Lands of the Aitape–Ambunti Area, Papua New Guinea

Comprising papers by H. A. Haantjens, P. C. Heyligers, J. R. McAlpine, J. C. Saunders, and R. H. Fagan

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Land Research Series No. 30

View complete series online

Commonwealth Scientific and Industrial Research Organization, Australia
1972

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Forest Resources and Land Use Intensity; Terrain Access Categories; Associations of Great Soil Groups

PART I. INTRODUCTION

By H. A. HAANTJENS* and J. R. MCALPINE*

I. THE SURVEY AREA

(a) Size and Location

The Aitape–Ambunti area covers approximately 4650 sq miles. As shown in Figure 1, it is situated in the north-west of Papua New Guinea between long. 142°

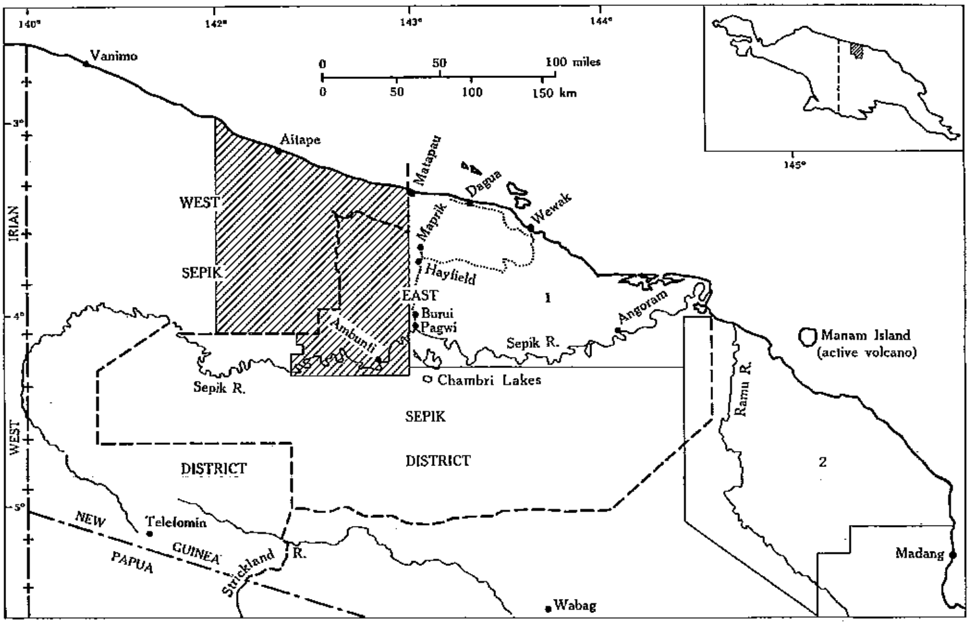

Fig. 1.—Location of the Aitape–Ambunti area (shaded) and of previously surveyed areas along the coast: 1, Wewak–Lower Sepik area; 2, Lower Ramu–Atitau area.

and 143°E. and stretches from the Bismarck Sea (3°S.) to just beyond the Sepik River (4° 20′ S.). In the east it borders on the Wewak–Lower Sepik area, previously surveyed by the Division of Land Research in 1959 (Haantjens *et al.* 1968).

(b) Principal Terrain Features

The area has a generally low relief although much of the terrain is very rough with close dissection and steep irregular slopes. Many different types of tropical rain forest and swamp forest cover most of the area and further restrict access.

The narrow, but very rugged Torricelli and Prince Alexander Mountains form a barrier between a smaller coastal region and larger inland areas. The mountains

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consist essentially of an east–west chain of up-thrust blocks of basic igneous rocks reaching maximum heights between 3500 and 6000 ft and separated by passes and ridges of lower elevation (see map of land altitude).

Northwards the mountains fall away steeply to complexes of weathered alluvial fans and of ridges on sedimentary rock. These are most extensive in the west, where they terminate in a secondary low mountain chain with much limestone. This "foothill" zone in turn gives way to a belt of alluvial plains and swamps, widest in the west and phasing out in the east and separated from the ocean by a narrow strip of very low beach ridges and mangrove flats.

Southwards the mountains merge gradually into a wide zone of hill ridges on relatively soft mudstone, siltstone, and sandstone. Relief and land forms vary widely in this zone which descends slowly and evenly to about 250 ft above sea level in the south and is broken only by two sets of pronounced north-facing scarps (see map of drainage divisions). Three-quarters of the area's population lives in these hills. As a result the rain forest has been extensively cleared and replaced by secondary vegetation.

The hill lands merge imperceptibly in the east, more abruptly in the west, into a rather wide belt of inland plains consisting of variably dissected weathered surfaces separated by and merging southwards into young alluvial plains and swamps. The weathered surfaces are characterized by large complexes of man-induced grassland, and contain (together with the weathered fans in the north) by far the largest areas of strongly weathered leached acid soils in the area. Almost everywhere else, both on plains and on hill slopes, undeveloped to little-weathered soils predominate, mostly weakly acid to weakly alkaline in reaction.

In the south these inland plains merge, again with scarcely perceptible transitions in the environment, into the wide flood-plain of the Sepik River. This second largest river in Papua New Guinea meanders within a belt of complex scroll ridges and swales. This belt is bordered on both sides by extensive back-plain swamps, mostly with herbaceous to low woody swamp vegetation but in places (particularly on peat soils) with swamp forest. Near Ambunti the river is confined between complexes of very rough hills and mountains, which rise abruptly from the swamps and consist of ancient metamorphic rocks.

(*c*) *Drainage*

The major rivers draining the area are shown on the toponymy map, whilst their catchments are outlined on the map of drainage divisions. The main watershed, separating short northern rivers from long southern ones, corresponds closely with the line connecting points of highest elevation, except in the extreme east and west, where the pattern is complicated by gaps and divisions in the mountain chain.

Whilst the scarp barriers in the hill zone hardly seem to affect the catchments of most southern rivers originating in the Torricelli Mountains, they do give rise to a number of "subsidiary" catchments for which these barriers act as watersheds. Together with some apparent major NW.–SE. structural trends, the scarps also seem to control the diversion of the drainage of the central part of the hill zone into the Screw River system in the east.

The lower reaches of most northern rivers have wide braided beds, as a result of the sudden sharp decrease in gradient when they emerge from the mountains.

Many small and a few larger streams are unable to maintain proper channels to the sea through plains with disorganized drainage which absorb much of their flow. This feature is more prominent in the south, where only the largest river, the Screw, maintains a proper channel to the Sepik River. This latter river has a very low gradient. It flows in a plain at 170–180 ft above sea level at an aerial distance of some 150 miles from its mouth. Although accompanied by many cut-off meanders its bed is relatively stable, since very few changes could be identified in comparing its present-day course with that charted by Behrmann (1917) in the beginning of this century.

(*d*) *Earthquakes*

The northern half of the area, particularly, lies in a major earthquake zone. Although passing reference is made to this elsewhere in the report, it has not been possible to incorporate earthquake hazards systematically in the evaluation of the area for agricultural and engineering purposes. The following account shows that such hazards are real and should be borne in mind whenever major development projects are being contemplated.

From 10 to 20 shocks of magnitude 6 or greater and more than one tremor of magnitude 7·5 or greater at the Richter scale can be expected per square degree per century in north New Guinea (Brooks 1965). Four major shocks have occurred in the survey area in the first half of this century, all with foci less than 45 miles (70 km) deep.

The effects of the 1935 earthquake of magnitude 7·9 have been described in detail by eye witnesses (Stanley *et al.* 1935). Rapid mass movement in the form of debris avalanches affecting the soil mantle and vegetation was the principal denudational effect. Near the epicentre, north of Lumi, up to 60% of the forest and subsoil was stripped from very steep slopes. Valleys were quickly choked with rock waste and forest debris. Mud and debris flows up to 100 ft thick surged down the mountain valleys, some continuing to flow for several months. Other valleys were dammed up by huge log jams. Their later destruction led to catastrophic flooding and deposition, particularly on the coastal plains (see also Nubia (2) land system). In other effects, hill ridges on sedimentary rock have been observed to be broken by fissuring and faulting, or to collapse into a series of irregular steps.

Shortly after a major earthquake in 1907, the epicentre of which was probably off shore, a large semicircular area of the coastal plain sank between 6 and 12 ft to form what is now known as Sissano lagoon.

(*e*) *History*

Virtually nothing is known of the prehistory of the Melanesian inhabitants. They are presumed to have entered the area from the west, whilst those people living on the eastern inland foothills may have arrived more recently from the Sepik River. The coastal area may have been subject to Malay influence in the era before European contact (Stanley 1934).

European contact commenced in the 1880s with the establishment of the German administration of Kaiser-Wilhelms-Land. It was largely restricted to the relatively accessible coastal and Sepik River regions. The Germans founded the first permanent European settlement at Aitape on the coast and at the outbreak of World War I were engaged in the first major scientific expedition of the inland Sepik basin (Behrmann 1917).

At the end of the war Kaiser-Wilhelms-Land became a mandated territory of the League of Nations, under the control of Australia. The pattern of direct administration begun by Germany was maintained, and was effected by patrolling into uncontacted areas and consolidating influence in previously contacted areas. Concurrently with this, and following a general pattern in New Guinea, missionaries and gold prospectors also entered the area.

Government stations were established at Ambunti in 1924 and at Maprik in 1937, where gold was discovered. The inland foothill country was contacted in 1926 but, while some labour was recruited from this area for work on coastal plantations during the 1930s (Marshall 1937), the consolidation of administrative influence (i.e. the establishment of Pax Britannica) did not occur in these populous areas until after World War II. During the war the area was occupied by Japan. Intermittent heavy fighting and bombing occurred in some parts, whilst others were patrolled by both Japanese and Allied forces.

(*f*) *Administration*

Australian administration was re-established immediately after World War II, in what is now a part of a trust territory of the United Nations. By the mid 1950s the whole area was under full Administration control.

At first the area formed a part of the Sepik District but in 1966 it was split up between the East and West Sepik Districts, with headquarters at Wewak and Vanimo respectively (Fig. 1). The area is further administered from subdistrict headquarters at Aitape and Lumi in the West Sepik District and at Maprik (just east of the area) and Ambunti in the East Sepik District. New patrol posts were established at Dreikikir, Nuku, and Sissano. The present centres of administration and the boundaries of the subdistricts and their component census divisions are shown on the map of administration.

In recent years the former direct rule has been gradually replaced by indirect administration through the establishment of elected local government councils. This political development has coincided with increased indigenous cash-cropping and employment. Post-war increases in governmental efforts have been closely paralleled by the founding of many more mission stations.

(*g*) *Transport*

(i) *Early Development*.—At the time of initial contact the area possessed a network of foot tracks which, while densest in the more populous areas, extended through unpopulated areas as well. Many of these represented the major pre-contact trade routes, for example, the tracks across the mountains linking the interior with the coast. Under European government influence, many of these tracks were improved and maintained by local villagers, to serve as the major lines of communication.

In the Sepik River area movement was and still is largely by canoe, the main river being linked with nearby villages by a series of natural waterways and cleared passages (see transport map). The coastal people also use canoes along the lagoons and tidal channels behind the coastal beach ridges,* and in pre-contact times traded far outside the area in large sea-going outriggers.

* Some of these channels were made suitable for larger craft in German times.

During the German and Australian administrations irregular small-ship services were established, linking Aitape on the coast and Ambunti on the Sepik with external ports. Some idea of the navigability of the Sepik River may be gained from the fact that in 1914 two Australian 700-ton torpedo-boat destroyers penetrated the river to the vicinity of Ambunti. A recent journey of Australian Navy patrol boats beyond Ambunti revealed that the channel depth in February 1969 varied from nearly 20 ft to 130 ft, and that submerged trees and floating grass floes are a greater hazard to navigation than shoals.

(ii) *Modern Development.*—Effective transport linkages to the interior foothills were not established until the construction of landing grounds for light aircraft during the early post-World War II period. The locations of the 34 airstrips present in 1964 are shown on the transport map. Most of them belong to the missions and a few more have been constructed since 1964. Larger Administration airstrips are located at Aitape, Tadji,* Lumi, Nuku, and Ambunti, as well as at Maprik and Hayfield* just to the east of the area.

The development of vehicular roads initially followed the construction of Administration airstrips and served to provide access to these from the local hinterland. In this way four separate road nets arose, based on Aitape, Lumi, Nuku, and Maprik (see transport map). Since 1966 a connection of sorts has been established between Nuku and Lumi. The total length of the roads in 1967, as shown on the map, was approximately 200 miles, of which 80% is defined as "intermittent access",† i.e. roads of any standard that are impassable for extended periods,‡ in some cases even for 4-wheel drive vehicles. Only the Maprik network is connected with regional road links outside the area to Wewak on the coast and to Pagwi on the Sepik River (Fig. 1). There are proposals for a similar link of the Aitape road system with the Dagua–Wewak road along the coast because of poor anchorage facilities at Aitape. Alternatively, harbour facilities could possibly be improved at Aitape or established in Sissano lagoon (see descriptions of Nubia (2) and Murik (3) land systems in Appendix III). It is intended to link the Lumi–Nuku road net with the Maprik system and thus with the outside world. Since the area is basically well situated in relation to cheap water transport of bulk commodities over sea or along the Sepik River, it would seem reasonable to consider the possibilities of internal linkages of the interior with the coast or the Sepik (Ambunti), despite undeniable difficulties in road building posed by mountainous or swampy terrain.

The current transport situation is that goods are still flown to Lumi and Nuku, while Dreikikir and the Wosera region in the east are supplied by boat and road via Pagwi, or by road from Wewak. Aitape and Ambunti are supplied by boat. All passenger traffic, mail service, and transport of perishables are still very largely by air, except between Maprik and Dreikikir.

* World War II airstrips, and the only ones suitable for DC3 aircraft.

† Willing, English, and Devon (Consulting Engineers) (1968).—Report on road development in the Sepik district of New Guinea. Prepared for Department of Public Works and Directorate of Transport, Administration of T.P.N.G. (unpublished).

‡ Source: Transport and communications. Bull. Bur. Statist. T.P.N.G. No. 6, 1966–67.

II. Notes on the Report

(a) General

(i) *Nature and Limitations.*—This report is, firstly, an information store. As such it is designed to be consulted rather than read, although it also contains more readable sections with a geographic-interpretative character.

A detailed list of contents and numerous cross references should enable the reader to locate material easily. It is usually possible and often advisable to proceed in stages from a general to a detailed account of a specific subject. The main findings and conclusions of the survey are contained in the maps and map references and in the synoptic description of the area and its resources (Part II).

It should be kept in mind that this report is based on a reconnaissance survey with very limited ground truth. The scarcity of actual measurements coupled with limitations in the air-photo interpretation cause many of the data presented, and even more of their evaluations, to be of a tentative nature.

(ii) *Land System Descriptions.*—The tabular description of land systems in terms of their component "land units", which is the customary method of description in this series of reports, has been replaced by a more detailed and comprehensive narrative description without formal recognition of land units. A second change is the replacement of the customary illustrative block diagrams and plans with air-photo stereograms and, in many cases, also stream pattern plans. These modifications are further discussed in Part III.

(iii) *Precision of Terminology.*—The practice established earlier by Speight (1967) of defining or explaining common usage parametric terms and classes (such as "very steep", "shallow", etc.) has been continued and expanded, although it could not be consistently applied in all cases. All information of this kind is collectively presented in Appendix I. It is recognized that such verbal classes are less precise than actual numerical values. However, the latter are not available in sufficient quantity to be presented with sufficient confidence. Moreover, the use of the verbal expression has some advantages in reading and comprehension.

(iv) *Presentation of Detailed Basic Information.*—Efforts have been made to make the report as useful as possible by including or referring to a large amount of practical information, not only in the traditional fields of agriculture and forestry but also for engineering purposes. Some of these detailed specialized data (including expanded forestry, agricultural, and engineering assessments of the land systems) have been placed in appendices. In this way, the main body of the report with its customary geographic overtones has been kept to a reasonable length and relatively readable. Detailed basic information referred to but not included in the report is contained in three unpublished reports, and on six unpublished maps derived from the land system map and depicting the distribution of several land attributes important for the evaluation of land use capability. These maps are listed in Part IX and, together with the Technical Memoranda, are available upon request.

(b) Geology and Geomorphology

The absence of a full-time geomorphologist from the team has made it impracticable to include in this report the usual Parts on geology and geomorphology. Except for the southernmost parts, the area is included on the photo-geological map of New Guinea north of the Sepik River prepared by Marchant (1969). This information together with field evidence and independent photo interpretation has been used in producing the lithological basis of the engineering materials map, one of the additional unpublished maps available upon request. An outline of the geological history is presented in Part III as background information for the land system descriptions. Certain geomorphological aspects are mentioned in various places, notably Section I of this Part, Section IV of Part III, Sections IV and V of Part VI, and the detailed land system descriptions in Appendix III.

III. Survey Methods

Survey methods were esssentially similar to those developed over the years in New Guinea (Haantjens 1965). They are based on a team approach to air-photo interpretation and field work, and rely heavily on the former for the extrapolation of the few ground observations. Field work took 10 weeks in 1966. Panchromatic aerial photographs at a scale of 1:50,000 at sea level were available for interpretation. Transportation in the field was mainly by helicopter, locally by motor vehicle. Photo interpretation, particularly that of vegetation (Heyligers 1968), planning of field work, and final mapping procedures differed somewhat from the customary ones. Details of the procedures followed, together with details on air-photo and map coverage, and of field work are presented in Appendix II.

IV. Acknowledgments

Many persons and organizations assisted in the field work. Thanks are due in particular to Mr. H. Roach, A.D.C., and Mr. B. Parer, planter/trader in Aitape, for sympathetically ministering to the needs of the team during the last weeks of the survey, and for the provision of accommodation and transport. Also gratefully acknowledged is the help given by Mr. M. Cockburn, A.D.C. Maprik, and his sub-district headquarters staff, in setting up the first base camp and in keeping the survey vehicles operational; Mr. B. Ryan, A.D.C. Ambunti, in providing accommodation and arranging the cutting of a helicopter pad in the mountains; Mr. F. Sabben, P.O., Nuku, and Mr. D. Steven, A.D.C. Lumi, in providing accommodation and transport; and Ansett-MAL Airlines of New Guinea, for prompt reliable charter services in the shifting of base camps.

Mrs. M. Osins, Miss P. M. Bridson, and Mr. P. A. Healy, of the Division of Land Research, and Richmond Tamanabae, of Canberra Grammar School, assisted in many ways in the preparation of the report and maps.

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PART II. SYNOPTIC DESCRIPTION OF THE AITAPE–AMBUNTI AREA* AND ITS RESOURCES

By H. A. Haantjens,† P. C. Heyligers,† J. R. McAlpine,† and J. C. Saunders†

I. Climate

Although the area is of the "wet tropical" type, the eastern inland sector of it is considerably drier than the remainder. Annual rainfall increases from 66 in. in the east to over 100 in. in the west (Fig. 2). This gradient cannot be explained by known climatic controls or topographic effects (see map of altitude). While the whole area exhibits a seasonal rainfall pattern, this characteristic is more marked inland where the wet season falls (November–April) are 2 to 3 times greater than those of the dry season. Annual rainfall variability is less than 15% inland but rises to 23% on the coast. Rainfall intensity as measured by daily falls is highest on the coast where falls of over 6 in. per day occur on average once every two years. Inland the heaviest falls are under 6 in. and occur less frequently.

In contrast to this rainfall variability temperature regimes are essentially constant over space and time. The differences that do occur are the result of increasing altitude. Mean annual temperature at sea level is about 80°F, dropping to 75°F at 1750 ft. The annual range of monthly mean temperature is only 2 degF but the average diurnal temperature range is considerably greater, varying from 12 to 16 degF.

Average monthly relative humidity is about 89% at 9 a.m. and 78% at 3 p.m., with little seasonal or spatial variation. There are no data for sunshine or wind. Estimated annual free water evaporation is lowest in the hills and mountains (49 in. per annum at Lumi, 1750 ft a.s.l.) and highest on the inland plains (59 in. at Ambunti, 160 ft a.s.l.). Evaporation and rainfall data when integrated in a water balance analysis reveal four major zones in the area (Fig. 2):

(1) *Inland Dry*.—Soil moisture deficits beyond 50% are common in the dry season and sometimes occur in the wet. Mean annual water surplus is about 25 in.

(2) *Inland Wet*.—Soil moisture depletion beyond 50% is very rare and mean annual water surplus is over 60 in.

(3) *Coastal*.—This zone is similar to (2) during the dry season but depletions of up to 50% in the wet season are more common. Annual water surplus is similar.

(4) *Mountain*.—There are no data. Soil moisture depletion beyond 50% is likely to be extremely rare. The mean annual water surplus is probably significantly greater than in zone (3).

* See Part I, Section I, for a brief introductory description of the area.

† Division of Land Research, CSIRO, P.O. Box 109, Canberra City, A.C.T. 2601.

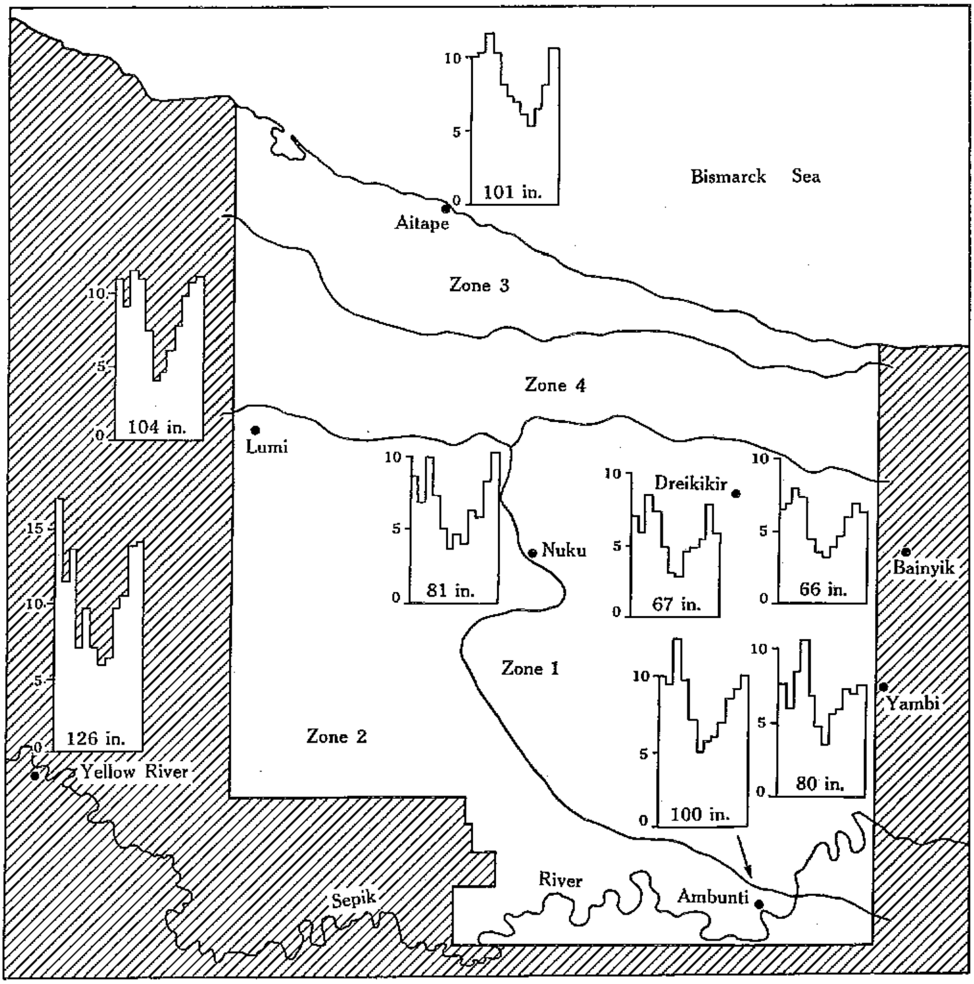

Fig. 2.—Water balance zones of the Aitape–Ambunti area, and mean monthly (Jan.–Dec.) and annual rainfall data. Zone 1, inland dry; zone 2, inland wet; zone 3, coastal; zone 4, mountain. Land outside the survey area is shaded.

II. Land Use Capability

(*a*) *Forest Resources*

As shown on an accompanying map, commercial forests cover almost half of the survey area. The most productive forest types are tall forest with a rather open canopy (Fo*), tall forest with a rather closed canopy (F), tall forest with a rather open canopy with light-toned crowns (Fod), and tall forest with a rather open, small-crowned canopy (Fos). Together, these types occupy 10% of the survey area and 22% of the commercial forest area. The first of these forest types is by far the

* Symbols are used for brevity in the text and on the forest resources map. Their derivation is explained in Appendix I.

most important areally, but all four types have high forest productivity indexes and good to very good access indexes. A summary of the forest resources is presented in Table 1.

TABLE 1

SUMMARY OF FOREST RESOURCES

Class of Forest	Area (sq miles)	Estimated Stocking Rate (super ft/ac)	Access Index*	Forest Productivity Index*
High productivity	484	7600–10,000	68–92	54–70
Moderate productivity	340	5100–8100	46–70	34–37
Low productivity	985	3000–7000	38–92	14–28
Very low productivity	364	3000–4500	15–35	7–11
Nil productivity	58	<4000	12–20	<6

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

The forest resources of each land system are assessed in Part III and in Appendix III. The land systems considered to have the highest potential are Aiome (23), Nagam (16), Paiawa (24), Pes (17), Ambunti (20), and Misinki (14). All have high to very high forest resource indexes, moderate to very good access, and a high percentage of forest cover. Totalling 15% of the survey area these land systems are dominated by Fo, FoM, Foi, and Fos forest types.

Regionally, the northern part of the area between the mountains and the coast offers the best immediate prospect for exploitation. It contains plains, fans, and hills with moderate to high productivity forest types. Access is generally good to moderate and the natural outlet is to the coast.

The central portions of the inland plains comprise large areas of forest of moderate productivity on alluvium. Access is generally good to moderate and swampy areas can be avoided. Because of the swamps along the southern edge of the zone the best present outlet is to the north and then east, although the nearness of the area to the Sepik River would warrant investigating the prospects of providing access to this river. Given the existence of a suitable outlet, this region could become an important source of timber.

The Torricelli Mountains generally carry forests of low to very low productivity, and also comprise large areas of non-commercial forest. Access is generally very poor because of the steep terrain and much of the zone is best left untouched for watershed conservation.

The large hill zone south of the mountains has been extensively cleared for cropping. The forest pattern consists of relatively small scattered stands of forest of low productivity except for a large area in the west, and a smaller complex of mainly moderately productive forest in the south-east. Access varies from good to poor, and the general grain of the country suggests an outlet towards the south-east and then east.

In the Sepik flood-plain only scattered areas of forest occur, commonly with moderate stocking rates, but with generally very poor access because of the swampy terrain. Only very small areas of forest on levees present moderate access. The Ambunti hills carry a forest of nil to very low productivity and access is poor to very poor because of the steep terrain. The obvious outlet of this zone is via the Sepik River.

(*b*) *Agricultural Land Use*

The lands of the area have been rated with respect to the following 16 potentially limiting factors: altitude, slope and erodability, stoniness, cobbliness, rockiness, short-duration river flooding, long-duration inundation, drainage status, soil permeability, agricultural soil depth, available soil water storage capacity, tillage problems, soil reaction, soil salinity, land surface unevenness, and topographic irregularity. Limitations due to slope (steepness, irregularity, and erosion hazards) and limitations caused by poor drainage and overflow are the most common. These are followed by soil limitations such as shallow effective depth, slow permeability, high acidity, and alkalinity. Data obtained from these ratings* were used to estimate the capability of each land system for arable crops, tree crops, improved pastures, and irrigated rice, in terms of six classes from very high to nil capability. Notes on chemical soil fertility and risks of soil water stress are presented separately in the agricultural assessment section of the detailed land system descriptions (Appendix III). Soil properties important to land use, including N, P, and K contents, are given elsewhere† for all lowest soil classes. General information on water balance and plant growth is discussed in Part IV.

The distribution of some land attributes important to agriculture is shown on five unpublished maps at a scale of 1:250,000 that are available upon request. The subjects of these maps are: ruggedness and relief; soil drainage status, flooding and inundation hazards; potential for land reclamation and available soil water storage capacity; agricultural soil depth and permeability; and soil reaction and N, P, and K contents. A map accompanying the report shows the distribution of 18 groups with different capabilities for various kinds of permanent commercial agricultural land use. The nature of the terrain and limiting factors of each group are briefly described in Part IX, Section I(*d*).

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 2. 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 most the suitabilities vary (commonly greatly) for different component types of land. Whilst the best land in the area is found on the plains and fans north of the Torricelli Mountains, there is slightly more land with high to very high capabilities on the southern inland plains than in the coastal zone. By far the largest area of land with moderate to high capabilities also occurs on the inland plains, with other sizable tracts in the coastal plains and in the eastern

* CSIRO Aust. Div. Land Res. tech. Memo. No. 71/1, Part V (unpublished).

† CSIRO Aust. Div. Land Res. tech. Memo. No. 71/1, Part IV (unpublished).

hill zone. Table 2 shows that, as is normal in New Guinea, more land is suitable for pasture development than for any other form of agricultural activity. The proportion of land with a very low to nil suitability for arable crops is smaller than usual in New Guinea, because the proportion of very steep slopes is smaller. The relatively large areas of low to nil suitability for tree crops are caused by the very common occurrence of drainage deficiencies, inundation hazards, and poor physical soil conditions.

