly acid	Moderate	Low	Moderate	MH	Moderate	Moderately deep
Dystrochrepts, oxic												
IODX	Very deep	L^+, MH, (V)H	Good	Moderate	Strongly acid	Low to moderate	Very low	High	MH	Extremely high	Deep
Ochraqualfs, orthic												
AAOO1	Moderately shallow	L^-, L, L	Poor	Slow	Neutral	Low	Low	High	CH	High	Shallow
AAOO2	(Moderately) deep	L, M(H), *M(H)*	Poor	(Very) slow	(Weakly) acid	(Very) low	Very low to moderate	Very low to high	CH	(Very) high	Very deep
AAOO3	Moderately shallow	L^-, M, M	Poor	Very slow	Acid	Moderate	Moderate	High	CH	High	Moderately deep
Typudalfs, aquic												
AUTA1	Moderately deep	L^-, M, M	Imperfect	(Very) slow	Neutral	Low to moderate	Moderate	High	CH	Very high	Moderately deep
AUTA2	Deep	L^-, MH, H	Imperfect	Moderate	Weakly acid	Low	Low	High	MH to CH	High	Very deep
AUTA3	Moderately deep	L^-, M, M	Imperfect	Very slow	Weakly acid	Moderate	Very high	High	CH	Very high	Moderately deep
AUTA4	Moderately deep	L^-, M, M	Imperfect	(Very) slow	Acid	Low	Very low to moderate	High	CH	Very high	Very deep
AUTA5	Deep	L^+, MH, (M)H	Imperfect	Moderate	Acid	Low	(Very) low	Very low	Thin CL to MH over CH	Moderate over (very) high	Very deep
Typudalfs, orthic												
AUTO1	Moderately deep	L^-, M, M	Good	Slow	Weakly alkaline to neutral	Moderate to low	(Very) low	Moderate to very high	CH	(Very) high	Moderately deep to shallow
AUTO2	Moderately shallow	L^+, L, L	Good	Moderate	Neutral	Moderate	Low	(Very) low	CH	Very high	Very shallow

TABLE 12 (*Continued*)

1 Soil class	2 Agricultural depth	3 Avail. soil water storage capacity*	4 Drainage status	5 Permeability	6 Soil reaction	7 Nitrogen	8 Phosphate	9 Potash	10 Unified Soil Classification	11 Linear shrinkage	12 Engineering depth
AUTO3	Shallow	L⁻, L, L	Good	Slow	Weakly acid	Low	Low	Low	CH	Very high	Shallow
AUTO4	(Moderately) deep	L, M(H), M(H)	Good	Slow	Weakly acid	Low	Moderate to low	Low to moderate	Thin MH over CH	Very high	Very deep
AUTO5	Moderately shallow	L⁻, L–M, L–M	Good	Slow	Weakly acid	Low to moderate	(Very) low	Moderate to high	CH	Very high	Shallow to moderately deep
AUTO6	Moderately deep	L⁺, M(H), M(H)	Good	Slow to moderate	(Weakly) acid	(Very) low	(Very) low	Low to moderate	CL to CH	Moderate to high	Shallow to moderately deep
AUTO7	Moderately deep	L⁺, M, M	Imperfect	Slow	Weakly acid	Low	Low	Low	Thin MH over CH	Very high	Deep
Typudalfs, ochrultic											
AUTU	Moderately shallow	L⁺, M, M	Good	Moderate	Neutral	Moderate	Low	Low	CH	Very high to extremely high	Shallow
Ochraquults, orthic											
UAOO	Deep	L⁺, MH, H	Poor	Moderate	Acid	Moderate	Low	Moderate	Thin MH over CH	High	Very deep
Typochrults, aquic											
UOTA1	Moderately deep to moderately shallow	L⁻, M, M	Imperfect	Slow	Acid	Low to moderate	Low	Moderate	CH	(Very) high	Shallow to moderately deep
UOTA2	Deep	L⁺, MH, H	Imperfect	Slow to moderate	(Strongly) acid	(Very) low	(Very) low	Very low to moderate	CH	Moderate to high	Very deep
UOTA3	Moderately deep	L⁻, M, M	Imperfect	Very slow	Strongly acid	Moderate	Very low	High	CH	Very high	Moderately deep
Typochrults, orthic											
UOTO1	Moderately deep to moderately shallow	L⁻, M, M	Good	Slow to moderate	Acid	Low to moderate	Low	High	Thin MH over CH	Very high	Moderately deep
UOTO2	Deep	L⁻, M, MH	Good	Moderate	Acid	N.d.	Very low	Moderate	MH	Extremely high	Moderately deep
UOTO3	(Very) deep	L, M(H), H	Good	Moderate	Strongly acid	Low to moderate	Very low	Very low	Thin MH to CL over CH	Thin high over extremely high	Very deep
Plintochrult, aquic											
UOPA	Deep	L⁻, M, MH	Imperfect	(Very) slow	(Strongly) acid	Low	Very low	Very low	Thin CL to MH over CH	Thin moderate over extremely high	Very deep
(Normaplox, typic)											
OHNT	Very deep	L⁺, MH, VH	Good	Moderate	Strongly acid	Moderate	Very low	Very low	MH	Very high	Deep
(Normargox, typic)											
OANT	(Very) deep	L⁺, MH, (V)H	Good	Moderate	Strongly acid	Very low to moderate	(Very) low	(Very) low	CH to MH	High to extremely high	Very deep

* VL, very low; L, low; M, moderate; H, high; VH, very high; L⁻, 2–2·9 in.; L⁺, 3–3·9 in.

to produce soils that are similar or transitional to typical soils on massively occurring soft sedimentary rocks. On pure limestone, on the other hand, soils tend to develop that are unique for this rock type. Soil differences between these groups are therefore more quantitative (dominance of different kinds of soil in each) than qualitative (total spectrum of soil variation). Nevertheless, the available data suggest that pure limestone is less exclusively the parent rock of soils in the group of land systems on limestone than would transpire from the land system descriptions.

TABLE 13

LOWEST SOIL CLASSES OBSERVED IN THE LAND SYSTEMS OF THE LITTORAL PLAINS

	Land system 1	Land system 2
EPOA	—	Frontal beach ridge
EPOO1	—	Frontal beach ridge
EAPO	—	Swale
EAHU*	Coastal plain; alluvium	—
EUHA5*	Coastal plain; alluvium	—
MUHP	—	Inland beach ridge
MR–P	Coral platform (2×)	—
IUHO	—	Inland beach ridge

* See also Table 15.

Somewhat surprisingly, there is a rather large difference in soil content between the first (Table 17) and the second (Table 18) group of land systems on soft sedimentary rocks. Possible reasons for this are a wetter climate, steeper slopes but also more frequent colluvial slope collapse in pre-weathered materials, and scarcity of marly sedimentary rocks near and in the mountains where the land systems listed in Table 18 mainly occur. Such factors might explain the occurrence of more acid and either deeper or shallower soils than in the intermontane basin and coastal ranges, and also the absence of poorly drained soils.

TABLE 14

LOWEST SOIL CLASSES OBSERVED IN LAND SYSTEMS OF THE FRESHWATER SWAMPS AND UNSTABLE FLOOD-PLAINS

	Land system 3	Land system 4	Land system 5	Land system 6
EAYS1	—	Blocked valley swamp	—	—
EAYO1	—	—	—	Flood-out plain
EAHO2	Seasonal swamp	Valley floor	Swamp plain	—
IAUO	Coastal swamp margin	—	—	—

(vi) *Note on Table 21.*—The few observations in the large area of land systems on igneous rocks can hardly be assumed to be fully representative. Nevertheless, there is a suggestion of a continuation of the trend noticeable in Table 18, leading to a dominance of characteristic unique soil classes. The MR-O4 soil in this group appears

TABLE 15

LOWEST SOIL CLASSES OBSERVED IN LAND SYSTEMS OF THE ALLUVIAL PLAINS (EXCEPT THOSE IN TABLE 14)

	Land system 7	Land system 8	Land system 10
EPOO2	—	—	Lower terrace
EPOU	—	—	Lower terrace
EAYO2	—	—	Alluvial plain
EAYO3	—	—	Alluvial plain
EAHY	—	Alluvial plain	Alluvial plain
EAHO1	—	—	Scroll plain
EAHU*	—	—	Alluvial plain (2×)
EAHS	—	—	Alluvial plain
EUHA1	—	—	Flood-plain near coast
EUHA2	—	—	Alluvial plain
EUHA3	—	Alluvial plain	Alluvial plain
EUHA4	—	—	Alluvial plain near coast Flood-plain near coast
EUHA5*	—	Upper terrace	—
EUHO1	—	Lower terrace	Scroll plain
EUHO2	—	—	Scroll plain
EUHO3	—	Alluvial plain	—
EUHO4	—	—	Alluvial plain (3×)
EUHO5	—	Alluvial plain	Alluvial plain (3×)
EUHO6	Alluvial plain	—	Alluvial plain (3×), middle terrace, lower terrace
EUHO7†	—	—	Middle terrace (2×)
EUHO8	Upper terrace	—	Middle terrace
EUHO9	Middle terrace	Upper terrace	—
AAOO2†	—	—	Upper terrace (2×)
AUTA2	—	Upper terrace	—
AUTA4†	—	—	Upper terrace
UAOO	Valley floor (!)	—	—
UOTA2	Upper terrace (3×)	—	—

* See also Table 13; † Table 16.

TABLE 16

LOWEST SOIL CLASSES OBSERVED IN LAND SYSTEMS OF THE ALLUVIAL FANS

	Land system 11	Land system 12	Land system 13	Land system 14
EUHO7*	Fan surface	—	—	—
EUHO11†	Very steep slope	—	—	—
IAOO1‡	—	Very steep slope; marl	—	—
IAOO2‡	—	—	—	Fan surface depression
IODO2§	Fan surface	—	—	—
AAOO2*	Fan surface	—	Broad hill crest	—
AUTA4*	—	—	Broad hill crest	—
AUTA5	Fan surface (2×)	—	—	—
AUTO4	—	—	Very steep slope (2×)	—
UOTO3	Fan surface (2×)	—	—	—
UOPA	Fan surface	Dissected fan surface	—	—
OANT§	Fan surface (2×)	Remnant fan surface	—	

* See also Table 15; † Table 18; ‡ Table 17; § Table 21.

TABLE 17

LOWEST SOIL CLASSES OBSERVED IN LAND SYSTEMS ON SOFT SEDIMENTARY ROCKS (FIRST GROUP)

	Land system 15	Land system 16	Land system 17	Land system 19	Land system 20	Land system 21
EUHA6	Valley floor		—	—	—	—
EUHO10	—	Slumped slope, ?high terrace remnant	—	—	—	Irregular slope
MR–O3*	—	—	—	Crest; limestone	—	—
IAOO1†	—	—	Dip slope	—	—	—
IAOO2†	Slump bench	—	—	—	—	—
IOEO1‡	Very steep upper slope	—	—	—	—	—
IOEO2*	—	—	—	Slump toe; with limestone	—	—
IOED‡	Moderately steep slope	Slump bench, crest	—	—	—	Crest, irregular long slope
IODE1‡	—	—	—	—	—	Irregular long slope
IODE2‡	—	Irregular slumped slope	—	Crest	—	—
IODE3	—	Steep upper slope	—	Very steep slope	—	—
IODE4*	Moderately steep slope (2×)	—	—	—	—	Steep upper slope
IODE5‡	—	—	Irregular slope	—	Steep slope	—
IODE6	—	—	—	Very steep slope (2×)	—	—
IODE7§	Slumped upper slope	—	—	—	—	—
IODO3	Moderate upper slope	—	—	—	—	Irregular steep upper slope
IODO4	—	—	—	—	—	Wide crest
AAOO1	—	—	—	Slump bench	—	—
AAOO3	—	—	Dip slope	—	—	—
AUTA1‡	—	Slump	—	—	—	—
AUTA3	Moderate slope	—	—	—	—	—
AUTO1*	Steep upper slope	Slump bench	—	—	—	—
AUTO5*	Moderate slope	—	—	—	—	—
AUTO6*	—	—	Outcrop slope	—	—	—
UOTA1	—	—	Dip slope	Moderately steep upper slope	—	—
UOTA3	Crest	—	—	—	—	—
UOTO1§	Moderately steep upper slope	Very steep upper slope	—	—	—	—
OANT†	—	—	—	Plateau remnant	—	—

* See also Table 20; † Table 16; ‡ Table 19; § Table 18.

to be an oddity (but pointing towards some affinity between basic igneous rock and limestone as a parent material). The similarity of the IODO2 soil with a soil on a fan surface in Table 16 would appear to be accidental, but indicating a basic similarity in parent material.

TABLE 18

LOWEST SOIL CLASSES OBSERVED IN LAND SYSTEMS ON SOFT SEDIMENTARY ROCKS (*SECOND GROUP, EXCLUDING LAND SYSTEM* 27)

	Land system 22	Land system 24	Land system 25	Land system 26
EUHL	—	—	Limestone scree slope	—
EUHO11*	—	—	Irregular slumped slope	—
EUHO12	—	Spur on slumped slope	Spur on irregular slope, irregular slumped slope	—
MUHE	Slumped slope	—	—	—
IODE7†	—	—	—	Slumped lower slope
UOTO1†	—	—	Irregular slumped slope (2×)	—
UOTO2	—	—	Irregular slumped slope	—

* See also Table 16; † Table 17.

(*b*) *Soil Formation*

The general similarity in the nature of the soils in the Vanimo and Aitape–Ambunti areas is obvious from Table 10. Equally, similarities in their distribution

TABLE 19

LOWEST SOIL CLASSES OBSERVED IN LAND SYSTEMS ON MIXED SEDIMENTARY ROCKS DOMINATED BY LIMESTONE

	Land system 28	Land system 30	Land system 31	Land system 32	Land system 33
MUHO	—	—	—	—	Wide crest
MR–O1	—	—	—	—	Very steep slope
MR–O2*	—	—	—	Gentle boulder slope	—
MR–O4*†	—	—	—	Steep slope	—
MR–E*	—	—	Lower slope slump	—	—
IOEO1‡	—	—	—	Steep slope	—
IOED‡	—	—	Crest	—	—
IODE1‡	Steep lower slope	—	—	—	—
IODE2‡	—	—	Very steep slope	—	—
IODE5‡	—	Gentle lower slope	—	—	—
AUTA1‡	Slump bench	—	—	—	—
AUTO3	Crest	—	—	—	—

* See also Table 20; † Table 21; ‡ Table 17.

emerge from the land system descriptions in Part III and from Tables 13–21. No new aspects of soil formation have emerged from the survey of the Vanimo area. In fact, all observations indicate that soil-forming processes in both areas are virtually the same. For all these reasons the reader is referred to the discussions on soil formation in the Aitape–Ambunti report (Haantjens 1972).

TABLE 20

LOWEST SOIL CLASSES OBSERVED IN LAND SYSTEMS ON LIMESTONE

	Land system 34	Land system 36
EAYS2	—	Slump or doline floor
MR–O2*	Crest	Crest, (very) steep slopes
MR–O3†	Platform	Very steep lower slope
MR–O4*‡	—	Crestal flat
MR–E*	Moderate upper slope	—
MR–X	Very steep lower slope	—
IOER	—	Steep upper slope
IOEO2†	—	Plateau crest
IODE4†	—	Gentle slope; mudstone
AUTO1†	—	Moderately steep upper slope; mixed siltstone
AUTO2	Platform remnant (2×)	—
AUTO5†	—	Platform or bench
AUTO6†	—	Steep upper slope; mixed siltstone
AUTO7	Filled-in doline	—
AUTU	Platform	—

* See also Table 19; † Table 17; ‡ Table 21.

TABLE 21

LOWEST SOIL CLASSES OBSERVED IN LAND SYSTEMS ON IGNEOUS ROCKS

	Land system 37	Land system 38	Land system 39
MR–O4*	—	Steep scree slope	—
IODO1	—	—	Very steep spur crest
IODO2†	Steep slope	—	—
IODO5	—	Steep upper slope	—
IODX	—	Slump	Small crestal flat
OHNT	—	Summit plateau	—

* See also Tables 19 and 20; † Table 16.

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PART VII. DESCRIPTIONS AND ECOLOGY OF THE VEGETATION TYPES OF THE VANIMO AREA

By P. C. Heyligers*

I. Introduction

The vegetation has been mapped according to the principles used in the adjacent Aitape–Ambunti area (Heyligers 1972). The actual mapping, however, could be carried out less satisfactorily than in that area because of the generally poor quality of the aerial photographs and their smaller scale (1 : 86,000). Boundaries, especially between related vegetation types, could not always be drawn reliably and this must be taken into account when the vegetation map is used.

The major groups of vegetation types in the Vanimo area are tall forest, mid-height forest, palm and pandan vegetation, herbaceous vegetation, and secondary vegetation. Tall forest is more than 100 ft and mid-height forest less than 100 ft high. They have been further subdivided on air-photo characteristics, e.g. openness of the canopy, even height versus irregular height, predominance of small crowns, occurrence of crowns of a very light tone, and visibility of the understorey.

The vegetation types are indicated by symbols on the map. Symbols identical to those used in the Aitape–Ambunti area indicate that these types are generally similar, but minor variations in structure and/or ecology are possible and will be evident from the descriptions given in the following sections.

For clarity, related forest types are grouped. In each group only one type is described *in extenso* and the characteristics of the other types are related to this description. After these descriptions the distribution and ecology of the particular group are discussed. The sections concerning the other vegetation types have not been subdivided because of the limited number of types falling in these categories. The same grouping of types has been followed on the vegetation map, the reference of which can be used as an index to the vegetation type descriptions.

In the observations density has been rated according to the following scale: dense, moderately dense, rather open, open, very open, or scattered; and commonness, which pertains to the numbers of individuals present in a certain area, as: abundant, very common, common, rather common, present, rare. Frequency, which expresses the number of times a particular characteristic or plant was observed in a certain vegetation type in comparison with the total number of observations in this type, is expressed in general terms to which the following approximate values can be given: seldom, sometimes, or occasionally is less than 25%; normally is between 25% and 75%; usually, commonly is more than 50%; often, mostly, or generally is more than 75%.

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II. Tall Forests with Open Canopies

(a) Descriptions

(i) *Tall Forest with a Rather Open Canopy* (Fo; 23 obs.; Plates 5, 13, and 19).—The crowns form a rather regular photo pattern of mid-grey tones with occasional lighter tones. Height variations tend to be regular. Crowns are relatively widely and evenly spaced and have a large range in size.

Field observations gave canopy cover values between 15 and 40% with 23% as average. The canopy was usually classed as open or rather open, occasionally as very open or moderately dense. Canopy height varies between 105 and 150 ft with 125 ft as average. Irregularly scattered more or less emergent trees usually occur and are commonly up to about 30 ft taller than the average canopy trees. Spacing of subcanopy trees is normally moderately dense, sometimes dense. Their crown cover varies between 40 and 70%, seldom 80%, and averages 56%. The trees have straight boles, except for some low-branching figs, and normally a large range of sizes is present. Buttresses of different form and size are always present, those of medium height with a wide base and of taller height with a narrow base being the most common types. Usually some trees with stilt roots occur.

The shrub layer is usually moderately dense and its cover varies between 15 and 60% with an average of 32%. The plants are irregularly spaced; some have a spreading habit, e.g. young palms and rattans, others are slender, e.g. saplings. The average visibility* through the shrub layer is 65 ft. This distance varies between 43 and 85 ft.

The herb layer is usually irregular and varies in cover between 1 and 10%. It is of mixed composition and comprises seedlings, ferns and *Selaginella*, forest grasses and sedges, and broad-leaved herbs, e.g. *Elatostema*, aroids, wild gingers, and Marantaceae. Mosses are sometimes common on exposed roots.

Thick woody lianes are present and thin woody ones rather to very common. The latter include rattan and occasionally *Flagellaria*. Epiphytes and epiphytic climbers are also rather to very common, and often slightly more common in the crown layer than lower down on the tree trunks. Aroids, ferns, and *Freycinetia* are usually common. Mosses are occasionally common.

Palms are normally present or rather common in the subcanopy tree layer, occasionally also in the canopy itself. Occurrence of palms in the shrub layer varies between rather common and very common. They belong to many genera and often more than one kind of young rattan is common. Pandans are rare to rather common in the shrub layer, but occur seldom in the tree layers.

(ii) *Tall Forest with a Rather Open Small-crowned Canopy* (Fos; 3 obs.; Plate 6).—The photo image is similar to that of tall forest with a rather open canopy (Fo), but there is a greater proportion of small crowns.

In the field it was found that the canopy was more open and the smaller girth classes more common than in the average stand of tall forest with a rather open canopy (Fo). In other characteristics this type is very much like tall forest with a rather open canopy (Fo).

* Visibility is defined as the distance at which a person walking away from an observer becomes obscured behind foliage.

(iii) *Tall Forest with an Open Canopy with Scattered Light-toned Crowns* (Fod; 6 obs.; Plates 7 and 9).—This forest type differs in photo image from tall forest with a rather open canopy (Fo) mainly in the larger number of light-toned crowns. It is assumed that these crowns are of trees with young leaves or flowers. In the field it was found that the canopy is more open than in the previous type.

(iv) *Tall Forest with an Open Small-crowned Canopy with Scattered Light-toned Crowns* (Fosd; 3 obs.; Plate 8).—This type combines the photo characteristics of the two previous types (Fos, Fod), and the field observations showed it to be very similar to them in structure.

(v) *Tall Forest with an Open Small-crowned Canopy and a Dense Understorey* (FosD; 2 obs.).—The photo pattern of this type shows a very open canopy mainly consisting of small crowns and with subcanopy layers clearly visible. Field observations showed the coverage of the canopy to be in the order of 10% and that of the lower tree layer of 60%. Tree height and girth distribution are similar to that of tall forest with a rather open small-crowned canopy (Fos). In the shrub layer palms are abundant; not only is rattan common, but also *Licuala* and "kabibi" which grows in clusters and has very irregularly split leaves. Several species of pandans are also present or common. Visibility is often reduced to 43 ft. Pneumatophores in the form of knee-shaped roots may be seen protruding from the soil.

(vi) *Tall Forest with an Open Canopy with Scattered Light-toned Crowns and a Dense Understorey* (FodD; 9 obs.; Plates 7 and 10).—This type combines in its photo pattern the characteristics of tall forest with an open canopy with scattered light-toned crowns (Fod) and tall forest with an open small-crowned canopy and a dense understorey (FosD). Observations showed this type to be rather similar to the former type (Fod), but the lower tree layer is denser and has a 10% greater cover. Young rattan was less common and in importance was replaced by *Licuala* and "kabibi".

(vii) *Tall Forest with an Open Canopy and with Sago Palms in the Understorey* (FoM; 1 obs.; Plate 19).—The photo pattern of this type has, in comparison with tall forest with a rather open canopy (Fo), an uneven texture due to irregular spacing between crowns. Crowns tend to be further apart and generally somewhat smaller. From previous field work this type was known to have a usually rather open understorey of sago palms. Other differences include the generally lower height of the canopy trees and a greater variation in canopy cover values.

(viii) *Tall Forest with an Open Canopy with Scattered Light-toned Crowns and with Sago Palms in the Understorey* (FodM; 1 obs.; Plate 8). This type is similar to the previous type (FoM). The major difference in photo pattern is the prominence of light-toned trees in the canopy. It lacks the conspicuous subcanopy layer characteristic for tall forest with an open canopy with scattered light-toned crowns and a dense understorey (FodD).

(ix) *Tall Forest with a Rather Open Even Canopy* (Fov; no obs.; Plate 19).—The photo image of this type is similar to that of tall forest with a rather open canopy (Fo) but with less variation in height.

(*b*) *Ecology and Distribution*

Tall forests with open canopies cover just over one-fifth of the survey area and are found from sea level to an altitude of about 1000 ft. They are restricted to alluvial plains and fans, except for tall forest with a rather open even canopy (Fov) which occurs on plateau remnants in Serra (36) land system.

Tall forest with a rather open canopy (Fo) generally occurs on well to imperfectly drained plains not liable to flooding, mainly found in Pual (10) land system and locally in Papul (8) land system. However, especially in the plains of the Bei'i Creek, drainage is poor. This is expressed by commonness of *Licuala* and "kabibi" in the undergrowth along with young rattan rather than through canopy and thus photo characteristics, and these stands seem to be transitional to the adjacent forest with an open canopy with scattered light-toned crowns and with sago palms in the understorey (FodM).

This last type (FodM) and tall forest with an open canopy and sago palms in the understorey (FoM) occur on imperfectly to very poorly drained back plains that are flooded once every three years to twice annually and are mapped as Po (9) land system. The drainage status of the plains carrying the former type is on the average better and flooding is less frequent than in areas carrying the latter type.

Tall forest with an open canopy with scattered light-toned crowns (Fod) occurs on lower flood-plains, generally well to imperfectly drained but flooded annually to once every five years. These plains are located in lower parts of Papul (8) and Pual (10) land systems.

Higher terraces in the same land systems which are imperfectly to very poorly drained (summarized as ill-drained in the rest of this Part) carry tall forest with a rather open small-crowned canopy (Fos). In narrow valleys mapped as Basu (7) land system, the flood-plains and terraces are covered by tall forest with an open small-crowned canopy with scattered light-toned crowns (Fosd). The deciduousness indicated by these crowns probably points to a certain seasonality in the drainage regime.

A comparable condition is found on the alluvial fans mapped as Pagei (11) and Luap (12) land systems which are covered by forests with open canopies and dense understoreys (FosD, FodD). The type with the light-toned crowns (FodD) generally occurs in less ill-drained areas with stronger seasonally fluctuating water-tables.

III. Tall Forests with Rather Open Irregular Canopies

(*a*) *Descriptions*

(i) *Tall Forest with a Rather Open Irregular Canopy with Scattered Lighter-toned Crowns* (Foid; 46 obs.; pictured on most plates).—The photo image of the canopy shows great variation in tree height and crown spacing. Closure also varies but is generally rather open. Light-toned crowns are scattered to rather common. When the general tone of the canopy is dark the light-toned crowns are conspicuous; however, sometimes the general tone is rather light and the light-toned crowns merge into the overall tone.

In the field the canopy was usually classified as open or moderately dense, uneven or irregular, often with gaps. Cover values ranged from 10 to 30% and averaged 18%.

Height values varied between 100 and 150 ft and averaged 118 ft. More or less emergent trees were on the average about 30 ft taller than the canopy trees, but occasionally up to 60 ft. Subcanopy trees are usually moderately dense and their crown cover values range from 30 to 80%, averaging 54%. Stem form is usually straight. Low-branching trees occur occasionally. On steeper slopes trees leaning over or bent at their base are commonly found. Small- and medium-girth sizes are dominant, large sizes are not common. Narrow buttresses are a common feature, but wide ones are relatively rare and are restricted to buttresses less than 5 ft high. Trees with stilt roots are virtually absent.

The shrub layer is usually moderately dense, but sometimes open or dense. Its cover varies between 10 and 40% and averages 20%. Plants of slender habit tend to be more common than those of spreading habit. Visibility varies between 36 and 102 ft and averages 62 ft. The cover of the herb layer varies between 1 and 15% and averages 7%. The plants are generally well distributed and of many kinds. Seedlings are often predominant.

Thick woody climbers are normally present, occasionally absent or common. Thin ones are present or common; rattan is absent, rare, or present, but seldom common. Epiphytes are usually present or common and of mixed composition.

Palms are normally absent in the canopy, rare to rather common in lower tree layers, and present to very common in the shrub layer. Many species occur; young rattan is usually present but generally not as conspicuous as in tall forest with a rather open canopy (Fo). Pandans are occasionally present amongst the lower trees and often present, sometimes rather common or common in the shrub layer.

(ii) *Tall Forest with a Rather Open Irregular Canopy* (Foi; no obs.).—This type is identical with the type of the same name occurring in the Aitape–Ambunti area.

(iii) *Tall Forest with a Rather Open Irregular Canopy with Scattered* Albizia (FoiA; no obs.; Plates 12 and 15).—This type is very similar to tall forest with a rather open irregular canopy with scattered light-toned trees (Foid). The shape of the lighter-toned crowns indicates that they belong to *Albizia*. This forest type is probably an old secondary one, but no field observations could be done to check this.

(*b*) *Ecology and Distribution*

Tall forests with rather open irregular canopies cover one-third of the survey area and are found on hilly terrain at low and medium altitudes.

Tall forest with a rather open irregular canopy with scattered light-toned crowns (Foid) is the most important type, the other types together covering less than 1% of the survey area. It occurs in most hilly land systems, but is less common in land systems overlying limestone. It is found under a wide range of conditions. Soils vary from silty loam to heavy clay and overlie different rock types. Slopes vary from gentle to very steep. Drainage is normally good to moderate, but is impeded on slump floors. The highest observation in this type was at an altitude of 1700 ft, about the maximum altitude at which it occurs.

Tall forest with a rather open irregular canopy with scattered *Albizia* (FoiA) occurs only in parts of Puari (20) and Puive (21) land systems under conditions similar to tall forest with a rather open irregular canopy with scattered light-toned crowns (Foid).

Tall forest with a rather open irregular canopy (Foi) occurs on Yassip (18) and Morumu (19) land systems in continuity with its occurrence in the Aitape–Ambunti area.

IV. Tall Forests with Rather Closed and Irregular Canopies

(*a*) *Descriptions*

(i) *Tall Forest with a Rather Closed Canopy* (F; 2 obs.).—The photo image is rather similar to that of tall forest with a rather open canopy (Fo), but differs in its closer crown spacing.

The canopy is moderately dense or dense and its cover is about 40%. The canopy height is about 140 ft with some scattered trees about 25 ft taller. Subcanopy trees are moderately dense and cover is 40–50%. Trees of large girth are more common than in tall forest with a rather open canopy (Fo). In other aspects the types are rather similar.

(ii) *Tall Forest with an Irregular Canopy* (Fi; 4 obs.).—The photo image shows irregular height and crown spacing of the canopy which is less open than in tall forests with rather open irregular canopies (Foi, Foid). Crown size tends to be rather uniform as large crowns are rare. Tones fall in the medium and lighter group, and very light-toned crowns are rare.

Many characteristics of this type are similar to tall forest with a rather open canopy (Fo). The main differences are found in the canopy, usually classified as rather open, from which scattered trees emerge up to 60 ft above the canopy trees. This is the main cause for the irregularity of the canopy as seen on the aerial photographs. Palms are absent or rare in the tree layer and only present or rather common in the shrub layer. Young rattan is usually present, but never in large amounts. Climbing rattan is rare. On steeper slopes some trees lean over or are bent at the base.

(iii) *Tall Forest with an Irregular Canopy with Scattered Light-toned Crowns* (Fid; 21 obs.; Plates 5 and 12).—The photo pattern of this type is similar to that of tall forest with a rather open irregular canopy with scattered light-toned crowns (Foid), but with a less open canopy, and also to tall forest with an irregular canopy (Fi), except for light-toned crowns which are more common.

The canopy is usually moderately dense or rather open and its cover averages 32%. Its height varies between 105 and 150 ft and averages 115 ft. Taller trees are not as conspicuous as in the previous type and are up to 50 ft above the canopy. Subcanopy trees are moderately dense and their cover averages 46%. The cover of the shrub layer averages only 14%. In other aspects this type is similar to tall forest with an irregular canopy (Fi).

(iv) *Tall Forest with an Irregular Small-crowned Canopy with Scattered Light-toned Crowns* (Fisd; 4 obs.; Plate 18).—The photo image has an even medium grey tone with often numerous light-toned specks which are the crowns of trees protruding above the canopy. The canopy is rather open and irregular and consists of even-sized small crowns.

In the field this type appeared rather similar to tall forest with an irregular canopy with scattered light-toned crowns (Fid). The average canopy height was slightly greater and the cover values for the subcanopy and shrub layers were about 10% higher than those of the latter type. Palms are absent in the tree layers and normally rare in the shrub layer. Rattan is normally absent.

(b) *Ecology and Distribution*

Tall forest with an irregular canopy with light-toned crowns (Fid) covers 5·5% of the survey area, tall forest with a similar but small-crowned canopy (Fisd) 6·0%, and the other types together just 1%. They all occur at lower and medium altitudes. Tall forest with an irregular canopy with scattered light-toned crowns (Fid) has the greatest range and reaches an altitude of about 2000 ft, north of the Bewani Mountains.

Tall forest with an irregular small-crowned canopy with scattered light-toned crowns (Fisd) is only found in the west of the survey area, scattered over eight land systems. With its largest areas in Ijapo (28), Jassi (31), Kohari (35), and Serra (36), it appears to be indicative of areas where limestone predominates in the lithology.

The occurrences of tall forest with an irregular canopy with scattered light-toned crowns (Fid) are spread over the survey area on 15 land systems. The largest areas are in Isi (15), Muru (17), Oenake (32), and Serra (36). This forest type is found on a variety of land forms: crests, slopes, slump benches, upper river terraces. Soils vary from clay loams to heavy clays and are generally well drained.

Tall forest with an irregular canopy (Fi) covers only minor areas in Fivuma (16) and Muru (17) land systems under conditions similar to the previous type (Fid).

Tall forest with a rather closed canopy (F) is virtually limited to the western occurrences of Papul (8) land system where it is found on well-drained river terraces.

V. Mid-height Forests with Open Canopies

(a) *Descriptions*

(i) *Mid-height Forest with a Rather Open Canopy* (Fmo; 5 obs.; Plates 9 and 13).—This type differs from tall forest with a rather open canopy (Fo) in its lower stature, smaller crowns, and slightly darker tone.

It is a seral forest type that succeeds cane grass vegetation (Gt) on lower river terraces and scrolls and leads to tall forest with a rather open canopy (Fo). Younger stages of this forest type are dominated by *Timonius*, with *Althoffia*, *Artocarpus*, *Casuarina*, and *Ficus* of lesser importance. Canopy height is about 50 ft and total cover of tree crowns is 40–60%. All trees have small girths. The shrub layer is very open; the herb layer dominated by grasses covers about 40%. Only thin woody climbers are present. There are no rattans or other palms and no epiphytes.

In later stages the pioneer species are replaced by other species, e.g. belonging to the genera *Albizia*, *Canarium*, *Mangifera*, *Rhus*, and *Spondias*. Canopy height increases and emergent trees occasionally reach 115 or 130 ft. The canopy is usually rather dense with the lower tree layer more open, a relationship that changes when the canopy height approaches 100 ft. Small girth classes are still predominant, but larger girths are also found. A shrub layer develops and grasses in the herb layer give way to other herbs. Climbers and usually epiphytes become common. Palms are present in the tree layers and common in the shrub layer. Young and climbing rattans normally become common. Pandans are usually rare but locally common in canopy and undergrowth, in which case they represent a transition to the next type (FmoP).

(ii) *Mid-height Forest with an Open Canopy in which Pandans are Predominant* (FmoP; 1 obs.).—The photo image is similar to that of the previous type (Fmo) but has a lighter tone and densely scattered light-toned crowns, both caused by a high percentage of pandans in, and emerging from, the canopy.

In the field a dense vegetation was found, only about 35 ft high but with scattered emergents up to 100 ft. A large-crowned and stilt-rooted pandan was very common in the canopy and amongst the emergents. The shrub layer, mainly composed of young pandans, was virtually continuous with the canopy layer. Visibility was only 35 ft. Some *Licuala* palms occurred, but rattan was absent. *Flagellaria* was common amongst the climbers.

(iii) *Mid-height Forest with an Open Irregular Canopy with Pandans and Sago Palms Common* (FmPM; no obs.; Plate 19).—The photo image is not unlike that of the previous type (FmoP), but it has more patchy tone contrasts due to the gregarious occurrence of sago palms.

No ground observations have been made. The canopy is probably higher and more open than in mid-height forest with an open canopy in which pandans are predominant (FmoP). In the understorey pandans and sago palms are very common, the latter locally forming almost pure patches.

(iv) *Mid-height Forest with an Open Canopy and Sago Palms in the Understorey* (FmoM; no obs.; Plate 6).—The photo image is rather similar to tall forest with an open canopy and sago palms in the understorey (FoM), but owing to a more irregular spacing of the crowns the fine texture of the understorey of sago palms is clearly visible.

Ground observations in the Aitape–Ambunti area have shown that the canopy is very irregular in height and closure. The average height is about 80 ft with occasional taller trees to 105 ft. The canopy cover varies between 10 and 25%. The rather dense to dense subcanopy is dominated by sago palms, 40–50 ft tall, covering 40–60%.

(*b*) *Ecology and Distribution*

Mid-height forest with a rather open canopy (Fmo) occurs on scrolls and lower terraces in Papul (8) and Pual (10) land systems, forming just over 1% of the survey area. These localities are generally poorly drained and flooded at least once every three years, but often more frequently. Mid-height forest with an open canopy in which pandans are predominant (FmoP) occurs only on ill-drained back plains in Leitre (3) land system which are flooded at least once a year. Mid-height forest with an open, irregular canopy with pandans and sago common (FmPM) occurs in Nubia (2) and Leitre (3) land systems in frequently flooded, periodically or permanently swampy situations caused by poor through drainage. Some mid-height forest with an open canopy and with sago palms in the understorey (FmoM) is also found here, but this type has its main occurrence in Pandago (5) land system in areas shallowly inundated for up to 5 months per year.

VI. Mid-height Forests with Irregular or Rather Open Irregular Canopies

(*a*) *Descriptions*

(i) *Mid-height Forest with an Irregular Canopy* (Fmi; 12 obs.; Plates 16 and 20).—The photo image shows a canopy composed of small and very small crowns in various tones of grey to light grey, which are irregularly spaced horizontally as well as vertically.

The field observations confirmed this irregular structure of the canopy. Tree layers were often indistinct; crowns of lower trees merge with and fill gaps in the canopy, thus forming part of it. The cover of the canopy crowns and those of the lower trees, where separable, is of the order of 40%; where they are indistinct, total crown cover is about 70%. Height varies considerably, also within stands. Average maximum height of the canopy is 90 ft. Scattered trees normally reach up to 30 ft above the canopy.

Trees of small and medium girths are common, but trees of large girths are rare if present at all. The stem form is usually straight, but trees leaning over or bent at their base are sometimes common, especially on less stable slopes.

The shrub layer covering about 22% is usually dense or moderately dense; the visibility averages 53 ft. Palms, normally rare or present in the tree layers, are rather common or common in the shrub layer. Young rattan is always present but rarely common. Pandans are rare or present, and saplings are usually quite common in the shrub layer.

The herb layer covers about 16% and always has a mixed composition. *Freycinetia* is often conspicuous.

Lianes are present, but only occasionally common. They are predominantly thin woody and include rattan. Epiphytes and epiphytic climbers are usually common and include aroids, ferns, mosses, and *Freycinetia*; the last is often common.

In some areas very irregular patches in mid-height forest with an irregular canopy (Fmi) were seen on the photographs. It is supposed that these are seral states of this forest following disturbance of the original forest cover by slumping. These patches are indicated by the symbol Fmi′.

(ii) *Mid-height Forest with an Irregular Small-crowned Canopy* (Fmis; no obs.; Plate 18).—The photo image shows patches of small-crowned, slightly irregular canopy alternating with less small-crowned more irregular patches. Very tall light-toned emergents can just be distinguished, which from aerial reconnaissance appear to be *Araucaria*.

(iii) *Mid-height Forest with an Irregular Canopy with Scattered* Albizia (FmA; no obs.).—In an area on the watershed of the Torricelli Mountains, light-toned emergent trees occurred in a forest otherwise similar to mid-height forest with an irregular canopy (Fmi). These trees were identified as *Albizia* and the type is probably an old secondary forest.

(iv) *Mid-height Forest with a Rather Open Irregular Canopy* (Fmoi; 6 obs.; Plates 13, 14, 16, 20).—The photo image is similar to that of mid-height forest with an irregular canopy (Fmi), but the canopy is more open.

Field observations also showed the similarity to this type. Spacing between the taller trees, however, is wider and this causes the open canopy image on the photographs. Canopy cover is only about 25%, but because the lower tree layers normally merge with the canopy, thus closing the gaps, the overall cover of the tree layers is the same as in mid-height forest with an irregular canopy (Fmi).

(*b*) *Ecology and Distribution*

Mid-height forest with an irregular small-crowned canopy (Fmis) occurs only in one area on the south-east slopes of Mt. Bougainville at an altitude between 1000 and 2600 ft in Oenake (32) land system. Because of the inaccessible nature of the terrain no ground observations were made, and no explanation can be suggested as to why *Araucaria* is particularly common in this forest type.

The other mid-height forests with irregular canopies are located in the Torricelli and Bewani Mountains, except for a few scattered occurrences on higher hills in the intermontane trough. Lowest boundaries of mid-height forests with irregular canopies (Fmi, Fmoi) are at about 300 ft on some of the hills and at about 800 ft at the foot of the mountains. These forests cover all of the lower parts of the mountains. They generally occur on very steep topography and the degree of closure of the canopy is probably influenced by slope stability. These areas, mapped as a mosaic of mid-height forest with an irregular canopy and its seral stages (Fmi/Fmi′), have probably a high degree of slope instability. The field observations for mid-height forest with an irregular canopy (Fmi) and mid-height forest with a rather open irregular canopy (Fmoi) suggest that the latter type generally occurs on steeper slopes than the former.

There is a considerable overlap in altitude between tall forests with irregular canopies (Foid, Fid) and the mid-height forests with similar canopies (Fmoi, Fmi). The tall forests generally occur on less steep topography. Another factor causing the lower height could be increased cloud cover and/or rainfall induced by the mountains.

VII. Mid-height Forests with Dense Canopies

(*a*) *Descriptions*

(i) *Mid-height Forest with a Rather Dark-toned, Rather Even Canopy* (Fm; no obs.; Plate 20) *and Mid-height Forest with an Even Canopy* (Fmv; 2 obs.; Plates 13 and 16).—The photo images of these types are similar; the canopy consists of small crowns all of nearly even height, and very small, slightly lower crowns. Both types are characterized by an even tone, in contrast with mid-height forests with irregular canopies (Fmi, Fmoi) which have mixed tones. However, mid-height forest with an even canopy (Fmv) has a lighter tone than mid-height forest with a rather dark-toned, rather even canopy (Fm).