TABLE 2

AREAS* (SQ MILES) WITH DIFFERENT LEVELS OF SUITABILITY FOR FOUR TYPES OF AGRICULTURAL ACTIVITY

Agricultural Activity	Level of Suitability					
	Very High	High	Moderate	Low	Very Low	Nil
Arable crops	Nil	505	410	1435	1025	1280
Tree crops	25	310	640	2975	320	1385
Improved pastures	405	525	2165	330	665	560
Irrigated rice	Nil	430	745	415	170	2895

* Each row totals 4655 sq miles, the size of the survey area.

(*c*) *Engineering Land Use*

Three main sets of circumstances pose considerable problems for engineering in the area, particularly in road and airfield construction. These are, firstly, the commonness of steep and/or very irregular slopes, in places together with high relief and nearly everywhere associated with high stream densities; secondly, the common occurrence of poor drainage and of flood and inundation hazards, particularly in areas lacking the first set of problems; and thirdly, the very common absence or scarcity of suitable construction materials, usually except in the most rugged areas. The regional distribution of these features is shown on three unpublished maps that are available upon request. These maps depict: ruggedness and relief; soil drainage status, flooding and inundation hazards; and engineering materials. The advantages and disadvantages for engineering of individual land systems are set out under the heading "engineering assessment" in the detailed land system descriptions in Appendix III. Timber resources for construction, although absent or very scarce in large areas with secondary or swamp vegetation, are plentiful in many parts of the survey area, and are discussed in Part VIII and shown on the map of forest resources.

The same factors that complicate engineering projects impede ground trafficability. Moreover, dense forest and palm vegetation constitute a considerable additional obstacle, except locally along the coast and on the mid-height grassland areas in the south. Some vegetation properties relevant to trafficability, visibility, and clearing have been listed elsewhere.*

In this difficult terrain, mobility is largely dependent on existing roads, tracks, and waterways. These are briefly discussed in Part I. Although the road mileage is relatively large for New Guinea conditions, the standard of the roads is mostly very low. Some idea of the density of walking tracks can be obtained from the population

* CSIRO Aust. Div. Land Res. tech. Memo. No. 71/1, Part III (unpublished).

distribution map, since nearly all villages are linked to a network of tracks. The Sepik River is navigable at all times for small sea-going vessels. Other waterways, navigable for outboard motor canoes and other craft of similar size, are restricted to the Sepik River flood-plain, a few rivers in the alluvial plains north of this flood-plain, and some channels just behind the coast in the western part of the area. There are no harbours and anchorage facilities are poor, the best occurring in the lee of the coral islands.

(*d*) *Tourism and Hunting*

The area is less liberally endowed with attractive scenery than many other parts of New Guinea. Areas with the greatest scenic appeal are the Sepik River between Ambunti and Angoram and including Chambri Lakes (Fig. 1), the coastal zone including off-shore coral islands and Sissano lagoon as well as the mountain front in the vicinity of Aitape, and the hilly and mountainous country around Lumi. Native buildings, wood carving, and folklore already attract visitors to the Maprik and Sepik areas. Stimulating or reviving these cultural activities would be in the interest of the tourist industry. Natural facilities for recreational activities are offered mainly by the ocean and inland waters. The beaches are moderately suitable for bathing and surfing, the coral islands are attractive for swimming and skin-diving. The open sea and probably the Sepik waterways and lakes are suitable for fishing. Coastal waters near the islands, lakes in the mountains north of Maprik and Dreikikir, and the waters of the Sepik River flood-plain appear to be suitable for swimming and/or boating and water-skiing. Duck shooting is a possible form of holiday recreation in the Sepik River area.

Crocodile hunting is still an important source of cash income for the indigenous population of the Sepik River area, but is threatened with collapse as a result of indiscriminate hunting practices. Protective and regenerating measures appear to be required to maintain and expand the crocodile skin industry which has a large biological potential and a favourable economic outlook.

III. Population and Land Use

Population and land use for subsistence cultivation are summarized in Table 3 in relation to broad geographical zones in the area. They are discussed in more detail in the following sections.

(*a*) *Population and Settlement*

The indigenous Melanesian population of more than 94,000, according to 1965–66 census data, lives in near-permanent villages and hamlets and is very unevenly distributed (see map of population distribution). Three-quarters are in the central hill zone with a major concentration in the east, and smaller agglomerations are near Lumi in the west and Nuku in the centre. These concentrations locally extend into similar country on the southern flank of the main mountain range. Nearly half the remainder of the population occurs along the sea-shore. Elsewhere in the area, and including the south-western hill zone, settlement is sparse to very sparse. Most of the main mountain range and large parts of the inland plains are uninhabited. The European population is approximately 150, and includes only a few permanent settlers.

Overall population density is 20 per sq mile, which is very high for the New Guinea lowlands. If expressed on the basis of population on land used for subsistence cultivation, figures of 100 to 250 (and even higher on a purely local basis) are obtained for densely settled areas in the central hill zone, for the coastal strip,

TABLE 3

POPULATION AND LAND USE FOR SUBSISTENCE CULTIVATION IN RELATION TO BROAD GEOGRAPHICAL ZONES

	Lowlands and Hills North of Mountains	Torricelli Mountains	Hills South of Mountains	Inland Plains	Sepik Swamps and Hills
Area (sq miles)	610	410	1930	980	680
Land used (sq miles)	100	60	1070	45	20
Population	13,350	4500	68,000	4250	4250

for the inland plains, and for the Sepik flood-plain and Ambunti hills. In the last three cases this is largely due to a great reliance on sago and/or fishing for subsistence. Although sago is also of importance as a staple or supplement food in the hill zone, the high population densities here also indicate a strong pressure on land resources. In order to alleviate this a resettlement scheme for Wosera people onto the inland plains is in progress whilst spontaneous migration from the Lumi area to the coastal plains is being formalized in new development plans near Aitape.

The average population growth rate is 2% per annum. The highest growth rates occur in the Aitape area (3%) and in the densely populated Wosera area (4%).

The very small (normally less than 300 people) basic social units form some 50 language groups which in turn are subdivisions of 5 regional broad language–culture groups: the Siau along the coast; the Wapei near Lumi and extending into the coastal plain; the Au-Palei near Nuku; the Abelam in the eastern hills and with very close relationships to the Sepik River people; and the Kwoma-Meio on the Ambunti hills.

(*b*) *Land Use*

Amongst the indigenous population employment for wages is still very rare. The people are almost wholly engaged in subsistence activities, although cash cropping of rice, copra, and particularly coffee is increasing. The chief staples are tubers (mainly yams) and sago. The former are grown in a bush fallow agricultural system, the latter is generally collected from natural stands but in the hills also from originally planted groves of palms. Fish is of great importance for subsistence along the coast particularly in Sissano and Malol lagoons, and also in the Sepik flood-plain.

Five classes of intensity of land use for subsistence cultivation have been mapped on the aerial photographs and are shown on an accompanying map. The classes are based on different proportions of land in current use, land with bush-fallow vegetation, and land with other vegetation. Very high land use intensity only covers less than 3 sq miles, nearly all on river terraces in the densely populated Wosera area (Plate 31, Fig. 1) and on Sepik River levees. High land use intensity covers 52 sq miles mainly

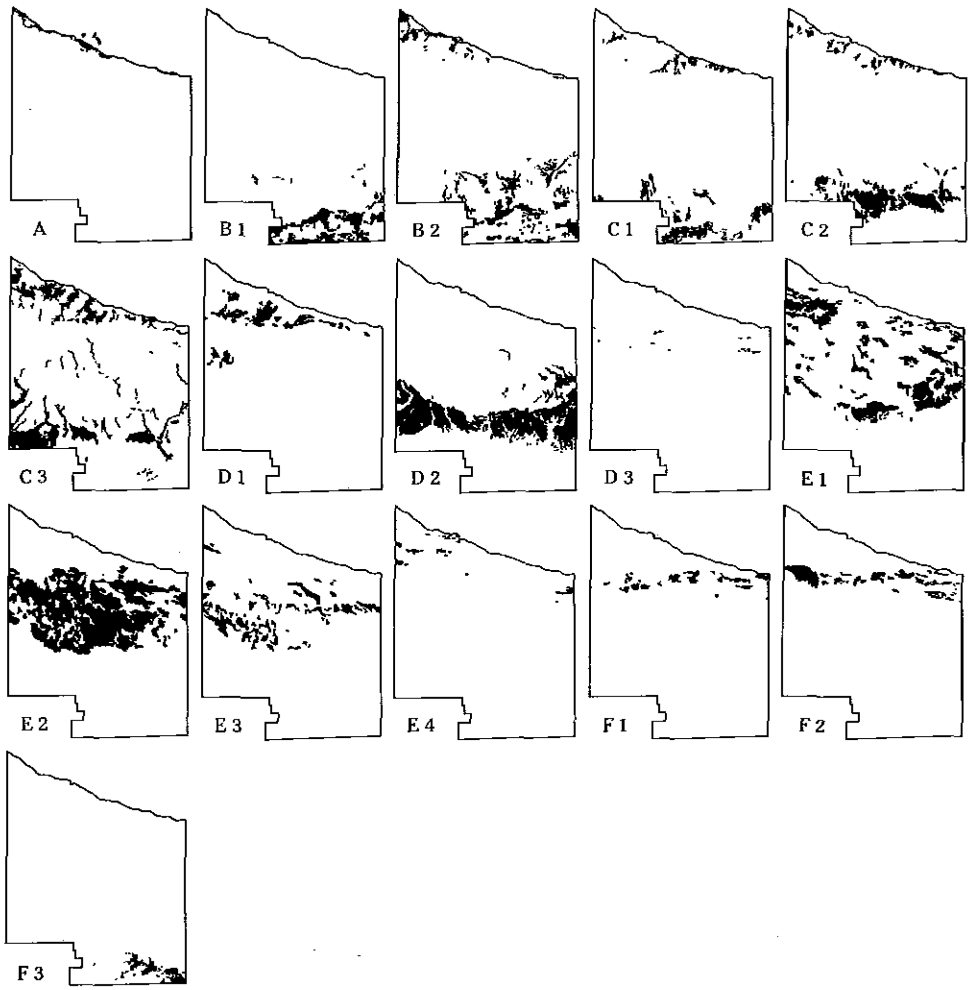

Fig. 3.—Distribution of land system groups and subgroups. A, littoral plains. B, freshwater swamps; B1, with aquatic vegetation and woodland; B2, with vegetation with sago palms. C, alluvial plains; C1, unstable plains with frequent flooding and impeded drainage; C2, plains with impeded drainage; C3, plains, terraces, and fans with mainly free drainage. D, weathered surfaces; D1, alluvial fans; D2, plains and dissected lowland surfaces; D3, dissected plateau surfaces. E, hills and mountains on sedimentary rock; E1, closely spaced, branching or short ridges; E2, ridges and slopes with land forms controlled by mass movement of softened rock; E3, ridges with land forms controlled by tilted rock beds; E4, ridges on limestone. F, hills and mountains on basement rock; F1, ridges on igneous rock, capped or flanked by sedimentary rock; F2, ridges on igneous rock; F3, ridges on metamorphic rock.

along the coast and in the densely populated eastern hill zone (Plate 31, Fig. 2). The medium, low, and very low land use intensity classes (Plate 31, Fig. 2; Plate 32, Fig. 1) occupy 450, 250, and 540 sq miles respectively and are widely distributed. Together the five classes occupy 28% of the survey area, a much higher proportion than in the adjoining Wewak–Lower Sepik area although the population difference between the two areas is relatively small. Nearly 90% of all used land is in the central hill zone and adjacent lower mountain areas.

IV. Land Systems

(*a*) *General*

Sixty-five land systems have been described and mapped. These are more or less complex mapping units corresponding to patterns of land forms and vegetation recognizable on aerial photographs at 1:50,000, and mappable at 1:250,000. They range in size from 1 to 280 sq miles. They have been described in narrative form at three levels of generalization: detailed descriptions in Appendix III; synoptic descriptions in Part III; and very brief descriptions on the land system map reference. Each land system is illustrated in a set of air-photo stereograms with descriptive captions immediately following page 32.

The land systems have been placed in six groups and 16 subgroups. These are listed on the land system map reference and briefly discussed in the following sections. Their distribution is shown in Figure 3.

(*b*) *Littoral Plains* (*40 sq miles*)

Covering less than 1% of the area, this group occurs as a discontinuous strip of land below 20 ft above sea level along the coast. The three land systems are the only ones in the area formed by marine processes, but are quite diverse in land form, soil, and vegetation. Madang land system (Plate 1, Fig. 1) consists of flat coral islands, Nubia land system (Plate 1, Fig. 2) of flattish sandy beach ridges and swales, and Murik land system (Plate 2, Fig. 1) of small tidal mangrove flats.

(*c*) *Freshwater Swamps* (*485 sq miles*)

Ten percent of the area, mainly in the Sepik flood-plain and adjoining inland plains but also near the coast, consists of plains with water-tables near or above the surface during the wet season as well as during part or all of the dry season. Strongly gleyed and commonly soft alluvial soils and peat soils carry a range of typical swamp vegetation communities.

(i) *Swamps with Aquatic Vegetation to Woodland* (190 sq miles).—This subgroup occurs between 160 and 220 ft above sea level, mainly as back swamps of the Sepik River but also on the nearby inland plains where it occupies the swampy floors of blocked valleys previously cut into the higher weathered surfaces of subgroup (*e*)(ii). Probably because of great fluctuations in the water level, there is no forest or sago palm vegetation. Chambri land system (Plate 2, Fig. 2) is permanently inundated and has (commonly floating) aquatic herbaceous vegetation. Sanai land system (Plate 3, Fig. 1) has swamp grassland and generally falls dry during the dry season. Pandamp land system (Plate 3, Fig. 2) has pandan and tall sedge vegetation and at least partly occupies more actively aggrading flood-plain swamps. Kobar land system (Plate 4, Fig. 1) has woodland with tall sedge undergrowth and is transitional to the next subgroup.

(ii) *Swamps with Vegetation with Sago Palms* (295 sq miles).—This subgroup is widely distributed at altitudes between 5 and 300 ft above sea level. The vegetation, ranging from pure sago palm vegetation to mid-height forest with sago palms, probably partly indicates smaller fluctuations in the water level and partly less swampy conditions than in the previous subgroup. Pora land system (Plate 4, Fig. 2) comprises mid-height forest with *Campnosperma* and sago palms growing on peat soils mainly in the Sepik back plains. Kabuk and Pandago land systems (Plate 5) have mainly alluvial soils and occur in many different situations but mainly on the lowermost parts of alluvial plains and in blocked valleys. Kabuk land system has the lowest and most open vegetation of the two and is generally the wettest.

(*d*) *Alluvial Plains* (*1055 sq miles*)

Nearly one-quarter of the area is occupied by land systems with well to poorly drained but never wholly swampy land, with generally undeveloped alluvial soils and negligible relief. Within this general framework there is great diversity in land characteristics.

(i) *Unstable Plains with Frequent Flooding and Impeded Drainage* (210 sq miles). —Occurring between 5 and 260 ft above sea level, this subgroup is transitional to the freshwater swamps. The finely patterned scroll plains of Palimbai land system (Plate 6, Fig. 1) border the Sepik River, have very silty soils, and are subject to changes caused by flooding, bank erosion, and deposition by this river. Nigia land system (Plate 6, Fig. 2) consists of aggrading distributary swamps and flood-plains with calcareous soils and seral forests with pandans. It occurs in the coastal and inland plains.

(ii) *Plains with Impeded Drainage* (335 sq miles).—These low-lying plains between 5 and 250 ft above sea level are characterized by forests with sago palms in the understorey and growing on poorly drained fine-textured soils. Yilui land system (Plate 7, Fig. 1) consists of stabilized distributary levee/back-plain complexes and flood-out plains, originally similar to Nigia (12) land system but now no longer subject to depositional flooding. It is associated on the inland plains with the extensive back plains of Misinki land system (Plate 7, Fig. 2), which have very slowly permeable clay soils, and on the coastal plains with the lowermost fan plains of Po land system (Plate 8, Fig. 1), where drainage is impeded by seasonal flooding and shallow water-tables rather than by slow soil permeability.

(iii) *Plains, Terraces, and Fans with Mainly Free Drainage* (510 sq miles).—This subgroup is characterized by tall forest on well to imperfectly drained soils, although more poorly drained low-lying land is generally also present. The largest areas, occurring between 10 and 300 ft above sea level, are the extensive alluvial clay plains of Nagam land system (Plate 7, Fig. 2) in the south and the mostly less clayey fan plains, levees, and back plains of Pes land system (Plate 8, Fig. 2) in the north.

By contrast, Screw and Papul land systems (Plate 9) consist of narrow discontinuous terraces, between 150 and 900 ft above sea level, along larger rivers whose valleys are confined between higher weathered surfaces of group (*e*) or sedimentary hills of group (*f*). Screw land system also includes levees along lower river courses in the south and tends to have finer-textured, less well-drained soils than Papul land system.

Small alluvial fans in this subgroup have been mapped as Ambunti land system (Plate 30, Fig. 2) when associated with mountains of metamorphic rock in the south; as Kabenau land system (Plate 10, Fig. 1) when consisting of terraces with much grassland along braiding rivers near the coast; and as Romei land system (Plate 10, Fig. 2) when situated at the foot of hills of sedimentary rock and containing limestone debris.

(*e*) *Weathered Surfaces* (*790 sq miles*)

Since rock weathering in the area is generally little advanced (although it can be rather deep) or non-existent, it is useful to group together those land systems in which there is evidence of strong weathering, albeit mostly shallow and commonly only partial. Such grouping is further justified because these land systems have distinct and basically similar air-photo patterns and occur in particular geographic positions. Occupying 17% of the area, this group comprises mainly depositional, but also erosional surfaces, ranging in land form from virtually undissected plains to the very low accordant ridges of maturely dissected surfaces.

(i) *Alluvial Fans* (145 sq miles).—This subgroup consists mainly of a series of Pleistocene to sub-Recent fans of poorly sorted sediments along the northern margin of the Torricelli Mountains between 40 and 1600 ft above sea level. The fans extend into the coastal plain, or unconformably overlie older sedimentary rocks. Local post-depositional warping is suggested by some broad undulations and gradient reversals. Covered with tall forest, the fans (Plate 11, Fig. 1) have been mapped as Aiome land system when little dissected, as Paiawa land system when moderately dissected, and as Panakatan land system when maturely dissected into ridges. Well-drained acid soils are dominant throughout, but those on the intact fan surfaces have the deepest, most developed profiles and the finest textures.

South of the mountains, Lumi land system (Plate 11, Fig. 2) consists of slightly to strongly dissected fan terraces overlying older mudstone in a few basins in the western hill zone. In location, soils, and vegetation this land system is transitional to those of the next group.

(ii) *Plains and Dissected Lowland Surfaces* (635 sq miles).—The first four land systems in this group occur on mostly fine-textured Pleistocene to sub-Recent alluvium and form a discontinuous zone, between 180 and 400 ft above sea level, south of the hills of group (*f*) on Tertiary sedimentary rocks. Up to three surface levels can be recognized in the higher, northern parts, but these tend to coalesce towards the south where they commonly merge imperceptibly with the younger alluvial plains of group (*d*). Evidence of post-depositional tilting, warping, and even faulting adds further to the difficulty of establishing a chronological sequence of depositional and erosional phases. The undissected wet plains of Nigre land system (Plate 12, Fig. 1) are always found on the lowest surface; the slightly dissected plains of Yambi land system (Plate 12, Fig. 2) are most common on low surfaces; the more strongly dissected plains of Burui land system (Plate 13, Fig. 1) occur mostly at high levels; and the accordant ridges with surface remnants, Kworo land system (Plate 13, Fig. 2), are restricted to the highest surface. The soils are acid to strongly acid and have marked coarser-textured surface horizons and slowly permeable, usually strongly mottled subsoils. Gleying decreases as dissection increases, and the largest percentage of the most strongly developed soils is on the dissected plains. Man-induced mid-height grassland, occurring in intricate patterns with remnant forest, is the characteristic vegetation.

Yindigo land system (Plate 14, Fig. 1) is on Pliocene mudstone and is partly very similar to Kworo (30) land system, partly transitional to Musendai land system (Plate 14, Fig. 2). The last-named consists of little-dissected interfluve surfaces on mudstone, flanked by more or less dissected terrace benches along major rivers. These benches appear to be correlated with the Pleistocene depositional plains. In these two land systems the altitude ranges from 250 to 1100 ft, the soils tend to be less acid and less gleyed than in the previous four, and grassland is scarcer or absent.

(iii) *Dissected Plateau Surfaces* (10 sq miles).—In this smallest subgroup, Atitau land system (Plate 15, Fig. 1) consists of small closely dissected mountain-summit plateaux between 2100 and 4300 ft above sea level. On the deeply weathered sedimentary rocks occur strongly acid thick friable to plastic heavy clay soils and a mid-height forest with a dense even canopy. These weathered summit surfaces may be related to the dissected lowland surfaces in the south, or may be older. Dossett land system (Plate 15, Fig. 2) is rather similar but is not restricted to summit surfaces, occurs mainly on igneous rock, and appears to include some karst topography on limestone.

(*f*) *Hills* and Mountains on Sedimentary Rock* (*1955 sq miles*)

Covering over two-fifths of the area, this is by far the largest group of land systems. The sedimentary rocks range in age from pre-mid Miocene to late Pliocene or even early Pleistocene. Siltstone and mudstone are the dominant rock types, sandstone is common, conglomerate and limestone are rare. Apart from the limestone and the oldest rocks, even the fresh rocks are rather soft. This circumstance, together with weathering, bedding, tilting, and faulting, has produced a series of land-form patterns that can be distinguished (commonly with ease, sometimes with difficulty) from the air-photo patterns of the harder rocks of group (*g*). A great variation in the factors mentioned above has caused an equally great variability in land forms. The soils are also varied, but nearly always very clayey, and more commonly gleyed than expected in such rough terrain. Various kinds of tall and mid-height forest appear to have a broad regional distribution, partly related to climate. Since, moreover, very large areas carry secondary communities, vegetation has had only little influence on land system definition and mapping.

(i) *Closely Spaced, Branching or Short Ridges* (555 sq miles).—This subgroup is generally characterized by very low to low relief, steep slopes, and fine grain, and normally has simple hill slopes with rather shallow, slightly to moderately developed, neutral to weakly acid residual soils.

* Except those included in weathered surfaces of group (*e*).

The first three land systems have accordant branching ridge crests and occur on subhorizontal or gently dipping rocks between 240 and 1200 ft above sea level. Closely associated with the dissected weathered lowland surfaces of group (*e*)(ii), they differ from them in having been almost or completely dissected below the weathered zone. Sandri land system (Plate 16, Fig. 1) is the lowest, most finely grained, and has the largest proportion of more acid, more developed soils. Emul land system (Plate 16, Fig. 2) occupies an intermediate position and Kaugiak land system (Plate 17, Fig. 1) has the least accordant, most widely spaced ridges and the least developed soils, commonly including colluvial soils on more gentle slopes with slump benches.

The three remaining land systems have irregular, not accordant, short ridges and are widely distributed through the area at altitudes from sea level to 2600 ft. Yassip land system (Plate 17, Fig. 2) is the lowest and least slumped and has the deepest soils, amongst which rather strongly developed acid soils are common. Morumu land system (Plate 18, Fig. 1) has a higher relief and more irregular slopes with small slumps and generally less developed soils. Numoiken land system (Plate 18, Fig. 2) has similar land forms to Morumu land system but a higher relief than any other land system in this group. The apparently large proportion of colluvial soils on slumped slope sectors makes this land system transitional to those of the next subgroup.

(ii) *Ridges and Slopes with Land Forms Controlled by Mass Movement of Softened Rock* (1100 sq miles).—Although most hill slopes throughout the area are affected to some degree by slumping and earth flow, these mass movement processes have been particularly important in shaping the land forms and influencing the soils of this subgroup. The importance of mass movement on sedimentary rocks is demonstrated by the large size of this subgroup which includes nearly 60% of all land on these rocks. In all land systems of this subgroup the majority of hill slopes are on colluvial materials with generally deep soils that are mostly undeveloped but, in other cases, have weathered *in situ* or consist of strongly weathered colluvial materials. Such slopes are very complex, due to benching, slumping, and gullying, and to the presence of protruding bodies of intact rock.

In the first five land systems, occurring between 250 and 4500 ft, the sedimentary rocks appear to have been previously weathered and deeply softened by hydration. During subsequent strong denudation only small remnants of the weathered zone, with strongly developed soils, were left. Mass movement caused the partial or almost complete collapse of ridges, producing relatively gentle overall slopes with an extremely irregular mesorelief and microrelief. The very long colluvial slopes of Karaitem land system (Plate 19, Fig. 1) are indicative of such nearly complete destruction of ridges. Sengi land system (Plate 19, Fig. 2) consists of widely spaced nondescript irregular low ridges, whilst Asier land system (Plate 20, Fig. 1) is similar but has greater relief. The very broad low mountain ridges of Flobum land system (Plate 20, Fig. 2) include good examples of mass movement involving whole mountainsides. Om land system (Plate 21, Fig. 1) includes the highest land in this group and comprises very rough terrain on steeper slopes that are basically similar to those of either Karaitem (41) or Flobum (44) land systems.

The last three land systems of this subgroup occur between 300 and 2100 ft above sea level, commonly closely together. They are characterized by the presence of many large slumps and slump benches which produce more distinctive air-photo patterns than those discussed above. The sagging of the side slopes by rotational slumping commonly causes the undisturbed ridge cores to stand out as sharp "emergent" ridge crests. In the low hilly Seim land system (Plate 21, Fig. 2), such crests are peaked and tend to form hexagonal patterns. This feature is less obvious in the higher ridges of Dreikikir land system (Plate 22, Fig. 1), where long benches and smaller slumps are more common. The largest slumps occur in the strongly peaked high hills of Mambel land system (Plate 22, Fig. 2), where remnants of dip slopes and outcrop slopes indicate more steeply tilted rock beds and thus conditions transitional to those of the next subgroup.

(iii) *Ridges with Land Forms Controlled by Tilted Rock Beds* (265 sq miles).—In contrast to the previous one, this subgroup is characterized by straight simple slopes which are directly related in altitude and steepness to the direction and angle of dip of tilted bedded rocks. The contrast with the previous group is tempered by the additional presence of slumps and irregular slopes due to mass movement. Dip slopes (along rock bedding planes) characteristically have soils that are basically similar to the soils of the weathered surfaces in the south. Although generally less deep and less acid, they have fine-textured commonly gleyed subsoils and coarser-textured surface soils. On the other hand, soils on the very steep outcrop slopes (across rock bedding planes) are very little developed, shallow, and often neutral to weakly alkaline.

In Ningil land system (Plate 23, Fig. 1) the dip slopes are so gentle that they resemble plateau surfaces. These are bounded and dissected by precipitous slopes. Slightly steeper, very large and partly slumped dip slopes characterize Minatei land system (Plate 23, Fig. 2) which occurs in a wet climate at higher altitude and has the most acid soils in this group. Most typical for the subgroup is Nuku land system (Plate 24, Fig. 1) with its moderately steep triangular dip slopes.

The last three land systems in the subgroup are on much more steeply dipping rocks. Consequently, slopes are much steeper and soils less developed and commonly very shallow. Musak (Plate 24, Fig. 2) and Wuro (Plate 25, Fig. 1) land systems have very sharp asymmetrical ridges with hilly and mountainous relief respectively. In Imbia land system (Plate 25, Fig. 2) the very sharp ridges are perpendicular to the strike, and the influence of dipping rocks is evident in sharp spurs on the side slopes and in steep straight frontal slope facets.

(iv) *Ridges on Limestone* (40 sq miles).—The smallness of this subgroup testifies to the scarcity of limestone in the area. Moreover, much of the limestone is not pure but argillaceous or tuffaceous or contains many volcanic boulders. Karst features are almost absent, and since slumping is of minor significance the land forms of this subgroup rather resemble those of group (*g*) on basement rock, although they tend to be more convex and smoother. The soils are shallow, dark, neutral to weakly alkaline, and very clayey. Aitape land system (Plate 26, Fig. 1) consists of isolated hills up to 500 ft above sea level in the coastal plain and Barida land system (Plate 26, Fig. 2) has higher hills and mountains up to 2800 ft above sea level and is associated with land systems on sedimentary rock.

(g) *Hills* and Mountains on Basement Rock* (*325 sq miles*)

Only 7% of the area falls in this group, and nearly one-quarter of this also contains appreciable amounts of associated sedimentary rocks. The basement rocks are the oldest in the area and consist of intermediate and basic igneous rocks in the Torricelli Mountains and more acid metamorphic rocks in the far south. These hard rocks have given rise to land forms with predominantly straight very steep slopes and many sharp spurs. Since the group includes the highest land in the area, it contains much mid-height forest with a dense even canopy on crests and upper slopes. The very steep slopes are unstable and carry forest with an irregular canopy and commonly of a seral nature and including *Casuarina* forest.

(i) *Ridges on Igneous Rock, Capped or Flanked by Sedimentary Rock* (90 sq miles).—This subgroup has land forms that are mixtures of or transitions between those typical for sedimentary and basement rocks. It covers a wide range of altitude. The soils are generally rather shallow, slightly to moderately developed, and weakly acid to acid. The high hills of Nopa land system (Plate 27, Fig. 1) appear to consist of igneous rocks with very steep spurred marginal slopes and capped by sedimentary rocks with irregular slumped slopes. The mountains of Sulen land system (Plate 27, Fig. 2) include the highest point in the area (6100 ft) and appear to comprise cores of igneous rock partly flanked and overlain by old rather hard sedimentary rocks. Its land forms are transitional between those of Om (45) and Somoro (63) land systems.