Field observations in mid-height forest with an even canopy (Fmv) confirmed the even height of the canopy: the average height was about 90 ft and scattered, slightly emerging trees were only 15 ft taller. Total cover of the tree layers is 60–70% and small girth classes predominate. No observations were made in mid-height forest with a rather dark-toned, rather even canopy (Fm), but it is expected to be identical to the same type mapped in the Aitape–Ambunti area.

(ii) *Mid-height Forest with a Very Dense Canopy* (Fmc; no obs.) *and Mid-height Forest with a Very Dense Canopy of Irregular Height* (Fmci; no obs.; Plate 14).—The photo image of mid-height forest with a very dense canopy (Fmc) is similar to that of mid-height forest with a rather dark-toned, rather even canopy (Fm) but the canopy is denser. The canopy of the other type (Fmci) has a greater variation in height and its tone is less even, similar to mid-height forest with an irregular canopy (Fmi).

No observations were made in these types, but from a distance some *Araucaria* was seen in mid-height forest with a very dense canopy of irregular height (Fmci) on Mt. Bougainville. *Casuarina* was observed to be at least locally common in the Bewani Mountains.

(*b*) *Ecology and Distribution*

Mid-height forests with dense canopies are found in mountain areas on the crests and upper slopes. These localities are normally clouded in for a shorter or longer part of the day due to the influence of the topography on the daily atmospheric rhythm.

Mid-height forest with a rather dark-toned, rather even canopy (Fm) is particularly common in Somoro (39) land system, but occurs throughout the highest parts of the Bewani and Torricelli Mountains. Its range in altitude is from 1600 to over 6000 ft.

Mid-height forest with an even canopy (Fmv) is almost restricted to the eastern half of the survey area. It occurs in eight land systems, but is most common in Piore (25). It is normally found at lower altitudes than the previous type (Fm), viz. 800–2600 ft, except for one occurrence that reaches 4250 ft.

Mid-height forest with a very dense canopy (Fmc) is confined to Mt. Bougainville. Mid-height forest with a very dense canopy of irregular height (Fmci) occurs also on this mountain, but has its largest distribution in the Bewani Mountains. They occur on limestone plateaux and plateau remnants of Serra (36) land system. Their altitudinal range is from 650 to 4000 ft.

VIII. Casuarina Vegetation

Three types of *Casuarina* vegetation are found in the survey area. They all have a restricted distribution and characterize unstable or young environments. On the aerial photographs these types stand out because of their dark tone and the smooth texture of the small crowns.

Casuarina equisetifolia forest (Cq; 2 obs.; Plate 19) occurs on beach ridges near the mouth of the Bliri River, which forms a part of Nubia (2) land system. It is an open forest of even height dominated by 160-ft-tall trees of *C. equisetifolia.*

Casuarina cunninghamiana–Eucalyptus deglupta forest (CE; 1 obs.; Plate 10) occurs on terraces along the Bewani and Puwani Rivers where the rivers flow out from the mountains. Height and closure vary considerably, because the destructive floods keep much of this vegetation in early seral stages. Mature stands, which develop when the river changes course, have a very open canopy about 100 ft high and are dominated by the two species mentioned.

Casuarina papuana (Ca; no obs.; Plate 20) colonizes landslides in the mountains mainly mapped as Somoro (39) land system.

IX. Palm and Pandan Vegetation

Sago palm vegetation (M; 2 obs.; Plates 6, 11, and 19) has a blotchy dark-toned photo image which has an even, very fine texture. Sago palm vegetation with emergent trees (Me; 1 obs.; Plates 10 and 19) differs from it in the occurrence of more or less numerous emergent trees. Immature palms are usually about 40–50 ft tall, but flowering palms can grow to 100 ft. Emergent trees reach heights of about 115 ft. *Stenochlaena*, a climbing fern, is often abundant on these trees. Both types are found in swales between beach ridges of Nubia (2) land system, in back swamps in the coastal plain belonging to Leitre (3) and Pandago (5) land systems, in blocked valleys mainly in Kabuk (4) and some in Pandago (5) land system, and on ill-drained areas of the alluvial fans mapped as Nabes (14) land system. The localities are annually inundated for at least one month, often longer, and the soil usually remains ill drained or swampy throughout the rest of the year. Sago palm vegetations (M, Me) cover about 0·8% of the survey area.

The seral vegetation on Nigia (6) land system has provisionally been mapped as sago palm vegetation (M) because the commonness of sago palms in this land system could lead to their dominance.

Nypa palm vegetation (N; no obs.; Plates 6 and 19) has a photo image similar to sago palm vegetation (M) but it is a little lighter in tone and often speckled rather than blotched. This vegetation type, indicative of brackish environments, is poorly developed in the survey area. It is only found in some swales and along tidal creeks in Nubia (2) and Leitre (3) land systems, often in juxtaposition with rather stunted sago palm vegetation (N/M).

Pandan vegetation (P; no obs.; Plate 6) was seen from the air to occur in mosaic with sago palm and herbaceous vegetation (H/M/P) in the back swamps of the coastal plains, mapped as Leitre (3) land system, and probably indicates permanently wet habitats.

X. Herbaceous Vegetation

Grasslands and other herbaceous vegetation types cover less than 1% of the survey area.

Cane grass (*Saccharum robustum*) vegetation (Gt; no obs.; Plates 9 and 13) occurs along rivers, especially along their middle courses, in Papul (8) and Pual (10) land systems. It colonizes bars and low banks where sand and silt are deposited during floods which occur at least twice per year.

Other grass vegetations in the survey area are fire disclimax communities which are restricted to older beach ridges in Nubia (2) land system. *Imperata* is usually predominant but other grasses and herbs are often intermixed. In ill-drained situations, e.g. shallow swales and higher parts of back swamps of Leitre (3) land system, sedges become predominant. Scattered fire-tolerant trees, pandans, and shrubs usually occur and give the vegetation a savannah-like physiognomy. This vegetation is indicated on the map by the symbol V (Plates 6 and 19).

In the blocked valleys and back swamps of Kabuk (4) land system where the water-table is too high to permit sago palm vegetation (M) to develop, *Hanguana* takes over. In Leitre (3) land system where the soil periodically becomes dry, sedge and fern vegetations are found. Aquatic vegetation occurs in the channels with open water in these land systems. These vegetation types have not been mapped separately and all are indicated by the symbol H (Plates 6 and 19).

XI. Secondary Vegetation

Vegetation types resulting from shifting cultivation cover less than 5% of the survey area and they are mainly found in the following land systems: Madang (1), Nubia (2), Fivuma (16), Puari (20), and Flobum (24). Smaller occurrences are spread over 14 other land systems.

Gardens, plantations, regrowth, and young secondary forest have been mapped by the symbol R, medium-aged secondary forest up to 65 ft tall by FRm, and old secondary forest by FR. Where all these stages occur together they are indicated by the symbol R-FR (Plates 5, 6, 11, and 19).

The symbol MR means that either sago palm vegetation has been noticeably exploited or sago palms have been planted, as for instance in Flobum (24) land system.

A more detailed description of secondary vegetation is given in the report on the Aitape–Ambunti region (Heyligers 1972) where secondary vegetation covers much larger areas than in the Vanimo region.

XII. Reference

Heyligers, P. C. (1972).—Vegetation and ecology of the Aitape–Ambunti area. CSIRO Aust. Land Res. Ser. No. 30, 73–99.

PART VIII. FORESTS RESOURCES OF THE VANIMO AREA

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 indexes of accessibility. A summary of the forest resources appears in Table 22.

Table 22

SUMMARY OF FOREST RESOURCES

Class of forest	Area (sq miles)	Estimated stocking rate (super ft/ac)	Access index*	Forest productivity index*
Very high productivity	110	14,000–14,500	86–88	85–86
High productivity	310	10,000–13,000	67–82	46–72
Moderate productivity	10	10,000–13,000	40–58	36–40
Low productivity	1080	3000–12,000	25–90	13–27
Very low productivity	400	3000–12,000	13–24	5–11
Nil productivity	25	< 3000	2–10	1–2

* These ratings are from 0 (totally inaccessible, zero productivity) to 100 (no access problems whatsoever, maximum productivity).

The forest types described are commercial forests, i.e. they contain at least 3000 super ft of standing timber per acre from trees having a minimum girth of 5 ft at breast height (or above buttresses). Therefore, although they retain the same nomenclature as those in Part VII to facilitate cross-reference with general descriptions, they may differ, often markedly, in areal extent.

Commercial forest (hereinafter referred to as forest) covers 90% of the area, occurring in a wide range of environments from sea level to approximately 6000 ft. Within this range the forests exhibit an almost continuous distribution pattern primarily due to the relatively low overall population density, both past and present, and to the scarcity of herbaceous and other non-woody swamps. Consequently the area is relatively rich in forest resources.

In the central higher parts of the inland ranges, landslides frequently occur and the resulting seral vegetation is non-commercial. Both this vegetation and the remaining forests are invaluable as protective cover for the watershed.

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Much of the Vanimo area had been previously surveyed in greater detail by the Department of Forests, Papua New Guinea (D. H. McIntosh, personal communication), with a view to purchasing timber rights. Part of the area had been leased and exploitation commenced, in the vicinity of Vanimo, prior to the CSIRO resources survey. The operation mainly involved the exporting of logs, but included a small local milling project to supply sawn timber for local consumption.

Appendix I should be consulted for definitions of the terms used in this Part except where they are explained in the text. It is stressed that all indexes used are designed to indicate the position of one land system (or forest type) relative to the others in respect of each index parameter and have no absolute values.

II. Photo Interpretation and Field Work

Preliminary photo interpretation was carried out in close association with the plant ecologist, and recognizable photo patterns were delineated. These patterns were distinguished on the basis of the recurrence of identical crowns, recognizable species, and canopy characteristics such as height, closure, evenness, crown size, occurrence of emergents, and topographic position.

In the field, where possible, the forest was sampled by three circular plots each $\frac{1}{8}$ ac (land surface) in extent. The first of the three plots was centred on the soil hole selected by the pedologist. The remaining two were located at least 150 ft in any direction from the centre of the first plot, and on the same type of land.

Data recorded for all trees of 5 ft girth or more included girth at breast height (or above buttresses), merchantable length, total height, botanical name, and local name in Amele (Madang) language. Each tree was also classed, on form and external symptoms of defects, as suitable or likely to be unsuitable for milling. In cases where a tree was found on the edge of a plot, the position of the geometric centre of the bole at breast height was the reference point for total acceptance into or rejection from the plot. Girth measurements were made by girth tape in 1-ft classes, and merchantable length by a Blume-Leiss altimeter in 5-ft classes. Where the botanical name of a tree was in doubt, a wood sample was taken and later compared with herbarium-supported wood samples.

Remarks on forest and site quality, including evidence of human interference and fallen trees, were also made, while other site factors such as slope, soil, etc., were observed by other team members. The foregoing information was augmented by visual observation when flying over forests at low altitude and by the observations of the plant ecologist. Where applicable, plot information observed on identical forest types in the Aitape–Ambunti area was included in the assessment.

From the qualitative and quantitative information collected on each plot, combined with a visual photo appraisal of each plot's representative value, estimated stocking rates were assigned to each forest type. The volumes quoted were based on the following formula and no allowance for internal defect was made. The bark allowance was 3 in. off girth.

$$V = 80 \cdot 31549 + 2 \cdot 18592G^2 - 1 \cdot 15235H + 0 \cdot 64224G^2H,$$

where

V = log volume under bark in super ft true measure,

G = girth over bark above buttresses in ft (calculated on the girth class mid-point),

H = log length in ft (calculated on the mid-point of 5-ft classes).

The assigned stocking rates are a very approximate indication of timber volume and must be used with caution as the total area of sample plots was only approximately 140 ac. They should be regarded as an indication of which forest types are worth more detailed investigation to assess accurate volume figures.

III. Classification and Mapping

(a) *Classification*

In all, 27 forest types and 5 forest-type complexes are recognized on the basis of photo pattern, the criteria used being mainly structure and, in some cases, species recognition. The forest types are placed in five forest productivity classes (high, moderate, low, very low, and nil) determined by their forest productivity indexes.

Within these classes the forest types are grouped according to their broad type of habitat (Table 23): coastal, swamp, plains, and upland, the last including all dissected country, fans, hills, and mountains. Because of their wide range of habitats, secondary forest types are separated at this level, unless associated with another forest type in a mapping complex.

(b) *Mapping*

A map (scale 1 : 250,000) showing forest types accompanies this report. Colours indicate each forest productivity class. In general, each forest type is mapped separately. However, in certain parts of the area, where the distribution of forest types is too complicated to map at this scale, forest-type complexes are mapped. The approximate proportional representation of the component forest types in each complex is shown in the map reference.

Terrain access categories are shown in Figure 10.

IV. Access

(a) *Terrain Access Categories*

Slope, soil drainage and inundation, and flooding are expressed as indexes for each land system. On the basis of these indexes all land systems are grouped into 10 broad access categories, as shown in Table 24 and explained in more detail in Appendix I. The slope, drainage/inundation, and flooding indexes for each land system are converted into an overall access index (Appendix I) showing its accessibility relative to other land systems. The range of access indexes in each access category is also shown in Table 24, together with its area, forest cover, and component land systems. The access categories, the distribution of which is shown in Figure 10, are briefly described below.

Access category S consists of swamps and unstable flood-out splays. It includes all land systems that are mainly inundated or very poorly drained for periods of 5 months or more per year. Some small areas may be accessible for brief periods during

TABLE

MEASURED AND ESTIMATED PRODUCTIVITY

Class of forest	Forest type	Area (sq miles)	Sample (ac)	Trees/ac Range	Trees/ac Av.	Reject (%)	Bole (ft) Range	Bole (ft) Modal class
Very high productivity								
Forest on plains	F	14	2	10–18	14	7	15–75	60–70
Forest on uplands	FodD	95	9	6–14	9	10	20–70	60–70
High productivity								
Forest on plains	Fo	135	21	1–15	10	9	15–70	50–60
	Fod	80	3	5–9	7	0	20–70	50–60
	Fos	12	2	8–9	8	5	20–60	40–50
	Fosd	35	1	—	9	0	20–60	50–60
Forest on uplands	FosD	35	2	8–10	9	16	45–65	50–60
Moderate productivity								
Forest on uplands	Fi	4	4	6–15	11	10	30–75	50–60
	Foi†	4	—	5–8	6	4	20–70	50–60
Low productivity								
Forest on plains	FodM	20	1	—	7	28	40–50	40–50
	FoM	30	1	—	8	12	20–70	50–60
	Fmo	12	2	3–7	5	10	10–50	50–60
Forest on uplands	Foid	730	42	4–17	9	9	15–90	50–60
	Fid	115	17	5–17	10	14	15–75	50–60
	Fisd	130	4	10–17	14	12	20–70	50–60
Coastal forest	Cq	1	2	9–11	10	—	40–70	50–60
Secondary forest	FR	45	4	2–10	5	4	15–70	50–60
Very low productivity								
Swamp forest	FmoM†	7	—	3–7	5	10	20–50	30–50
Forest on uplands	FoiA	13	—	(4–17)	(9)	(9)	(15–70)	(40–50)
	Fov	4	—	(4–17)	(9)	(9)	(15–70)	(50–60)
	Fmis	5	—	(1–10)	(9)	(5)	(10–90)	(50–60)
	Fmi	200	11	1–10	7	5	10–65	50–60
	Fmv	50	2	9–10	9	0	20–70	50–60
	Fm†	10	—	8–10	9	6	15–65	40–50
	Fmoi	125	5	8–11	9	10	15–70	40–50
Nil productivity								
Forest on uplands	Fmc	4	—		(9)			(40–50)
	Fmci	20	—		(9)			(40–50)

* Indexes: SI, slope; DI, soil drainage/inundation; F, flooding; AI, access; SR, stocking rate;

† Observations from Aitape–Ambunti area only.

( ), Estimated values, no field observations.

23

PARAMETERS OF FOREST TYPES

Girth (ft)		Usage group (% vol.)							Stocking rate (super ft/ac)		Index*					
Range	% in 7 ft†	1	2A	2B	3	4A	4B	5	Max. record	Est. av.	SI	DI	F	AI	SR	FP
5–11	46	2			5	15	58	20	37,643	14,000	0	8	4	88	97	85
5–12	43	3		1	7	51	21	17	26,989	14,500	0	14	0	86	100	86
5–12	36	4			7	12	39	38	23,002	13,000	0	19	<1	80	90	72
5–10	34				8	19	44	29	20,709	11,000	0	14	4	82	76	62
5–8	38	4			5	49	24	18	10,538	10,000	0	33	0	67	69	46
5–8	55	3			35		31	31	14,541	11,000	0	30	3	67	76	51
5–10	27				4	76	8	12	13,342	11,000	0	31	0	69	76	53
5–11	40	4			17	29	23	27	22,562	10,000	29	13	0	58	69	40
5–10	22				6	32	25	37	14,552	13,000	47	13	0	40	90	36
5–6	0				17	20	28	35	4821	7000	0	39	4	57	48	27
5–6	0				8	19	44	29	8981	7000	0	45	5	50	48	24
5–10	30						34	66	6676	4000	0	8	2	90	28	25
5–13	36	1		<1	2	54	21	22	40,438	12,000	59	10	0	31	83	25
5–12	36	4		1	4	41	20	30	30,083	10,000	55	12	0	33	69	23
5–9	34					55	16	29	23,725	10,000	67	8	0	25	69	17
5–6	0					100			13,104	3000	0	30	<1	70	21	15
5–8	29				11	31	40	18	13,973	6000	59	9	0	31	41	13
5–7	11				5	33	5	57	3760	3000	0	77	0	24	21	5
(5–13)	(36)	(1)			(2)	(21)	(22)	(54)		10,000	75	10	0	15	69	11
(5–13)	(36)	(1)			(2)	(54)	(21)	(22)		12,000	78	10	0	12	83	10
(5–13)	(40)		(5)		(7)	(42)	(20)	(26)		8000	72	8	0	20	55	11
5–12	31				7	47	20	26	13,996	7500	71	9	0	20	52	10
5–8	11				16	31		53	12,654	7500	73	9	0	18	52	9
5–7	12			17		10	27	46	7590	8500	76	8	0	16	59	9
5–10	24				2	38	35	25	13,127	7500	78	9	0	13	52	7
(5–8)			(5)				(45)	(50)		3000	82	8	0	10	21	2
(5–8)							(50)	(50)		3000	89	8	0	3	21	1

FP, forest productivity.

TABLE 24

NATURE OF ACCESS CATEGORIES AND DISTRIBUTION OVER LAND SYSTEMS

Access category	Area (sq miles)	% Forest	Indexes* SI	DI	F	AI	Accessibility	Land systems
S	35	21	0	75–100	0–6	0–24	Nil to very poor, rarely poor	Leitre (3), Kabuk (4), Pandago (5), Nigia (6), Nabes (14)
W	60	100	2	45	3	50	Moderate	Po (9)
Iw	100	92	0–1	23–30	0	70–76	Good	Nubia (2), Pagei (11)
IFw	290	90	2–4	22–25	2–3	71	Good, subject to flooding	Papul (8), Pual (10)
IF	35	94	6	17	2	75	Good, subject to flooding	Basu (7)
I	70	91	4–18	8–10	0	64–87	Good to very good	Madang (1), Luap (12)
II	420	99	28–43	8–13	0	49–64	Moderate, rarely good	Isi (15), Puive (21), Punan (29), Jassi (31), Oenake (32)
IIw	40	100	40	21	0	39	Moderate, rarely poor	Muru (17)
III	640	94	45–68	8–15	0	21–42	Poor, rarely moderate	Punwep (13), Fivuma (16), Yassip (18), Morumu (19), Numoiken (22), Flobum (24), Piore (25), Wuro (26), Ijapo (28), Limio (30), Barida (33)
IV	450	80	73–93	8–13	0	0–19	Nil to very poor	Puari (20), Musak (23), Sulen (27), Musu (34), Kohari (35), Serra (36), Kum (37), Mup (38), Somoro (39)

* Indexes: SI, slope; DI, soil drainage/inundation; F, flooding; AI, access.