(ii) *Ridges on Igneous Rock* (170 sq miles).—This subgroup has very steep, spurred or grooved slopes and spans an altitudinal range between 30 and 5400 ft. The rocks are mainly gabbro, diorite, and granodiorite, with some basalt and other basic igneous rock. Most soils are shallow, weakly acid to acid, and not very clayey, but deeper more acid friable clay soils occur on broader crests and upper slopes. The elongated high hill ridges of Wanabutu land system (Plate 28, Fig. 1) are probably on basic volcanic rock. The complex of fine-grained ridges of Kumbusaki land system (Plate 15, Fig. 2) has a larger than normal proportion of strongly developed soils. Mup land system (Plate 28, Fig. 2) consists of isolated hills and ridges protruding above more gentle irregular slopes on sedimentary rock. Daum land system (Plate 29, Fig. 1) comprises an asymmetrical mountain block of faulted or tilted rock masses. Somoro land system (Plate 29, Fig. 2) consists of extremely rugged mountains with a rectangular pattern of joint- and fault-controlled torrential streams and with many long shallow landslide scars.

(iii) *Ridges on Metamorphic Rock* (65 sq miles).—This subgroup comprises very rugged hills and mountains between 200 and 1500 ft above sea level and rising abruptly from the Sepik flood-plain swamps. The mica-schist, gneiss, and quartzose sandstone are the oldest rocks in the area and are rather deeply weathered. The strongly acid friable soils are rather deep and clayey on the very finely branching and spurred hill ridges of Maio land system (Plate 30, Fig. 1), but are generally shallow and sandy or gritty on the mountain ridges of Waskuk land system (Plate 30, Fig. 2). This subgroup has a distinct type of mid-height forest not found elsewhere in the area.

* Except those included in weathered surfaces of group (*e*).

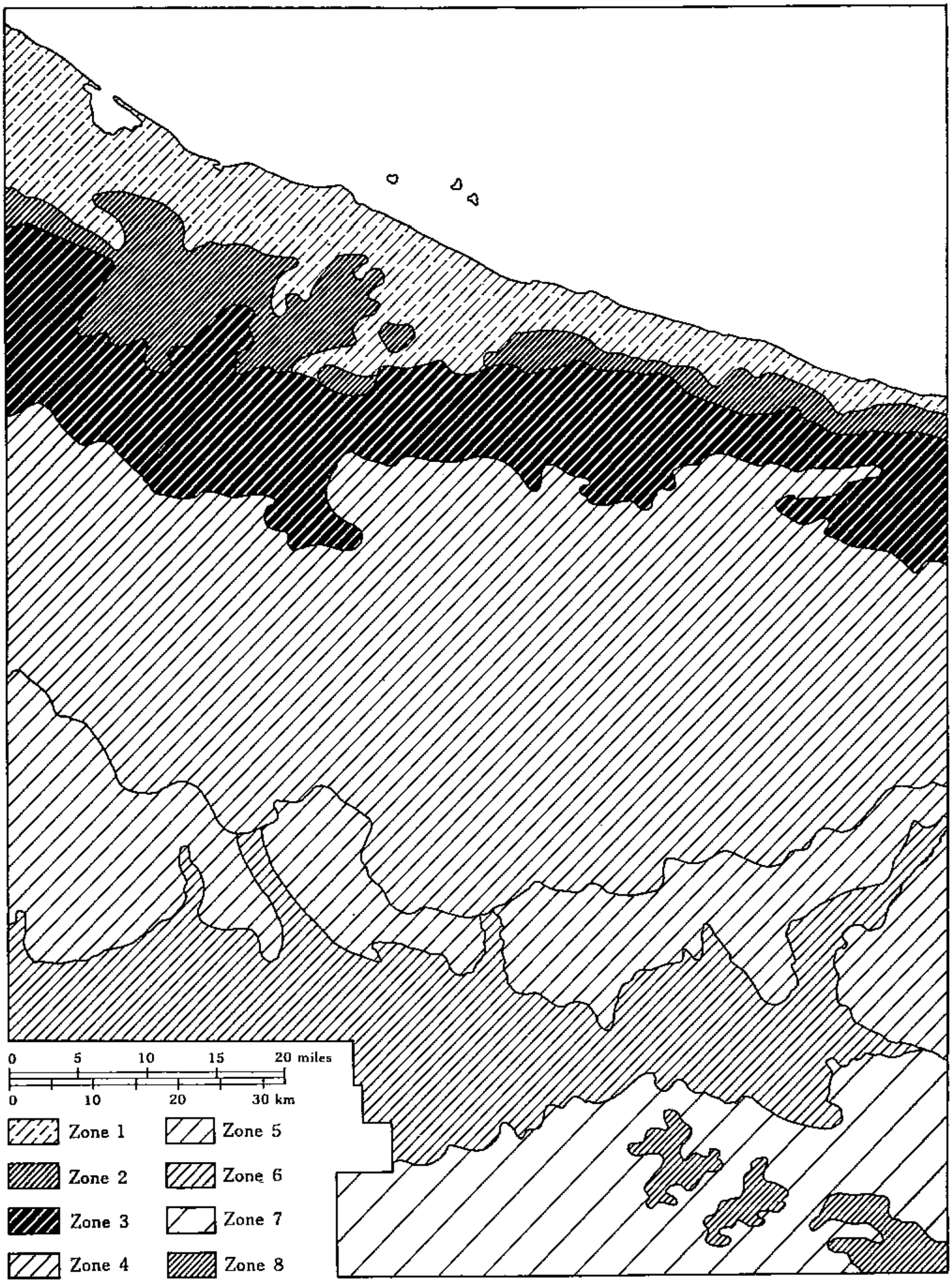

Fig. 4.—Vegetation zones of the Aitape–Ambunti area.

V. Vegetation

(a) Vegetation Types

In Part V, 51 vegetation types are described. They have been recognized and mapped from their image on 1:50,000 aerial photographs and supporting field observations. Canopy and crown properties and tree height were used in subdivision of forest, woodland, and palm/pandan vegetation; texture and tone for palm/pandan vegetation, grassland, and herbaceous vegetation.

Tall forest with an average height of 100 ft or more covers 33% of the area and comprises 10 types, of which the type with an open canopy (Fo*) and that with an irregular canopy with light-toned crowns (Fid) are the commonest. Mid-height forest between 50 and 100 ft high covers 22% of the area and includes mangrove forests, *Casuarina* forests, and 14 other types, of which forest with an irregular canopy (Fmi) and that with an open canopy and with sago palms in the understorey (FmoM) are the most important.

Only one type of woodland occurs which has tall sedge undergrowth (WT) and it covers 0·5% of the area. Palm vegetation comprises *Nypa* palm vegetation (N) and three types of sago palm vegetation (M, Me, Ml) which cover 3% of the area. Pandan vegetation (P), which can be difficult to distinguish from sago palm vegetation on the one hand and from tall grassland on the other, covers 1·5% of the area.

Grassland is subdivided into mid-height and tall, which cover 5% and 3% of the survey area. In mid-height grassland (G), which is up to 5 ft tall, several communities can be distinguished on dominance, but these could not be recognized on the air photos. Tall grassland comprises cane grass vegetation (GtS) and reed lands (GtPh). Mixed herbaceous vegetation covers less than 3% of the survey area and is represented by three types, including aquatic vegetation. Fern vegetation, often with sedges common (HD), is the commonest type.

Secondary vegetation replaces natural vegetation after interference by man. It covers 30% of the area and comprises gardens, plantations of coffee, coconut palms and sago palms, *Imperata* grassland (GI), and regrowth forest (FR).

(b) Vegetation Zones

From north to south, eight zones can be distinguished (Fig. 4) in the distribution pattern of the vegetation types shown in detail on an accompanying map.

Zone 1.—Tall forest with a rather open canopy (Fo) is dominant on the coastal plain. As drainage deteriorates sago palms enter into the undergrowth (FoM) and become more common as the canopy becomes lower and more open (FmoM). Finally, trees become scattered (Me) and disappear (M). Pandans in the canopy, in the undergrowth, or in both, are characteristic of the mid-height forests (FmoP, Fmop, FmPM) on some unstable scroll plains and flood-outs. Secondary vegetation is common along the coast, but restricted inland.

* Symbols are used for brevity in the text and on the vegetation map. Their derivation is explained in Appendix I.

Zone 2.—Although secondary vegetation is rather common in the western part this zone is dominated by tall forest with a rather open canopy, the type with an irregular canopy (Foi) occurring on foot slopes and hills, as well as on higher fan surfaces otherwise covered with small-crowned forest (Fos).

Zone 3.—Mid-height forest characterizes the mountains. Forests with an irregular canopy (Fmi, Fmio) occur on slopes together with seral stages (Fmi′) and *Casuarina* forest (Ca) on the most unstable slopes and landslide scars. Forest with a dark-toned even canopy (Fm) is characteristic for crests and upper slopes, whilst tall forest with an irregular canopy (Fi) grows on the lowest slopes.

Zone 4.—Tall forest with an irregular canopy with light-toned crowns (Fid) occurs throughout the central hill lands but has been replaced by secondary vegetation over very large areas. In the east of this zone regrowth dominated by cane grass (GtR) is frequent, whilst in the west planted sago palms are commonly associated with the secondary vegetation. This difference appears to be at least partly related to an increase in rainfall from east to west (Fig. 2). Tall forest with a rather closed canopy (F) is typical for river terraces in this zone.

Zone 5.—Mid-height grassland (G) is the dominant vegetation together with a large tract of fern vegetation (HD) in the wetter south-western part of the zone. Mid-height forests are also important: a type with a small-crowned canopy (Fms) on ridges and slopes mainly toward the boundary with the previous zone; and types with an irregular canopy with or without *Campnosperma*, and with sago palms in the understorey (FmM, FmCM) in the valleys or on plains. Blocked valleys in this zone carry similar forest with an open canopy (FmoM) and sago palm vegetation (M, Me). Limited areas of secondary vegetation are concentrated around exploited stands of sago palms.

Zone 6.—The vegetation of this zone is comparable with that of zone 1, but tall forest with an open canopy with light-toned crowns (Fod) occurs on river levees and terraces liable to flooding. Apart from a few intensively used terraces in the east and stabilized flood-out levees in the centre, secondary vegetation is rare.

Zone 7.—Vegetation ranging from mixed herbaceous (H, HT) and tall grassland (GtS, GtPh) via woodland (WT), pandan (P), and sago palm (Me, M) vegetation to mid-height forest with an open canopy with *Campnosperma* and with sago palms in the understorey (FmoCM) occupies back swamps and swales of the Sepik River flood-plain. Higher scrolls and levees carry tall forest with an open canopy with light-toned crowns (Fod), which is very locally cleared for gardens.

Zone 8.—Most of the hills rising above the Sepik River plain are covered with mid-height forest with a small-crowned rather even canopy (Fmsv). Secondary vegetation is restricted to lower slopes and a few small fans.

VI. Soils

(*a*) *Soil Cover*

Information on soils is derived from 360 auger-hole observations to 6 ft or to a shallower impenetrable layer, and on the correlation of these data with land forms and vegetation on the aerial photographs. The soils were classed into 7 orders, 15 suborders, 23 great groups, and 54 subgroups according to the American comprehensive soil classification system known as the 7th Approximation. The subgroups were divided into 112 lower soil classes on the basis of locally important similarities and differences. Brief soil descriptions are given in a form that enables them to be used also as a key for soil identification and as explanations of the 7th Approximation names of the order to subgroup classes.

Soils of the entisol order, comprising undeveloped alluvial soils, as well as regosolic soils on hill slopes, cover the largest area of approximately 2200 sq miles. Of this, 1300 sq miles throughout the area, except the Sepik flood-plain, have non-gleyed or slightly gleyed medium- to fine-textured soils (hapludents) and near the coast a few coarse-textured soils (orthopsamments); 650 sq miles throughout the area, except in the mountains, have strongly gleyed medium- to fine-textured soils (haplaquents) and near the coast a few coarse-textured (psammaquents) soils; and over 250 sq miles in swamps near the coast and in the south have very strongly gleyed soils that are soft underfoot (hydraquents).

Inceptisols, soils with slight to strong profile development but without textural B horizons or base-rich dark topsoils, are the next largest order, covering nearly 1300 sq miles. Nearly 1200 sq miles throughout the area have soils with (weakly acid) colour and structure B horizons (dystrochrepts). The remainder of the area is occupied partly by similar but alkaline and calcareous soils (eutrochrepts) on sedimentary hills, and mainly by strongly gleyed (umbraquepts) or non-gleyed (haplumbrepts) soils with acid thick dark topsoils, the umbraquepts mainly on the inland plains and the haplumbrepts along the coast and scattered in the wetter hills and mountains.

Although covering much smaller areas than the two previous orders, soils with textural B horizons, belonging to two orders, are better represented in this area than in many other parts of New Guinea. Ultisols, which are rather strongly to very strongly developed acid to strongly acid soils, cover 600 sq miles. They belong to six great groups. A majority comprises non-gleyed or slightly gleyed soils, either with brightly mottled subsoils (plintochrults, 130 sq miles), or similar soils also with dark topsoils (plintumbrults, 30 sq miles), or with neither mottled subsoils nor dark topsoils (typochrults, 130 sq miles). Others are strongly gleyed soils, either without (ochraquults, 50 sq miles) or with (umbraquults, 40 to 50 sq miles) dark topsoils, or with brightly mottled subsoils (plintaquults, 140 sq miles). Of these, the typochrults occur mostly on fans in the north and locally in the mountains and hills, whilst the other great groups are largely restricted to weathered surfaces in the south and east. Alfisols, which are moderately developed alkaline to weakly acid soils, cover less than 300 sq miles and occur mostly as non- or slightly gleyed soils (typudalfs, 200 sq miles) in hills and mountains; less commonly as strongly gleyed soils, with (umbraqualfs, 60 sq miles) or without (ochraqualfs, 20 sq miles) dark topsoils on weathered surfaces.

Oxisols, very strongly developed strongly acid friable latosolic soils, are even scarcer in this area than usual in New Guinea and occupy only 40–50 sq miles on weathered surfaces from mountain summits to inland plains. All have textural B horizons and have been called normargox.

Mollisols, which have an alkaline to weakly acid thick dark topsoil, cover slightly less than 70 sq miles. Nearly half of this area has shallow rendzinas (rendolls) on limestone in and north of the Torricelli Mountains, and one-half consists of alluvial soils (hapludolls) on river terraces in hilly terrain. Mollisols with a textural B horizon (argudolls) occur very rarely on weathered surfaces in the south.

Histosols (organic soils), ranging from raw peat to organic mud and peaty clay soils, are relatively common, occupying nearly 160 sq miles largely in the Sepik flood-plain. The histosols have not been subdivided into great soil groups, but only directly into lower soil classes.

An accompanying map shows the distribution of 43 associations of great soil groups based on land system boundaries. The distribution of the soil orders and great groups in these associations is described in relation to rock type, land form, and vegetation. The land system map can be used as a map of associations of subgroups (from the synoptic land system descriptions) or of lower soil classes (from the detailed land system descriptions).

(*b*) *Soil Formation*

Apart from obvious correlations such as those between organic soils and peat deposits, undeveloped alluvial soils and Recent unconsolidated sediments, and rendzinas with limestone, the influence of parent material on soil formation is most noticeable in the lower category soil classes, although even here many occur on more than one kind of rock. The largest contrast exists between soils on basement rocks and those on Tertiary sedimentary rocks, particularly mudstone. Gleying is much more common on the latter due to slow rock permeability. A similar difference exists between well-developed soils on fanglomerates in the north derived largely from basement rock and those on clayey deposits in the south derived mainly from sedimentary rocks. Since mere softening of the sedimentary rocks is required to turn them into soils, whilst real weathering is needed prior to soil formation on the hard basement rocks, undeveloped regosolic soils and little-leached residual soils are much more common on sedimentary than on basement rocks. More pronounced textural differentiation and greater subsoil plasticity in soils on sedimentary rocks are probably related to the fact that these soils have inherited amounts, often large, of clay already present in the parent rock, whilst all clay in soils on basement rocks is formed during the simultaneous processes of rock weathering and soil formation. Differences in parent material resulting from different source areas are responsible for the greater acidity of very young alluvial soils in the Sepik River flood-plain as compared with those occurring on locally derived alluvial sediments.

The most striking soil contrast in the area is that between relatively little-developed soils on erosional hill slopes and strongly developed soils on weathered fan and plain surfaces and mountain summit plateaux. Where erosional slopes have developed within the weathered zone they too commonly have strongly developed soils, and thus the contrast is less pronounced. Soils on dip slopes occupy an intermediate position between these two and tend to resemble basically the more or less gleyed and plastic soils of the weathered surfaces in the south. There are two other minor but characteristic land form/time soil sequences. There is a rapid loss of carbonates and a gradual increase in acidity, and a development of a dark topsoil in alluvial soils from scrolls and flood-plains to higher older terraces. There is a rapid increase in acidity and formation of a dark topsoil, together with slight clay formation in upper horizons and brown coloration in subsoils in sandy beach ridge soils from the coast inland.

With the possible exception of a tendency to greater soil acidity in wetter areas, there are no clear examples of the influence of climatic variations on soil formation. Soils in the wettest areas tend to be more friable and permeable. Similarly, no clear-cut instances of the influence of vegetation differences on soil formation were observed, although soils with thick dark topsoils are much more common under grassland than under forest.

VII. Explanatory Notes on Plates

The plates (except Plate 32, Fig. 2) illustrate the land systems by means of stereograms which can be scanned with a pocket stereoscope. They are constructed of vertical aerial photographs taken with a 6-in. lens at an altitude of 25,000 ft, and are reproduced at the original photo scale of about 1:50,000. The north direction points to the upper margin of the stereograms.

Land system boundaries are drawn in white lines. The number of the land system forming the subject of a particular stereogram is generally left out in order not to obscure the image, and only the adjacent land systems are indicated.

In the captions a diagnostic statement about the land form is made, followed by remarks on the vegetation, which only pertain to the occurrence of the land system depicted. The vegetation of the adjacent land systems may be deduced from their detailed or synoptic descriptions.

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PART III. LAND SYSTEMS OF THE AITAPE–AMBUNTI AREA

By H. A. Haantjens,* P. C. Heyligers,* J. C. Saunders,* J. R. McAlpine,* and R. H. Fagan†

I. Introduction

Sixty-five land systems, ranging in size from 1 to 280 sq miles, have been mapped and described. The land systems are mapping units corresponding to patterns of land forms and vegetation on the aerial photographs of the area. For a list of literature references on the land system concept the reader is referred to Haantjens, Reiner, and Robbins (1970). As discussed below and in Appendix II, land system mapping and description in the Aitape–Ambunti area deviate in several respects from the methods discussed in this literature.

(*a*) *Methods of Description*

An important difference between this report and all others in the Land Research Series except the first (Christian and Stewart 1953) is that no "land units" have been established as formal components of a land system. As a result, the customary tabular land system descriptions have been replaced by narrative descriptions. Whilst the reasons for this change are more fully discussed by Haantjens (1968), it is sufficient here to point out that the manner of description adopted focuses on the actual mapping unit (the land system) as a whole, and does not primarily aim at establishing precise correlations between land form, soil, and vegetation in each unmapped component part of the land system. The reconnaissance nature of the survey and the complexity of the terrain prevented the collection of sufficient data to establish such correlations, as is clearly evident from many land system descriptions. Where such correlations did emerge from the available data they can be easily deducted from the descriptions. The method adopted allows any detail of description of any aspect of the land systems. In this report the subjects included are: land forms, streams and drainage, vegetation, geology, weathering and soils, population and land use, transitions to other land systems, forest resources, agricultural assessment, and engineering assessment.

The homogeneity of the land system mapping units achieved during this survey made it possible to use actual air-photo stereograms as illustrations instead of drawn block diagrams or plans. To avoid subjective selection of the stereograms, they were consistently taken from the largest, or one of the largest, occurrences of each land system, by a team member who was not involved in their land form description.

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Partly counter-balancing the absence of "land units" is the listing in a separate report* of all different land form/rock type combinations sampled in the field. As presented, these "types of land" are somewhat broader entities than sites or land elements (Brink *et al.* 1966), as is shown, amongst other things, by the fact that two observations of the same type of land rarely have identical ratings of factors limiting land use capability.

The land systems are described at three levels of generalization. Because of their great length, the detailed descriptions are given in Appendix III. Short but comprehensive synoptic descriptions are presented in this Part. Very brief descriptions confined to the most important diagnostic characteristics of the air-photo patterns make up the reference of the land system map, and occur again in a slightly modified form as captions of the air-photo stereograms in Part II. Terms used to indicate parameter classes (such as slope classes, size classes, soil property classes, etc.) are defined or explained in Appendix I, except for the lowest soil class symbols, which are explained in Part VI, Section II.

Data about the altitude of the land systems, particularly those given in the detailed descriptions in Appendix III, were obtained from a comparison of the land system map with the 500-ft interval contour lines shown on the U.S.A.F. Aeronautical Approach Chart, 1:250,000 (see also the map of land altitude and sea depth).

(*b*) *Correlation with Areas Previously Surveyed*

Because the survey methods used in the Aitape–Ambunti area differ greatly from those used seven years before in the adjoining Wewak–Lower Sepik area (see Part I, Section I(*a*)), the Aitape–Ambunti survey has been conducted as an independent project. No deliberate attempt has been made to link up land system boundaries between the two areas, or to seek continuity in land system mapping. Nevertheless, in a few cases there was sufficient agreement between land systems in both areas to justify using the land system names allotted in the Wewak–Lower Sepik area. In other cases existing names from the Lower Ramu–Atitau area† further east (Fig. 1) could be used. Some details about land system correlation between the three areas are given elsewhere.‡

II. Outline of the Geological History of the Area§

The area forms a section through the northern New Guinea basin which began as a eugeosyncline in late Cretaceous or early Eocene time. This eugeosyncline may be of the open marginal type and continue northwards beyond the present coastline. During the Tertiary some 35,000 ft of clastic sediments with intercalated basalt near their base were deposited in the basin. These sediments probably derived

* CSIRO Aust. Div. Land Res. tech. Memo. No. 71/1, Part VI (unpublished).

† Lands of the Lower Ramu–Atitau area, New Guinea. CSIRO Aust. Div. Land Res. Reg. Surv. divl Rep. No. 59/1 (unpublished).

‡ CSIRO Aust. Div. Land Res. tech. Memo. No. 71/1, Part I (unpublished).

§ Because of the lack of a separate Part on geology, this section is presented here as background information for the land system descriptions. It has been contributed by B. P. Ruxton, Division of Land Research, CSIRO, Canberra.

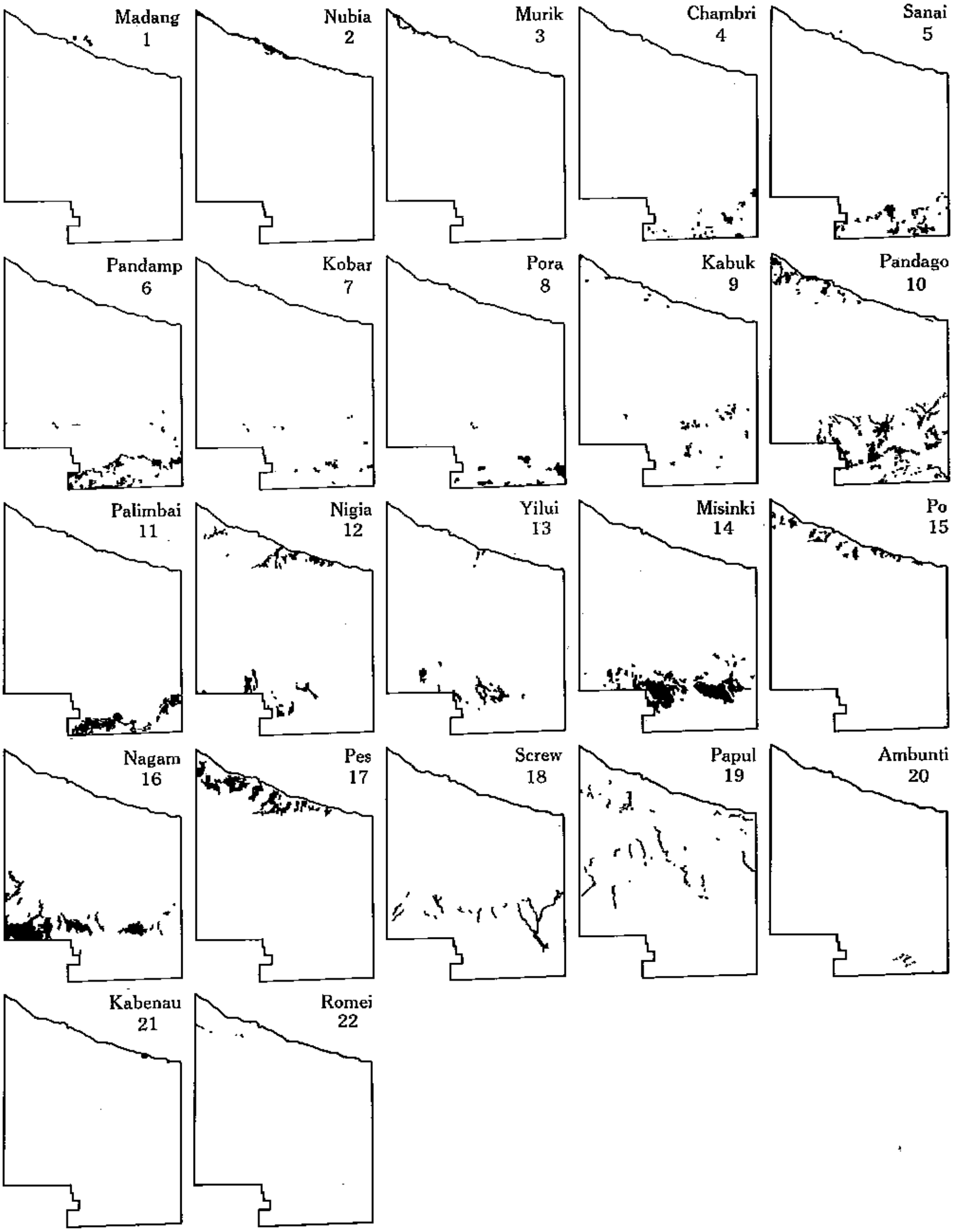

Fig. 5.—Distribution of land systems of the littoral plains (land systems 1–3), freshwater swamps (4–10), and alluvial plains (11–22).

from the central cordillera to the south which has been emergent since at least mid Miocene time.

Land probably emerged in mid Pliocene time as a result of faulting in the basement rocks along the axis of the eugeosyncline located in the area of the present Torricelli Mountains. This emergence initiated a process of erosion of the Mio–Pliocene sediments and later also of the igneous basement rocks, and of deposition of the erosion products north and south of the emerging ranges as a succession of late Pliocene, Pleistocene, and Recent fanglomerates, piedmont deposits, and alluvium with an increasing terrestrial component as more of the area rose above sea level.

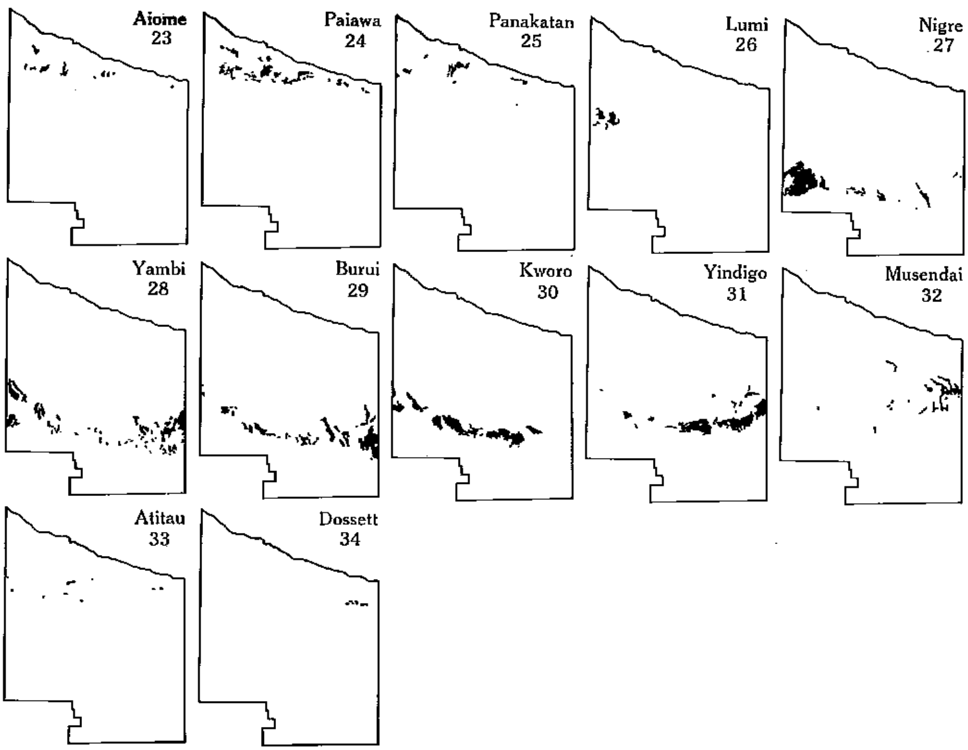

Fig. 6.—Distribution of land systems of the weathered surfaces (land systems 23–34).