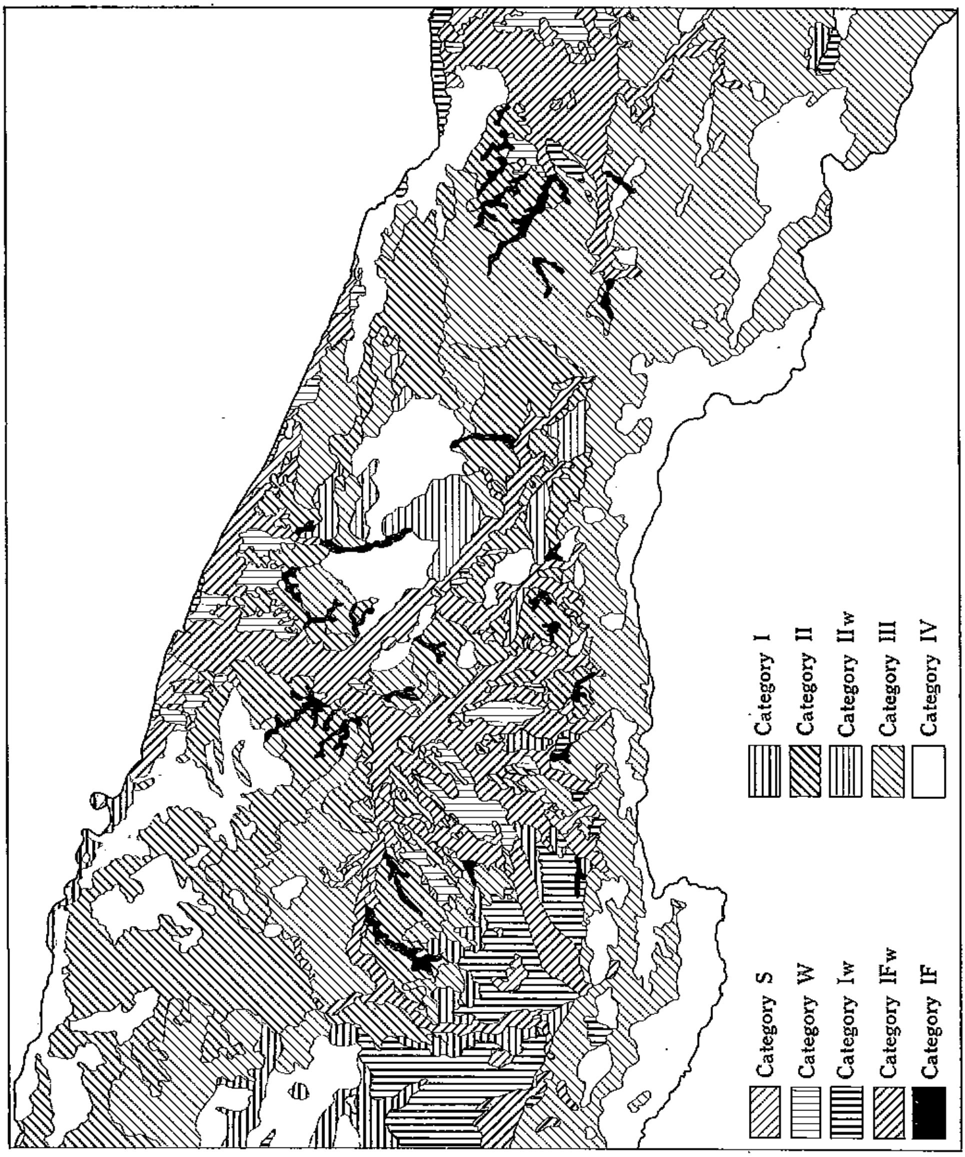

Fig. 10.—Terrain access categories.

the dry season. This category covers substantial areas of the coastal plain, scattered parts of the alluvial plains of the major rivers, and minor areas on the fans of the intermontane lowlands. It covers an area of 35 sq miles including 7 sq miles of forest.

Access category W consists of poorly drained plains. Slope and relief are negligible. Because of inundation and drainage conditions large areas may be inaccessible for up to 5 months per year, and minor areas for longer periods. However, by selecting routes and building causeways access may be possible to large areas for most of the year. This category is distributed throughout the coastal and alluvial plains and covers a total area of 60 sq miles, all of it forested.

Access category Iw land consists of alluvial fans and fan remnants. It also includes the beach ridge/swale complex. Much of the land is well to imperfectly drained but some parts may be poorly to very poorly drained, and minor areas may be inundated for up to 5 months per year. As a whole the category presents good access. It is distributed mainly in the western part of the intermontane lowlands with smaller areas along the coast and scattered throughout the inland ranges. Access category Iw covers a total area of 100 sq miles of which 92 sq miles are forested.

Access category IFw consists of flood-plains including terraces and scroll plains and is generally similar to category Iw except that it is subject to flooding, sometimes serious, at least once a year. Access is considered to be good. It includes the greater part of the alluvial plains and occurs as scattered areas throughout adjacent regions, covering a total area of 290 sq miles of which 261 sq miles are forested.

Access category IF consists of valley floors and terraces which receive damaging floods at least once a year. Except for this hazard it is comparable with access category I. It occurs almost exclusively in the intermontane lowlands along larger streams. Of a total area of 35 sq miles, 34 sq miles are forested.

Access category I land consists mainly of better-drained areas, including the coastal plain and some fans and undulating surfaces, generally with slopes of less than 10° and with nil to low relief. It presents no internal access problems except perhaps minor areas of imperfect to poor drainage and minor areas of steep slopes. It is distributed mainly along the western part of the coastal plain and of the intermontane lowlands. Access category I covers a total area of 70 sq miles of which 61 sq miles are forested.

Access category II land consists mainly of low hilly country and summit plateaux. Slopes are generally moderate and relief varies from very low to moderate. Some areas of steep slopes and minor areas of imperfect to poor drainage occur but are easily avoided. This category occurs mainly on the coastal ranges and throughout the intermontane lowlands. It covers a total area of 420 sq miles, almost entirely forested.

Access category IIw land consists of low to moderate ridges often with moderately steep dip slopes and very steep outcrop slopes. The dip slopes and slump floors may be imperfectly to very poorly drained causing moderate to poor access. It occurs in the central part of the intermontane lowlands covering a total area of 40 sq miles, all of which is forested.

Access category III land consists mainly of high hilly country or strongly dissected low hills with steep slopes and relief varying from very low to high. Access difficulties are caused by steep slopes and minor areas of poor drainage, e.g. slump floors. It occurs mainly at lower altitudes along the inland and coastal ranges and in parts of the intermontane lowlands. It covers a total area of 640 sq miles including 600 sq miles of forest.

Access category IV land consists mainly of very high hilly and mountainous country with very steep slopes, and relief varying from low to very high. Some areas of lesser slope may be utilized but generally the slopes are too steep for road-building and forest areas are best left as watershed protection. This category is associated almost entirely with the coastal and inland ranges but scattered occurrences are found elsewhere. It covers an area of 450 sq miles of which 360 sq miles are forested.

(*b*) *General Conclusions*

Although vehicular access in the area was extremely limited at the time of the survey, a study of the land systems and their attributes would suggest that the limitations were largely economic rather than physiographic. It appears that road links between Vanimo and most of the area are feasible via the alluvial plains and adjacent foothills of the Pual River and its tributaries. Such a road network would allow access to most of the intermontane lowlands, to the alluvial plains of both the Pual and Bliri River systems, to the foothills of the inland ranges, and to the more accessible southern parts of the coastal ranges.

The coastal plain, west of the Basu River, generally has good access but to the east has poor access owing to the prevalence of poorly drained and swampy areas. East of the Serra Hills access is again good, particularly on beach ridges.

The alluvial plains of the major rivers generally have good access except for minor occurrences of poor drainage and swamp. Much of this region is subject to short-duration flooding but the higher terraces are free from this hazard.

The coastal ranges have high very steep to precipitous slopes with scarps along much of their northern face and are better approached from the south in most cases. In general the plateaux have reasonable access if the deeply incised rivers can be avoided.

In general the intermontane lowlands have good access with minor exceptions in poorly drained or swampy parts and on very dissected land.

The inland ranges are generally inaccessible except for the foothills zone adjacent to the intermontane lowlands. Even here access is poor mainly because of steep slopes.

The major rivers (Pual and Bliri) would not appear to be navigable for practical purposes, nor suitable for floating logs in any quantity, except perhaps in their lower reaches.

As mentioned in Part I, Vanimo is the only suitable anchorage in the area and is the obvious outlet for the area. Port facilities for handling cargoes of timber are already in existence.

V. Description of Forest Types

(*a*) *General*

Only one forest type grows on the coast and only one in the swamps, each occupying its own restrictive habitat. Nine forest types are recognized on plains, the habitat of each being dictated mainly by soil drainage, inundation, and flooding.

TABLE

TREES RECORDED AND THEIR FREQUENCY

P, predominant, >80%; D, dominant, 50–80%; S, subdominant, 20–50%; V, very common, 15–20%;

Botanical name	F†	Fo	FoM†	Fod	FodM†	Fos†	Fosd	Foi†	Foid	FosD
Aglaia	R	R	R		R	R		O	R	
Ailanthus									R	
Albizia									R	
Alstonia scholaris	R			R					R	
Anthocephalus		R							R	
Aporosa										
Artocarpus	R	R							R	
Buchanania	O	R	R						R	
Calophyllum									R	
Campnosperma		R	R	R		R		R	R	R
Cananga odorata	R		R							
Canarium	R	R	R			O		R	R	
Casearia										
Castanopsis									R	
Casuarina equisetifolia										
Celtis	R	R					R	O	R	
Celtis nymanii	R	R	R					R	R	
Cerbera floribunda		R								
Chisocheton									R	
Chrysophyllum	R							R	R	
Cinnamomum										
Claoxylon									R	
Cordia									R	
Cryptocarya		R		R		R		R	R	R
Dillenia		R	R	R				R	R	
Diospyros									R	
Dracontomelum	R	R	R			R	R		R	
Dysoxylum	R	R		R		R			R	
Elaeocarpus									R	
Endospermum		R								
Euodia										
Fagraea		R								
Ficus	O	R							R	
Ficus (stranglers)	O	O	O					R	R	O
Flindersia									R	
Garcinia		R								
Garuga floribunda									R	
Glochidion									R	
Gymnacranthera										
Gynotroches		R							R	
Hernandia	R	R								
Homalium	R	R				O		O	R	O
Homonoia									R	
Hopea									R	C
Horsfieldia	R	R								

25

OF OCCURRENCE IN FOREST TYPES*

C, common, 10–15 %; O, occasional, 5–10 %; R, rare, < 5 %; ( ), locally

FodD	Fi†	Fid	Fisd	Fmo†	FmoM†	Fmi	Fmoi	Fmv	Fm†	Cq	FR
R	V	R			R						R
	R		R								
	R	R									
R	O	R					R	R			
		R									
R	R	R	(C)								
		R		R	O			R			
O		R			O		R				
O	R	R		R		R			O		R
		R									
									S		
										P	
R	R	O	R			R	O		R		O
		R									
		R	R			R			R		
	R	R									
R											
											R
R	R	R				O		R			
	R	R				R					
									R		
R	R	R	R								
R		R				R					
				R							
		R									
						R					
R	R	R	R		R		R				
O	O	O		R	O		O		R		R
		R				R	R				
		R							R		
							R				
								R			
R											
R	O	R				R					
R	R										
		R	V			R					
	R	R		R		R					

TABLE 25

Botanical name	F†	Fo	FoM†	Fod	FodM†	Fos†	Fosd	Foi†	Foid	FosD
Intsia bijuga	R	R	R	R		S		O	S	R
Jagera									R	
Kingiodendron		R							R	
Litsea		R							R	
Mangifera		R				R	R		R	
Maniltoa	R	R		R				R	R	
Maranthes									R	
Mastixiodendron									R	
Microcos		R							R	
Myristica		R			V		C	R	R	
Nauclea									R	
Neonauclea	R	R	S	O	(S)				R	
Neuburgia									R	
Octomeles	R	R		R						
Palaquium	R	R	R	R		R			R	
Pangium	R	R							R	
Parartocarpus		R						R	R	
Parastemon										
Pimeleodendron	R	R							R	
Planchonella	R	R							R	
Planchonia	R		C	R	S					
Podocarpus									R	
Polyalthia	R	R		R					R	
Pometia pinnata	S	S	O	O		R	C	O	O	R
Pometia tomentosa						V		O	O	
Pterocarpus	O	R	R	C			C		R	O
Pterocymbium		R							R	
Randia		R								
Sloanea	O	R	O	O				R	R	
Solenospermum		R								
Spondias	R	R	R						R	
Sterculia	R	R	R	R					R	
Syndyophyllum									R	
Syzygium		R			R	O		O	R	C
Terminalia	C	R	O	V	S			O	R	O
Tetrameles										
Teysmanniodendron		R		R				R	R	
Thespesia										
Tristania										
Tristiropsis	R								R	
Vitex								O	R	
?(malakbaiya)	R	R						R	R	

* No field observations in forest types FoiA, Fov, Fmis, Fmc, Fmci.

(Continued)

FodD	Fi†	Fid	Fisd	Fmo†	FmoM†	Fmi	Fmoi	Fmv	Fm†	Cq	FR
S	O	S	O			V	C	S			R
	R					R		R			
R	R	R				R					
	R	R					O				
		R	O								
											R
R		R	R			R					
	R	R	R								
	R	R		O	V	R	O		R		
		R									
R		R				R		V			
R		R				R		R			
						R					
	R	R				R					
	R		O			R					
R		R							R		
		R				R					
O	O	C		V	O	R	S				S
	V	R	S			O	R				R
		R									R
R								R			
									O		
R	R	R				R					R
R											
R		R		O							
	R	R		(D)	R			(V)			
O	O	R	O		R	O	R	R	O		O
R	O	R	R	R		R	R				R
		R									
R	R	R				R	R				R
						R	R				
						(D)	(D)				
R		R	R								
	R	R									R
	R										

† Augmented by Aitape–Ambunti data.

Fifteen forest types are recognized in upland situations. Generally the taller, more productive forest types occur on gentler slopes at lower altitudes. No doubt many environmental elements interact to produce each habitat, some of the more obvious involved being climate as reflected in the proportion of deciduous trees (Fid forest), climate and altitude (Fm forest), and parent material (Fmc forest). The secondary forest type results from interference by man and in this area may be found in any habitat, except in swamps and at high altitudes. Because of their seral status no firm description can be given, many stages often occurring in a mosaic pattern.

To facilitate comparisons between the various forest types and to avoid repetition, both measured and estimated parameters applying to each forest type are listed in Table 23. Species recorded for each type are given in Table 25. The general descriptions are restricted to points of forestry interest and for full descriptions of each forest type, Part VII should be consulted.

(*b*) *Very High Productivity Forest*

(i) *Forests on Plains*

(1) *Tall Forest with Rather Closed Canopy* (F).—This forest has a very high productivity index. Apart from the subdominant *Pometia pinnata*, species composition is mixed, no single species contributing more than 10% of trees present. Boles are generally straight, long, and clear with the exception of *Pometia pinnata*, *Pterocarpus indicus*, and *Ficus* spp. (strangler*). Girths are large and the estimated stocking rate is high.

The forest occurs on alluvial terraces that are not subject to flooding or receive minor rare floods only.

The access index is very good and the forest is found mainly in the western part of the alluvial plains region, along the Pulan and Jassi Rivers.

F forest is restricted to Papul (8) land system.

(ii) *Forests on Uplands*

(1) *Tall Forest with an Open Canopy with Scattered Light-toned Crowns and a Dense Understorey* (FodD).—This forest has a very high productivity index and is of mixed species composition with *Intsia bijuga* subdominant. No other single species contributes more than 10% of the individuals present. Boles are generally straight, long, and clear and girths large. The estimated stocking rate is high.

The forest occurs on alluvial fans, generally well drained but sometimes imperfectly drained, mainly in the western part of the intermontane lowlands. Access is very good.

FodD forest is restricted to Pagei (11) and Luap (12) land systems.

(*c*) *High Productivity Forest*

(i) *Forests on Plains*

(1) *Tall Forest with a Rather Open Canopy* (Fo).—This forest has a high productivity index and is of mixed species composition with *Pometia pinnata* subdominant. No other single species contributes more than 10% of individuals present. Generally

* These species together with *Vitex cofassus* generally have a poor stem form and are the main contributors to the reject percentage.

boles are long, straight, and clear. Girths are moderately large and stocking rate is high, locally very high.

The forest occurs mainly on the better-drained, rarely flooded parts of alluvial plains and thus has a very good access rating. It is found mainly on the alluvial and coastal plains with isolated occurrences elsewhere. It is the dominant forest on Pual (10) land system and covers 10% of Papul (8) land system. Minor inclusions of other forest types do occur and are generally recognized by a striking change in species composition. Old flood-outs generally have a predominance of *Octomeles sumatrana* and frequently flooded plains and lower terraces commonly carry *Neonauclea*, *Terminalia*, and *Nauclea*. Levees generally carry a forest rich in *Planchonia* and *Terminalia*.

(2) *Tall Forest with an Open Canopy with Scattered Light-toned Crowns* (Fod).—This forest has a high productivity index and is of mixed species composition, deciduous trees being conspicuous. Boles are generally straight, moderately long, and clear. Girths are moderately large and the estimated stocking rate is moderate to high.

The forest occurs on levees, higher scrolls, alluvial terraces, and the higher parts of back plains. Although sites are frequently flooded and drainage may be imperfect to poor, the access index is rated as good. It is found mainly along the middle parts of the Pual River and its tributaries.

Fod forest covers about 30% of both Papul (8) and Pual (10) land systems.

(3) *Tall Forest with a Rather Open Small-crowned Canopy* (Fos).—The forest has a high productivity index and is of mixed species composition with *Intsia bijuga* subdominant. Boles are generally moderately long, straight, and clear, and girths moderate to large. The estimated stocking rate is moderate to high.

The forest is found on imperfectly to poorly drained alluvial terraces and has a good access index. It is confined to Papul (8) and Pual (10) land systems and has a scattered distribution pattern along the courses of larger rivers.

(4) *Tall Forest with an Open Small-crowned Canopy with Scattered Light-toned Crowns* (Fosd).—The forest has a high productivity index and is of mixed species composition. Boles are moderately long, straight, and clear and girths tend to be moderately large. The estimated stocking rate is moderate to high.

The forest is found on alluvial terraces and flood-plains in narrow valleys on imperfectly to poorly drained soils subject to occasional to frequent flooding. Nevertheless, access is considered good to moderate. Fosd forest is the predominant forest type on Basu (7) land system but minor areas are found on Papul (8) land system.

(ii) *Forests on Uplands*

(1) *Tall Forest with an Open Small-crowned Canopy and a Dense Understorey* (FosD).—The forest has a high productivity index and is of mixed species composition. Boles are moderately long and generally straight and clear. Girths are variable but tend to be small and the estimated stocking rate is moderate to high.

The forest is found on imperfectly to poorly drained parts of alluvial fans in the intermontane lowlands region, mainly in the western part of the area. Access is moderate to good. FosD forest covers 30% of Pagei (11) land system, and also is present on Po (9) land system.

(*d*) *Moderate Productivity Forest*

(i) *Forests on Uplands*

(1) *Tall Forest with an Irregular Canopy* (Fi).—This forest has a moderate productivity index. Species composition is mixed, with *Pometia tomentosa* very common. Boles are straight, clear, and long and girths are generally large. The estimated stocking rate is moderate to high and locally very high on areas of gentle slope.

The forest is found on dissected fan plains and hills, generally at altitudes below 2000 ft, and has a moderate access index with minor areas subject to imperfect or poor drainage. Areally it is of minor importance, the largest occurrence being in the eastern part of the area on Pagei (11) and Fivuma (16) land systems.

(2) *Tall Forest with a Rather Open Irregular Canopy* (Foi).—This forest has a moderate productivity index. The species composition is mixed, no single species contributing more than 10% of individuals present. Boles are generally long, straight, and clear. Girths are moderately large and the stocking rate is moderate.

The forest occurs on hills at low altitudes exclusively in the eastern part of the area, and has a moderate access index because of slope and occasionally poor drainage conditions. It covers 50% of Yassip (18) land system and minor areas of Morumu (19) land system.

(*e*) *Low Productivity Forest*

(i) *Forests on Plains*

(1) *Tall Forest with an Open Canopy with Scattered Light-toned Crowns and with Sago Palms in the Understorey* (FodM).—The forest has a low productivity index and is of mixed species composition with a fair proportion of deciduous trees, e.g. *Planchonia* and *Terminalia*. *Neonauclea* is often locally subdominant. Boles are generally long, straight, and clear and girths are moderately large. The estimated stocking rate is moderate.

It is found on imperfectly to very poorly drained sites subject to occasional to frequent flooding on the alluvial and coastal plains, the largest areas being found inland. Access is moderate to rarely good. The forest occurs typically on Po (9) land system with minor areas on more poorly drained parts of Pual (10) land system.

(2) *Tall Forest with an Open Canopy and with Sago Palms in the Understorey* (FoM).—The forest has a low productivity index and in composition is very similar to FodM forest except in having a lower proportion of deciduous trees. Boles are generally long, straight, and clear and girths are moderately large. The estimated stocking rate is moderate.

Like the FodM forest, it is found on imperfectly to very poorly drained sites subject to occasional to frequent flooding and generally on wetter sites than FodM forest. Access is considered to be moderate, rarely poor. It occurs scattered throughout the alluvial and coastal plains, typically on Po (9) land system but occasionally on more favourable sites in the more swampy land systems.

(3) *Mid-height Forest with a Rather Open Canopy* (Fmo).—The forest has a low productivity index and includes only the more advanced stages of the synonymous

vegetation type. Species composition is mixed and variable due to its seral nature. Boles are straight and moderately long but girths are small. The estimated stocking rate is low.

It is found on scroll plains and lower river terraces that are generally well drained but regularly flooded. Access is considered good, subject to flooding, and the forest occurs on Pual (10) and Papul (8) land systems as scattered stands along the alluvial plains of the major rivers.