The faulting of the basement rocks produced tight folding and thrusting of the overlying Mio–Pliocene sediments including high-angled northward thrusting of the Torricelli Mountains front. The thrust faults trend WNW. and are cut by NW. and NE. transcurrent faults, causing large-scale fragmentation of the basement. In places the upthrusting of the mountains has led to stratigraphic displacements of 15,000 ft. One result of this complex fault system has probably been the fragmentation and dispersal of any sizable oil pools. Thus oil seepages and gas flows occur in shear zones in diorite at Matapau.

A much simpler homoclinal structure with rather uniform west to north-west strike and south to south-west dips prevails in the sedimentary rocks south of the mountains, where only a few narrow faulted and disrupted folds occur. However,

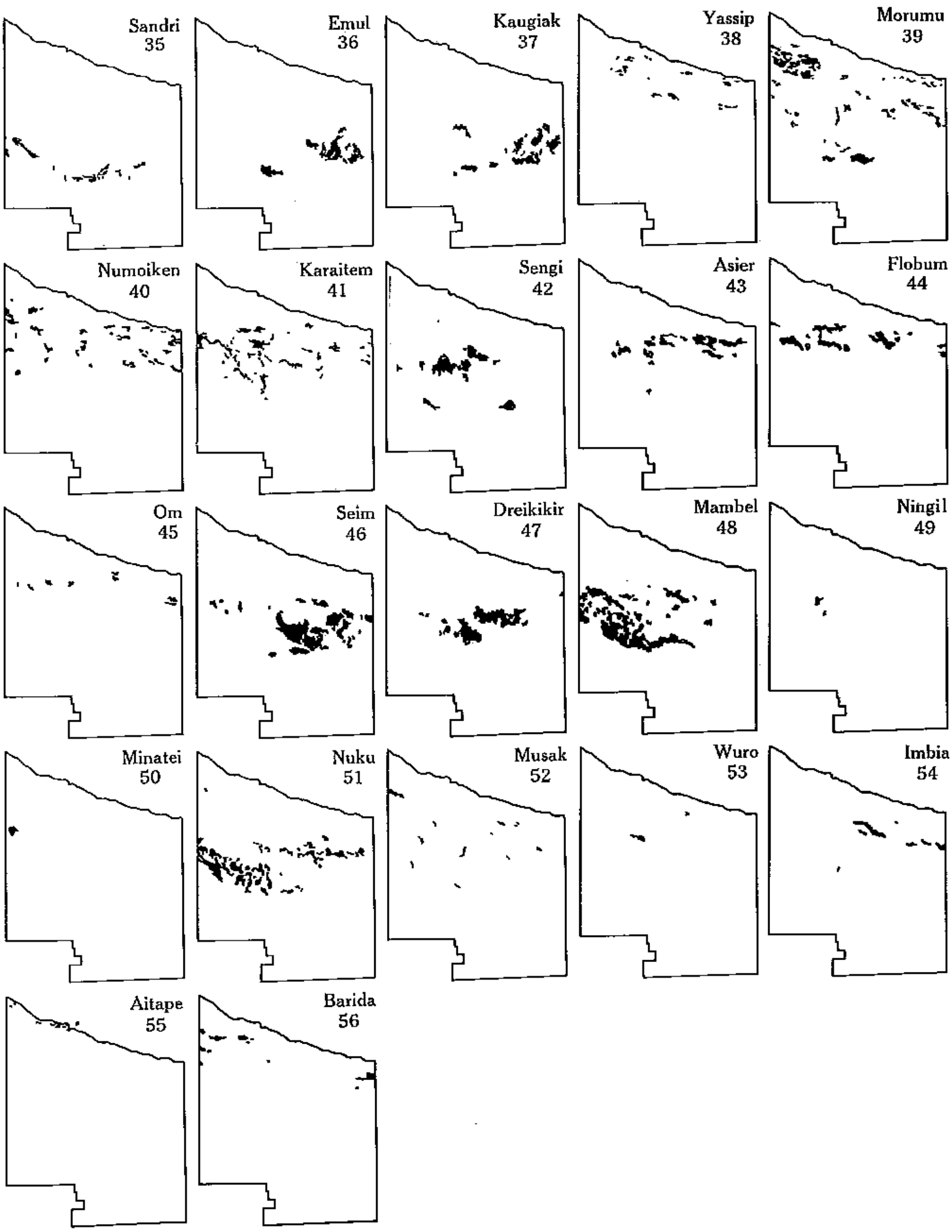

Fig. 7.—Distribution of land systems of the hills and mountains on sedimentary rocks (land systems 35–56).

north of Maimai there is a narrow but conspicuous zone in which the regional strike and trend of fold axes are northerly. This local twist in the regional structure is reflected in marked north–south anticlines breaching the scarp lines shown on the map of drainage divisions. It tends to divide the hill zone into a more rugged and more steeply tilted western part, and into an eastern part with generally less relief and gently dipping to subhorizontal strata, conditions that appear to be responsible for the greater extent and better preservation of the weathered surfaces in the east. This north–south-trending anticlinal warping appears to extend throughout the area since it could explain, all within a zone 10 miles wide, the existence of the lowest gap in the mountain range, the presence of coral islands in a shallow sea, the most southerly extension of Pliocene rocks, and the presence of unusual scroll plains in the coastal and inland plains (see Nigia (12) land system).

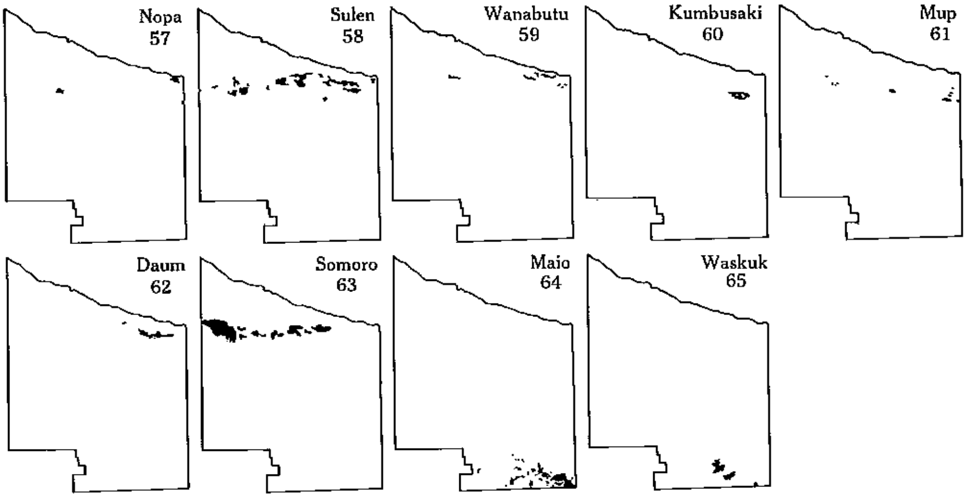

Fig. 8.—Distribution of land systems of the hills and mountains on basement rocks (land systems 57–65).

In general, there appears to be no sharp transition from Pliocene to Pleistocene sediments in the south. The tentative boundary coincides with the northern boundary of Yambi (27), Burui (28), and Kworo (30) land systems, whilst Sandri (33) land system appears to be on both Pliocene and Pleistocene rocks.

For further details on geology and landscape history, the reader is referred to the literature references on which this section is based. These are listed in Section IV of this Part.

III. Synoptic Land System Descriptions

(a) *Notes on Descriptions*

(i) *General*.—The land systems have been grouped under the same headings as those in the reference to the land system map. The distribution and relative size of each land system is shown on a small plan in Figures 5–8. Reference is made in

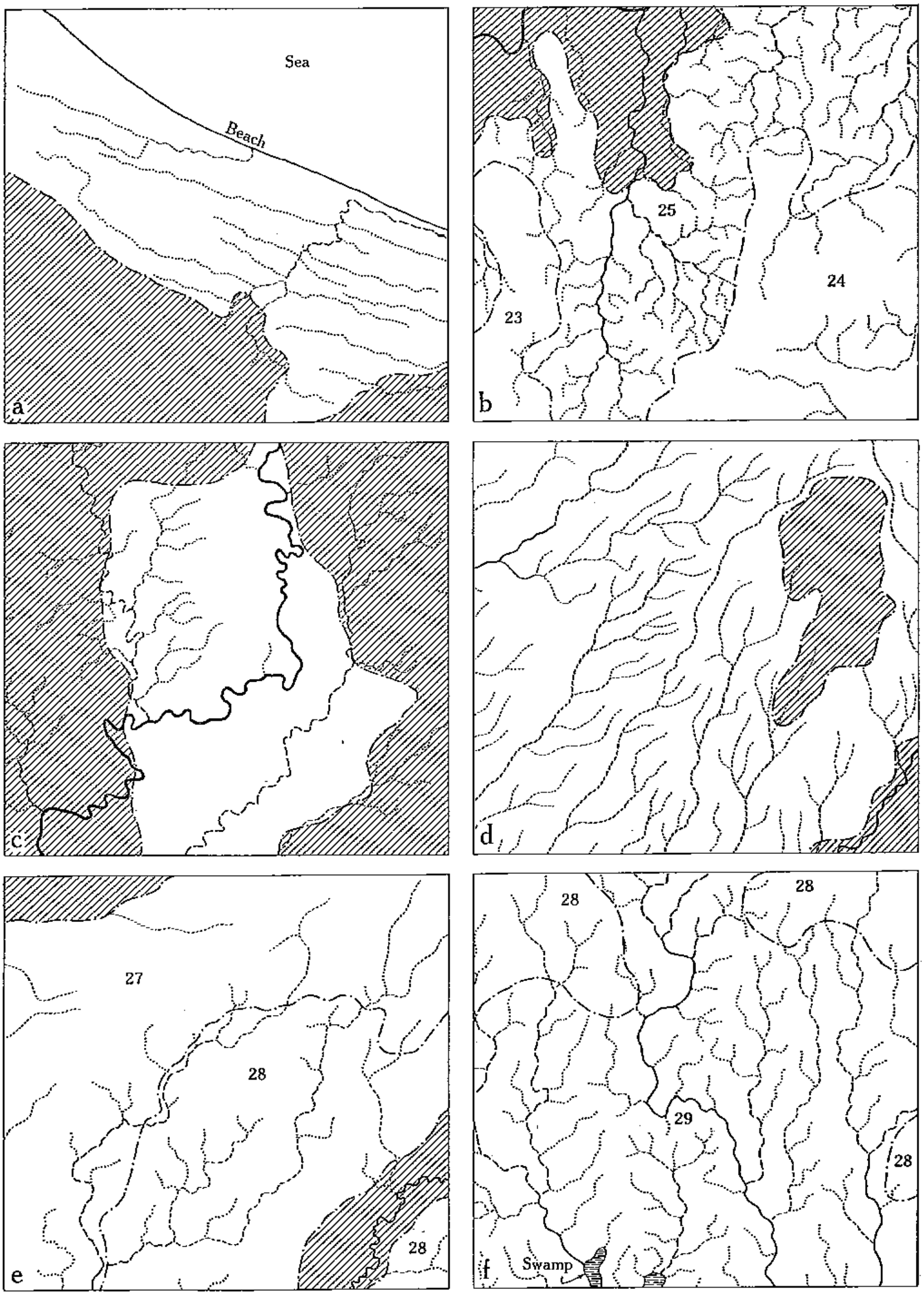

Fig. 9.—Stream patterns of land systems. See Figure 15(*b*) for explanation of features. (*a*), Nubia (2); (*b*), Aiome (23), Paiawa (24), Panakatan (25); (*c*), Lumi (26); (*d*), Nigre (27); (*e*), Nigre (27), Yambi (28); (*f*), Yambi (28), Burui (29).

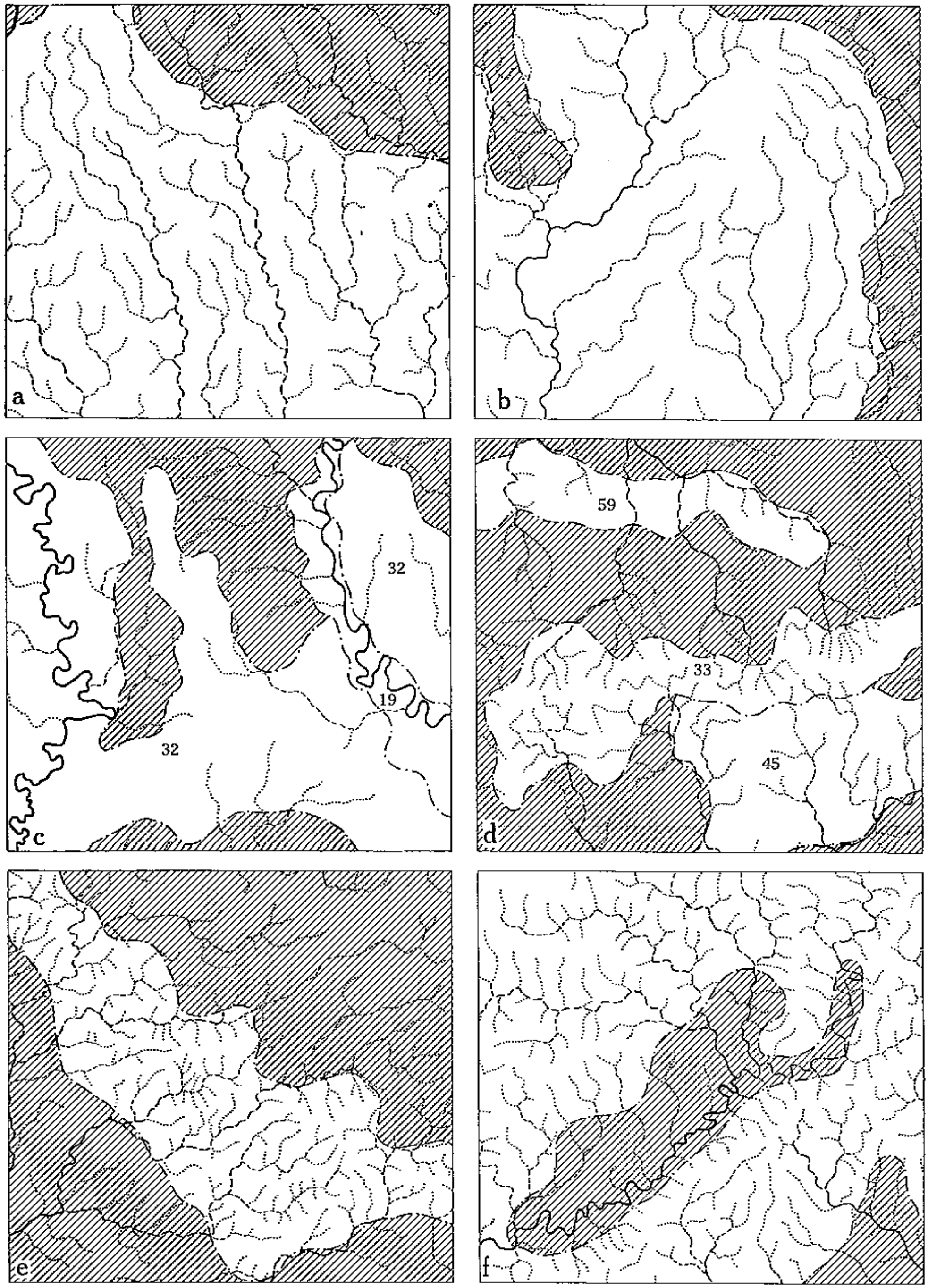

Fig. 10.—Stream patterns of land systems. See Figure 15(*b*) for explanation of features. (*a*), Kworo (30); (*b*), Yindigo (31); (*c*), Papul (19), Musendai (32); (*d*), Atitau (33), Om (45), Wanabutu (59); (*e*), Sandri (35); (*f*), Emul (36).

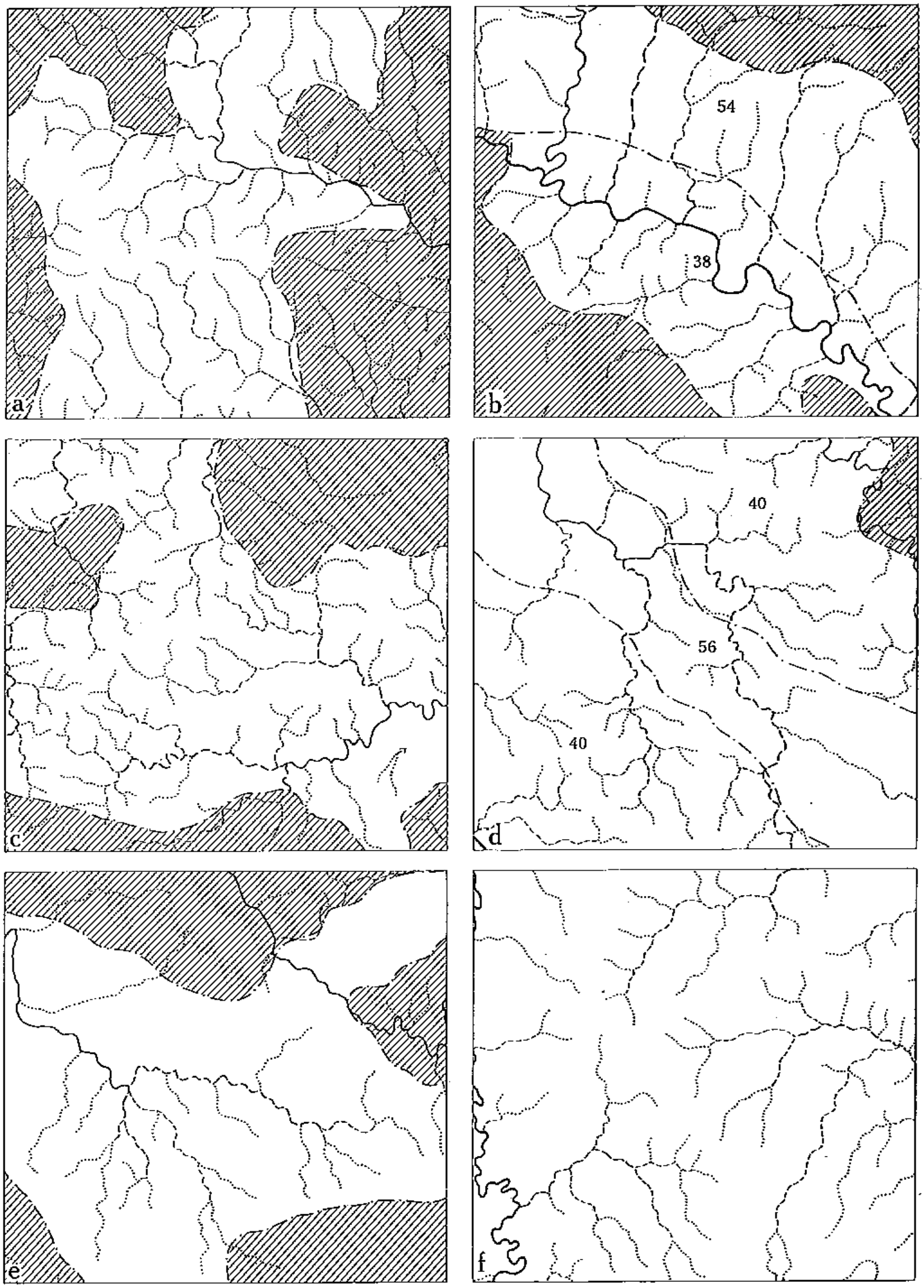

Fig. 11.—Stream patterns of land systems. See Figure 15(*b*) for explanation of features. (*a*), Kaugiak (37); (*b*), Yassip (38), Imbia (54); (*c*), Morumu (39); (*d*), Numoiken (40), Barida (56); (*e*), Karaitem (41); (*f*), Sengi (42).

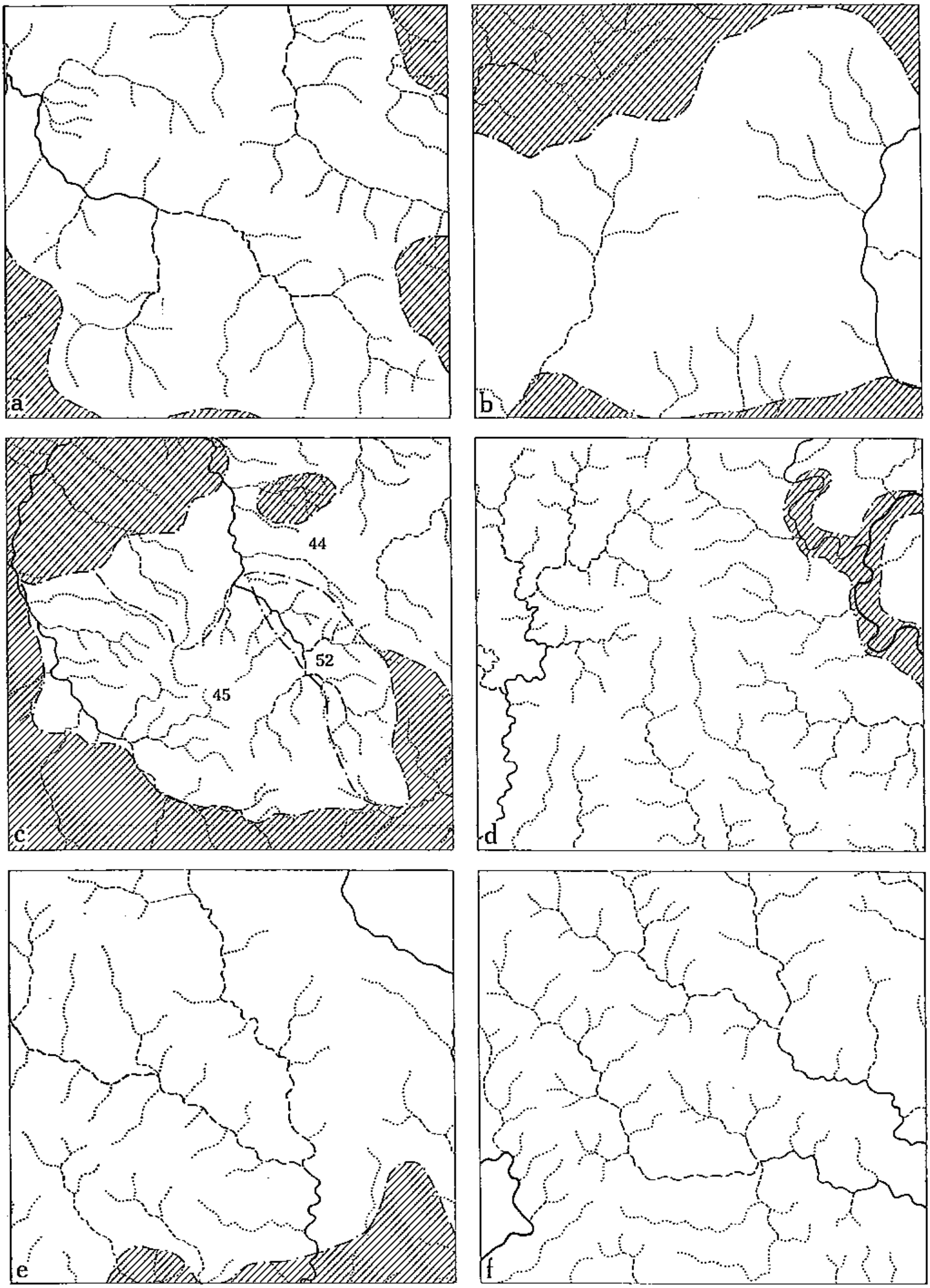

Fig. 12.—Stream patterns of land systems. See Figure 15(*b*) for explanation of features. (*a*), Asier (43); (*b*), Flobum (44); (*c*), Flobum (44), Om (45), Musak (52); (*d*), Seim (46); (*e*), Dreikikir (47); (*f*), Mambel (48).

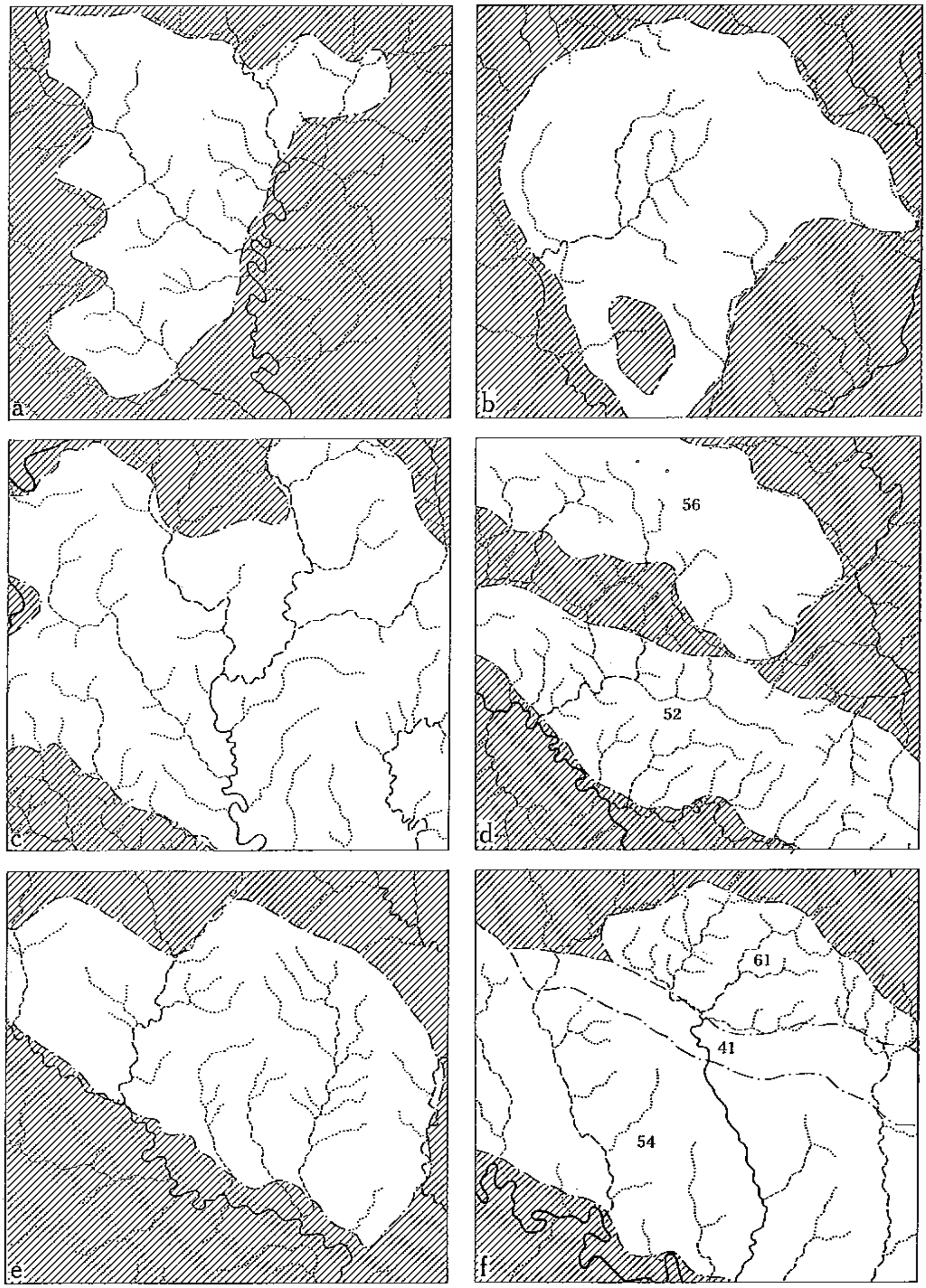

Fig. 13.—Stream patterns of land systems. See Figure 15(*b*) for explanation of features. (*a*), Ningil (49); (*b*), Minatei (50); (*c*), Nuku (51); (*d*), Musak (52), Barida (56); (*e*), Wuro (53); (*f*), Karaitem (41), Imbia (54), Mup (61).

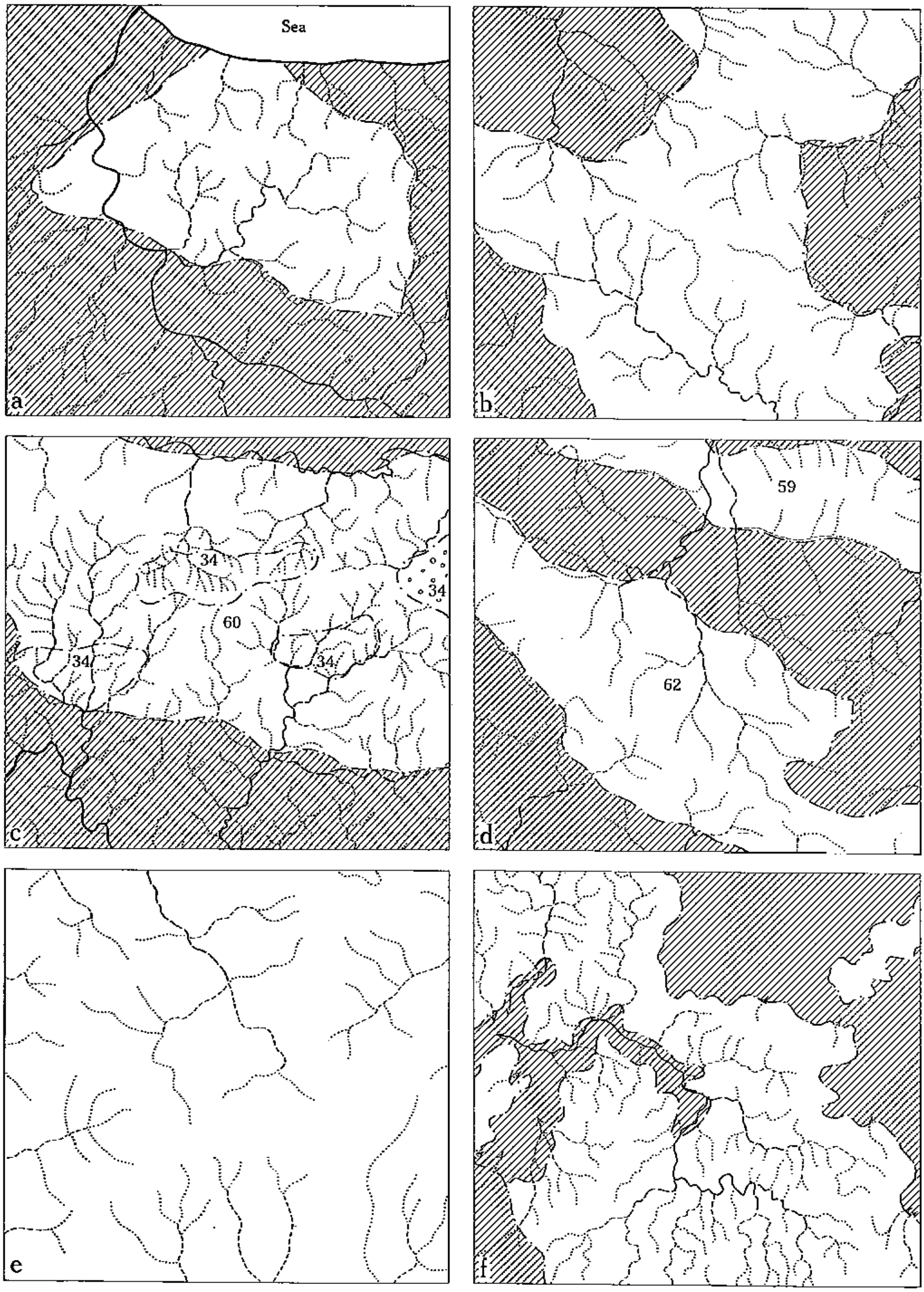

Fig. 14.—Stream patterns of land systems. See Figure 15(*b*) for explanation of features. (*a*), Nopa (57); (*b*), Sulen (58); (*c*), Dossett (34), Kumbusaki (60); (*d*), Wanabutu (59), Daum (62); (*e*), Somoro (63); (*f*), Maio (64).

the descriptions to illustrations of stream patterns* of 44 land systems in Figures 9–15, and of air-photo patterns of all land systems in Plates 1–30 (Part II, Section VII).

Each land system description contains information on the following subjects in the order listed here: land forms, streams and drainage, vegetation, climate, lithology,† soils, population and land use, transitions to other land systems, forest resources, agricultural land use capability, and engineering materials. Full stops separate information on different subjects.

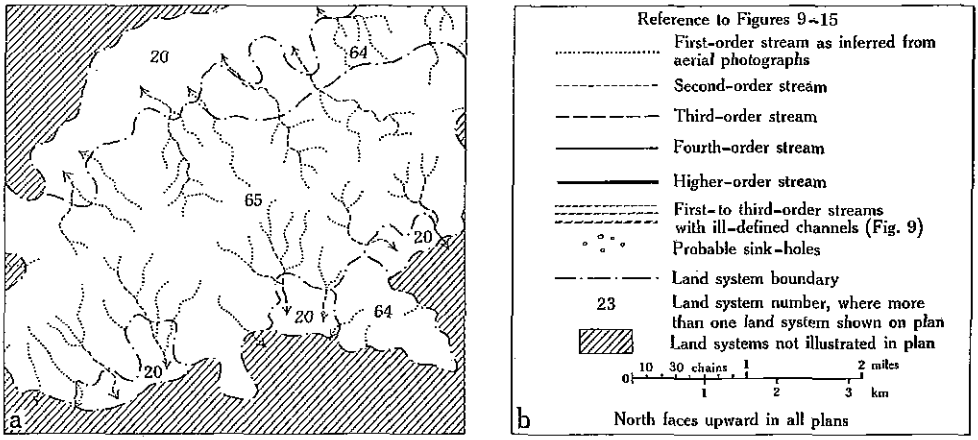

Fig. 15.—Stream patterns of land systems. (*a*), Ambunti (20), Waskuk (65); (*b*), explanation of features and approximate scale for Figures 9–15.

Although they are basically summaries of the detailed land system descriptions in Appendix III, the synoptic descriptions include in addition the index figures discussed in the next section, and some climatic information given in the form of the distribution of each land system over the four water-balance zones shown in Figure 2 and discussed in Part IV, Section III.

(ii) *Indexes*.—The land systems have been numerically rated on a scale of 0–100 for the following attributes: slope steepness, impeded drainage and inundation, land use intensity, forest productivity, terrain accessibility, land use capability for four kinds of agricultural activity, and engineering soil depth. The numerical ratings are called indexes. They have been arrived at by a differential weighting of classes of the above attributes and by estimating the percentage area occupied by these classes in a land system. The percentages in each land system of the classes of several of these attributes are given elsewhere.‡ Further details of the procedures are given in

* Although the stream patterns are drawn from actual aerial photographs, it must be realized that the actual stream beds generally cannot be observed on the photos unless they are at least 20 yd wide. Smaller stream beds are normally obscured by vegetation and their presence can only be inferred from land form detail and field experience. In the drawing of the patterns many very small streamlets and gullies have been knowingly or unknowingly omitted. Thus streams shown as first-order streams may commonly already be second- or even third-order streams in the strict sense.

† Included with land forms in Madang (1) and Nubia (2) land systems.

‡ CSIRO Aust. Div. Land Res. tech. Memo. No. 71/1, Part II (unpublished).

the relevant sections of Appendix I. It must be stressed that the expression of the indexes as two-digit figures does not imply a corresponding degree of reliability. The main objective in presenting the indexes is to produce rankings of the land systems, in which the relative position of each one with respect to all others has been estimated according to the best judgment of the survey team and in a manner that is free of the disadvantages inherent in the use of broad classes.

(iii) *Abbreviations.*—In order to reduce the length of the descriptions, constantly recurring terms have been abbreviated. Abbreviations associated with index figures are:

SI, slope steepness index
DI, impeded drainage and inundation index
II, land use intensity index
FI, forest productivity index
AI, terrain access index
CI, overall land use capability index
A, capability index* for arable crops
T, capability index* for tree crops
P, capability index* for improved pastures
R, capability index* for irrigated rice
EI, engineering soil depth index

Other abbreviations used in the synoptic descriptions are:

a.s.l., above sea level
pd, predominant (>80%)
d, dominant (51–80%)
sd, subdominant (20–50%)
c, common (8–19%)
LS, land system
USC, Unified Soil Classification (subsequent symbols are not abbreviations, see Appendix I, Section (*h*)(iv)).

(iv) *Miscellaneous.*—The soil composition of each land system is given in terms of subgroups of the 7th Approximation, or of higher category classes in the few cases where no subgroups have been defined. The soil classes have been arranged in apparent order of decreasing areal importance. Readers unfamiliar with the 7th Approximation nomenclature can obtain brief descriptions of the classes in Part VI, Section III.

For brevity, the land systems to which a particular land system is transitional are listed only by their numbers. The term "transitions to" can refer to gradual or indistinct boundaries between adjoining land systems, but usually indicates the existence of basic similarities or transitional gradations in photo patterns of land systems that may or may not be widely separated geographically.

* Not given when this index is zero. When the index is supported by less than two field observations its value is given in brackets.

(*b*) *Littoral Plains*

(1) *Madang* (Plate 1, Fig. 1).—Raised coral platform islands at 0–20 ft a.s.l; SI 4. No surface drainage; DI 8. Secondary vegetation, plantations. Water balance zone 3. Orthic rendolls pd; local rock outcrop. Population 1060; II 60. No transitions to other land systems. FI 0, AI 88. CI 9 (A 6, T 5, P 15). EI 0; USC SW to SC.

(2) *Nubia* (Plate 1, Fig. 2).—Sandy beach ridges and swales at 0–15 ft a.s.l.; SI 0. Small drainage channels and wide tidal creeks (Fig. 9(*a*)); DI 30. Mid-height grassland, secondary vegetation, plantations, sago palm vegetation. Water balance zone 3. Psammentic haplumbrepts, psammentic umbraquepts sd; psammentic hapludolls, thapto psammentic hapludents, hydraquents c. Population 7540; II 55. Transitions to LS 10, 12, 15. FI 3, AI 70. CI 78 (A 80, T 69, P 86, R 25). EI 100; USC SP dominant.

(3) *Murik* (Plate 2, Fig. 1).—Tidal flats near sea level; SI 0. Few small tidal creeks; DI 85. Mangrove and nipa palm vegetation. Water balance zone 3. Clay, less sand. Saline hydraquents d; saline orthic psammaquents sd. Population nil; II 2. Transitions to LS 9, 10. FI 0, AI 15. CI (1) (P (3), R (5)); land reclamation very difficult. EI 100; USC MH, less SM.

(*c*) *Freshwater Swamps*

(i) *Swamps with Aquatic Vegetation to Woodland*

(4) *Chambri* (Plate 2, Fig. 2).—Level plains at 160–180 ft a.s.l.; SI 0. Much open water, few flood and drainage channels; DI 100. Herbaceous vegetation, commonly floating. Water balance zone 50% 1, 50% 2. Clay and peat. Histosols, hydraquents sd. Population nil; II 0. Transitions to LS 5, 11. FI 0, AI 0. CI 0; land reclamation very difficult. EI 100; USC Pt, CH.

(5) *Sanai* (Plate 3, Fig. 1).—Level plains at 170–200 ft a.s.l.; SI 0. Few flood and drainage channels; DI 89. Tall reed grassland. Water balance zone 30% 1, 70% 2. Clay and peat. Histosols, hydraquents, hydric haplaquents, orthic umbraquepts sd. Population nil; II 0. Transitions to LS 4, 6, 7, 11, 27. FI 0, AI 11. CI 1 (P 4, R 23); land reclamation very difficult. EI 100; USC CH dominant, Pt, OH subdominant.

(6) *Pandamp* (Plate 3, Fig. 2).—Level plains at 170–220 ft a.s.l.; SI 0. No surface drainage, or few flood and drainage channels; DI 93. Pandan and tall sedge vegetation. Water balance zone 40% 1, 60% 2. Mainly clay. Hydraquents pd; histosols c. Population 260; II 1. Transitions to LS 5, 7, 8, 10, 11. FI 0, AI 7. CI (0) (R (5)); land reclamation very difficult. EI 100; USC CH dominant, MH subdominant.

(7) *Kobar* (Plate 4, Fig. 1).—Level plains at 170–210 ft a.s.l.; SI 0. No surface drainage; DI 93. Woodland with tall sedge undergrowth. Water balance zone 45% 1, 55% 2. Peat over clay. Histosols pd. Population nil; II 0. Transitions to LS 6, 8, 9. FI 0, AI 7. CI 0 (R 4); land reclamation very difficult. EI 100; USC Pt dominant, OH subdominant, at depth CH.

(ii) *Swamps with Vegetation with Sago Palms*

(8) *Pora* (Plate 4, Fig. 2).—Level plains at 170–200 ft a.s.l.; SI 0. No surface drainage; DI 93. Mid-height forest with open canopy with *Campnosperma* and sago palms in understorey. Water balance zone 50% 1, 50% 2. Peat over clay. Histosols pd. Population nil; II 0. Transitions to LS 7, 10. FI 26, AI 7. CI 0 (R 4); land reclamation very difficult. EI 100; USC Pt, at depth CH.

(9) *Kabuk* (Plate 5).—Level plains at 5–260 ft a.s.l.; SI 0. No surface drainage; DI 93. Sago palm and stunted sago palm vegetation. Water balance zone 45% 1, 25% 2, 30% 3. Clay and peat. Histosols d; hydraquents sd; hydric haplaquents c. Population nil; II 0. Transitions to LS 6, 7, 9, 10, 12. FI 0, AI 7. CI 0 (R 5); land reclamation difficult. EI 100; USC CH, Pt subdominant.

(10) *Pandago* (Plate 5).—Level plains at 5–300 ft a.s.l.; SI 0. No surface drainage or few small drainage channels; DI 78. Mid-height forest with open canopy and sago palms in understorey, sago palm vegetation with emergent trees. Water balance zone 35% 1, 35% 2, 30% 3. Clay to sand, some peat. Orthic, udic, hydric haplaquents sd; histosols c. Population 80; II 0. Transitions to LS 9, 12, 14, 15, 27. FI 13, AI 22. CI 5 (A 4, P 10, R 46); land reclamation moderately difficult. EI 100; USC CH dominant, MH, Pt subdominant.

(*d*) *Alluvial Plains*

(i) *Unstable Plains with Frequent Flooding and Impeded Drainage*

(11) *Palimbai* (Plate 6, Fig. 1).—Sepik River scroll and minor splay plains with very slight ridges and swales, at 170–220 ft a.s.l.; SI 1. Sepik River 220–520 yd wide, banks 15–18 ft high, low water depth ?20–>30 ft; DI 78, very large proportion affected by annual flooding. Tall cane grass and reed grassland, tall forest with open canopy with light-toned crowns, pandan vegetation. Water balance zone 30% 1, 70% 2. Silt and clay. Hydraquents, hydric and udic haplaquents sd. Population 1340; II 1. Transitions to LS 4, 5, 6, 10. FI 11, AI 19. CI 3 (A 3, P 5, R 12); land reclamation very difficult. EI 100; USC MH dominant, CH subdominant.

(12) *Nigia* (Plate 6, Fig. 2).—Unstable flood-out splays and scroll plains of low to very low gradient, at 5–260 ft a.s.l.; SI 0. Unincised small distributary, and large braiding to meandering streams; DI 78, moderate to very serious flood hazards throughout. Mid-height forest with pandans in canopy or understorey, also with sago palms. Water balance zone 10% 1, 40% 2, 50% 3. Clay to sand, commonly calcareous. Hydraquents d; spodic haplaquents, aquic hapludents, orthic psammaquents c. Population nil; II 0. Transitions to LS 9, 10, 13, 15. FI 0, AI 19. CI 2 (A 1, P 5, R 16); land reclamation very difficult. EI 100; USC CH, CL, ML, SM.

(ii) *Plains with Impeded Drainage*

(13) *Yilui* (Plate 7, Fig. 1).—Very low gradient to level stabilized distributary levee/back-plain complexes and flood-out plains, at 10–220 ft a.s.l.; SI 1. Degraded branching incised streams, or very small channels; DI 68. Tall forest with open canopy with woolly-textured or light-toned crowns, partly with sago palms in understorey; secondary vegetation. Water balance zone 45% 1, 45% 2, 10% 3. Clay and silt. Hydraquents, hydric and spodic haplaquents, aquic hapludents sd. Population 1380; II 5. Transitions to LS 10, 12, 14, 15, 16. FI 30, AI 31. CI 33 (A 35, T 13, P 51, R 60); land reclamation moderately difficult. EI 100; USC CH dominant, CL subdominant.

(14) *Misinki* (Plate 7, Fig. 2).—Alluvial plains of very low gradient, at 180–250 ft a.s.l.; SI 0. Few very small drainage channels; DI 58. Tall forest with open canopy and sago palms in understorey. Water balance zone 55% 1, 45% 2. Clay. Udic haplaquents pd. Population nil; II 0. Transitions to LS 10, 13, 15, 16. FI 51, AI 42. CI 21 (A 17, T 4, P 42, R 60); land reclamation simple. EI 100; USC CH predominant.

(15) *Po* (Plate 8, Fig. 1).—Low-gradient flood-plains of lowermost fan-plain sectors, at 5–250 ft a.s.l.; SI 0. Ill-defined shallow wash courses and small meandering draining streams; DI 25, very large proportion affected by occasional, locally frequent, flooding. Tall forest with open canopy and sago palms in understorey, also with light-toned crowns; secondary vegetation including exploited sago. Water balance zone 3. Mixed clay, silt, sand. Aquic hapludents pd. Population 200; II 7. Transitions to LS 10, 12, 14, 17. FI 31, AI 72. CI 38 (A 41, T 14, P 58, R 30); land reclamation moderately difficult. EI 100; USC CH, MH, CL.

(iii) *Plains, Terraces, and Fans with Mainly Free Drainage*

(16) *Nagam* (Plate 7, Fig. 2).—Alluvial plains mainly of very low gradient, at 180–300 ft a.s.l.; SI 2. Rather few small channels, locally more and larger; DI 22. Tall forest with rather open canopy. Water balance zone 25% 1, 75% 2. Clay. Aquic hapludents pd, orthic hapludents c. Population 360; II 1. Transitions to LS 13, 14, 17, 19, 27, 28. FI 77, AI 76. CI 68 (A 74, T 32, P 98, R 37); land reclamation simple. EI 100; USC CH dominant.

(17) *Pes* (Plate 8, Fig. 2).—Low- to high-gradient fan plains and levees and low-gradient back plains, at 10–300 ft a.s.l.; SI 2. Few large braiding and meandering streams with banks 4–8 ft high; DI 14. Tall forest with rather open canopy, some secondary vegetation, and plantations. Water balance zone 3. Mixed clay, sand, gravel. Orthic hapludents d; aquic hapludents sd. Population 1160; II 6. Transitions to LS 15, 16, 19, 21, 22, 23. FI 63, AI 84. CI 73 (A 77, T 60, P 83, R 65); land reclamation simple. EI 100; USC mainly CL to CH; much gravel in braided river beds.

(18) *Screw* (Plate 9, Fig. 1).—Confined levees, flood-plains, and terraces, at 180–280 ft a.s.l.; SI 2. Very low-gradient meandering streams with banks 12–15 ft high; DI 24, moderate to large proportion affected by very frequent to rare flooding. Tall forest with open canopy with light-toned crowns, mid-height forest with rather open canopy. Water balance zone 80% 1, 20% 2. Clay to fine sand, partly calcareous. Aquic hapludents d; orthic hapludents sd; udic haplaquents c. Population 100; II 8. Transitions to LS 10, 12, 13, 16, 19. FI 47, AI 71. CI 51 (A 49, T 30, P 74, R 48); land reclamation difficult. EI 100; USC CH dominant, MH subdominant.

(19) *Papul* (Plate 9, Fig. 2).—Confined flood-plains and terraces, at 150–900 ft a.s.l.; SI 4. Low-gradient braiding to angular point bar streams with banks 5–10 ft high (Fig. 10(*c*)); DI 12, moderate to large proportion affected by very frequent to rare flooding. Tall forest with rather closed, locally rather open canopy, merging into tall cane grass vegetation near rivers. Water balance zone 35% 1, 30% 2, 20% 3, 15% 4. Mixed clay, silt, sand, gravel, partly calcareous. Orthic hapludents d; entic hapludolls sd; aquic hapludents c. Population 320; II 4. Transitions to LS 16, 17, 18, 32. FI 45, AI 81. CI 62 (A 60, T 59, P 66, R 32). EI 98; USC CH, MH, CL; little or scattered gravel.

(20) *Ambunti* (Plate 30, Fig. 2).—Very gently sloping to low gradient colluvio–alluvial fans, at 190–230 ft a.s.l.; SI 2. Few small streams (Fig. 15 (*a*)); DI 27. Tall forest with rather open canopy, partly with sago palms in understorey. Water balance zone 2. Mixed clay, silt, gravel. Orthic hapludents d; aquic hapludents sd; udic haplaquents c. Population nil; II 4. Transitions to LS 10, 22. FI 57, AI 71. CI 62 (A 58, T 57, P 72, R 41); land reclamation simple. EI 100; USC MH, CL, ML; little or scattered gravel.

(21) *Kabenau* (Plate 10, Fig. 1).—Low- to high-gradient fan plains and terraces, at 0–30 ft a.s.l.; SI 3. Large braiding streams and small distributary and drainage channels; DI 21. Mid-height grassland, secondary vegetation, some sago palm vegetation. Water balance zone 3. Mixed clay, sand, gravel. Entic hapludolls, orthic hapludents sd; aquic hapludents, udic haplaquents c. Population 560; II 18. Transitions to LS 2, 10, 12, 15, 17. FI 0, AI 76. CI (55) (A (55), T (40), P (70), R (20)); land reclamation moderately difficult. EI 98; USC MH, CL, ML; little or scattered gravel, much in river beds.

(22) *Romei* (Plate 10, Fig. 2).—Very gently sloping colluvio–alluvial fans and aprons, at 230–280 ft a.s.l.; SI 2. Small intermittent streams and gullies; DI 8. Secondary vegetation, some tall forest with rather open canopy. Water balance zone 3. Mixed calcareous clay, silt, gravel, stones. Orthic hapludents pd. Population 440; II 37. Transitions to LS 17, 20. FI 26, AI 90. CI 66 (A 62, T 42, P 85, R 31). EI 100; USC MH, ML; probably much limestone gravel.

(*e*) *Weathered Surfaces*

(i) *Alluvial Fans*

(23) *Aiome* (Plate 11, Fig. 1).—Marginally dissected flat to undulating surfaces with steep 6–200-ft edges, altitude 100–900 ft; SI 10. High gradient to gently sloping very small marginal streams (Fig. 9(*b*)); DI 9. Tall forest with rather open canopy, small-crowned or irregular. Water balance zone 75% 3, 25% 4. Silt, clay, gravel, stones. Orthic typochrults d; orthic dystrochrepts sd. Population 60; II 0. Transitions to LS 17, 24. FI 82, AI 81. CI 79 (A 70, T 94, P 72, R 11). EI 100; USC MH dominant, CH subdominant; little or scattered gravel.

(24) *Paiawa* (Plate 11, Fig. 1).—Very gently to moderately sloping fan and terrace surfaces, and dissection slopes, at 40–1100 ft a.s.l.; SI 35; very low relief. Low- to high-gradient small streams (Fig. 9(*b*)); DI 21. Tall forest with rather open or closed, irregular or small-crowned canopy. Water balance zone 70% 3, 30% 4. Silt, clay, gravel, stones. Orthic typochrults, orthic dystrochrepts sd. Population 390; II 1. Transitions to LS 23, 25. FI 74, AI 44. CI 45 (A 37, T 53, P 45, R 2). EI 100; USC MH dominant, CH subdominant; little or scattered gravel.

(25) *Panakatan* (Plate 11, Fig. 1).—Accordant ridges, at 50–1600 ft a.s.l.; SI 61; very low to low relief. Many low- to high-gradient small streams (Fig. 9(*b*)); DI 8. Tall forest with rather open irregular or small-crowned canopy, secondary vegetation, some mid-height forests mainly with irregular canopy. Water balance zone 70% 3, 30% 4. Silt, clay, gravel, stones. Orthic dystrochrepts pd; orthic typochrults c. Population nil; II 3. Transitions to LS 24, 38, 39, 40. FI 47, AI 31. CI 13 (A 5, T 19, P 16). EI 95; USC MH dominant; little or scattered gravel.

(26) *Lumi* (Plate 11, Fig. 2).—Variably dissected fan surfaces and terraces, at 600–1200 ft a.s.l.; SI 21; low relief. Through-going low- to high-gradient meandering rivers with steeper small tributaries (Fig. 9(*c*)); DI 21. Secondary vegetation including old secondary forest, tall forest with irregular canopy with light-toned crowns. Water balance zone 2. Silt, clay, gravel, stones; overlying mudstone, siltstone. Orthic typudalfs, aquic dystrochrepts sd; orthic and aquic typochrults, aquic plintochrults, orthic and aquic hapludents c. Population 510; II 15. Transitions to LS 24, 32, 39, 41. FI 26, AI 58. CI 42 (A 34, T 43, P 50, R 3). EI 77; USC CH dominant, CL subdominant, minor or scattered gravel.

(ii) *Plains and Dissected Lowland Surfaces*

(27) *Nigre* (Plate 12, Fig. 1).—Low- to very low-gradient almost undissected plains, at 190–280 ft a.s.l.; SI 2. Ill-defined very small streams (Figs. 9(*d*), (*e*)); DI 68. Mid-height grassland, fern vegetation, mid-height forests with sago palms in understorey. Water balance zone 20% 1, 80% 2. Mainly clay. Umbraquultic plintaquults sd; aquic typumbrults, ochraquultic plintaquults, umbraquults, aquic plintochrults, umbraquic typochrults c. Population 190; II 0. Transitions to LS 10, 16, 28. FI 0, AI 30. CI 18 (A 14, T 4, P 35, R 39); land reclamation moderately difficult. EI 100; USC CH with veneer of MH, CL, ML, OH.

(28) *Yambi* (Plate 12, Fig. 2).—Slightly dissected low- to very low-gradient plains with steep margins, at 180–320 ft a.s.l.; SI 4; ultra-low relief. Very small streams (Figs. 9(*e*), (*f*)); DI 38. Mid-height grassland, mid-height forests with irregular or small-crowned canopy, or with sago palms in understorey. Water balance zone 50% 1, 50% 2. Mainly clay and silt. Umbraquultic and umbric plintaquults, umbraquults, umbric ochraquults, umbraquic plintochrults c. Population 560; II 0. Transitions to LS 16, 27, 29. FI 14, AI 58. CI 32 (A 29, T 16, P 52, R 18). EI 100; USC CH with veneer of MH, CL, ML, OL.

(29) *Burui* (Plate 13, Fig. 1).—Dissected undulating to flat plains of high to very low gradient, at 190–350 ft a.s.l.; SI 11; ultra-low to very low relief. Many small streams (Fig. 9(*f*)); DI 38. Mid-height grassland, mid-height forests commonly with sago palms in the understorey, some secondary vegetation. Water balance zone 60% 1, 40% 2. Mainly clay and silt. Aquic plintochrults sd; plintumbrults, aquic dystrochrepts, umbraquultic and umbric plintumbrults c. Population 1510; II 4. Transitions to LS 28, 30, 32. FI 8, AI 51. CI 27 (A 21, T 13, P 47, R 15). EI 100; USC CH, mainly with veneer of MH, CL, ML, OL, SC.

(30) *Kworo* (Plate 13, Fig. 2).—Slumped concave, or smooth to spurred convex, accordant ridges with few crestal flats, altitude 210–400 ft; SI 31; very low relief. Many very low- to high-gradient small streams (Fig. 10(*a*)); DI 30. Mid-height forest with small-crowned canopy or with sago palms in understorey, mid-height grassland. Water balance zone 50% 1, 50% 2. Mixed clay, silt, some sand and gravel. Aquic dystrochrepts sd; umbric ochraquults, aquic typumbrults, umbraquic plintochrults, orthic typochrults, typic normargox c. Population 730; II 1. Transitions to LS 29, 31, 35. FI 20, AI 45. CI 22 (A 11, T 17, P 39, R 2). EI 100; USC CH, MH subdominant, commonly with veneer of MH, CL, ML.

(31) *Yindigo* (Plate 14, Fig. 1).—Convex, or slumped and concave, accordant broad ridges, at 210–700 ft a.s.l.; SI 18; very low relief. Very low- to low-gradient small streams (Fig. 10(*b*)); DI 30. Secondary vegetation including cane grass regrowth, tall forest with irregular canopy with light-toned crowns, mid-height forest with small-crowned canopy, mid-height grassland. Water balance zone 90% 1, 10% 2. Mudstone, some siltstone. Aquic dystrochrepts, umbraquic plintochrults, umbraqualfs, orthic hapludents, umbraquultic plintaquults c. Population 6340; II 11. Transitions to LS 29, 30, 32, 37, 42. FI 23, AI 52. CI 22 (A 15, T 8, P 42, R 3). EI 67; USC CH, and CH with veneer of MH, CL, ML.

(32) *Musendai* (Plate 14, Fig. 2).—Undulating to rolling interfluve surfaces, 200–400 ft above major streams, and flat to undulating partly dissected terrace benches; altitude 300–1100 ft; SI 12; very low relief. Very small gullies and streamlets, and few through-going meandering large rivers (Fig. 10(*c*)); DI 27. Secondary vegetation including much forest, also tall forest with irregular canopy commonly with light-toned crowns. Water balance zone 1. Interbedded mudstone and siltstone; also mixed clay and sand. Aquic typudalfs sd; aquic and typic plintochrults, (umbr)aquic typochrults, eutric dystrochrepts, orthic hapludents c. Population 620; II 23. Transitions to LS 19, 28, 29, 31, 37, 39. FI 21, AI 61. CI 42 (A 40, T 26, P 60, R 12). EI 76; USC CH with veneer of MH, CL, ML, dominant, CH subdominant.

(iii) *Dissected Plateau Surfaces*

(33) *Atitau* (Plate 15, Fig. 1).—Strongly dissected mountain summit surfaces, at 2100–4300 ft a.s.l.; SI 40; very low relief. Very many high-gradient to very gently sloping very small streams with rapids near margins (Fig. 10(*d*)); DI 8. Mainly mid-height forest with even canopy. Water balance zone 4. Interbedded mudstone, siltstone, sandstone, conglomerate. Orthic typochrults, typic normargox, orthic dystrochrepts sd. Population nil; II 1. Transitions to LS 34, 35, 38. FI 25, AI 52. CI 21 (A 12, T 22, P 30). EI 85; USC MH dominant, CH subdominant.

(34) *Dossett* (Plate 15, Fig. 2).—Finely spurred branching ridges and conical hill complex, occurring at various levels between 1100 and 2400 ft a.s.l.; SI 57; very low relief. Very many high-gradient to very gently sloping very small streams, or no visible surface drainage (Fig. 14(*c*)); DI 8. Mid-height forest with irregular canopy, but with even canopy in summit area. Water balance zone 4. Probably basic igneous rock, limestone, siltstone, and mudstone. Orthic dystrochrepts, orthic typochrults, typic normargox sd; orthic rendolls c. Population nil; II 0. Transitions to LS 33, 60. FI 42, AI 35. CI (14) (A (5), T (18), P (20)). EI 68; USC MH dominant, CH subdominant.