(ii) *Forests on Uplands*

(1) *Tall Forest with a Rather Open Irregular Canopy with Scattered Lighter-toned Crowns* (Foid).—The forest has a low productivity index and a mixed species composition with *Intsia bijuga* subdominant. Boles are generally long, straight, and clear with generally large girths. The estimated stocking rate is high.

The forest is found on hilly country at low and medium altitudes on a wide variety of land systems. Access is variable depending upon slope but overall is considered to be poor.

Poor accessibility gives this forest a low productivity index. Nevertheless it is the most important type in the area since it is the largest, covering nearly 700 sq miles.

(2) *Tall Forest with an Irregular Canopy with Scattered Light-toned Crowns* (Fid).—This forest has a low productivity index and is of mixed species composition with *Intsia bijuga* subdominant, and with deciduous species as an important component. Boles are generally straight, moderately long, and clear, girths moderately large but variable. The estimated stocking rate is high.

The forest is found on dissected fans and hilly country up to an altitude of approximately 2000 ft on a large number of land systems. Access is considered to be poor largely because of slope and to a minor extent poor drainage on slump floors.

(3) *Tall Forest with an Irregular Small-crowned Canopy with Scattered Light-toned Crowns* (Fisd).—The forest has a low productivity index and is of mixed species composition with *Pometia tomentosa* subdominant and *Hopea* very common. Boles are moderately long, straight, and clear and girths are moderate. The estimated stocking rate is high.

The forest is found on dissected fans, hills, and plateaux of the coastal ranges in the western part of the area. Access is variable but classed generally as very poor, mainly because of steep slopes and the occurrence of scarps. It occurs on eight land systems, on all of which limestone is found pure or in variable proportions with other rock types.

(iii) *Coastal Forest*

(1) Casuarina equisetifolia *Forest* (Cq).—The forest has a low productivity index and consists predominantly of *C. equisetifolia*. The trees have moderate to long boles, branching at low levels, and girths rarely exceed 6 ft. The estimated stocking rate is low overall but locally can be high.

The forest occurs on the outermost beach ridges on well-drained soils and access is good. However, the intervening swales are poorly drained and frequently inundated, presenting some problems of access. Cq forest is confined to Nubia (2) land system and the only occurrence of mappable size is at the eastern edge of the area.

(iv) *Secondary Forest*

(1) *Secondary Forest* (FR).—This forest has a low productivity index. It differs from the old secondary forest (FR) described in Part VII in that it also includes some of the more advanced stages of medium-aged secondary forest (FRm). Being a mixture of seral stages, it is of variable floristic composition; however, *Pometia pinnata* is often subdominant. Boles are generally short to moderately long and girths are small to medium in size. The estimated stocking rate is moderate.

Being anthropogenic, its occurrence is associated with centres of population, both in the recent past and at present, and thus it is found on a wide variety of habitats and land systems. Access is generally poor due to steep slopes.

(*f*) *Very Low Productivity Forest*

(i) *Swamp Forest*

(1) *Mid-height Forest with an Open Canopy and Sago Palms in the Understorey* (FmoM).—This forest has a very low productivity index and although it is of mixed species composition, *Neonauclea* is very common. Boles are straight and short to moderately long and girths are of small to moderate size. The estimated stocking rate is low.

The forest occurs on poorly to very poorly drained alluvial plains often subject to long periods of inundation. Hence the access is very poor. It is found as a number of small patches scattered throughout the alluvial and coastal plains regions and is confined to Pandago (5) land system.

(ii) *Forests on Uplands*

(1) *Tall Forest with a Rather Open Irregular Canopy with Scattered* Albizia (FoiA).—The forest has a very low productivity index and is of mixed species composition with *Albizia* as a subdominant. The forest was not sampled in the field but the stocking rate is estimated as high, mainly due to *Albizia*.

It occurs on sites that are elsewhere occupied by Foid forest and so it is assumed to be an old secondary forest. Access is very poor owing to steep slopes and the forest is confined to Puari (20) land system in the eastern part of the coastal ranges.

(2) *Tall Forest with a Rather Open Even Canopy* (Fov).—This forest has a very low productivity index and in the absence of any field observations is assumed to have a high estimated stocking rate. Species composition is mixed.

The forest is found on plateau remnants in the eastern part of the coastal ranges and is confined to Serra (36) land system. Because of very steep slopes, access is considered to be very poor to nil.

(3) *Mid-height Forest with an Irregular Small-crowned Canopy* (Fmis).—The forest has a very low productivity index. No ground observations were possible but from aerial reconnaissance the forest is assumed to be similar to Fmi forest but with emergent *Araucaria*. The estimated stocking rate is moderate but may be locally very high in areas of denser *Araucaria*.

The forest is restricted to the north-western part of the coastal ranges, on the slopes of Mt. Bougainville, on Oenake (32) land system. Access within the forest is considered to be moderate but poor to very poor in surrounding areas.

(4) *Mid-height Forest with an Irregular Canopy* (Fmi).—The forest has a very low productivity index and is of mixed species composition. *Intsia bijuga* is very common and *Tristania* may be locally dominant. Boles are generally straight and moderately long and girths are small to moderate in size, rarely large. The estimated stocking rate is moderate.

The forest is found mainly along the lower parts of the inland ranges above the foothills zone. Access is considered to be very poor because of steep slopes and the forest is found on a wide variety of land systems.

(5) *Mid-height Forest with an Even Canopy* (Fmv).—The forest has a very low productivity index and is of mixed species composition, *Intsia bijuga* often being subdominant. Boles are moderately long and straight but girths are typically small. The estimated stocking rate is moderate.

Although the forest is found on crests and upper slopes where slopes are often gentle to moderate, access is considered to be very poor because of the steepness of the surrounding land. It is confined to the inland ranges, particularly in the eastern part of the area and rarely exceeds 2600 ft altitude. The forest is found on a variety of land systems but in particular on Piore (25).

(6) *Mid-height Forest with a Rather Dark-toned, Rather Even Canopy* (Fm).—Although no field observations were made in this forest it is assumed to be similar to Fm forest in the adjoining Aitape–Ambunti area. The forest has a very low productivity index and species composition is generally mixed. *Castanopsis* is subdominant, and may locally predominate on ridge crests. Boles are generally moderately long and girths generally small to moderately large. The estimated stocking rate is moderate.

It is found on ridge crests and upper slopes at altitudes above 1600 ft on the inland ranges. As it is surrounded by steeper slopes, access is considered to be very poor. Fm forest is found on several land systems but in particular on Somoro (39).

(7) *Mid-height Forest with a Rather Open Irregular Canopy* (Fmoi).—The forest has a very low productivity index and is of mixed species composition, much the same as Fmi forest. *Pometia pinnata* and more rarely *Tristania* may be locally dominant. Boles are generally straight and moderately long and girths are generally small, rarely large. The estimated stocking rate is moderate.

It is found on the inland ranges in similar situations to Fmi forest but perhaps on slightly steeper and less stable slopes. Access is very poor. The forest occurs on a wide range of land systems.

(*g*) *Nil Productivity Forest*

(i) *Forests on Uplands*

(1) *Mid-height Forest with a Very Dense Canopy* (Fmc).—The forest has an extremely low productivity index and was not visited in the field. It is assumed to have a low estimated stocking rate.

The forest is confined to Mt. Bougainville on the limestone plateaux in Serra (36) land system, and access is very poor.

(2) *Mid-height Forest with a Very Dense Canopy of Irregular Height* (Fmci).— The forest has an extremely low productivity index and, like Fmc forest, was not sampled in the field. From aerial observation some *Araucaria* was noticed on Mt. Bougainville, and *Casuarina* was locally common in the Bewani Mountains. The estimated stocking rate is low and access is very poor to nil, mainly because of scarps and karst land forms. The forest is found on plateaux and plateau remnants on limestone in Serra (36) and Kohari (35) land systems.

APPENDIX I

Definition or Explanation of Descriptive Terms and of Classes of Land Attributes

By H. A. Haantjens,* P. C. Heyligers,* E. Löffler,* and J. C. Saunders*

I. Introduction

The information contained in this Appendix is presented in subject groups under the same headings as used in the land system descriptions, but it applies to all sections of the report. More detailed information is given elsewhere by Haantjens (unpublished data, 1969†) on drainage status, agricultural soil depth, soil gleying, soil permeability, available soil water storage capacity, soil reaction, soil nutrient status (N, P, K contents), and on the methods of assessing land use capability for arable crops, tree crops, improved pastures, and irrigated rice.

II. Definitions and Explanations

(a) *Land Forms*

(i) *Slope Steepness.*—Measured in the field or estimated on aerial photographs, slope steepness is expressed in classes defined in Table 26. The classes are based essentially on equal intervals on a logarithmic slope tangent scale (Speight 1967). They are applied to stream gradients as well as land forms.

Table 26

slope classes

Class	Angle	Percentage	Gradient
Level		0–0·03	<1:3300
Very low gradient		0·03–0·1	1:3300–1:1000
Low gradient		0·1–0·3	1:1000–1:330
High gradient		0·3–1	1:330–1:100
Very gentle slope	0°30′–2°	1–3·5	1:100–1:30
Gentle slope	2°–6°	3·5–10·5	1:30–1:10
Moderate slope	6°–10°	10·5–17	1:10–1:5·7
Moderately steep slope	10°–17°	17–30	1:5·7–1:3·3
Steep slope	17°–30°	30–56	1:3·3–1:1·8
Very steep slope	30°–45°	56–100	1:1·8–1:1
Precipitous slope	45°–72°		
Cliffed slope	>72°		

* Division of Land Research, CSIRO, P.O. Box 1666, Canberra City, A.C.T. 2601.
† CSIRO Aust. Div. Land Res. tech. Memo. No. 69/4 (unpublished).

(ii) *Relief.*—Defined as the difference in altitude between major* ridge crest or peak and nearest major* valley floor, relief is largely estimated from aerial photographs, locally measured in the field. The relief classes are shown in Table 27.

TABLE 27

RELIEF CLASSES

Class	*Relief* (ft)
Nil	<20
Ultra-low	20–50
Very low	50–150
Low	150–300
Moderate	300–750
High	750–1500
Very high	>1500

(iii) *Grain.*—Grain is defined as the modal value of half the distance between major stream beds as estimated from aerial photographs (Speight 1967). Grain categories are defined in Table 28.

TABLE 28

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

(iv) *Crest Width.*—Based on field measurements and estimates from aerial photographs, crest width is indicated as: knife-edged, <15 ft; very narrow, 15–50 ft; narrow, 50–150 ft; broad, 150–500 ft; very broad >500 ft.

(*b*) *Streams and Drainage*

(i) *Stream Gradient.*—See slope steepness classes under Subsection (*a*) (i).

(ii) *Stream Width.*—This is either qualitatively described or estimates of measurements (field measurements for small streams, air-photo measurements for large rivers) are given. These data apply to the whole of the bare or sparsely vegetated stream bed, not necessarily to the channel alone.

(iii) *Flood and Inundation Hazards.*—Of necessity these are qualitatively assessed from land form, vegetation, and soil indications and from information supplied by local residents. Although a rating system exists for the seriousness of these hazards, information in this report is always given in a self-explanatory form.

* This term is not used in an absolute sense but in relation to the conditions prevailing in each land system.

(*c*) *Soils*

(i) *Degree of Soil Development.*—This is qualitatively expressed as: undeveloped, slightly developed, moderately developed, strongly developed, very strongly developed. It is assessed from such features as apparent degree of alteration relative to the underlying parent rock, soil horizon differentiation, degree of leaching (pH), soil colour, and solum thickness.

(ii) *Soil Colour.*—Colour is not normally mentioned in the soil descriptions since this attribute is not used directly in the 7th Approximation. For information on soil colour the reader is referred to the detailed descriptions of the lower soil classes available upon request.

(iii) *Soil Depth** (*Agricultural*).—Agricultural soil depth is assessed to a routine maximum of 6 ft. In the first instance, depth is measured to a horizon considered impenetrable for any but a few roots. Above any such horizons soil layers considered to offer only normal resistance to root penetration are assessed to contribute fully to soil depth, but only half the thickness is used to calculate soil depth for layers considered to offer much resistance to root penetration. Normally such layers are extremely hard, firm, or plastic. Soil aeration is *not* used in calculating soil depth, since this is accounted for in drainage status. The depth classes arrived at in this manner have the following limits: very shallow, <10 in.; shallow, 10–20 in.; moderately shallow, 20–30 in.; moderately deep, 30–45 in.; deep, 45–60 in.; very deep, >60 in.

(iv) *Soil Drainage Status.*—This is assessed from a combination of indications including depth and degree of gleying in the soil profile (see also soil gleying under Subsection (*c*) (v)), vegetation characteristics, and water-tables observed and also takes into account climatic, slope, and other soil factors. Six classes are recognized and can be described as follows.

Excessively drained.—Lack of soil moisture occurs during rainless periods of short duration and common occurrence.

Well drained.—Absence of features pointing to excessive moisture in the soil above a depth of 5 ft; sustained supply of soil moisture during rainless periods, at all times or except towards the end of exceptional droughts.

Imperfectly drained.—Permanent or prolonged excessive soil moisture in the deeper subsoil (usually below 40 in.) or short periods of excessive moisture in the surface or throughout the profile; dry-season water-tables below 4 ft.

Poorly drained.—Permanent or prolonged excessive soil moisture in the subsoil (usually between 20 and 40 in.), or relatively long periods of excessive moisture in the surface soil or throughout the profile; commonly shallow water-tables during the wet season.

Very poorly drained.—Permanent or prolonged excessive soil moisture throughout the profile, except for the surface soil to a depth of at most 9 in.; commonly dry-season water-tables between 2 and 4 ft rising to close to the surface during the wet season.

* For engineering soil depth see Subsection (*g*) (i).

Swampy.—Permanent excessive soil moisture throughout the profile; water-tables at or near the surface during the dry season.

(v) *Soil Gleying.*—As used in this report, the terms slightly, moderately, strongly, and very strongly gleyed are based on the depth at which gleying occurs, and on the expression of the gley phenomena in terms of degrees of greyness and percentage and colour of mottles. This introduction of depth of gleying as a criterion is not strictly correct and has resulted in too close a relation between gleying classes and drainage status classes.

(vi) *Soil Permeability.*—This has been assessed qualitatively on the basis of soil texture and structural and consistency properties. Ideally, rates of water movement associated with the classes are: very rapid, >8 in./hr; rapid, 2·5–8 in./hr; moderate, 0·5–2·5 in./hr; slow, 0·1–0·5 in./hr; very slow, <0·1 in./hr.

(vii) *Soil Texture.*—This is assessed in the field without supporting laboratory analyses and is based on the textural classes of the United States Department of Agriculture (1951). For Unified Soil Classification, see Subsection (*g*) (ii).

(viii) *Soil Reaction* (pH).—Based on colorimetric field measurements of pH, soil reaction is expressed as a weighted average for topsoil and subsoil, emphasizing topsoil pH, in seven classes: strongly acid, pH <5; acid, pH 5–5·9; weakly acid, pH 6–6·5; neutral, pH 6·6–7·5; weakly alkaline, pH 7·6–8·0; alkaline, pH 8·1–8·5; strongly alkaline, pH >8·5.

(ix) *Nitrogen, Phosphate, and Potash Contents.*—Soil nitrogen ratings are based on N determinations by the modified Kjeldahl method for topsoil samples only (usually 0–6 in., in cases somewhat deeper). Classes are: very low, <0·1% N (minimum recorded 0·05%); low, 0·1–0·2% N; moderate, 0·21–0·5% N; high, 0·51–1·0% N; very high, >1·0% (maximum recorded 1·44%).

Soil phosphorus and soil potassium ratings are based on weighted averages for samples of topsoil and subsoil (mostly between 2 and 3 ft depth), emphasizing topsoil values. Phosphate was measured in a supposedly available form by 0·01N sulphuric acid extraction according to the Kerr and von Steiglitz (1938) method and results classed as: very low, <10 p.p.m.; low, 10–20 p.p.m.; moderate, 21–50 p.p.m.; high, 51–100 p.p.m.; very high, >100 p.p.m. (maximum recorded 360 p.p.m.). Potassium was determined by the stronger sulphuric acid extraction method of Hunter and Pratt (1957) and results classed as: very low, <0·2 m-equiv. % K (minimum recorded 0·04 m-equiv. %); low, 0·2–0·4 m-equiv. % K; moderate, 0·41–0·75 m-equiv. % K; high, 0·76–1·5 m-equiv. % K; very high, >1·5 m-equiv. % K (maximum recorded 3·26 m-equiv. %).

(*d*) *Population and Land Use*

(i) *Population.*—Population data are derived from the district village census for the year 1965–66. Their presentation for the land systems is based on the census villages located within each land system.

(ii) *Land in Current Use.*—This includes all native garden land which has been cleared, planted, is in production, or has been recently abandoned. It covers a cycle of 4–5 years.

(e) *Forest Resources*

(i) *Soil Drainage and Inundation Index* (DI) *and Flooding Index* (F).—The main objective of these indexes is to indicate the limiting effect of soil wetness and overflow on vehicular access to the land. It is assumed that due to precipitation alone all land will be inaccessible for a certain length of time each year, even under optimum drainage conditions. The time is estimated from the period in which soil moisture rises above field capacity and is calculated from the results of the application of the water balance model in Part IV. Above field capacity conditions are assumed to occur in those weeks when soil moisture storage has reached maximum level (4 in.) and in which more than 3 in. of run-off occurs. The length of the period varies from 20 days per year at Imonda and Ossima to 47 days per year at Vanimo (Table 29). Generally it can be expected that shorter periods occur in the intermontane lowlands and longer periods elsewhere. An average figure of 30 days per year is used over the whole area in assessing the DI index.

TABLE 29

NUMBER OF DAYS WHEN SOIL WATER STORAGE EQUALS 4 IN. AND RUN-OFF IS MORE THAN 3 IN.*

	Amanab	Imonda	Ossima	Pagei	Vanimo
May–Oct.	19	6	6	7	13
Nov.–Apr.	17	14	14	20	34
Yearly	36	20	20	27	47

* Length of records: Amanab, Ossima 7 yr; Imonda, Pagei 5 yr; Vanimo 17 yr.

The DI index is calculated for each mapping unit (land system or forest type). It is the sum of the products of percentage area of the unit affected by a particular class of hazard, and a weighting factor equivalent to the maximum expected number of days per year the hazard could render the land inaccessible, as set out in Table 30. Thus:

$$\mathrm{DI} = 0\cdot08\ (w0) + 0\cdot22\ (w1) + 0\cdot44\ (w2) + 0\cdot71\ (w3) + 0\cdot85\ (w4) + 0\cdot27\ (i1) + 0\cdot41\ (i2) + 0\cdot55\ (i3) + 0\cdot82\ (i4) + 1\cdot0\ (i5),$$

where (w0), (w1), . . . (w4) and (i1), . . . (i5) are the percentage areas in each access hazard class. However, where a soil drainage and an inundation hazard occur together only the maximum (according to Table 30) is used in the formula.

The F index is derived in the same way as the DI index, but in the case of flooding occurring at least twice per year the minimum figure of 30 days per year is used.

(ii) *Terrain Access Index* (AI).—For the purposes of Part VIII, access is considered to be affected by the following environmental factors: slope and relief, precipitation, soil drainage, inundation, and flooding. The degree of access hazard attributable to each of these factors, except slope and relief, is compounded in a series of weighted factors based on the number of days per year that the land affected will be inaccessible to conventional wheel vehicles (see previous section).

Although all of the environmental factors interact, their effects are often additive, e.g. imperfectly drained soils on moderately steep slopes. For this reason, the terrain access index is calculated as the sum of the slope index,* the soil drainage and inundation index, and the flooding index for each mapping unit, subtracted from 100. In some land systems the terrain access index is upgraded because of very low relief or favourable location. Terrain access index classes are: nil, 0–5; very poor, 6–20; poor, 21–40; moderate, 41–60; good, 61–80; very good, 81–100.

TABLE 30

PERIODS OF INACCESSIBILITY ASSOCIATED WITH VARYING DEGREES OF HAZARDS DUE TO WETNESS

Nature and class of hazard	Expected maximum duration of inaccessibility (days/yr)	Weight factor for calculating drainage/ inundation or flooding index
Soil drainage status		
Well drained (w0)	30	0·08
Imperfectly drained (w1)	80	0·22
Poorly drained (w2)	160	0·44
Very poorly drained (w3)	260	0·71
Swampy (w4)	310	0·85
Inundation		
Period $\leqslant$ 50 days/yr (i1)	80	0·27
51–100 days/yr (i2)	130	0·41
101–150 days/yr (i3)	180	0·55
151–250 days/yr (i4)	280	0·82
$>$ 250 days/yr (i5)	365	1·00
River flooding		
Once in 6–10 yr (f1)	3	0·01
Once in 2–5 yr (f2)	8	0·02
Once every yr (f3)	15	0·04
More than once every yr (f4)	$>$ 30	0·08

(iii) *Stocking Rate Index* (SR).—The forest type with the highest estimated stocking rate is given an index of 100. Other types are given indexes proportionate to their estimated stocking rates.