(*f*) *Hills* and Mountains on Sedimentary Rock*

(i) *Closely Spaced Branching or Short Ridges*

(35) *Sandri* (Plate 16, Fig. 1).—Slumped and very closely spurred branching accordant ridges, at 240–500 ft a.s.l.; SI 69; very low relief. Very many low-gradient to gently sloping very small streams (Fig. 10(*e*)); DI 9. Tall forest with irregular canopy mostly with light-toned crowns, some small-crowned mid-height forest, secondary vegetation including old secondary forest. Water balance zone 55% 1, 45% 2. Semi-consolidated sand, silt, with gravel; interbedded siltstone, sandstone, mudstone. Eutric dystrochrepts sd; orthic hapludents, aquic typochrults, orthic typudalfs, orthic and lithic dystrochrepts c. Population nil; II 2. Transitions to LS 30, 31, 36, 37, 38, 39. FI 45, AI 31. CI 15 (A 7, T 14, P 24). EI 42; USC CH, CL, ML.

(36) *Emul* (Plate 16, Fig. 2).—Convex finely branching accordant ridges, at 240–1000 ft a.s.l.; SI 52; low relief. Many low-gradient to gently sloping very small streams (Fig. 10(*f*)); DI 13. Secondary vegetation from gardens and cane grass regrowth to old secondary forest, tall forest with irregular canopy with light-toned crowns. Water balance zone 1. Interbedded sandstone, siltstone, partly calcareous. Eutric dystrochrepts sd; orthic dystrochrepts c. Population 4510; II 19. Transitions to LS 31, 35, 37, 42, 46. FI 18, AI 35. CI 21 (A 12, T 15, P 36). EI 43. USC CH, MH, ML.

* Except those included in weathered surfaces of group (*e*).

(37) *Kaugiak* (Plate 17, Fig. 1).—Benched to slumped subparallel or branching semi-accordant ridges, at 240–1200 ft a.s.l.; SI 36; low relief. Low- to high-gradient small streams (Fig. 11(*a*)); DI 9. Secondary vegetation including cane grass regrowth and much medium-aged to old secondary forest, tall forest with irregular canopy with light-toned crowns. Water balance zone more than 90% 1. Mudstone, less siltstone. Eutric dystrochrepts d; orthic hapludents sd. Population 5590; II 23. Transitions to LS 31, 32, 35, 36, 39, 46. FI 16, AI 55. CI 31 (A 17, T 25, P 51). EI 46; USC CH predominant.

(38) *Yassip* (Plate 17, Fig. 2).—Irregular slumped ridges, at 20–1700 ft a.s.l.; SI 52; very low relief. Many low- to high-gradient small streams (Fig. 11(*b*)); DI 8. Secondary vegetation including old secondary forest, tall forest with rather open irregular canopy, also mid-height forests with irregular canopy. Water balance zone 10% 1, 50% 3, 40% 4. Interbedded mudstone, siltstone, at least partly calcareous. Eutric dystrochrepts pd; orthic typochrults c. Population 440; II 3. Transitions to LS 25, 34, 35, 37, 39. FI 36, AI 40. CI 19 (A 9, T 22, P 25). EI 46; USC CH dominant.

(39) *Morumu* (Plate 18, Fig. 1).—Irregular spurred and slumped short ridges, at 100–2000 ft a.s.l.; SI 58; low relief. Many high-gradient small streams (Fig. 11(*c*)); DI 13. Secondary vegetation including old secondary forest, tall and mid-height forest with irregular canopy. Water balance zone 15% 1, 10% 2, 35% 3, 40% 4. Interbedded siltstone, mudstone, sandstone. Eutric dystrochrepts sd; orthic dystrochrepts, orthic typudalfs, orthic typochrults c. Population 2540; II 8. Transitions to LS 36, 37, 38, 40, 42, 46, 52. FI 31, AI 29. CI 15 (A 6, T 15, P 25). EI 40; USC CH, MH, CL.

(40) *Numoiken* (Plate 18, Fig. 2).—Irregular spurred grooved and slumped short ridges, at 0–2600 ft a.s.l.; SI 64; moderate relief. High-gradient to moderately sloping small streams (Fig. 11 (*d*)); DI 8. Mid-height forest with irregular canopy, secondary vegetation including old secondary forest. Water balance zone 20% 1, 15% 2, 20% 3, 45% 4. Interbedded siltstone, mudstone; some conglomerate, metagreywacke, metabasalt. Orthic hapludents d; eutric dystrochrepts sd. Population 1250; II 5. Transitions to LS 39, 43, 52, 57, 58, 59, 61. FI 28, AI 28. CI 5 (T 6, P 10). EI 50; USC CH, MH, CL, ML.

(ii) *Ridges and Slopes with Land Forms Controlled by Mass Movement of Softened Rock*

(41) *Karaitem* (Plate 19, Fig. 1).—Long to very long concave slopes with gullied hummocky to very low hilly surfaces, altitude 240–3700 ft; SI 39; moderate overall, but ultra-low to very low local relief. Few low-gradient to gently sloping streams (Figs. 11(*e*), 13(*f*)); DI 13. Secondary vegetation including planted sago palm vegetation, tall and mid-height forests with irregular canopy. Water balance zone 15% 1, 20% 2, 65% 4. Deeply colluvially disturbed siltstone, sandstone, mudstone, at least partly calcareous. Orthic hapludents d; orthic dystrochrepts sd. Population 2500; II 11. Transitions to LS 38, 39, 42, 44, 48. FI 25, AI 48. CI 31 (A 17, T 33, P 43). EI 51; USC CH, MH, ML.

(42) *Sengi* (Plate 19, Fig. 2).—Broad, mostly long, even to undulating ridges with complex slopes, altitude 240–2000 ft; SI 37; low relief. Rather few low-gradient to very gently sloping small streams (Fig. 11(*f*)); DI 9. Secondary vegetation with much old secondary forest and in west locally planted sago palm vegetation, also tall forest with irregular canopy with light-toned crowns. Water balance zone 50% 1, 50% 2. Mainly mudstone and siltstone, at least partly calcareous; much surficial colluvium. Orthic hapludents, orthic dystrochrepts sd; eutric dystrochrepts c. Population 1660; II 9. Transitions to LS 31, 35, 36, 37, 39, 40, 41, 43, 48. FI 26, AI 54. CI (30) (A (15), T (40), P (35)). EI 52; USC CH, MH, ML.

(43) *Asier* (Plate 20, Fig. 1).—Broad even to undulating ridges with straight to concave grooved or hummocky slopes, altitude 500–3600 ft; SI 47; moderate relief. Rather few high-gradient to moderately sloping streams (Fig. 12(*a*)); DI 9. Secondary vegetation including old secondary forest and planted sago palm vegetation, tall and mid-height forests with irregular canopy. Water balance zone 10% 1, 20% 2, 70% 4. Mainly siltstone and mudstone, much surficial colluvium. Orthic hapludents, orthic dystrochrepts sd; eutric dystrochrepts, aquic hapludents c. Population 2560; II 7. Transitions to LS 40, 42, 44, 58. FI 28, AI 44. CI 25 (A 10, T 35, P 26). EI 53; USC CH, MH, ML.

(44) *Flobum* (Plate 20, Fig. 2).—Broad ridges with coarse-hummocky slumped and gullied slopes, altitude 400–3700 ft; SI 45; high relief. Few high-gradient to moderately sloping streams (Figs. 12(*b*), (*c*)); DI 13. Secondary vegetation including planted sago palm vegetation, mid-height forest with irregular canopy. Water balance zone 4. Siltstone, some sandstone, conglomerate, local limestone; much surficial colluvium. Orthic hapludents d; orthic dystrochrepts sd; orthic typochrults c. Population 4230; II 11. Transitions to LS 41, 43, 45, 50. FI 23, AI 42. CI 19 (A 10, T 16, P 31). EI 52; USC MH dominant, CH, ML subdominant.

(45) *Om* (Plate 21, Fig. 1).—Very irregularly slumped and dissected slopes and ridges, at 400–4500 ft a.s.l.; SI 82; high overall, but low local relief. Many moderately steep to steep small streams (Figs. 10(*d*), 12(*c*)); DI 8. Mid-height forest, mostly with irregular canopy, locally seral and with *Casuarina papuana*. Water balance zone 4. Interbedded conglomerate, siltstone, limestone, with much colluvium. Orthic hapludents, orthic dystrochrepts sd; lithic dystrochrepts, orthic rendolls c. Population nil; II 0. Transitions to LS 41, 44. FI 28, AI 10. CI (3) (T (3), P (5)). EI 38; USC MH dominant, CL, ML subdominant.

(46) *Seim* (Plate 21, Fig. 2).—Concave polygonally branching peaked ridges, at 400–1700 ft a.s.l.; SI 38; low relief. Low-gradient small streams (Fig. 12(*d*)); DI 21. Secondary vegetation including old secondary forest, and much cane grass regrowth in east. Water balance zone more than 90% 1. Mainly mudstone, at least partly calcareous; surficial colluvium. Orthic and aquic hapludents sd; eutric dystrochrepts c. Population 16,630; II 29. Transitions to LS 36, 37, 39, 42, 46, 49. FI 8, AI 41. CI 32 (A 18, T 24, P 52, R 2). EI 55; USC CH dominant, MH subdominant.

(47) *Dreikikir* (Plate 22, Fig. 1).—Semi-polygonally branching or straight, even or slightly peaked ridges with complex slopes, altitude 400–2000 ft; SI 47; mostly moderate relief. High-gradient streams with steeper small tributaries (Fig. 12(*e*)); DI 21. Mostly secondary vegetation including old secondary forest and in the west planted sago palm vegetation, tall forest with irregular canopy with light-toned crowns. Water balance zone 60% 1, 40% 2. Interbedded siltstone, sandstone, mudstone; surficial colluvium. Orthic hapludents, eutric dystrochrepts sd; orthic typudalfs c. Population 6730; II 23. Transitions to LS 46, 48. FI 15, AI 32. CI 26 (A 12, T 25, P 42, R 2). EI 49; USC CH dominant, MH, CL subdominant.

(48) *Mambel* (Plate 22, Fig. 2).—Irregular peaked ridges with very large to small slump alcoves, and dip-slope and outcrop-slope remnants, altitude 300–2100 ft; SI 45; moderate relief. Low-gradient to moderately sloping mostly small streams (Fig. 12(*f*)); DI 27. Secondary vegetation including cane grass regrowth, planted sago palm vegetation, and old secondary forest; tall forest with irregular canopy with light-toned crowns. Water balance zone 25% 1, 75% 2. Interbedded siltstone, sandstone, mudstone; surficial colluvium. Eutric dystrochrepts sd; aquic hapludents, orthic umbraquepts, orthic typudalfs c. Population 8960; II 12. Transitions to LS 42, 44, 46, 47, 50, 51. FI 27, AI 28. CI 26 (A 15, T 21, P 42, R 4). EI 51; USC CH dominant, CL subdominant.

(iii) *Ridges with Land Forms Controlled by Tilted Rock Beds*

(49) *Ningil* (Plate 23, Fig. 1).—Gently sloping surfaces bounded by scarps and back-cutting ravines, altitude 600–1500 ft; SI 17; low relief. Through-going high-gradient rivers with very gently sloping very small tributaries (Fig. 13(*a*)); DI 27. Tall forest with irregular canopy with light-toned crowns, also secondary vegetation including planted sago palm vegetation and secondary forest. Water balance zone 2. Calcareous siltstone and mudstone. Aquic typudalfs and typochrults sd; eutric dystrochrepts, orthic typochrults c. Population nil; II 7. Transitions to LS 42, 46, 51. FI 38, AI 56. CI 39 (A 34, T 21, P 62). EI 47; USC CH predominant.

(50) *Minatei* (Plate 23, Fig. 2).—Very long dip slopes, short outcrop slopes, hummocky slumped lower slopes, altitude 1400–3300 ft; SI 26; moderate relief. Few high-gradient to gently sloping small streams (Fig. 13(*b*)); DI 21. Mainly secondary vegetation including planted sago palm vegetation, some mid-height forest with irregular canopy. Water balance zone 4. Siltstone, mudstone, sandstone. Orthic typochrults sd; orthic and lithic dystrochrepts, aquic typochrults, orthic hapludents c. Population 510; II 6. Transitions to LS 44, 51. FI 24, AI 53. CI 31 (A 20, T 27, P 47, R 2). EI 56; USC CH dominant, MH, CL subdominant.

(51) *Nuku* (Plate 24, Fig. 1).—Peaked ridges of smooth, gullied, or hummocky long dip slopes and short outcrop slopes, locally forming scarps, altitude 400–2600 ft; SI 38; low and moderate relief. Low-gradient to gently sloping mostly small streams (Fig. 13(*c*)); DI 30. Tall forest with irregular canopy with light-toned crowns; secondary vegetation including old secondary forest, cane grass regrowth and sago palm vegetation. Water balance zone 30% 1, 70% 2. Interbedded siltstone, sandstone, mudstone, commonly calcareous. Aquic typudalfs sd; eutric dystrochrepts, orthic hapludents, umbric ochraquults c. Population 5550; II 9. Transitions to LS 48, 49, 50, 52, 53. FI 33, AI 32. CI 21 (A 11, T 14, P 39, R 2). EI 50; USC CH dominant, MH subdominant.

(52) *Musak* (Plate 24, Fig. 2).—Variably peaked sharp asymmetrical ridges, at 400–3000 ft a.s.l.; SI 74; low to moderate relief. High-gradient to steeply sloping very small streams (Fig. 12(*c*), 13(*d*)); DI 8. Mid-height and tall forest with irregular canopy, secondary vegetation with much old secondary forest. Water balance zone 10% 1, 30% 2, 60% 4. Interbedded siltstone, sandstone, conglomerate, at least partly calcareous. Orthic and eutric dystrochrepts, orthic typochrults sd; lithic dystrochrepts, lithic hapludents c. Population 620; II 12. Transitions to LS 39, 40, 51, 53. FI 23, AI 18. CI 4 (T 3, P 8). EI 36; USC CH, MH, CL.

(53) *Wuro* (Plate 25, Fig. 1).—Variably peaked sharp asymmetrical ridges, at 400–3500 ft a.s.l.; SI 77; high relief. Steep very small streams along strike, high-gradient rivers across strike (Fig. 13(*e*)); DI 8. Mid-height forest with irregular canopy. Water balance zone 4. Interbedded siltstone, sandstone, conglomerate. Orthic and eutric dystrochrepts sd; orthic typochrults, lithic dystrochrepts, lithic hapludents, lithic haplumbrepts c. Population 210; II 2. Transitions to LS 51, 52, 54. FI 29, AI 15. CI (2) (T (3), P (4)). EI 33; USC CH, MH, CL.

(54) *Imbia* (Plate 25, Fig. 2).—Even to slightly stepped sharp ridges with chevron spurs and frontal dip slope facets, altitude 800–3000 ft; SI 76; moderate relief. High-gradient rivers with gently to moderately steeply sloping tributary streamlets (Figs. 11(*b*), 13(*f*)); DI 8. Secondary vegetation, tall and mid-height forests with irregular canopy. Water balance zone 60% 1, 10% 2, 30% 4. Interbedded siltstone, mudstone, less sandstone, conglomerate. Eutric dystrochrepts, orthic hapludents sd; lithic dystrochrepts, lithic hapludents c. Population 1400; II 14. Transitions to LS 43, 51, 52, 53. FI 28, AI 16. CI (5) (T (5), P (9)). EI 29; USC CH, MH, CL.

(iv) *Ridges on Limestone*

(55) *Aitape* (Plate 26, Fig. 1).—Isolated or branching ridges with straight or convex slopes, altitude 0–500 ft; SI 59; very low to moderate relief. Few small gullies; DI 8. Tall forest with rather open small-crowned canopy, some secondary vegetation and plantation. Water balance zone 3. Limestone, andesitic conglomerate with calcareous matrix. Orthic rendolls pd; orthic dystrochrepts, rock outcrop c. Population nil; II 27. Transitions to LS 38, 39, 40. FI 43, AI 38. CI 11 (A 4, T 6, P 24). EI 7; USC MH.

(56) *Barida* (Plate 26, Fig. 2).—Mostly convex smooth, locally coarse-hummocky, ridges with local broad crests, dissected scarps, and foot slopes, altitude 220–2800 ft; SI 56; moderate to high relief. Few steep very small streams (Figs. 11(*d*), 13(*d*)); DI 8. Mid-height forest with even or irregular canopy, secondary vegetation. Water balance zone 30% 3, 70% 4. Limestone, commonly tuffaceous or argillaceous. Orthic and eutrochreptic rendolls sd; orthic typudalfs c. Population 130; II 3. Transitions to LS 45, 61. FI 36, AI 36. CI 13 (A 5, T 6, P 27). EI 11; USC MH dominant, CH subdominant.

(*g*) *Hills* and Mountains on Basement Rock*

(i) *Ridges on Igneous Rock Capped or Flanked by Sedimentary Rock*

(57) *Nopa* (Plate 27, Fig. 1).—Blocks of irregular slumped short ridges with long grooved or spurred marginal slopes, altitude 0–3200 ft; SI 65; mostly moderate relief. High-gradient to gently sloping small streams with rapids near margins (Fig. 14(*a*)); DI 8. Mid-height forest with irregular canopy, tall forest with rather open irregular canopy. Water balance zone 45% 3, 55% 4.

* Except those included in weathered surfaces of group (*e*).

Probably basic igneous rocks overlain by siltstone, mudstone. Orthic hapludents, eutric dystrochrepts sd; orthic and lithic dystrochrepts c. Population nil; II 1. Transitions to LS 40, 59. FI 47, AI 27. CI (5) (T (8), P (7)). EI 47; USC CH, MH, ML.

(58) *Sulen* (Plate 27, Fig. 2).—Slumped and grooved spurred ridges, at 250–6100 ft a.s.l.; SI 81; high relief. High-gradient rather large to steeply sloping very small streams (Fig. 14(*b*)); DI 8. Mid-height forests with even or irregular canopy, locally seral and with *Casuarina papuana.* Water balance zone 4. Sedimentary rocks (including metamorphosed fault-zone rocks such as brecciated hard mudstone, metagreywacke, metabasalt, crystalline limestone) flanking and capping basic to intermediate igneous rocks. Orthic and lithic dystrochrepts sd; orthic and mollic typudalfs c. Population 50; II 0. Transitions to LS 40, 43, 45, 59, 63. FI 22, AI 11. CI 2 (T 2, P 3). EI 36; USC CH, MH, CL.

(ii) *Ridges on Igneous Rock*

(59) *Wanabutu* (Plate 28, Fig. 1).—Narrow blocks of grooved or spurred commonly peaked ridges, at 30–2200 ft a.s.l.; SI 75; moderate relief. Moderately steep to steep very small streams and gullies (Figs. 10(*d*), 14(*d*)); DI 8. Mid-height forest with irregular canopy and seral stages, tall forest with rather open irregular canopy on lower parts. Water balance zone 40% 3, 60% 4. Probably basic igneous rocks. Orthic and lithic dystrochrepts, orthic typudalfs sd; orthic typochrults c. Population nil; II 0. Transitions to LS 40, 58, 60, 61, 62. FI 42, AI 17. CI (5) (T (8), P (6)). EI 47; USC CH, MH, CL.

(60) *Kumbusaki* (Plate 15, Fig. 2).—Finely spurred branching ridges, at 1100–2500 ft a.s.l.; SI 74; moderate relief. Many very gently to moderately sloping small streams (Fig. 14(*c*)); DI 8. Mid-height forests with irregular canopy, but with even canopy in summit areas; tall forest with irregular canopy with light-toned crowns at lower altitude. Water balance zone 4. Basic igneous rocks. Orthic dystrochrepts d; typic normargox sd; lithic dystrochrepts c. Population nil; II 0. Transitions to LS 59, 61, 62. FI 43, AI 18. CI 8 (A 5, T 10, P 10). EI 65; USC MH dominant, CH, CL subdominant.

(61) *Mup* (Plate 28, Fig. 2).—Protruding isolated hills and branching to parallel ridges, at 400–3700 ft a.s.l.; SI 87; moderate relief. Few steep gullies, or many very gently to moderately sloping very small streams (Fig. 13(*f*)); DI 8. Mainly mid-height forests with irregular canopy and seral stages, but with even canopy on summits. Water balance zone 4. Igneous rocks. Eutric dystrochrepts d; orthic and lithic hapludents c. Population nil; II 0. Transitions to LS 60, 63. FI 23, AI 5. CI (2) (T (3), P (4)). EI 35; USC CL dominant, MH subdominant.

(62) *Daum* (Plate 29, Fig. 1).—Asymmetrical, mostly even long ridges with grooved long slopes, broken scarps, and ravines, altitude 400–4100 ft; SI 73; high relief. Many gently sloping to moderately steep small streams (Fig. 14(*d*)); DI 8. Mid-height forests with even canopy and with irregular canopy and seral stages. Water balance zone 4. Probably igneous rock. Orthic and lithic dystrochrepts sd; orthic typochrults, typic normargox c. Population nil; II 0. Transitions to LS 58, 59, 60, 63. FI 7, AI 19. CI (5) (T (7), P (9)). EI 40; USC CL dominant, CH, MH subdominant.

(63) *Somoro* (Plate 29, Fig. 2).—Massive to spurred sharp ridges with long peaked crests and straight slopes with landslips, altitude 250–5400 ft; SI 87; high and locally very high relief. Rather few very gently sloping rather large to steeply sloping small streams (Fig. 14(*e*)); DI 8. Mid-height forests with even, but mostly with irregular, canopy and seral stages including *Casuarina papuana.* Water balance zone 4. Igneous rocks, mostly gabbro and granodiorite. Eutric dystrochrepts d; lithic hapludents sd; orthic dystrochrepts c. Population nil; II 0. Transitions to LS 58, 61. FI 2, AI 5. CI 0. EI 29; USC CL dominant, MH subdominant.

(iii) *Ridges on Metamorphic Rock*

(64) *Maio* (Plate 30, Fig. 1).—Finely branching ridge complexes and isolated grooved or spurred ridges, altitude 200–850 ft; SI 70; mostly low but variable relief. Very many low-gradient to gently sloping very small streams (Fig. 14(*f*)); DI 8. Mid-height forest with small-crowned even canopy, some secondary vegetation. Water balance zone 10% 1, 90% 2. Mica–quartz schist, some quartz-rich sandstone. Orthic dystrochrepts d; oxic dystrochrepts sd; lithic dystrochrepts c. Population 1960; II 4. Transitions to LS 34, 55, 60, 65. FI 33, AI 22. CI 9 (A 3, T 14, P 10, R 1). EI 61; USC MH dominant, CL subdominant.

(65) *Waskuk* (Plate 30, Fig. 2).—Spurred ridges with sharp stepped crests or very low hilly summit areas and with grooved to finely spurred slopes, altitude 180–1500 ft; SI 85; high and locally moderate relief. Gently to moderately steeply sloping small streams (Fig. 15(*a*)); DI 8. Mid-height forest with small-crowned even canopy, also secondary vegetation. Water balance zone 2. Mainly mica-schist and micaceous gneiss. Lithic dystrochrepts pd; orthic dystrochrepts c. Population 600; II 4. Transitions to LS 59, 62, 64. FI 31, AI 7. CI 1 (T 1, P 1). EI 23; USC CL dominant, MH, SC subdominant.

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PART IV. CLIMATE OF THE AITAPE–AMBUNTI AREA

By J. R. McAlpine*

I. Introduction

(a) Principal Climatic Features

The climate of the area falls within the Köppen (1931) tropical rain forest (*Af*) or Thornthwaite (1931) wet tropical (*AA'r*) type. However, considerable local variation within these types over small distances is a distinctive feature of the region. On the eastern inland plains and foothills mean monthly dry-season rainfall approaches the tropical savannah (*Aw*) or subhumid tropical (*CA'r*) types, as monthly rainfalls lower than 2·50 in. occur in 5 years out of 8. Near the summits of the main ranges mean monthly temperatures may fall low enough to approach the moist temperate or mesothermal types of higher latitudes.

(b) Climatic Records

The climate of the adjoining area to the east has previously been described by Arnold (1968). Climatic records longer than those used by Arnold were available for writing this report, and hence certain sections of the earlier data and findings have been extended or modified here. In this regard particular attention should be paid to Table 6 in Arnold's report and Table 10 in this. The large differences in the lengths of periods with water deficits for Bainyik which are revealed in the present analysis result chiefly from the different methods used here to calculate these periods.

The length and quality of the climatic records in the area are highly variable. Table 4 indicates both the number of years for which rainfall records have been kept and the number of years for which complete monthly data are available. Unfortunately, daily rainfall records are even less satisfactory than monthly records. At Ambunti an inspection of the distribution and amounts of pre-war daily rainfalls suggests considerable doubt as to their reliability, and for the post-war period daily data are available only from 1960 to 1966.

Records for other stations are more satisfactory, but cover too short a period to establish an adequate standard period for spatial comparisons. The standard period selected has been for the 12 years from 1955 to 1966 for Aitape, Lumi, and Bainyik. In the south the only suitable record available is for Yambi, between 1959 and 1966, and this has been adjusted where necessary to provide some comparison with the standard 12-yr period. The shortness of this standard period may be less of a handicap than might first appear since those stations possessing longer records are characterized by a fairly low annual variability in rainfall. For purposes of comparison Table 4 gives mean monthly rainfall for both the standard period and the full length of complete yearly records. Although the records for other climatic data are all very short (< 6 yr), the very low degree of monthly variability in such measures as temperature and relative humidity suggests that the results presented here are reasonably reliable.

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TABLE 4

MEAN MONTHLY AND ANNUAL RAINFALL (IN.) AND HIGHEST AND LOWEST ANNUAL RAINFALL FOR FULL PERIODS OF RECORDS AND FOR STANDARD 12-YR PERIOD FROM 1955 TO 1966

Station	Length of Record (yr)	Jan.	Feb.	Mar.	Apr.	May	June	July	Aug.	Sept.	Oct.	Nov.	Dec.	Annual	Highest Annual	Lowest Annual
Aitape	40 (27*)	9·88	10·17	11·66	10·19	8·02	7·19	7·08	6·00	5·18	6·66	8·00	10·75	100·78	126·36	73·76
(8 ft)	12	9·95	10·49	11·92	10·43	8·68	7·98	7·16	4·71	6·05	6·66	7·77	11·50	103·35		
Ambunti	25 (16)	10·04	9·56	12·63	9·75	7·11	4·98	5·72	6·00	7·02	8·48	9·09	10·07	100·48	117·40	62·55
(160 ft)	12	10·89	9·85	12·32	10·46	8·70	5·18	5·81	6·72	7·64	7·92	10·10	9·69	105·92		
Bainyik	17 (15)	6·30	6·65	7·77	7·12	4·18	3·29	3·11	3·80	4·59	5·92	6·88	6·18	65·79	83·06	50·86
(600 ft)	12	5·92	6·41	7·40	7·43	4·59	3·40	3·12	3·52	4·12	5·97	6·67	5·95	64·56		
Dreikikir (1250 ft)	8 (6)	6·99	5·94	8·35	7·21	4·63	2·97	2·90	4·55	4·60	5·28	7·86	5·65	66·93	75·56	51·00
Lumi	15 (13)	10·95	9·03	11·40	10·95	7·37	4·02	4·55	6·07	7·79	9·83	10·85	11·15	103·96	121·89	91·99
(1750 ft)	12	10·72	9·06	12·13	10·43	7·18	4·56	4·50	5·88	7·56	9·80	10·35	11·65	103·87		
Maprik (600 ft)	8 (8)	6·79	6·72	8·30	7·95	4·44	4·08	3·11	3·47	4·56	5·96	5·69	7·79	68·79	86·89	61·32
Nuku (1100 ft)	8 (6)	8·75	6·97	10·09	7·29	5·03	3·69	4·73	4·15	6·36	5·80	8·34	10·14	81·34	107·45	67·98
Yambi (150 ft)	8 (8)	7·54	5·88	8·36	10·53	6·59	4·64	3·41	5·74	5·88	7·18	7·07	7·37	80·20	92·19	70·32
Yellow River (1100 ft)	4 (3)	16·99	11·59	13·78	6·96	9·75	7·03	5·94	6·28	9·74	10·48	13·99	14·04	126·58	130·25	120·51

* Figure in parentheses indicates the number of years with complete records.

(c) *Climatic Controls*

The discussion of climatic controls presented here is based on that of Brookfield and Hart (1966) and of Fitzpatrick, Hart, and Brookfield (1966). Throughout lowland New Guinea the major climatic controls are those of the seasonal latitudinal movements of two major air masses separated by a discontinuous intertropical convergence zone (ITCZ). The controls consist of a perturbation belt of westerly-moving vortical circulations to the north and the south-east trade wind belt to the south. The south-east trades, which dominate from May to mid October, consist of essentially shallow surface air masses overlain by dry zonal easterlies. Upper wind data for Lae indicate that the air masses of the perturbation belt that dominates the weather from December to March extend to much higher altitudes. Thus, in general, the zonal easterly and south-east trade air masses tend to have a lower capacity to produce heavy sustained rainfall than those of the perturbation belt, except where very strong orographic influences occur. This latter belt was referred to in previous literature as the north-west season. Mean monthly surface wind data for Wewak indicate that during the south-east season winds are lighter and less variable in direction than during the north-west season.

The effectiveness and dominance of these overall controls are modified by the presence of local circulations in relation to topography, particularly during the south-east season. Precipitation associated with the perturbation belt is typically high and uniformly widespread with some slight decline on the inland foothills and plains compared with the coast and ranges. This may possibly result from the sheltering effect of the Torricelli Mountains, although the fact that the inland plains have higher rainfall than the hill zone during the perturbation belt season remains anomalous. During the south-east trade wind season the plains and nearby foothills are relatively dry. This may result from the protection afforded by the presence and alignment of topographic barriers to the south-east and from the lack of any sufficiently large orographic features in the area, except the Torricellis, to induce rainfall. Or, as suggested by Brookfield and Hart (1966), this drier inland area may also be caused by the dominance of local circulations such as "dry descending foehn-like winds" during the south-east season.

This short and highly generalized discussion of climatic controls is of necessity largely speculative and cannot explain what appears to be a major climatic anomaly, namely that the general rainfall gradient is east–west along the physiographic trend rather than north–south across it (see altitude map).

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 complete yearly records and for the standard period in Table 4. Their spatial distribution is indicated by means of histograms in Figure 2 in Part II. Mean annual rainfall is least in the east and highest in the west on the coast, inland foothills, and plains. In the east, Bainyik on the periphery of the foothill zone has 66 in. per annum while Yambi on the plains has 80 in. Lumi to the west of

Bainyik has 104 in. and Yellow River to the west of Yambi has 126 in. Aitape on the coast has 101 in. per annum. While there are no climatic data for the Torricelli Mountains, this range may provide an orographic effect which produces somewhat

TABLE 5

AVERAGE NUMBER OF OCCURRENCES PER QUARTER OF RAIN DAYS WITH RAINFALL WITHIN SPECIFIED LIMITS (1955–66)

Station and Amount (in.)	Jan.–Mar.	Apr.–June	July–Sept.	Oct.–Dec.
Aitape				
0·01–0·24	30	28	26	27
0·25–0·99	17	13	13	15
1·00–1·99	7	5	3	5
2·00–3·99	3	2	2	2
4·00–5·99	0·5	0·5	0·1	0·2
⩾6·00	0·2	0·3	0	0
Bainyik				
0·01–0·24	23	16	12	16
0·25–0·99	18	12	11	13
1·00–1·99	5	4	3	4
2·00–3·99	0·5	0·3	0·2	0·7
4·00–5·99	0	0	0	0·1
⩾6·00	0	0	0	0
Lumi				
0·01–0·24	34	34	32	30
0·25–0·99	26	18	16	21
1·00–1·99	6	4	3	8
2·00–3·99	2	0·8	0·7	2
4·00–5·99	0·1	0·2	0·1	0·2
⩾6·00	0	0	0	0
Yambi (1959–66)				
0·01–0·24	25	27	21	22
0·25–0·99	16	11	9	12
1·00–1·99	5	3	3	3
2·00–3·99	0·7	2	0·7	2
4·00–5·99	0·1	0·2	0	0
⩾6·00	0	0	0	0

higher precipitation on and near it. However, this effect of increased rainfall with altitude, which might be assumed from findings elsewhere in the humid tropics (Beckinsdale 1957), has not yet been clearly demonstrated in New Guinea.

Fitzpatrick, Hart, and Brookfield (1966) discuss rainfall seasonality in the whole south-west Pacific region. Within this particular area of that region the degree of rainfall seasonality, as expressed by mean conditions, varies little between stations. Wet-season monthly falls are between two and three times greater than dry-season falls for all stations except Aitape which shows a less marked seasonality.

TABLE 6

AVERAGE AND MAXIMUM LENGTH OF RAINY AND RAINLESS PERIODS AND AVERAGE NUMBER OF RAINY* AND RAINLESS DAYS PER QUARTER (1955–66)

Station and Quarter	Rainy Period Average (days)	Rainy Period Maximum (days)	Av. No. Rain Days	Rainless Period Average (days)	Rainless Period Maximum (days)	Av. No. Rainless Days
Aitape						
Jan.–Mar.	3·0	6	58	1·8	10	33
Apr.–June	2·4	14	48	2·4	10	43
July–Sept.	2·1	8	44	2·6	14	48
Oct.–Dec.	2·4	15	49	2·2	10	42
Bainyik						
Jan.–Mar.	2·1	13	43	2·2	12	45
Apr.–June	1·7	11	33	3·2	20	58
July–Sept.	1·4	6	26	3·9	35	66
Oct.–Dec.	1·8	13	34	3·0	34	57
Lumi						
Jan.–Mar.	4·4	25	69	1·6	6	22
Apr.–June	3·1	14	58	1·9	9	33
July–Sept.	2·5	16	53	2·1	11	39
Oct.–Dec.	3·1	16	63	1·7	11	29
Yambi (1959–66)						
Jan.–Mar.	2·5	17	53	1·9	10	38
Apr.–June	2·1	20	49	2·3	33	42
July–Sept.	1·9	7	38	3·0	25	54
Oct.–Dec.	1·8	11	44	2·2	9	47

* Rain day $\geqslant 0 \cdot 01$ in.

The variability of annual rainfall (expressed by the standard deviation as a percentage of the mean) is 8% at Lumi and Ambunti, 11% at Aitape, and 13% at Bainyik. A comparison of the full length of record with the standard period variability reveals that annual variability increases from 11 to 23% for the long term at Aitape and from 8 to 14% at Ambunti. Generally dry-season monthly variability averages about 45% at all stations and in the wet season it varies from 30% at Lumi to 45% at Ambunti.

No direct measure of rainfall intensity is available. Table 5 presents the number of occurrences of rain days with rainfalls within specified intervals for the standard period. Aitape has a significantly greater frequency of daily falls of 2 in. and more and is the only station to record daily falls of over 6 in. Lumi has a greater number of falls of over 2 in. per day than Bainyik, while Yambi compared with Bainyik has a greater preponderance of light falls under 0·25 in. An analysis of these results by seasons indicates that for all stations except Yambi the frequency of daily falls of 2 in. and over is greatest in the wet season, although this tendency does not appear to be as marked as in other areas of New Guinea. A comparison of the standard period with the long-term records for this rainfall characteristic shows little difference between stations except at Aitape, where for the long term the number of occurrences of falls under 0·25 in. decreases in all quarters by about 10%.

TABLE 7

AVERAGE NUMBER OF OCCURRENCES AND DURATION OF WET AND DRY SPELLS OF WEATHER BY SEASONS (1955–66)

Station and Season*	Dry Spells Duration (weeks)							Wet Spells Duration (weeks)				
	1	2	3	4	5	6	≥7	1–4	5–8	9–12	13–16	>16
Aitape												
Dry season	4	1	0·2	0·3	0·2	—	0·1	6	0·6	—	0·1	—
Wet season	3	1	0·4	0·2	—	—	—	3	0·7	0·7	0·1	—
Bainyik												
Dry season	3	2	1	0·2	0·2	0·2	0·1	6	0·2	—	—	—
Wet season	3	1	0·5	0·1	0·1	0·1	—	4	0·7	0·3	—	—
Lumi												
Dry season	3	0·7	0·5	0·1	0·1	0·2	—	3	0·7	0·2	0·3	—
Wet season	2	0·2	0·1	—	—	—	—	1	0·6	0·2	0·2	0·3
Yambi (1959–66)												
Dry season	3	1	0·4	0·7	0·1	0·1	0·1	4	0·4	—	—	—
Wet season	3	1	0·6	0·3	—	—	—	4	0·6	0·3	—	0·1

* Dry season Apr. 22–Oct. 22; wet season Oct. 23–Apr. 21.

While Table 5 already gives some impression of the relatively rainy nature of the climate, this is shown more clearly in Table 6 which gives, for the standard period, the average and maximum length of rainy and rainless periods as well as the average number of rain days within 3-month intervals. The considerably rainier nature of Lumi compared with other stations in both wet and dry seasons is well illustrated, as is the drier nature of Bainyik. Aitape possesses characteristics midway between these two types, and as in Table 5 Yambi occupies an anomalous position showing little difference between wet and dry seasons. The long-term record for Aitape is little different in these respects except that the longest rainless period observed almost doubles in each quarter.

A better indication of the frequency and duration of wet and dry spells of weather is given in Table 7. A wet spell is here defined as the number of consecutive weeks in which rainfall exceeds estimated evapotranspiration, and a dry spell as the number of consecutive weeks in which evapotranspiration exceeds rainfall. These

TABLE 8

TEMPERATURE CHARACTERISTICS (°F)

	Jan.	Feb.	Mar.	Apr.	May	June	July	Aug.	Sept.	Oct.	Nov.	Dec.	Annual
					Aitape								
Mean maximum	85·4	85·0	85·2	86·2	87·4	85·9	85·4	85·7	85·8	86·1	86·1	85·2	85·8
Mean	79·5	79·3	79·5	80·0	80·6	79·5	79·1	79·2	79·3	79·6	79·8	79·4	79·6
Mean minimum	73·6	73·6	73·8	73·9	73·9	73·1	72·7	72·8	72·9	73·2	73·4	73·6	73·4
Highest maximum	89·8	89·2	90·2	99·0	96·1	88·7	90·0	90·0	89·0	89·9	91·8	86·6	
Lowest minimum	70·4	70·4	70·0	69·0	70·8	68·5	69·2	69·8	70·0	70·3	69·0	69·3	
					Ambunti								
Mean maximum	91·2	88·9	87·9	88·8	88·8	88·2	87·8	87·3	88·9	89·4	88·9	94·3	89·2
Mean	82·0	81·1	80·2	81·2	81·1	80·5	80·3	80·1	81·1	81·3	80·7	81·6	80·9
Mean minimum	72·7	73·3	72·6	73·7	73·5	72·8	72·8	72·9	73·4	73·3	72·6	69·0	72·7
Highest maximum	98·1	91·6	90·5	91·2	91·3	90·8	90·2	90·2	91·3	92·4	97·1	99·1	
Lowest minimum	70·9	69·8	70·9	70·9	71·2	70·3	66·3	69·9	70·3	70·1	70·1	64·1	
					Maprik								
Mean maximum	86·7	85·9	86·2	87·0	86·5	85·3	84·4	83·7	85·6	84·2	86·4	87·2	85·8
Mean	79·2	78·8	79·1	79·6	79·2	78·6	77·6	77·7	78·1	77·4	78·6	79·2	78·8
Mean minimum	71·7	71·6	72·0	72·2	72·3	71·8	70·8	71·7	70·6	70·7	70·8	71·1	71·9
					Lumi								
Mean maximum	82·0	81·5	81·4	81·2	81·6	80·5	80·4	81·0	81·3	82·0	82·3	81·6	81·4
Mean	75·4	75·1	75·1	75·0	75·3	74·3	74·0	74·2	74·5	75·0	75·4	75·3	74·9
Mean minimum	68·8	68·7	68·8	68·8	69·0	68·1	67·5	67·5	67·7	67·9	68·4	69·0	68·4
Highest maximum	89·4	89·8	86·6	86·3	88·4	90·3	86·8	77·2	89·7	89·0	89·7	96·8	
Lowest minimum	64·6	53·0	64·6	64·7	65·0	63·1	61·9	60·4	62·9	54·0	64·0	60·0	

spells have been calculated by the application of the water balance model described in Section III. The results have been arranged in 6-monthly periods to provide a comparison between wet and dry seasons. Where a spell of weather has carried through from one period to the other it has been included in that season in which the longest sector of it occurred. During the wet season wet spells are of considerably shorter duration at Yambi and Bainyik than at Aitape or Lumi, where wet spells of over one month's duration are more common than those under one month. Conversely, dry spells are fairly frequent at Bainyik and Yambi during the wet season. During the dry season these regional differences are not as marked; the frequency and length of dry spells are greater at Bainyik than elsewhere, but not markedly so; Aitape has somewhat longer wet spells in this season than other stations, but again not markedly so.

(*b*) *Temperature*

Table 8 indicates the restricted range of mean monthly and other temperature characteristics. As shown by data for Aitape, the coastal zone has a mean annual temperature of 80°F and a mean maximum of 86°F; inland (e.g. Ambunti) the corresponding figures are 81°F and 89°F. At Maprik, 600 ft above sea level, mean temperature is 79°F, and at Lumi, 1750 ft above sea level, it is 75°F, thus indicating an approximate overall decrease in mean temperature of 3 degF per 1000 ft. This mean lapse rate is similar to that found in other mountainous areas in New Guinea.

The average diurnal range varies from 12 to 16 degF (lowest at Aitape, highest at Ambunti) and is considerably greater than the annual range of mean monthly temperature which varies by less than 2 degF. The highest maximum and lowest minimum temperatures on record are also given and these vary by 10–15 degF around the mean range.

(*c*) *Other Climatic Characteristics*

Mean monthly relative humidity for 0900 and 1500 hours, together with estimates of evaporation, are given in Table 9. 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 nearly saturated. Morning fogs are frequent and these occasionally persist until mid morning along valley bottoms. Mean monthly dew point temperatures range only from 2 to 3 degF above mean monthly minimum temperatures. 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 ranges from 49 to 59 in. and shows only slight seasonal variation. These estimates indicate that annual evaporation is 6 in. higher inland than on the coast and that it is 4 in. lower at Lumi (1750 ft above sea level) than at sea level.

Records of amount of cloud are available only for Aitape and Lumi. As the mean monthly figures vary insignificantly through the year they are not tabulated. At both Aitape and Lumi average total cloud cover at 0900 and 1500 hr is 6/8. Low cloud cover varies at Aitape from 2/8 at 0900 hr to 3/8 at 1500 hr and remains constant at 4/8 at Lumi for both these times.

TABLE 9

MEAN MONTHLY RELATIVE HUMIDITY AND EVAPORATION

	Jan.	Feb.	Mar.	Apr.	May	June	July	Aug.	Sept.	Oct.	Nov.	Dec.	Annual
					Aitape								
Relative humidity—0900 hr (%)	91	93	92	91	88	94	95	93	90	89	90	90	—
1500 hr (%)	79	81	79	81	80	76	80	81	80	77	80	82	—
Evaporation (in.)	4·6	3·8	4·3	4·4	5·0	4·0	4·5	4·6	4·6	4·7	4·4	4·3	53·2
					Ambunti								
Relative humidity—0900 hr (%)	91	90	93	90	87	90	91	91	88	88	88	90	—
1500 hr (%)	79	78	78	78	75	78	75	75	75	75	78	79	—
Evaporation (in.)	5·7	5·1	4·4	4·6	5·0	4·7	4·9	5·0	4·9	5·2	5·0	5·3	59·8
					Maprik*								
Relative humidity—0900 hr (%)	90	95	95	88	91	98	88	94	93	88	89	89	
Evaporation (in.)	5·1	3·9	4·5	4·6	4·4	3·9	3·8	3·2	3·8	4·2	4·8	5·3	51·5
					Lumi								
Relative humidity—0900 hr (%)	87	90	90	90	92	90	91	90	89	88	87	88	
1500 hr (%)	79	80	78	79	79	79	76	80	80	78	77	80	
Evaporation (in.)	4·6	3·9	4·1	3·8	4·0	3·6	3·9	4·1	4·1	4·6	4·5	4·1	49·3

* Very limited records.

III. Water Balance and Plant Growth

The interactions between rainfall, evapotranspiration, soil water storage, and run-off and infiltration considered here are based on a water balance model similar to that developed by Slatyer (1960). The model is designed to give estimates of week-to-week changes in available soil water, and these have been obtained through computer processing using estimated evapotranspirational withdrawals and weekly rainfall inputs. The assumptions in applying the model are that actual evapotranspiration (*ET*) is related to estimated evaporation from a standard tank evaporimeter (Fitzpatrick 1963) by the relationship $ET = 0 \cdot 8E$ (est.) for those weeks with storage plus rainfall exceeding 2·50 in. and by $ET = 0 \cdot 4E$ (est.) below this level.

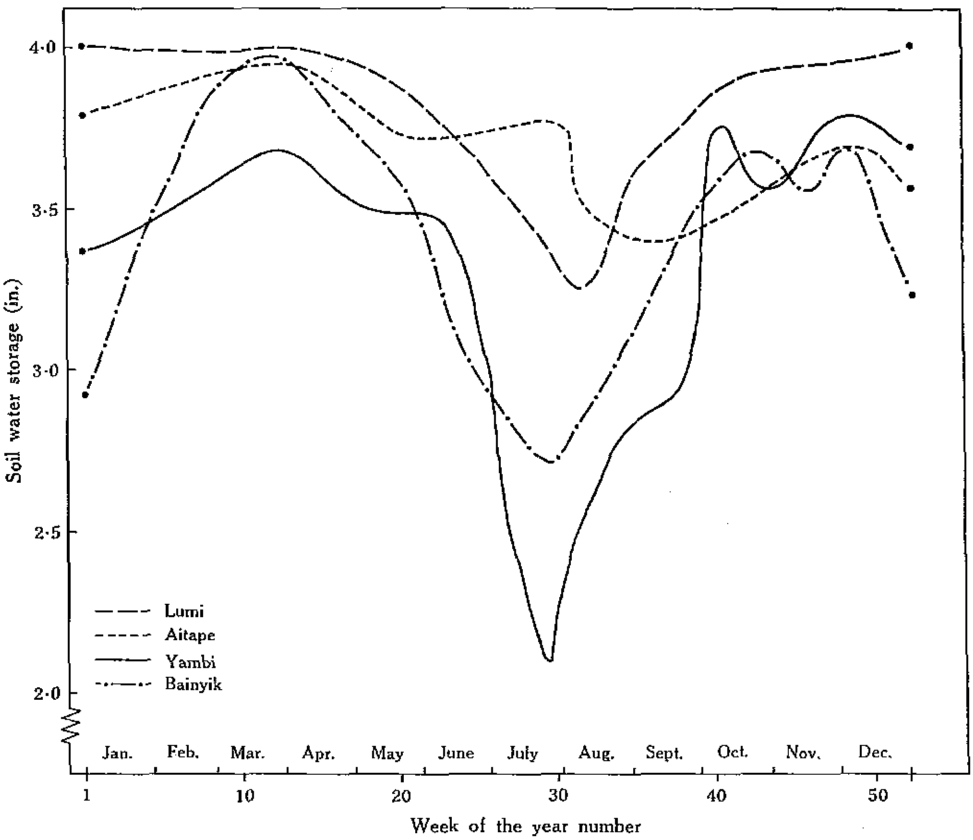

Fig. 16.—Average weekly soil water storage at four stations.

The model may tend to underestimate evapotranspiration losses when the upper parts of an otherwise dry soil profile receive rains less than 2·50 in. and overestimate them during weeks without rainfall when stored soil water in the upper profiles is nearing depletion. However, these variations are not likely to introduce large errors in a general assessment over a number of years. Soil water storage capacity is assumed to be 4·00 in. and the appropriateness of this assumption may be checked against a map (available upon request) showing estimated available soil water storage capacity. Run-off is assumed to occur only when this soil water storage is filled. This model, using weekly data, has been applied to obtain an evaluation of the differences in soil water regimes within the area which are not apparent from a more general examination based on mean monthly rainfall and evaporation data.

TABLE 10

AVERAGE, MAXIMUM, AND MINIMUM NUMBER OF WEEKS PER SEASON WITH SOIL WATER STORAGE WITHIN SPECIFIED LIMITS OF DEPLETION (1955–66)

Station and Storage Levels	Wet Season (Oct. 23–Apr. 21)			Dry Season (Apr. 22–Oct. 22)		
	Av.	Max.	Min.	Av.	Max.	Min.
Aitape						
Full	18	22	15	14	23	7
1–49% depleted	8	4	11	12	3	16
50–99% depleted	0	0	0	0	0	3
Empty	0	0	0	0	0	0
Bainyik						
Full	12	18	7	7	13	3
1–49% depleted	13	8	15	17	13	14
50–99% depleted	1	0	4	2	0	9
Empty	0	0	0	0	0	0
Lumi						
Full	23	26	19	15	21	4
1–49% depleted	3	0	7	11	5	21
50–99% depleted	0	0	0	0	0	1
Empty	0	0	0	0	0	0
Yambi (1959–66)						
Full	13	18	4	10	18	4
1–49% depleted	11	8	12	12	8	15
50–99% depleted	2	0	10	3	0	7
Empty	0	0	0	0	0	0

The weekly changes in soil water level indicated by the application of this model have been averaged for the standard period and the results illustrated in Figure 16. This clearly indicates that although the degree of seasonality of rainfall is similar throughout the area, the lower absolute amounts of rainfall in the east, compared with the west and the coast, have a relatively pronounced effect on the soil water storage term of the water balance. These curves represent only average weekly conditions and do not in themselves portray the risk of serious soil water deficits that might influence plant growth and production. A measure of such risk is revealed in Table 10 showing the mean number of weeks per season for the standard period in which soil moisture was depleted to specified limits. The table also gives a range indicating the greatest and least number of weeks in any season for which the specified soil moisture depletion level occurred.

It can be seen that although Lumi has a higher average soil water depletion in the dry season than Aitape, as indicated in Figure 16, in effect the distribution of these weekly deficits is similar. At both these stations the probability that soil water depletion beyond 50% will occur is low and if it did it would be only for short periods. The mean conditions at Yambi and Bainyik are fairly similar but the chance of serious wet-season depletion at Yambi is somewhat greater.

These results and the shorter records for Ambunti, Dreikikir, Nuku, and Yellow River have been used, together with vegetation patterns, to construct a tentative water balance map of the area (Fig. 2, Part II). Four water balance zones have been distinguished. The correlation of these with vegetation is discussed in Part V and with soils in Part VI of this report.

TABLE 11

AVERAGE NUMBER OF WEEKS PER SEASON* WITH WATER SURPLUS WITHIN SPECIFIED LIMITS, AND MEAN ANNUAL WATER SURPLUS (1955–66)

Station and Season	Number of Weeks with Water Surplus of					Mean Annual Water Surplus (in.)
	Nil	0·01–2·99 in.	3·00–5·99 in.	6·00–8·99 in.	≥9·00 in.	
Aitape						
Wet season	8·5	12·4	4·0	0·9	0·2	60
Dry season	13·0	11·2	1·4	0·3	0	
Bainyik						
Wet season	13·6	11·8	0·6	0	0	21
Dry season	19·3	6·7	0	0	0	
Lumi						
Wet season	3·2	17·9	4·6	0·3	0	63
Dry season	11·6	12·9	1·3	0·1	0·1	
Yambi (1959–66)						
Wet season	13·1	11·2	1·4	0·2	0	31
Dry season	15·9	9·1	1·0	0	0	

* Wet season Oct. 23–Apr. 21; dry season Apr. 22–Oct. 22.

The Dreikikir, Bainyik, and Yambi area (zone 1) is one in which soil water depletion beyond 50% occurs for a significant period during most dry seasons and may even occur during the wet season. To the west, at Lumi and Yellow River (zone 2), the regime is one in which soil water depletion beyond 50% in the dry season is not significant and any depletion at all during the wet season is unusual. On the boundary of these western and eastern inland regimes a transition indicated by Nuku and Ambunti occurs. Here the dry-season regime appears similar to that at Lumi yet in the wet season it is similar to that at Yambi. The coastal regime (zone 3), as indicated by Aitape, is similar to that of Lumi during the dry season but in the wet season soil moisture depletions of up to 50% are fairly common. No climatic data exist for the Torricelli Mountains but it is likely that any soil moisture deficit is rare and hence it is mapped separately as zone 4.

After evapotranspirational and soil water demands have been met in the water balance model, excess precipitation becomes water surplus. This surplus may be considered as an approximation of run-off and deep percolation. Table 11 gives the average number of weekly occurrences of water surplus per season within specified classes. Both the frequency and magnitude of these surpluses are greater at Aitape and Lumi than at Bainyik or Yambi and hence accord with the water balance regimes mentioned above. Mean annual water surplus is also given in Table 11, and at Lumi and Aitape it is three times greater than at Bainyik. The shorter records of Nuku and Ambunti indicate an east–west transitional increase in annual surpluses.

IV. Acknowledgments

Climatic data were provided by the Commonwealth Meteorological Bureau, and Mrs. A. Komarowski helped process and tabulate these data.

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PART V. VEGETATION AND ECOLOGY OF THE AITAPE–AMBUNTI AREA

By P. C. HEYLIGERS*

I. INTRODUCTION

Variations in structure, tone, and texture were the main criteria used to distinguish vegetation types on the 1:50,000 scale aerial photographs. The major groups of vegetation types identified during the survey of the Port Moresby–Kairuku area in 1962 (Heyligers 1965) were adhered to, but in differentiating between vegetation types greater emphasis was placed on structural characteristics than hitherto. The symbols used to characterize the vegetation types are explained in Appendix I, Section II(*d*).

The preliminary photo interpretation was checked by observations on the ground and by helicopter, after which the mapping was amended. The nature of the errors in the preliminary mapping is discussed elsewhere (Heyligers 1968). Fifty-one vegetation types were distinguished, but it should be pointed out that there is considerable variation in hierarchical status between the types. Some types are rather broad owing to the lack of distinctive photo characteristics, e.g. most of the mid-height grassland communities could not be mapped out consistently and therefore appear as a single type on the map. On the other hand, species recognition, e.g. of *Campnosperma* or *Saccharum*, made it possible to define other types fairly closely.

On the vegetation map at scale of 1:250,000 it was not always possible to map the types separately. In complex mapping units the types are put in order of their importance, but where secondary vegetation occurs in mosaic with the original vegetation the latter is put first, even when only patches of it remain. In many areas secondary vegetation has been mapped as a range of types, for instance R-FRy means gardens, possibly plantations, and secondary vegetation usually not developed further than young secondary forest.

II. DESCRIPTION OF VEGETATION TYPES

The vegetation types are described starting with the most complex, tall forest, and working down the scale to mixed herbaceous vegetation. The secondary vegetation types are then dealt with. Some of the terms used in the descriptions are explained in Appendix I, and a table listing structural features of the vegetation which may be of interest from the engineering point of view is available on request.† The descriptions follow this pattern: 1, photo-image characteristics; 2, field observations relating to this; 3, other observations, given *in extenso* for some types only, and briefly for the rest, as comparative or differential descriptions; 4, habitat and distribution.

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(*a*) *Tall Forest*

Tall forest has a canopy over 100 ft high and a well-developed storey of subcanopy trees. It is usually called "rain forest". The description of tall forest with a rather open canopy is taken as the standard for the description of the tall forest group. Tall forest covers one-third of the survey area.

(i) *Tall Forest with a Rather Open Canopy* (Fo; 18 observations; Plate 7, Fig. 2; Plate 8, Fig. 2; Plate 10, Fig. 1; Plate 30, Fig. 2).—The crowns form a rather even-textured photo pattern of mid-grey tones with occasional lighter tones. Height variations in the canopy tend to be regular. Crowns are relatively widely and evenly spaced and have a large size range.

Ground observations gave canopy cover values between 15 and 50%, with 30% as average. Height varies between 100 and 120 ft, and averages 110 ft. Taller trees usually occur and protrude 20–30 ft above the canopy. Since their crown is seldom completely above the canopy, they are not often true emergents. Subcanopy trees are rather closely or closely spaced, their crown cover varies between 30 and 60%, averaging 45%, and tends to be inversely related to the canopy cover although some notable exceptions were seen where both canopy and subcanopy cover were small, 20% and 30% respectively. The trees have straight boles, except for some low-branching specimens of *Vitex* and *Ficus*, and normally all size classes are represented. In some cases, however, trees of moderate girth were uncommon. Occasionally, and mainly north of the Torricelli Mountains, some trees are slanted which may be fortuitous or related to high winds or earthquakes (see mid-height forest with an irregular canopy). Buttresses are common, medium, high, and often very high, reaching 6 ft or more from the base. Stilt roots are sometimes encountered, as for instance on *Myristica* and some *Pandanus* species. Species composition is diverse and always very mixed. The more commonly found genera are *Canarium, Celtis, Cryptocarya, Dracontomelum, Dysoxylum, Ficus, Homalium, Intsia, Myristica, Neonauclea, Parartocarpus, Pimelodendron, Polyalthia, Pometia, Syzygium, Sterculia, Teijsmanniodendron, Terminalia*, and *Vitex*. Occasionally deciduous trees were seen, probably those with the lighter-toned crowns on the air photos. They belonged to the following genera: *Anisoptera, Bombax, Garuga, Intsia, Nauclea, Planchonia*, and *Terminalia*.

The shrub layer, up to about 15 ft high, is normally rather dense, occasionally scattered; its cover varies between 5 and 35%, averaging 20%. Palms, often young rattans, are prominent among the saplings and undergrowth trees. Visibility has been rated as moderate to poor.

The herb cover is usually very sparse, often less than 1%. Together with seedlings, grasses (e.g. *Lepidaspis*), ferns, and *Selaginella* may be found. Gingers and Marantaceae are commonly found north of the ranges but seem to be rarer in the Sepik area.

Lianes are rather common, common, or very common and are of the thick woody and thin woody types, the latter including rattan, usually common and of several species.

Epiphytes and epiphytic climbers are common or very common. Common amongst them are ferns (*Lomariopsis*), aroids (*Scindapsis*), and climbing pandans (*Freycinetia*).

Palms are always conspicuous and belong to many species. In the canopy and lower tree layers they are usually present or rather common. The genera identified are *Ptychosperma*, *Hydrastele*, *Caryota*, *Licuala*, and probably *Livistona*, but most of the palms, even the more common, are identified only by their indigenous name (Amele dialect), e.g. "siliki", "aguris", "hehek", "berem". In the shrub layer palms are rather common to abundant. Young rattans are always present and often common; *Licuala* with its conspicuous palmate leaves is usually represented by one or more species and is sometimes common. Another striking small tree palm is "kabibi", which grows in clusters and has very irregularly split leaves.