(iv) *Estimated Stocking Rate*.—The derivation of this figure is explained in Part VIII. Stocking rates are classed as follows: very high, $>$12,000 super ft/ac; high, 9000–12,000 super ft/ac; moderate, 6000–9000 super ft/ac; low, 3000–6000 super ft/ac.

(v) *Forest Resource Index* (FI).—Calculated for each land system, it is the sum of the products of percentage area and stocking rate index for each forest type present. The forest resource index classes are: nil, 0–5; very low, 6–20; low, 21–40; moderate, 41–60; high, 61–80; very high, 81–100.

(vi) *Forest Productivity Index* (FP).—This is the product of the access index and the stocking rate index of the forest type, divided by 100. The forest productivity classes are: nil, 0–5; very low, 6–12; low, 13–28; moderate, 29–50; high, 51–80; very high, 81–100.

* This index is calculated for each land system from: $0 \times$ (% slopes $<10°$) + $0·33 \times$ (% slopes 10–17°) + $0·66 \times$ (% slopes 17–30°) + $1 \times$ (% slopes $>30°$).

(vii) *Access Categories*.—The land systems are first grouped into four categories (I–IV) on the basis of their slope index (I, 0–20; II, 21–40; III, 41–70; IV, >70), which gives an assessment of the proportion of accessible slope in one land system relative to another. Some of the more rugged land systems are placed in a better access category where very low or low relief may increase their accessibility.

Land systems with soil drainage and/or inundation deficiencies are subdivided on their drainage/inundation indexes (w, 22–30; W, 31–70; S, 71–100). Four more access categories (Iw, IIw, W, and S) are thus recognized, presenting increasingly difficult access.

Those land systems in access categories I and Iw that are subject to flooding once a year or more often over at least 20% of their area are placed in access categories IF and IFw respectively.

(viii) *Reject Percentage*.—In each forest type this is the percentage of total trees recorded that was rejected as being unsuitable for milling. To obtain the number of usable trees per acre, the trees/ac figure must be reduced by this percentage.

(ix) *Usage Group*.—These groups are identical with those used by the Department of Forests, Papua New Guinea, as at 1 March 1963, and may be defined briefly as follows:

Group 1.—Suitable for high-quality veneer timber.
Group 2A.—Conifers—Araucariaceae.
Group 2B.—Conifers—Podocarpaceae and Cupressaceae.
Group 3.—Suitable for high-quality cabinet timber.
Group 4A.—Construction timber, but can also be used for cabinet timber.
Group 4B.—Construction timber only.
Group 5.—Construction timber, not well known and generally requiring treatment.

(x) *Frequency of Occurrence*.—Frequency classes for species recorded are listed in Table 31.

TABLE 31

FREQUENCY CLASSES OF OCCURRENCE OF TREE SPECIES

Frequency class	Symbol	Frequency (%)
Predominant	P	>80
Dominant	D	50–80
Subdominant	S	20–50
Very common	V	15–20
Common	C	10–15
Occasional	O	5–10
Rare	R	<5

(*f*) *Agricultural Assessment*

(i) *Land Use Capability Indexes*.—The capability of land for arable crops, tree crops, improved pastures, and irrigated rice has been assessed using six levels of suitability ranging from very high to nil.

For each land system, four capability indexes (A for arable crops, T for tree crops, P for improved pastures, and R for irrigated rice) are calculated by adding weighted estimated proportions of land with a certain level of suitability as follows: $1 \times$ (% land with very high suitability) + $\frac{3}{4} \times$ (% land with high suitability) + $\frac{1}{2} \times$ (% land with moderate suitability) + $\frac{1}{6} \times$ (% land with low suitability) + $\frac{1}{12} \times$ (% land with very low suitability) + $0 \times$ (% land without suitability).

The overall land use capability index (CI) of a land system is calculated as the mean of the indexes for arable crops, tree crops, and improved pastures. The index for irrigated rice is excluded because of the very special conditions applying to this form of land use.

(ii) *Land Use Capability Class*.—Six classes of land use capability, applied to the four major kinds of agricultural land use, are based on the land use capability indexes (CI, A, T, P, R) as follows: nil, index 0–5; very low, index 6–12; low, index 13–28; moderate, index 29–50; high, index 51–80; very high, index 81–100.

(iii) *N, P, K Contents*.—See Subsection (*c*) (ix).

(*g*) *Engineering Assessment*

(i) *Soil Depth* (*Engineering*).—Engineering soil depth is measured or estimated to underlying hard rock. Hard rock is defined as being impenetrable by hand auger or spade, but excluding gravel or stones. It is *not* synonymous with fresh rock, and engineering soil depth is no more than a rough guide to the depth at which fresh rock may be found. The following depth classes have been used: very shallow, <2 ft; shallow, 2–4 ft; moderately deep, 5–9 ft; deep, 10–15 ft; very deep, >15 ft.

(ii) *Unified Soil Classification*.—The classes used are described by Wagner (1957). The placement of soils in these classes is partly based on sample tests carried out by the Department of Public Works, Port Moresby, partly on extrapolation of these data to untested soils by means of correlation with field soil textures and soil type.

III. References

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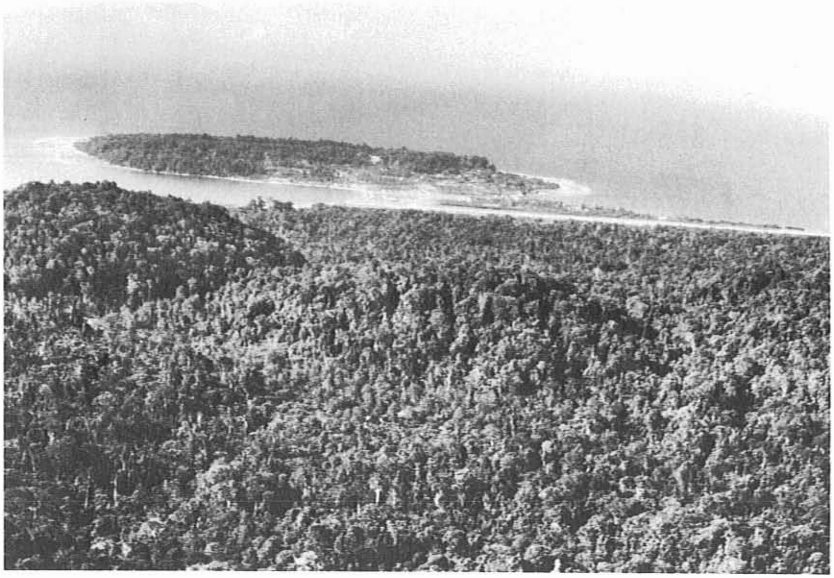


Fig. 1.—View from Oenake Mountains to Vanimo peninsula. Vanimo harbour (to the left) provides good anchorage for ocean-going vessels. The peninsula consists of uplifted coral limestone and is surrounded by a fringing reef. Hemispherical limestone hills in the foreground.

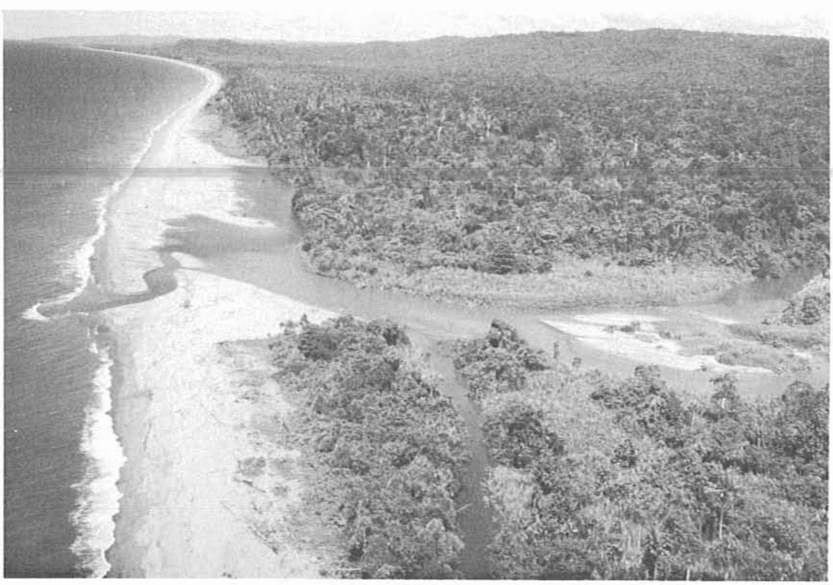


Fig. 2.—Beach ridges and swales in front of the coastal ranges. Beach ridges carry mainly secondary vegetation and inundated swales herbaceous vegetation. In the left background there is some sago palm vegetation.

Fig. 1.—Coral platforms in front of the Oenake Mountains. In the foreground, coral platforms rising gently from the fringing reef; in the background, uplifted coral platform forming flat terrace.

Fig. 2.—Extensive areas of tall forest cover most of the alluvial plains of the area. The forest resources are high.

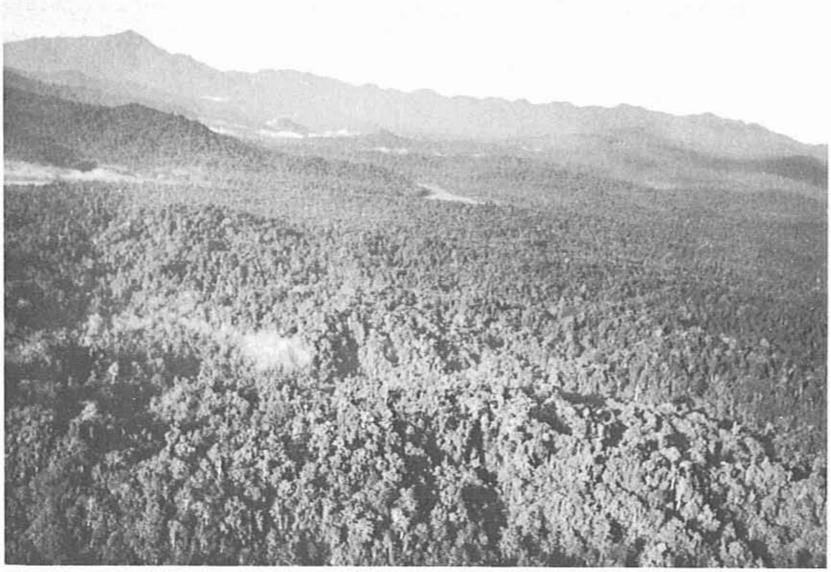


Fig. 1.—Low ridges of marl and mudstone form the eastern part of the intermontane lowlands. The Bewani Mountains (background) rise sharply from these lowlands. The vegetation is tall forest of high forest resources.

Fig. 2.—Flat fan surface with swampy depressions in the western part of the intermontane lowlands. In the foreground, swampy depression with sago palm vegetation; in the middle and background, tall forest with open canopies. Forest resources are very high.

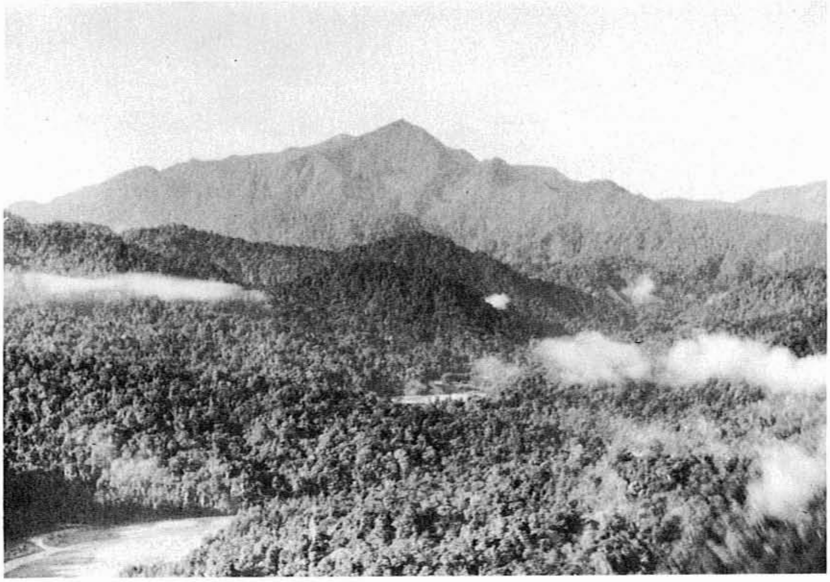
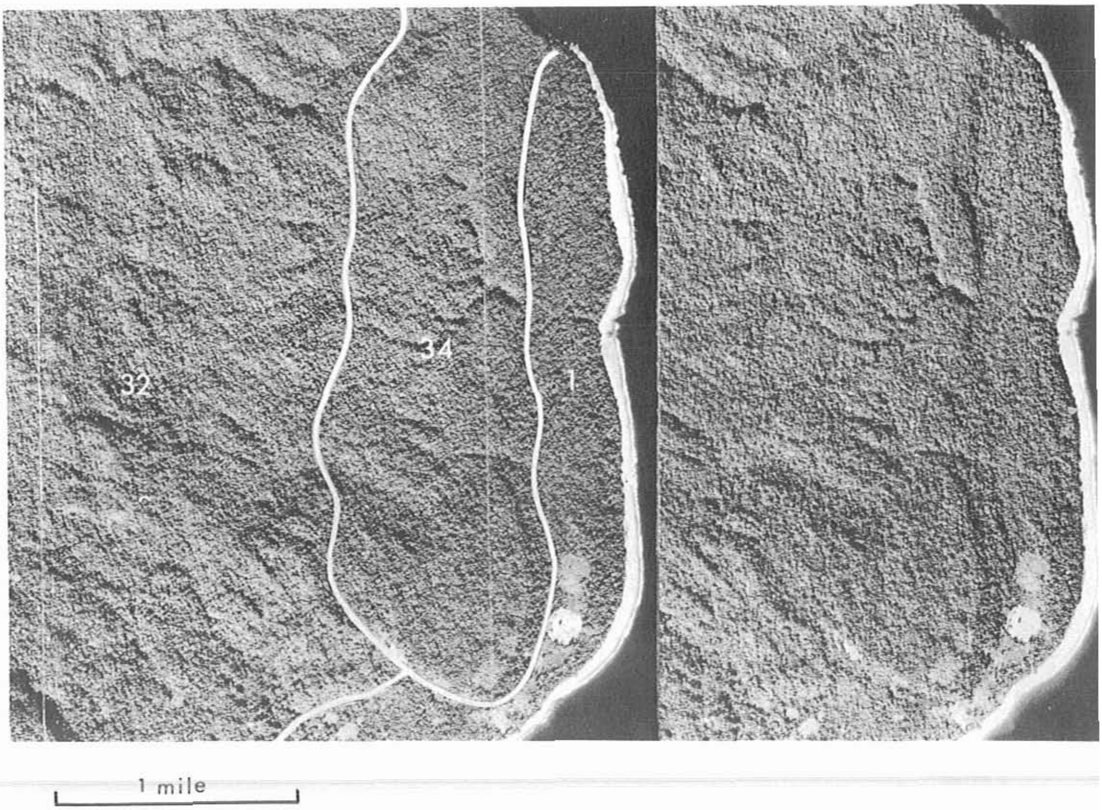


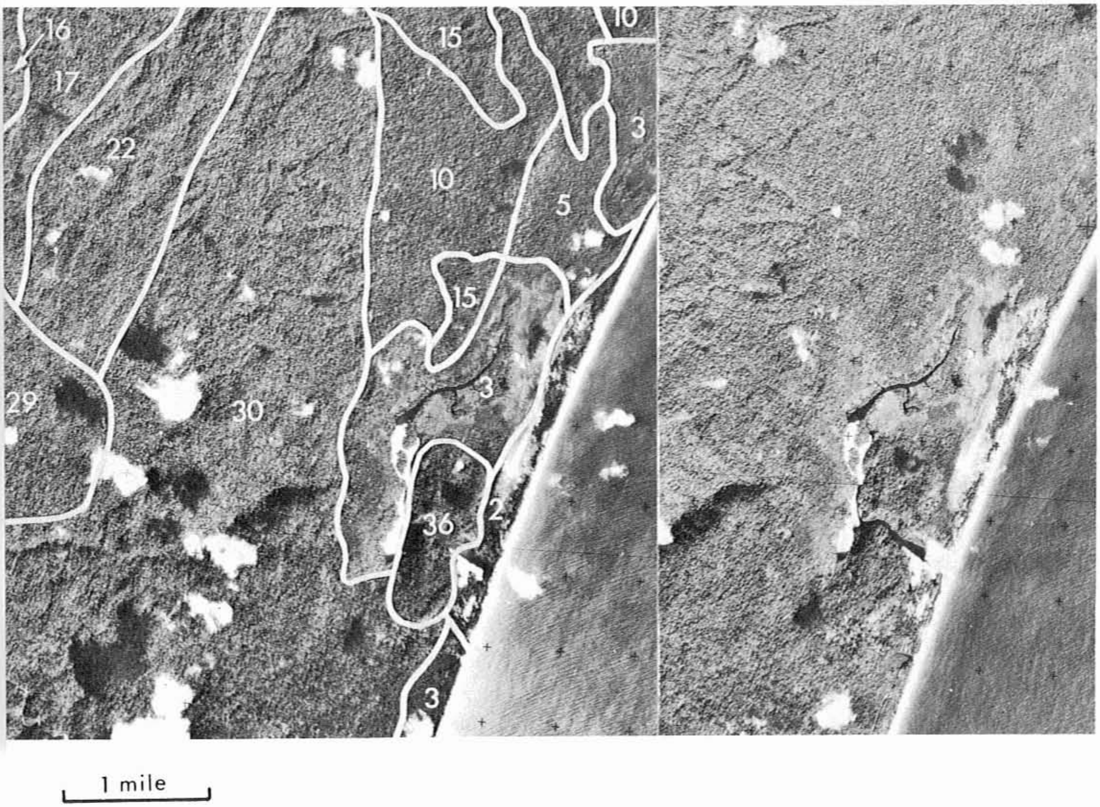
Fig. 1.—Central and highest part of the Bewani Mountains formed of massive mountain ridges on basement rocks. Vegetation is mid-height forest of low forest resources.

Fig. 2.—Small village perched on narrow ridge crest. The village is surrounded by coconut palms and gardens.



Madang (1) land system: raised coral platform with tall forest with a rather open canopy (Fo), gardens, and secondary vegetation. At the sea side, coral reef rising slightly above high tide.

Musu (34) land system: uplifted and dissected remnants of coral reef platforms with tall forest with a rather open irregular canopy with scattered lighter-toned crowns (Foid), denser in the western part (Fid).

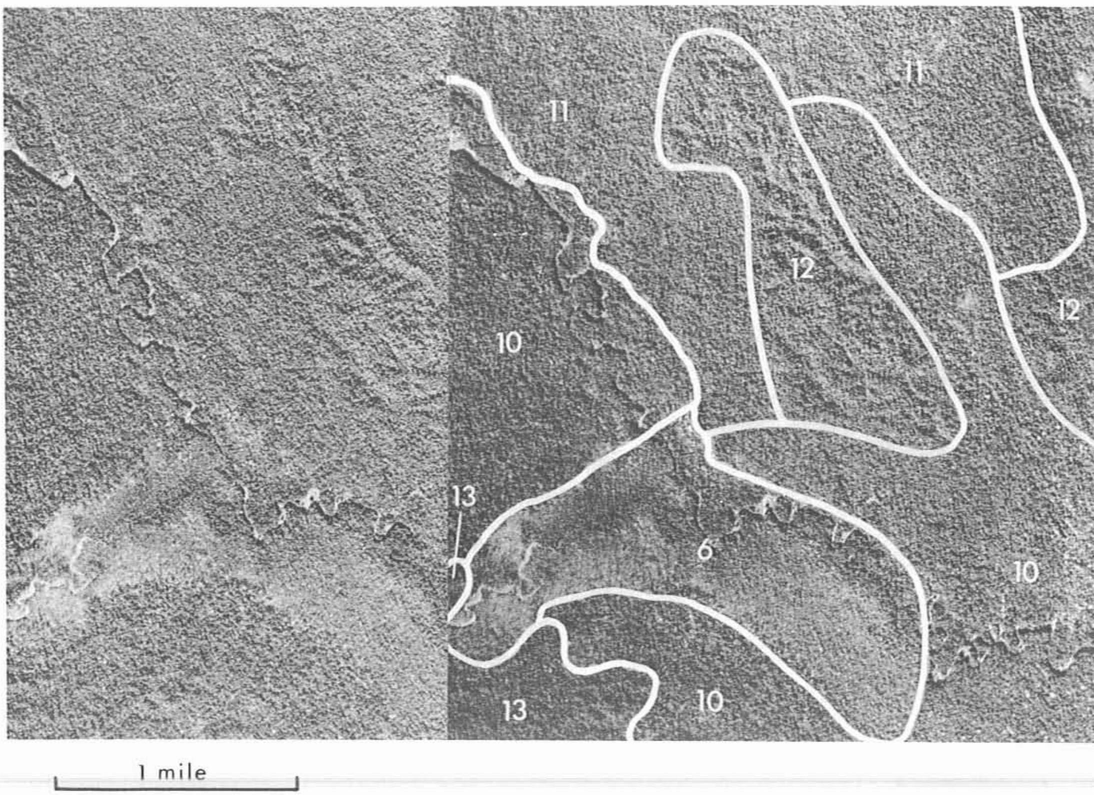


Nubia (2) land system: sequence of low very gently undulating beach ridges and swales with gardens and coconut groves.

Leitre (3) land system: permanent coastal back swamps with aquatic herbaceous vegetation (H) and mixtures of *Nypa* and sago palms (N/M) in permanently inundated situations and sedge vegetation with scattered pandanus (V) in periodically flooded areas.

Pandago (5) land system: flood-plain swamps with mid-height forest with an open canopy with sago palms in the understorey (FmoM). The small flood-plain mapped as Pual (10) is covered with tall forest with a rather open small-crowned canopy (Fos).

Limio (30) land system: high steeply dissected limestone plateau with tall forest with a rather open irregular canopy with scattered lighter-toned crowns (Foid).

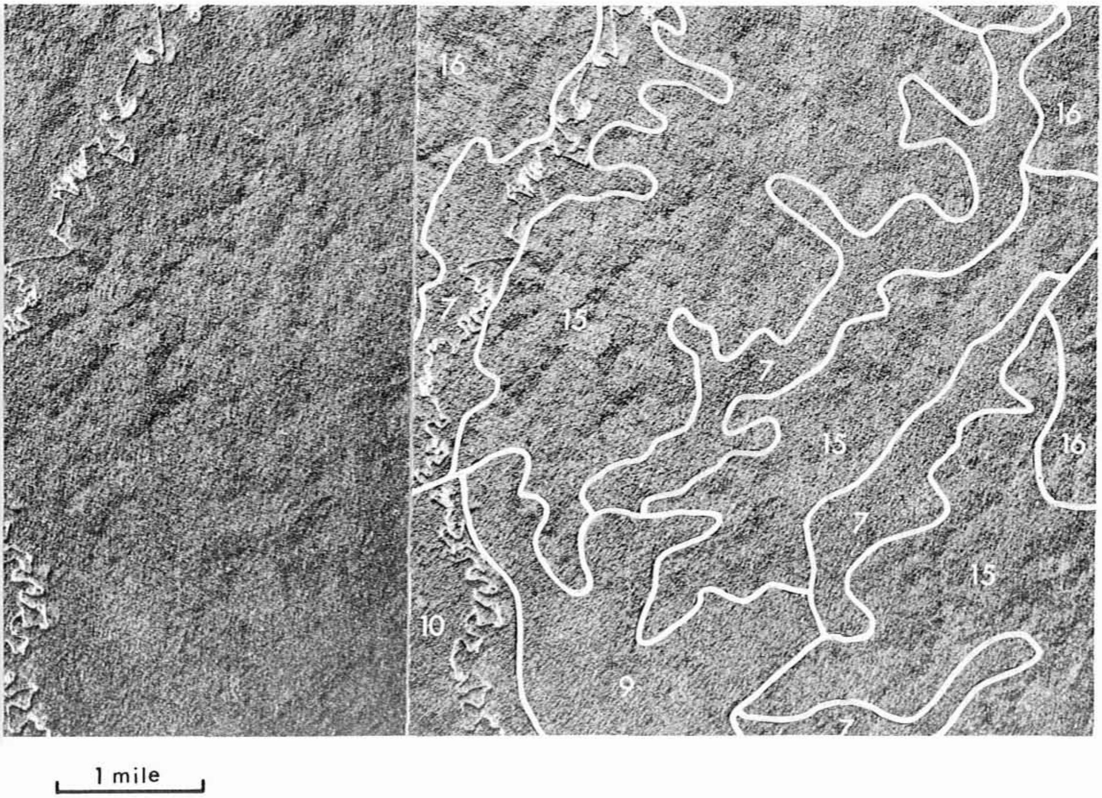


Nigia (6) land system: unstable flood-out plains near Bewani Mountains front. The original forest vegetation has been largely destroyed by flooding and is being replaced by sago palm vegetation.

Pual (10) land system: extensive alluvial plains with tall forest with an open canopy with scattered light-toned crowns (Fod).

Pagei (11) land system: flat to very gently sloping alluvial fans with tall forest with an open canopy with scattered light-toned crowns and a dense understorey (FodD).

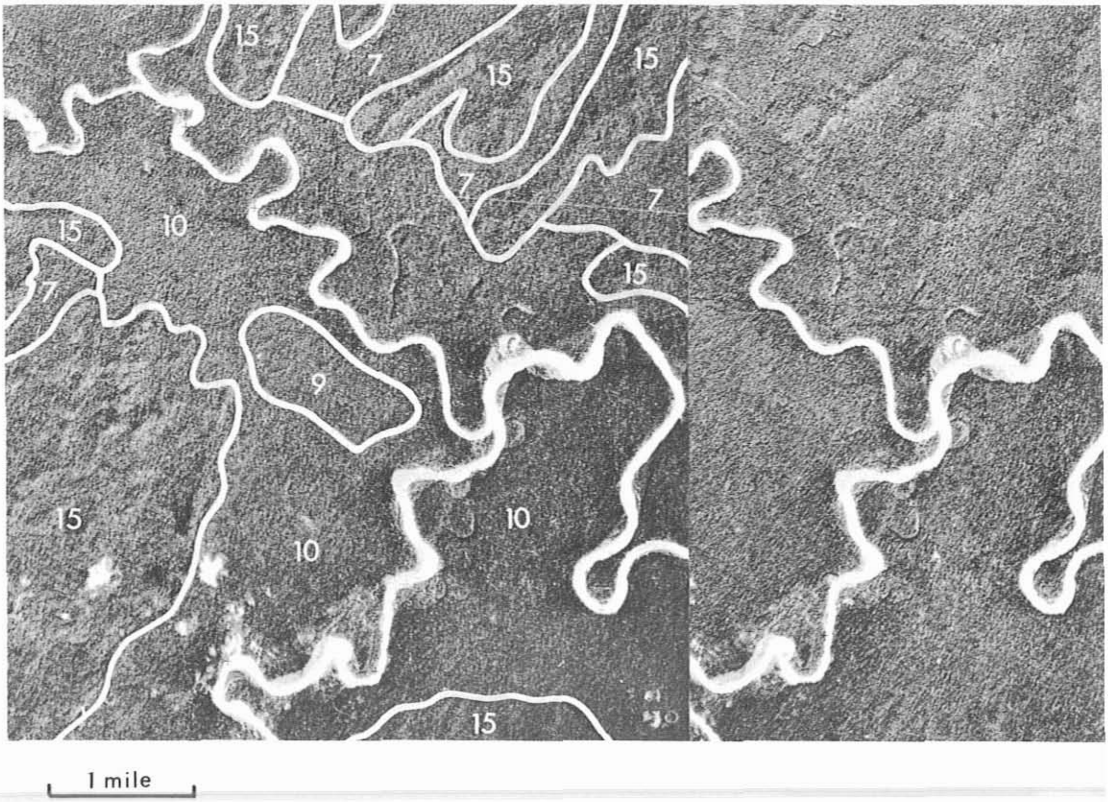
Luap (12) land system: slightly dissected fans with tall forest with an open canopy with scattered light-toned crowns and a dense understorey (FodD).



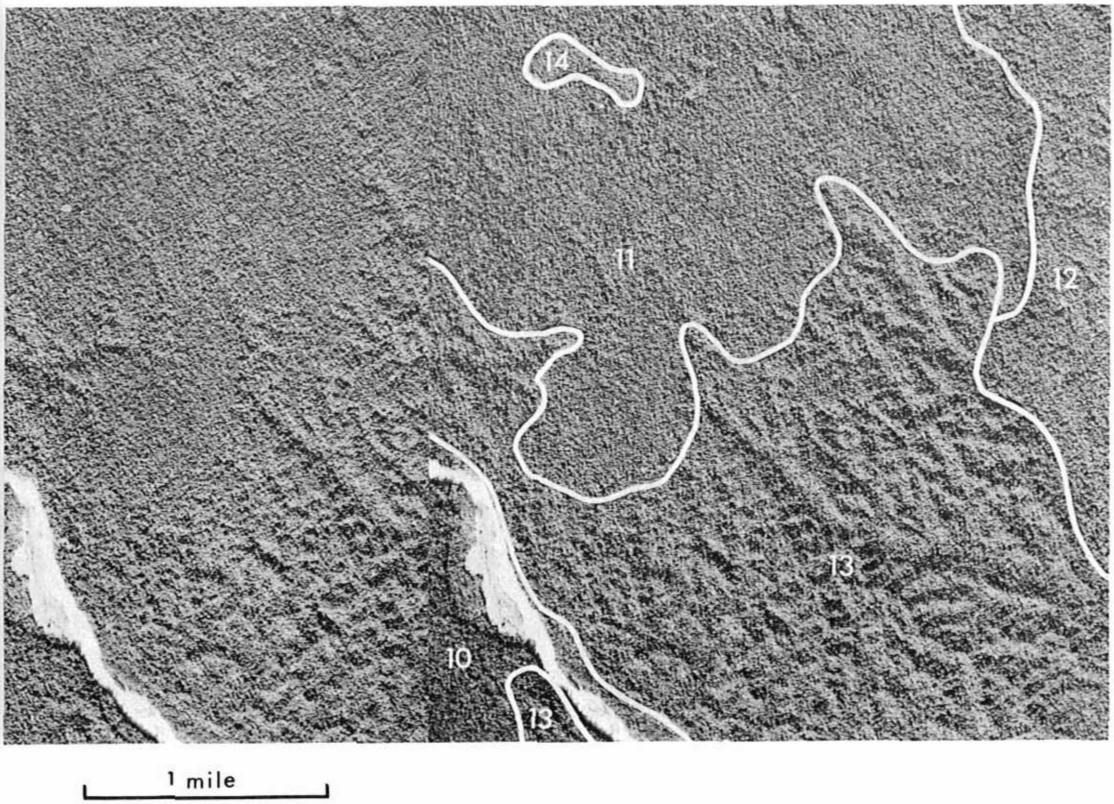
Basu (7) land system: valley floors along smaller and medium-sized streams with discontinuous terraces covered with tall forest with an open small-crowned canopy with scattered light-toned crowns (Fosd).

Po (9) land system: poorly drained alluvial plains with tall forest with an open canopy with scattered light-toned crowns and with sago palms in the understorey (FodM).

Isi (15) land system: very low hills and ridges on marl with tall forest with a rather open irregular canopy with scattered lighter-toned crowns (Foid).



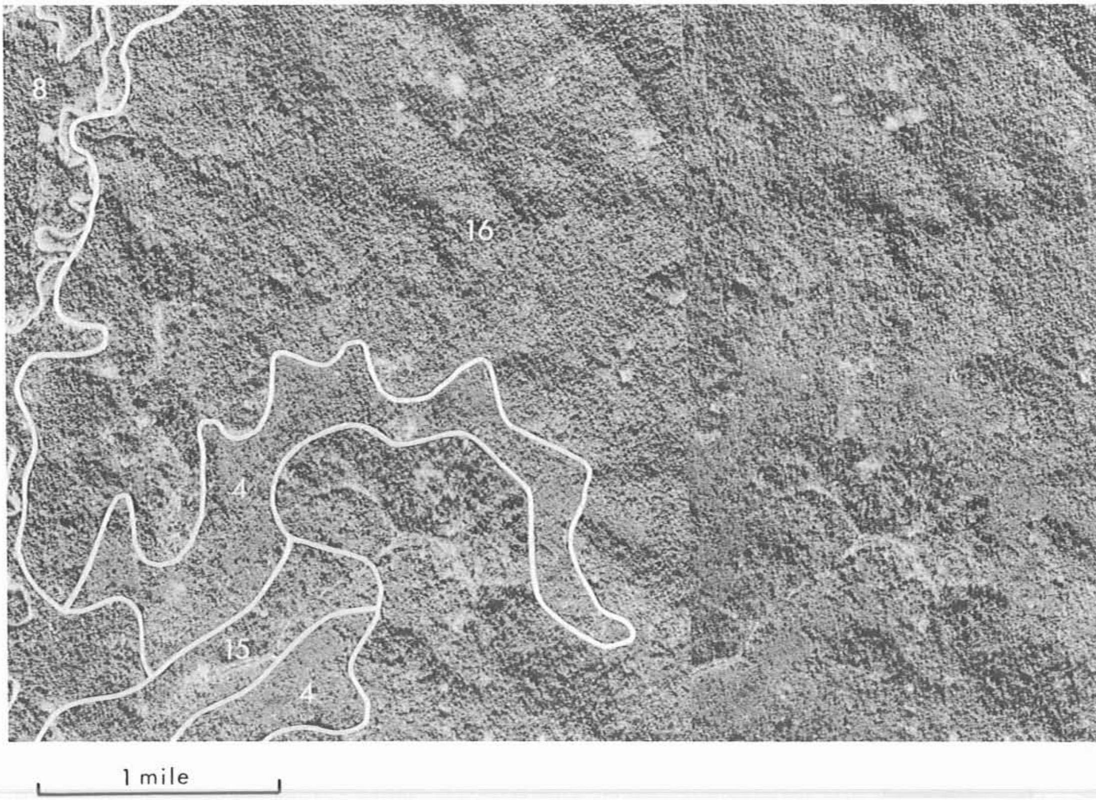
Pual (10) land system: extensive alluvial plains along the major rivers with up to three terraces. Along the meandering river there are scroll complexes and cut-off meander tracts. Cane grass vegetation (Gt) covers bars and banks and develops into mid-height forest with a rather open canopy (Fmo) on the lowest terraces. The plain is covered with tall forest with a rather open canopy with scattered light-toned crowns (Fod).



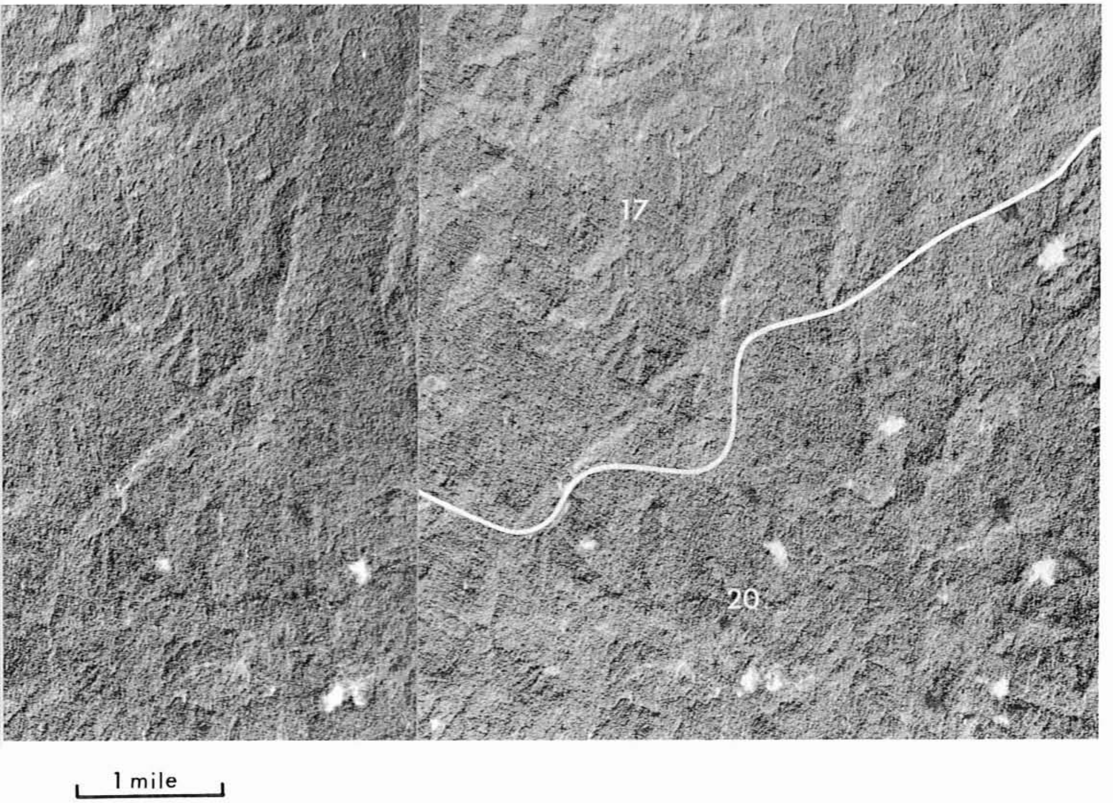
Pagei (11) land system: flat to very gently sloping alluvial fans with tall forest with an open canopy with scattered light-toned crowns and a dense understorey (FodD).

Punwep (13) land system: strongly dissected fan remnants with tall forest with a rather open irregular canopy with scattered lighter-toned crowns (Foid).

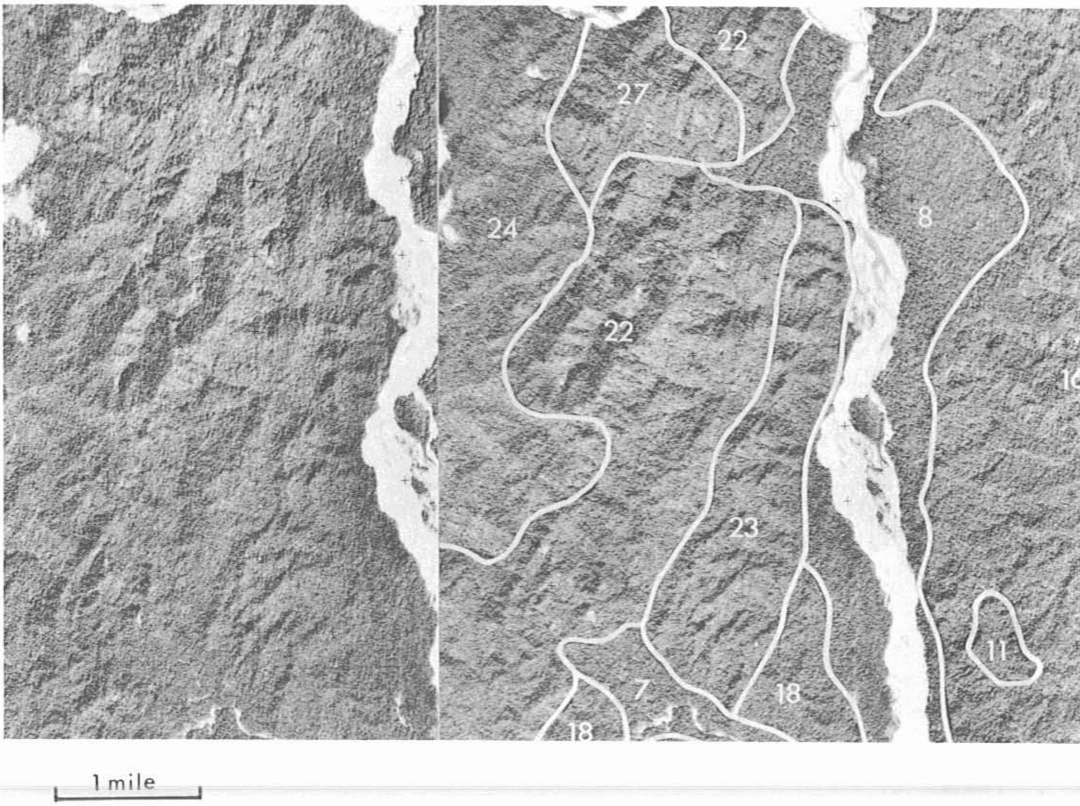
Nabes (14) land system: permanent swamps in closed depressions on fan surface with sago palm vegetation with emergent trees (Me). On the terraces of the Puwani River in Pual (10) *Casuarina cunninghamiana–Eucalyptus deglupta* forest (CE) occurs.



Kabuk (4) land system: flood-plain swamps in floors of blocked valleys with sago palm vegetation (M).
Fivuma (16) land system: long subparallel to dendritic ridges with short spurs on marl and mudstone. The original vegetation is tall forest with a rather open irregular canopy with scattered lighter-toned crowns (Foid) but this has been replaced by secondary vegetation in areas around the swamps.



Muru (17) land system: asymmetric (homoclinal) ridges with dip slopes formed of marl and mudstone, and outcrop slopes formed of sandstone. Vegetation is tall forest with irregular canopy with scattered light-toned crowns (Fid). Puari (20) land system: irregular pattern of ridges with short spurs on marl and mudstone. Slumping is common. The vegetation is tall forest with a rather open irregular canopy with scattered lighter-toned crowns (Foid), which on the high ridge crest are *Albizia* (FoiA).



Papul (8) land system: flood-plains and river terraces along larger streams in areas of higher relief. The vegetation is cane grass (Gt) and mid-height forest with a rather open canopy (Fmo) on the terraces and tall forest with a rather open canopy (Fo) on the flood-plain.

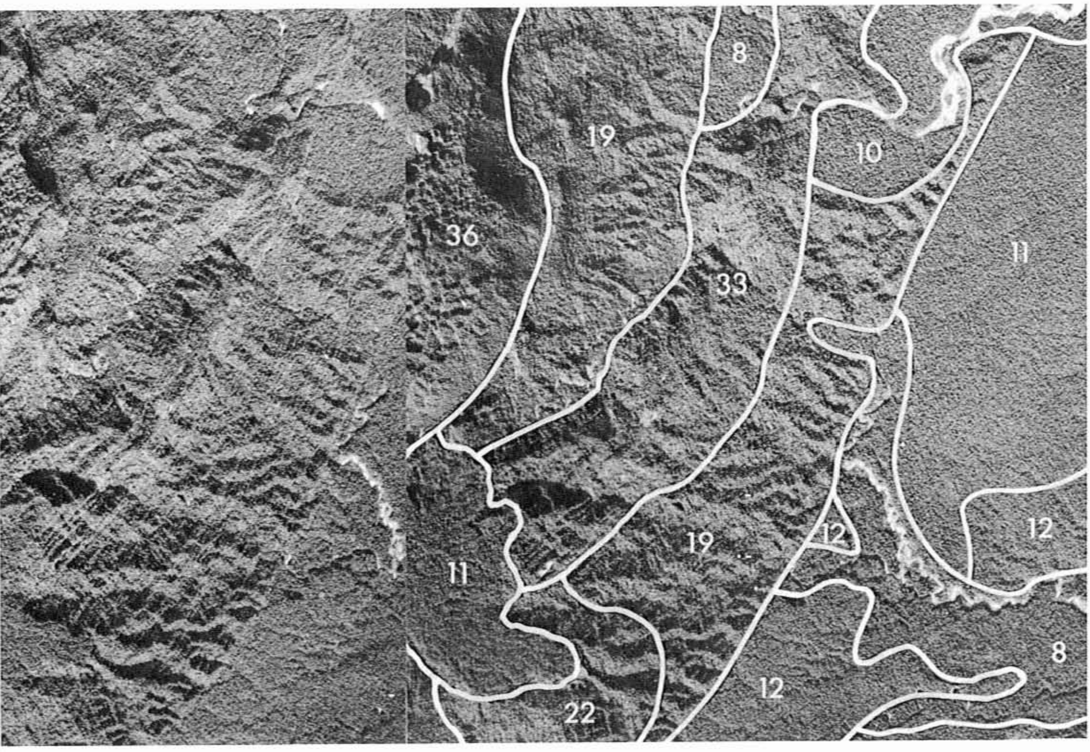
Yassip (18) land system: very low ridges on interbedded siltstone, mudstone, and sandstone covered with tall forest with a rather open irregular canopy with scattered lighter-toned crowns (Foid).

Numoiken (22) land system: short very irregular steep hills and ridges on interbedded siltstone and sandstone. Slumping is common. The vegetation belongs to the same type as in Yassip (18), except in the south-east corner where it is mid-height forest with a rather open irregular canopy (Fmoi).

Musak (23) land system: asymmetrical hills and ridges on interbedded siltstone, sandstone, and conglomerate with steep dips. The forest is of the Foid type.

Flobum (24) land system: low mountain ridges with moderately steep slopes on siltstone, mudstone, and sandstone. Slumping is very common. The vegetation is mid-height forest with an even canopy (Fmv) which extends to adjacent parts of Numoiken (22).

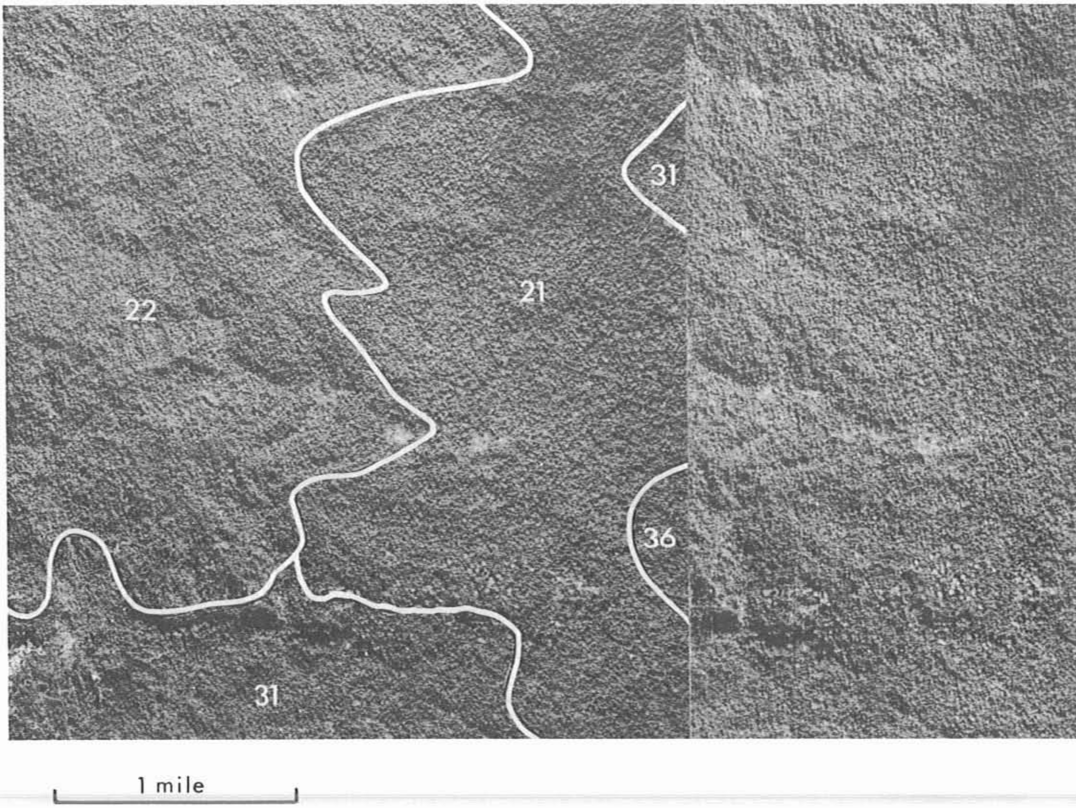
Sulen (27) land system: slumped and gullied mountain ridges with very steep slopes on mudstone and siltstone with tall forest (Foid).



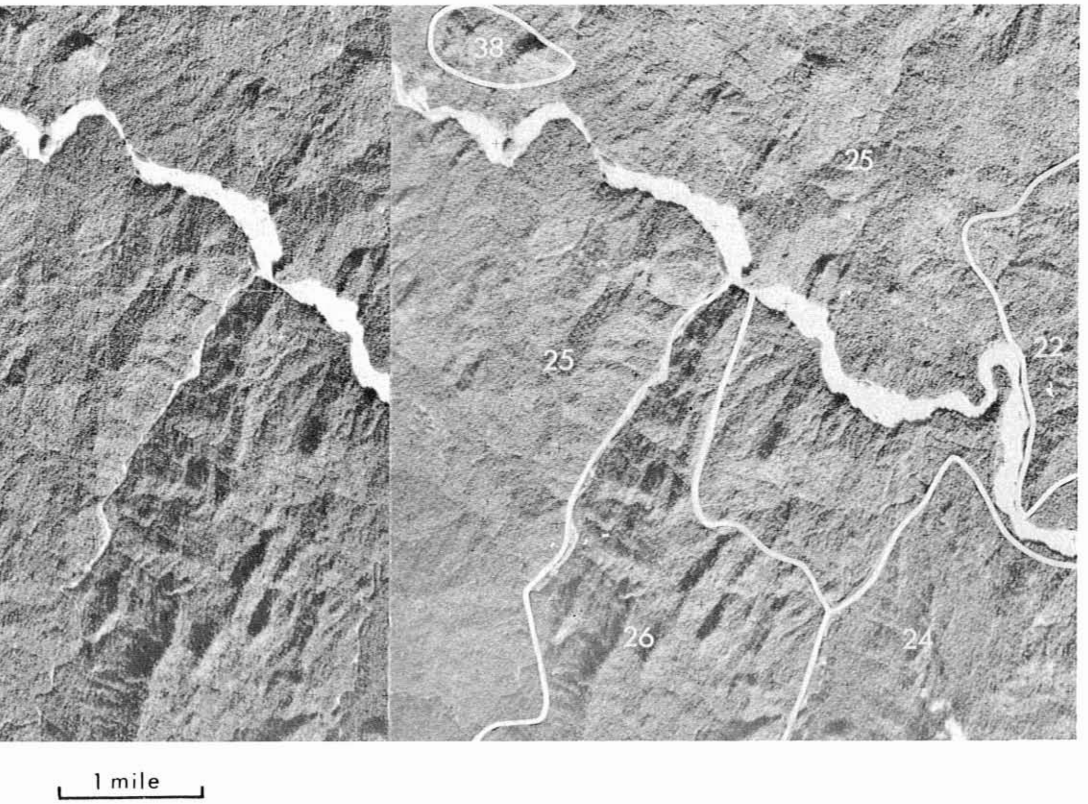
Morumu (19) land system: dendritic to subparallel short ridges probably representing remnants of former fans. The vegetation is tall forest with a rather open irregular canopy with scattered lighter-toned crowns (Foid) or, on the southern occurrence, mid-height forest with a rather open irregular canopy (Fmoi) which also covers Barida (33).

Barida (33) land system: high ridges with broad crests and very steep straight side slopes on sandstone.

Serra (36) land system: high limestone ridge with prominent karst features. The vegetation is mid-height forest with a very dense canopy of irregular height (Fmci).



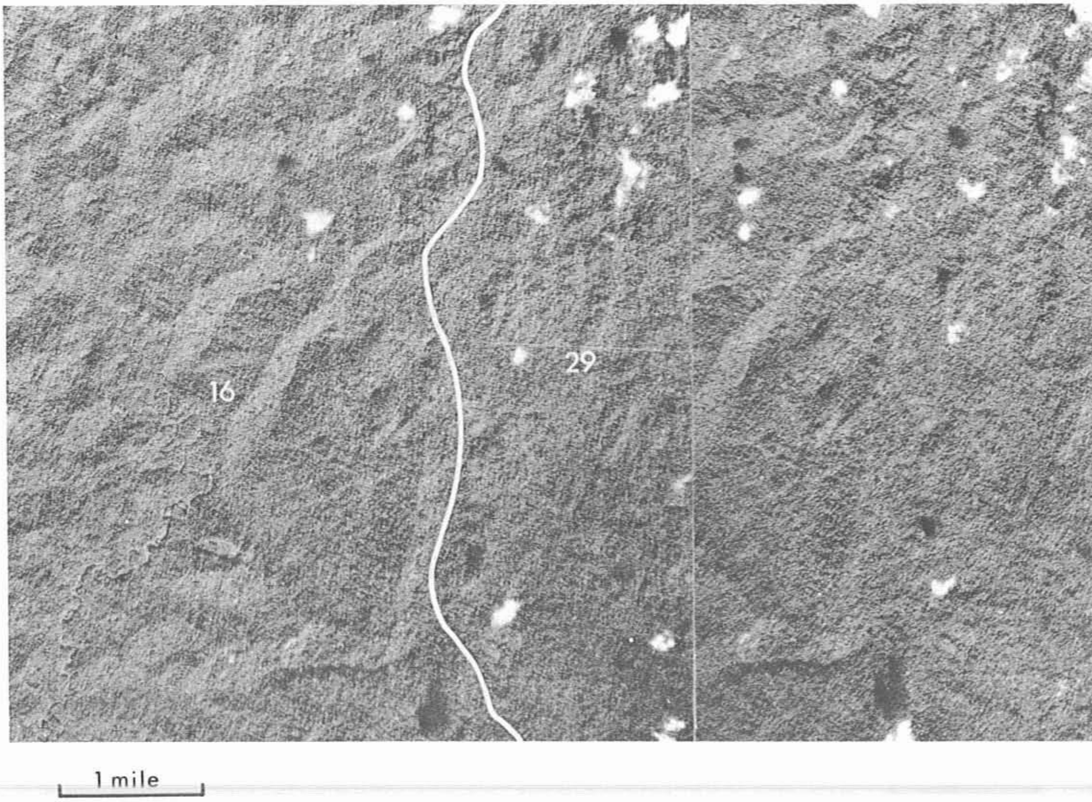
Puive (21) land system: broad ridges witn moderate side slopes. Slumps are common. The tall forest has a rather open irregular canopy with scattered lighter-toned crowns (Foid), the largest of which are *Albizia* (FoiA).



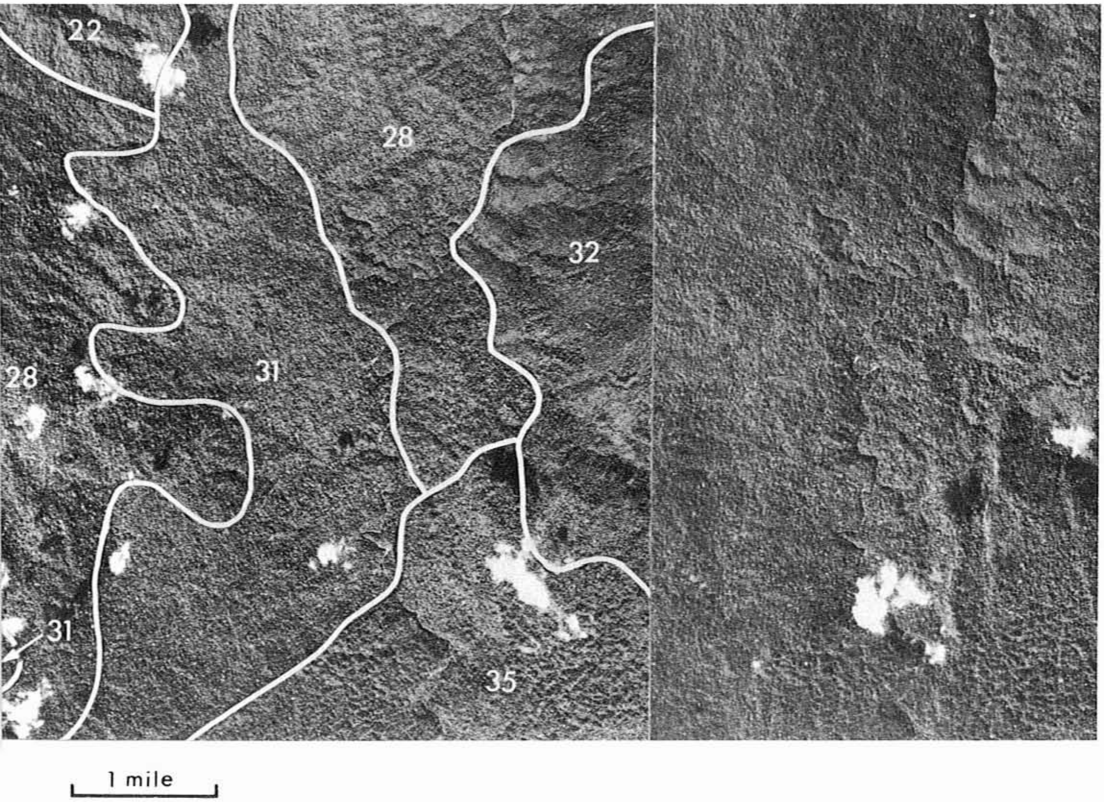
Piore (25) land system: coarse-grained dendritic ridges with broad rounded crests on consolidated siltstone, sandstone, and mudstone. Mid-height forest with an even canopy (Fmv) and mid-height forest with a rather open irregular canopy (Fmoi) cover most of the area.

Wuro (26) land system: hog back mountain ridges with steep dip slopes and very steep outcrop slopes. The vegetation is mid-height forest with an irregular canopy (Fmi).

Mup (38) land system: isolated hills and ridges on basement rocks rising above the surrounding sedimentary areas and covered with mid-height forest with a rather open irregular canopy (Fmoi).



Punan (29) land system: irregular pattern of low broad ridges and hills formed on impure limestone with frequent intercalations of sandstone, siltstone, and mudstone. The vegetation is tall forest with a rather open irregular canopy with scattered lighter-toned crowns (Foid) which also covers the adjacent area.



Jassi (31) land system: plateau-like areas with irregular low hilly or ridgy surface on limestone intercalated with mudstone, siltstone, sandstone, and volcanics. The tall forest has a rather open irregular canopy with scattered lighter-toned crowns (Foid), but is denser and smaller-crowned (Fisd) in the western part of the area.

Oenake (32) land system: coarse- to very coarse-grained pattern of ridges with very irregular slopes. Limestone dominant but intercalations of marl, mudstone, and siltstone are frequent. The vegetation is mid-height forest with an irregular small-crowned canopy (Fmis). The very tall light-toned emergents are *Araucaria*.

Kohari (35) land system: very fine-grained pattern of low and very low mostly conical-shaped karst hills enclosing sink holes formed on reef limestone. Tall forest with an irregular small-crowned canopy with scattered light-toned crowns (Fisd) covers most of this land system as well as the next one, Ijapo (28).

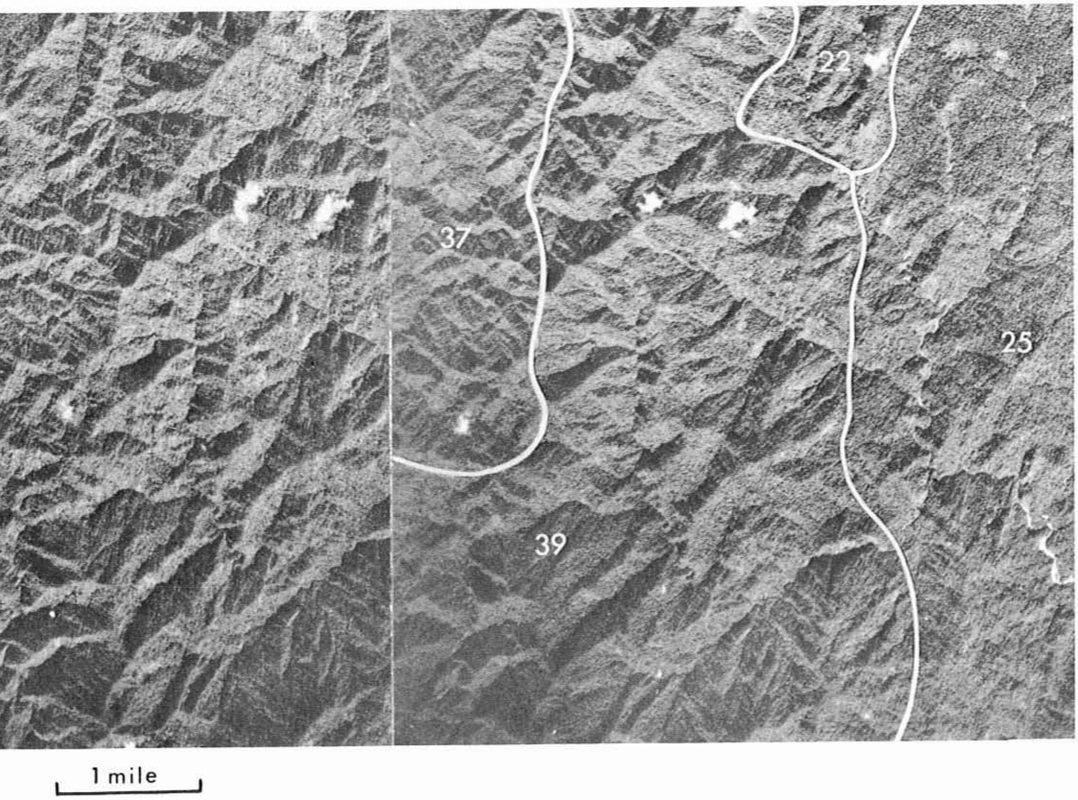
Ijapo (28) land system: fine-grained pattern of low ridges limestone, volcanics, and mudstone. Slumping is common.

Serra (36) land system: high limestone plateau with prominent karst features. The vegetation consists of tall forests with rather open canopies, even (Fov) in the lowest, northern part, irregular (Foid) on the remainder.

Nubia (2) land system: sandy beach ridges and swales with gardens and secondary vegetation, including grasslands with scattered trees (V). Sago vegetation with emergent trees (Me) occurs in the western back swamp; east of the tidal creek a mid-height forest occurs with pandans and sago palms (FmPM) and in the extreme north-eastern corner a pure stand of *Casuarina equisetifolia* (Cq).

Leitre (3) land system: permanent coastal back swamp with herbaceous vegetation (H) and a mixture of *Nypa* and sago palms (N/M).

Pual (10) land system: extensive alluvial plain along the Bliri River covered with tall forest with a rather open canopy (Fo) and, in the north-eastern corner, with scattered light-toned crowns (Fod). Tall forest with an open canopy with sago palms in the understorey (FoM) indicates an ill-drained part, mapped out as Po (9).



Kum (37) land system: sharply and densely spurred ridges with very steep straight slopes formed on gabbro and diorite. The vegetation is mid-height forest with a rather open irregular canopy (Fmoi).

Somoro (39) land system: massive mountain ridges with very steep and straight slopes on granodiorite, gabbro, and diorite. The vegetation is mainly mid-height forest with an irregular canopy (Fmi) with seral stages (Fmi′) on steepest slopes. In the east, the highest crests are covered with mid-height forest with a rather dark-toned even canopy (Fm), and on the slopes stands of *Casuarina papuana* (Ca) are found.