There are fewer pandans than palms; they are usually limited to shrub and herb layers, are not always present, and are only occasionally rather common.

Tree ferns are seldom encountered and are either *Angiopteris* or *Marattia.*

Tall forest with a rather open canopy is found in the plains, and observations indicate that it occupies the better-drained parts which are not flooded or infrequently flooded. North of the ranges this type covers 115 sq miles and is diagnostic of Pes (17) land system. In the Sepik plains, where it covers 235 sq miles, it is diagnostic of Nagam (16) land system.

(ii) *Tall Forest with a Rather Open, Irregular Canopy* Foi; (7 observations; Plate 18; Plate 27, Fig. 1; Plate 28, Fig. 1).—This forest type resembles tall forest with a rather open canopy (Fo). The differences in the photo image are the irregular variations in height of the canopy which are partly caused by some clustering of the tallest trees. The height and cover of canopy, subcanopy, shrubs, and herbs are much the same as for the Fo type, as are many of the other features. In the shrub layer, however, young rattans are seldom common, and in the subcanopy layer pandans are sometimes found. Epiphytic mosses are often common on the lower parts of trunks and on shrubs, especially near the Torricelli Mountains. The climbing tree fern *Cyathea biformis* is also found there.

Tall forest with a rather open irregular canopy is found north of the ranges, mainly on remnant fan surfaces and adjacent hill slopes. About one-third of its 110 sq miles lies within Paiawa (24) land system, another one-third is about equally divided over Panakatan (25), Morumu (39), and Yassip (38) land systems. The rest occurs scattered over nine other land systems.

(iii) *Tall Forest with a Rather Open and Small-crowned Canopy* (Fos; 4 observations; Plate 11, Fig. 1; Plate 26, Fig. 1).—The photo image is much like 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 smaller girth classes were rather strongly represented.

Palms are rare or absent in the tree layers and rare to rather common in the shrub layer. In other features it resembles tall forest with a rather open and irregular canopy (Foi).

Tall forest with a rather open and small-crowned canopy is most commonly found on the undissected fan surfaces; of the 35 sq miles under this forest type 50% lies in Paiawa (24) land system, 30% in Aiome (23) land system, and 6% in Panakatan (25) land system. The remaining 14% is found in Aitape (55) and Morumu (39) land systems.

(iv) *Tall Forest with a Rather Open Canopy with Groups of Woolly-textured Crowns* (Fow).—The main difference in photo image between this type and tall forest with a rather open canopy (Fo) is evident from the name. From the air it was observed that these woolly-textured crowns, which can be very light-toned on the photographs, are *Terminalia*. No ground observations were made.

This forest type seems to occur on more stabilized parts of flood-outs and its occurrences have been mapped as part of Yilui (13) land system. The total area amounts to 11 sq miles.

(v) *Tall Forest with an Open Canopy with Light-toned Crowns* (Fod; 7 observations; Plate 6, Fig. 1; Plate 9, Fig. 1).—The photo image of this type shows many more light-toned crowns than in tall forest with a rather open canopy (Fo). It is assumed that these light-toned crowns are of trees with young leaves or flowers. This does not necessarily mean that these trees shed their leaves before flushing. When pictures taken at different seasons are compared it appears that at least part of these trees keeps the light tone all year round. Therefore other characters, e.g. position of leaves with respect to angle of illumination, could be involved as well. Species that have light-toned crowns are probably among *Terminalia*, *Elaeocarpus*, *Pterocymbium*, *Maniltoa*, *Nauclea*, *Intsia*, *Planchonia*, and *Sterculia*.

The canopy tends to be more open than in the Fo type. Ground observations gave cover values for the canopy between 15 and 25%, averaging 20%, and for the subcanopy between 10 and 60%, averaging 35%. Because of these more open tree layers, the shrub layer and mainly the herb layer are denser than in the Fo type, averaging 25 and 5% respectively. However, the herb cover varies greatly and in the lightest spots a cover of 100% can be attained by *Cyclosorus* ferns. Mature as well as young rattan is always common, and *Stenochlaena* fern is commonly found climbing on trees. Other features are much the same as those of the Fo type.

The total area covered by tall forest with an open canopy with light-toned crowns is about 90 sq miles and comprises the scrolls of the Sepik River (Palimbai (11) land system) and the levees and terraces of its tributaries (Screw (18) land system). Flooding varies from occasional to 1·5 ft for two months per year.

(vi) *Tall Forest with an Open Canopy and with Sago Palms in the Understorey* (FoM; 5 observations; Plate 7, Fig. 2; Plate 8, Fig. 1).—In comparison with tall forest with a rather open canopy (Fo) the texture of the photo image is rather uneven, due to the irregularity in spacing between the crowns which tend to be further apart and generally somewhat smaller. On some large-scale aerial photographs of an area south of Tadji airstrip near Aitape sago could be detected in the understorey, hence this type was called FoM, the M standing for *Metroxylon*, the genus to which the sago palm belongs.

Ground observations brought out more differences between this and the Fo type: height is generally lower, emergent trees are on the average 112 ft, at best 120 ft, canopy trees 100 ft, varying between 90 and 115 ft, cover is generally less and more variable; values ranged from 5 to 60%, averaging 25%, for the canopy and from 20 to 60%, averaging 35%, for the subcanopy layer.

Lianas are always very common, most of them being rattans of several kinds. Epiphytes are common or very common throughout and find a very suitable substrate in the crowns and trunks of the sago palms. *Stenochlaena* is always present and often common. Palms are rather common in the subcanopy tree layer, to which not only maturing sago palms penetrate, but also "aguris", "lio", *Areca, Licuala, Caryota,* and *Arenga.* Sago is usually present in the shrub layer and tends to be more common if the forest is lower and the canopy and subcanopy are more open. Other palms present are young rattans and often young specimens of those mentioned for the tree layer. Pandans are normally absent or rare, occasionally they are present in the shrub as well as the tree layers. In other characteristics this forest type has much in common with tall forest with a rather open canopy (Fo).

Tall forest with an open canopy and with sago palms in the understorey is found on flood-plains. It is diagnostic of Misinki (14) and Po (15) land systems, respectively in the Sepik and the coastal plains. It covers 97% and 52% of these land systems, equivalent to 240 and 24 sq miles. Some small areas of this type amounting to 8·5% of its total area are found in Nubia (2), Pes (17), Palimbai (11), and Ambunti (20) land systems. In the dry season the ground-water table was found between 3 and 7 ft. Flooding seems to occur every rainy season for up to a month and to a depth of 2 ft.

(vii) *Tall Forest with an Open Canopy with Light-toned Crowns and with Sago Palms in the Understorey* (FodM; 3 observations).—This type is closely related to tall forest with an open canopy and with sago palms in the understorey (FoM); the major difference in the photo pattern is the prominence of light-toned trees in the canopy, which during ground checking turned out to be mainly *Planchonia* and *Terminalia,* with some *Nauclea.*

It is limited to older flood-out areas in Yilui (13) and Nigia (12) land systems and adjacent plains of Misinki (14) land system (37, 4, and 59% respectively, of a total area of 16 sq miles). From these positions and the commonness of a limited number of species it may be deduced that the FodM type is an old seral stage. Soils are imperfectly or poorly drained and inundation occurs to a depth of 1·5 ft for up to two months per year.

(viii) *Tall Forest with an Irregular Canopy* (Fi; 13 observations; Plate 20, Fig. 1).—The photo image is of a rather rough texture, due to irregular height and crown spacing. Crown sizes tend to be rather uniform, at least large crowns are very rare. Tones fall in the medium and lighter greys, and very light-toned crowns are rare.

Cover, average height of the canopy, and cover of the subcanopy layer, as well as many other features, are similar to those of tall forest with a rather open canopy (Fo). Genera common to both types are *Canarium, Celtis, Homalium, Intsia, Neonauclea, Pimelodendron,* and *Pometia*; those common in forest with an irregular canopy only are *Aglaia*, *Horsfieldia*, and *Maniltoa*. An individual of *Neonauclea* and one of *Bombax* were the only deciduous trees seen. The average cover of the shrub layer is 15%, somewhat less than in tall forest with a rather open canopy, and the herb cover is usually somewhat more, averaging 5%. Gingers and Marantaceae are usually present. Lianas are not always common; rattans were in only about two-thirds of the samples and seldom common. Epiphytes and epiphytic climbers are more often present or rather common than common or very common. *Freycinetia* and aroids are usually more common than ferns. Palms tend to be fewer; in the tree layers they are sometimes absent, in the shrub layer present to very common. Young rattan is not often common. No tree ferns were found.

Tall forest with an irregular canopy occurs on the foothills mainly in Paiawa (24), Morumu (39), Asier (43), and Flobum (44) land systems, and also on Yambi (28) land system in the west of the survey area. It is found on well-drained soils and covers a total of 65 sq miles.

(ix) *Tall Forest with an Irregular Canopy with Light-toned Crowns* (Fid; 23 observations; Plate 11, Fig. 2; Plate 15, Fig. 2; Plate 19, Fig. 2; Plate 22, Fig. 2; Plate 24, Fig. 1).—The photo image is similar to that of tall forest with an irregular canopy (Fi), except for very light-toned crowns which are more common. Regarding the nature and genera of trees with light-toned crowns, the same remarks apply here as in the section about tall forest with an open canopy with light-toned crowns (Fod).

The ground observations brought out only minor differences between this type and Fi. The average height of the canopy and the emergent trees is about 5 ft lower (103 ft and 125 ft respectively) and their average cover is 5% higher (35%). Young rattan was absent in one-quarter of the samples. Gingers were found only in one-third, Marantaceae in half of the samples. Tree ferns (*Cyathea*) were occasional.

Tall forest with an irregular canopy with light-toned crowns is widespread in the hill zone between the ranges and the grassland zone in well to imperfectly drained situations. It still covers large unbroken tracts, but especially in the north and east its area has decreased because of shifting cultivation, and in places it has completely disappeared. Nevertheless, 460 sq miles are covered by Fid, a larger area than that of any other vegetation type. Mambel (48) and Nuku (51) land systems together comprise about 55% of this area, the remainder is scattered over about 20 other land systems.

(x) *Tall Forest with a Rather Closed Canopy* (F; 7 observations; Plate 9, Fig. 2). —The photo image differs from that of tall forest with a rather open canopy (Fo) in the narrower crown spacing and the smaller variations in height.

Ground observations gave for the canopy an average cover of 40% and heights between 110 and 140 ft, averaging 115 ft. Emergent trees are absent or few. In many other respects this forest type is similar to tall forest with a rather open canopy. Differences are that the herb layer is denser, its average cover being 9%, climbing rattan is usually not common, and tree ferns are absent.

Tall forest with a rather closed canopy occurs on river levees and terraces which are flooded rarely or not at all. Of the total area of 45 sq miles, 96% is in Papul (19) land system, the rest mainly in Musendai (32) land system.

(b) *Mid-height Forest*

The group of mid-height forests comprises all those forests in which the average canopy height is between 50 and 100 ft. There is more variation in structure within this group than in the tall forests. For this reason a rather detailed description is given of several types, e.g. mid-height forest with an open canopy and with sago palms in the understorey (FmoM) and mid-height forest with an irregular canopy (Fmi). Moreover, in the mid-height forest group several types are dominated by a single species, e.g. by the genus *Casuarina*, or by a few species as with the mangrove forests.

Mid-height forest covers 23% of the survey area, rugged mountainous country comprises about one-third of this area, and poorly drained sites another one-third.

(i) Rhizophora–Bruguiera *Mid-height Forest and Other Mangrove Vegetation* (B; no ground observations; Plate 2, Fig. 1).—Mangrove vegetation is very limited because of the sandy wind-exposed coast, and covers only 5 sq miles. The sheltered Sissano lagoon, where finer sediments are laid down, forms virtually the only suitable environment (Murik (3) land system). Mangrove vegetation can be seen here in all its aspects. *Avicennia*, light in tone on the air photos, colonizes muddy off-shore flats; *Rhizophora* and *Bruguiera* form the mid-height forest, very dark-toned on the air photos, occupying the flats under daily tidal influence; and *Avicennia* again, or *Acrostichum* fern vegetation, occurs in the spring tidal zone. For a description of these communities the reader is referred to reports of previous surveys (especially Robbins 1968; also Heyligers 1965).

(ii) Casuarina *Mid-height Forests* (Ca, Cq, Cs, CK).—*Casuarina* often forms single-species communities that stand out on the air photos through the dark tone and the smooth texture of the small crowns. The following types are distinguished, of which only some larger occurrences are mapped.

(1) Casuarina papuana *Forest* (Ca; 1 observation).—This species colonizes rock slides in the mountains and, therefore, is commonly found in Somoro (63), Sulen (58), and Daum (62) land systems, associated with mid-height forest with a rather even canopy (Fm) and with an irregular canopy (Fmi). On the lower slopes it can be mixed with *Schuurmansia henningsii*, also a pioneer species.

(2) Casuarina equisetifolia *Forest* (Cq; 1 observation).—The canopy is formed exclusively by *Casuarina equisetifolia* which reaches a height of 90 ft and has an open habit. The undergrowth is dense, about 30 ft tall, and dominated by *Hibiscus*, with some other shrubs such as *Premna* and *Pandanus* and some young *Calophyllum* and *Terminalia catappa* trees. There is a very sparse herb layer of grasses, gingers, and *Crinum*. Leaf litter forms a thick mat on the mineral soil.

Casuarina equisetifolia forest is limited to frontal beach ridges (Nubia (2) land system). The largest stand is in the extreme north-west corner of the survey area. Smaller occurrences are scattered along the coast, and often the forest is reduced to a single row of trees.

(3) Casuarina (Gymnostoma) *sp. Forest* (Cs; no ground observations).—An undescribed species of *Gymnostoma* (Casuarinaceae) occurs in the upper reaches of

braiding rivers on boulder bars and terraces. Because of the unstable environment most of the stands are young and dense. Probably in a later stage "kait" (*Ficus arbuscula*) comes in, and the vegetation develops into *Casuarina–Ficus* forest.

(4) Casuarina–Ficus *Forest* (CK; 1 observation).—This forest is 65 ft tall and has an even canopy cover of about 50%. Shrubs are scattered but the herb layer is dense, covering about 70%, and consists mainly of a horse-tail (*Equisetum debile*) and *Selaginella*. There are no lianes and only a few epiphytes. Some palms and pandans occur in the shrub layer.

(iii) *Mid-height Forest with a Rather Open Canopy* (Fmo; 4 observations).—The photo image is similar to that of tall forest with a rather open canopy (Fo) but the features are slightly scaled down and the canopy tends to be more open.

The average height of the canopy is 80 ft, its cover between 10 and 40%, and emergent trees are up to 100 ft tall. The subcanopy layer varies between open and dense, with cover values between 20 and 50%. Most other features are much the same as for tall forest with a rather open canopy (Fo). The assortment of palms is poorer. Occasionally on lower river terraces in Papul (19) land system some species predominate in the canopy, e.g. *Neonauclea* and *Timonius*, which points to the seral character of this type in these situations. The type also occurs in upstream parts of smaller valleys that form a part of Screw (18) land system. Flooding seems to occur at least once a year. The areas covered by Fmo total 14·5 sq miles.

(iv) *Mid-height Forest with an Open Canopy and with Sago Palms in the Understorey* (FmoM; 5 observations; Plate 5).—The photo image is not unlike that of its tall forest counterpart (FoM), but owing to a more irregular spacing of the crowns the fine texture of the understorey of sago palms is clearly visible.

The canopy is very irregular in height and closure, the average height varying between 75 and 85 ft with occasional taller trees up to 105 ft, and the cover varying between 10 and 25%. The rather dense to dense subcanopy layer is formed by sago palms about 40–50 ft tall covering 40–60%. The shrub layer is patchy and open and mainly of saplings, young sago and rattan, and some other palms. The herb layer is very open but mosses often cover rises of the hummocky soil. Lianes are present, sometimes common; rattan is usually present. Epiphytes and epiphytic climbers are common or very common. Among the latter, *Stenochlaena* is conspicuous, covering the lower parts of the sago palm trunks whilst aroids and smaller ferns occur in the upper parts. In the depressions between the hummocks the small pneumatophores of the sago are found, also some knee-shaped roots reminiscent of some mangrove trees. Ground water was found at shallow depth during the dry season and the depressions probably fill with water for the length of the wet season and after showers in the dry.

This forest type can be regarded as intermediate in the series from stands of pure sago and sago with some emergent trees (M and Me) to tall forest with sago scattered in the understorey (FoM). Together with Me, most of it (90%) is mapped as Pandago (10) land system which occupies low-lying plains in the coastal and Sepik areas. Minor occurrences are found in valleys in some other land systems: mainly Aiome (23) and Paiawa (24) land systems in the north and Nigre (27), Yambi (28), and Kworo (30) land systems in the south. The total area covered by the FmoM type is about 185 sq miles.

(v) *Mid-height Forest with an Open Canopy with* Campnosperma *and with Sago Palms in the Understorey* (FmoCM; 1 observation; Plate 4, Fig. 2).—The photo image is rather similar to mid-height forest with an open canopy and with sago in the understorey (FmoM), but crown spacing tends to be more regular and *Campnosperma* through its predominance in the canopy evens out tone contrasts and differences in texture.

The structure of this forest is much the same as that of FmoM, the major difference being that *Campnosperma* dominates in the canopy.

This type occurs mainly in the Sepik flood-plain where it is mapped as Pora (8) land system (48 sq miles). In the north, 3 sq miles are covered with FmoCM and are mapped in Po (15) land system. The soil, if not under water for most of the year, is permanently waterlogged.

(vi) *Mid-height Forest with an Irregular Canopy and Sago Palms in the Understorey* (FmM; 2 observations; Plate 12, Fig. 1; Plate 13, Fig. 2).—The photo image resembles that of denser patches in mid-height forest with an open canopy and with sago palms in the understorey (FmoM). Because of the denser canopy the sago is usually not visible.

Field observations gave canopy cover values of 30 and 40%, and a height of 90 ft. The subcanopy layer is rather open; its cover was between 30 and 40%. Palms are common in it, and sago is accompanied by species of *Licuala*, *Hydriastele*, *Areca*, and others. Palms, including young rattan, are common and pandans are present in the rather dense shrub layer. Lianes are common and several species of rattan are found. Epiphytes, e.g. *Freycinetia*, and epiphytic climbers, e.g. *Stenochlaena*, are also common.

This forest type occurs on poorly drained soils of the valleys in and around the grasslands north of the Sepik plain, two-thirds of it in Nigre (27) land system, the rest in Yambi (28), Burui (29), and Kworo (30) land systems. The total area covered by FmM is 54 sq miles.

(vii) *Mid-height Forest with* Campnosperma *Predominant in the Canopy and Sago Palms in the Understorey* (FmCM; 3 observations).—The photo image is similar to that of mid-height forest with an open canopy with *Campnosperma* (FmoCM) but the canopy is more closed, enhancing the effect of *Campnosperma* on tone and texture of the image.

This type resembles mid-height forest with an irregular canopy and with sago palms in the understorey (FmM), but emergent trees are normally absent and *Campnosperma* is common amongst the canopy trees. It occurs in more poorly drained and longer inundated situations than the FmM type. Its total area is only 6·5 sq miles.

(viii) *Mid-height Forest with an Open Canopy with Pandans* (FmoP; 4 observations; Plate 6, Fig. 2).—The photo image shows a canopy of light tone and even texture with or without patches of slightly darker small-crowned trees. Field observations revealed that the canopy characteristics were determined by a species of *Pandanus* with large crowns and high spiny stilt roots ("foi") and one without such roots ("olsa"). Trees occur scattered among the pandans, and change the image only when they form an appreciable proportion of the canopy or become more or less emergent.

The height of the canopy varies between 65 and 90 ft and emergents can be up to 110 ft tall. Canopy cover ranges from 10 to 40%, subcanopy cover between 30 and 60%. Plants in the shrub layer are mostly scattered pandans and young palms and rattans. The herb layer is only poorly developed. Rattans and other lianes are present or common, epiphytes are present to abundant. Tall palms such as "aguris", "lio", and *Caryota* are present or rather common amongst the pandans.

Mid-height forest with an open canopy with pandans is found on scroll plains and in flood-outs, areas which when flooded are subject to strong currents. It covers 20 sq miles in Nigia (12) land system and 1·5 sq miles in Pandamp (6) land system.

(ix) *Mid-height Forest with an Open Canopy and with Pandans in the Understorey* (Fmop; 2 observations; Plate 6, Fig. 2).—The photo image is of mixed tones and rough texture owing to considerable variation in height and spacing in the canopy. Occasional lighter-toned patches are caused by pandans and palms in the understorey.

The height of the canopy varies between 65 and 80 ft, with scattered emergents up to 115 ft. The cover varies between 20 and 30%, with the subcanopy storey covering 40–50%. In the subcanopy palms are present to common and pandans are present. In the rather dense to dense shrub layer both palms and pandans are common. Climbing rattans are very common and so usually are epiphytes and epiphytic climbers.

This forest is commonly found in association with mid-height forest with pandans in the canopy (FmoP) in areas where currents have decreased. It covers 50 sq miles in Nigia (12) land system and 3 sq miles in Yilui (13) land system. It also occurs in valleys locally in the grassland zone (12 sq miles in Pandamp (6) land system).

(x) *Mid-height Forest with an Irregular Canopy with Pandans and with Sago Palms and Pandans in the Understorey* (FmPM; 1 observation; Plate 7, Fig. 1).—The photo image is not unlike that of the mid-height forest with an open canopy with pandans (FmoP), but it has more patchy tone contrasts due to gregarious occurrence of sago palms.

The canopy is about 55 ft and very irregular, its cover varying between 5 and 60%. Amongst the trees the pandans "foi" and "olsa" are common. The understorey was dense and dominated by sago and pandans, the herb layer was sparse with some ferns, and with the water plant *Monochoria hastata* growing in pools. *Stenochlaena* was climbing high up in the trees. The soil was completely water-logged and pneumatophores were common, mostly the small ones of sago but thick carrot-like roots were also seen.

From the air photos it seems that there is quite a variation in the density of the canopy and in the distribution of sago which locally forms almost pure patches.

This forest occurs in swampy localities which are regularly flooded but where stream velocities are low. It is found in Pandago (10) and Nigia (12) land systems in the north, with a minor occurrence in Po (15) land system; in the south it is included in Nigia (12) and Yilui (13) land systems. Its total area is 35 sq miles.

(xi) *Mid-height Forest with an Irregular Canopy* (Fmi; 17 observations; Plate 12, Fig. 2; Plate 21, Fig. 1; Plate 24, Fig. 2; Plate 25, Fig. 1; Plate 26, Fig. 2; Plate 27, Fig. 2; Plate 28, Fig. 2).—The photo image is of a fine but rather rough texture, composed of small and very small crowns in various tones of grey to very light grey which are irregularly spaced horizontally as well as vertically.

The field observations confirmed this irregular structure of the canopy. The average height of most of the canopy trees is between 80 and 85 ft, but variations of up to 50 ft were recorded within a sample. Trees reaching above the canopy are scattered, their height averaging 110 ft and occasionally reaching 130 ft. They have smaller crowns than in tall forest with an irregular canopy (Fi). The cover of the canopy varies between 15 and 60% and averages 33%. The subcanopy trees are dense to rather dense inversely according to the cover of the canopy; their cover averages 43%. Large girths are rare and most of the trees have small girths. Stem form is usually straight, but normally some slanted trees and/or trees with a bent base also occur due to soil movement on slopes. At the northern side of the ranges along the river gorges uprooted trees and trees with broken tops were observed; this is attributed to strong local winds. Buttresses of several size classes are usually present, but only low buttresses are common.

Shrubs and saplings are scattered, occasionally rather dense which reduces the visibility from moderate to poor. Their cover averages 10%. The herb layer is variable in density and species. Its cover ranges from 1 to 40% and is 10% on the average. *Elatostema*, *Selaginella* spp. (e.g. *S. velutina* and *S. caudata*), ferns (e.g. *Asplenium spathulum*, *Tectoria cesatiana*, *T. decurrens*, *Lindsaea azurea*, *Thelipteris*, *Dennstaedtia*, *Trichomanes grande*, *Tapeinidium marginale*, and *Cystodium sorbifolium*), sedges (*Paramapania*), snake grass (*Dianella*), Marantaceae, gingers, *Begonia*, and mosses can be conspicuous in the herb layer.

Lianes are usually common, sometimes only present; rattan is usually present but seldom common. Occasionally, climbing bamboo is found. Epiphytes range from present to very common. Aroids, climbing ferns (e.g. *Stenochlaena*, *Lomariopsis*), several *Freycinetia* species, *Piper*, and mosses are often found.

Palms are as often as not found in the tree layers but are generally present to rather common in the shrub layer. Young rattan was seen in only half of the samples and was never common. *Licuala* was only occasionally seen. As a rule pandans are present in the shrub and/or herb layer and extend only occasionally into the tree layers. Tree ferns were seen in half of the samples, they belonged to the Marattiaceae and *Cyathea*.

Mid-height forest with an irregular canopy occurs mainly in the ranges and the adjacent hilly country, often in mosaic with other mid-height forest types (Fmi', Fm, Ca). Therefore, only an estimate of the total area can be given; it is of the order of 300 sq miles and spreads over about 20 land systems. Some isolated areas, totalling 11 sq miles, are found in the grassland belt on Yambi (28) land system.

(xii) *Seral Mid-height Forest with an Irregular Canopy* (Fmi'; no ground observations; Plate 18, Fig. 2; Plate 21, Fig. 1; Plate 24, Fig. 2; Plate 25, Fig. 1).—Patches of lower forest are found in mosaic with mid-height or tall forest with an irregular canopy (Fmi, Fi). Their position and the presence of *Schuurmansia* and tall trees of *Albizia falcata*, *Casuarina papuana*, and *Artocarpus* suggest that they are tracts of forest disturbed possibly by landslides, earthquakes, or strong winds and now in a fairly advanced stage of regeneration.

About 160 sq miles of this seral forest is associated with mid-height forest with an irregular canopy and about 16 sq miles with tall forest. It is always found in small patches and occurs in a great many land systems, but mostly in Numoiken (40), Flobum (44), and Sulen (58) land systems.

(xiii) *Mid-height Forest with a Very Irregular Canopy* (Fmio; 3 observations).—The photo image resembles that of mid-height forest with an irregular canopy (Fmi), but spacing of crowns is more irregular.

Field observations showed that it was not significantly different from mid-height forest with an irregular canopy. It is classed as a separate mapping type on the assumption that its irregularity could be caused by frequent minor slumping, earthquakes, or strong winds and from that point of view could be important in land capability assessment.

It is spread in the hilly country around the Torricelli Mountains over about 10 land systems and totals 240 sq miles, half of which is in Morumu (39) land system.

(xiv) *Mid-height Forest with a Small-crowned Canopy* (Fms; 15 observations; Plate 13, Fig. 2).—In comparison with mid-height forest with an irregular canopy (Fmi), the photo image of this type is of a less rough texture, mainly through a lesser height of emergent trees and a more even spacing of crowns which tend to be less variable in size as well.

The canopy is of the same height as in mid-height forest with an irregular canopy, but generally somewhat denser and with an average cover of 40%. The maximum height of emergent trees is 115 ft. Cover of the subcanopy trees and for shrubs and herbs is much the same as for mid-height forest with an irregular canopy. Differences from this type are mostly found in the shrub layer, where palms are rather common to very common and among which rattan is present and usually common. *Licuala* is present and sometimes common. Tree ferns, however, are absent.

Mid-height forest with a small-crowned canopy occurs on ridges in and just north of the grassland zone. Of the 12 land systems in which it is found, Yambi (28), Kworo (30), Yindigo (31), and Emul (36) are more important ones. The total area covered is about 120 sq miles.

(xv) *Mid-height Forest with a Small-crowned Rather Even Canopy* (Fmsv; 8 observations; Plate 30).—The photo image is very similar to mid-height forest with a small-crowned canopy (Fms), but spacing of the crowns is closer and emergent trees are less common, both features enhancing the impression of an even-textured canopy.

Cover values for the canopy ranged from 40 to 70%, with 55% as average, which is considerably higher than for other mid-height forests. The subcanopy tree layers were more open, with an average cover of 34%.

In contrast to Fmi and Fms, certain tree species of *Syzygium*, *Myristica*, *Xanthophyllum*, and *Cryptocarya* tend to be common. Lianes are usually present, sometimes rare, and no rattan was found. Palms are usually found in the shrub layer but are sometimes conspicuously absent. Young rattan is absent. Pandans are sometimes present in the shrub layer. No tree ferns were seen.

Mid-height forest with a small-crowned rather even canopy is found exclusively on the hills in the Sepik plains, mapped as Maio (64) and Waskuk (65) land systems, and covers 57 sq miles.

(xvi) *Mid-height Forest with a Rather Dark-toned Even Canopy* (Fm; 6 observations; Plate 15, Fig. 1; Plate 20, Fig. 1; Plate 21, Fig. 1; Plate 29).—The rather dark-toned photo image is of an even texture, caused by a canopy of uniform crowns of regular spacing and height.

The darker tone seems to be correlated with generally smaller size of the leaves. The species concerned occur scattered in mid-height forest with an irregular canopy (Fmi), but in this type they are more common and sometimes gregarious, e.g. *Castanopsis*, *Lithocarpus*, *Podocarpus blumei*, *P. neriifolius*, *Phyllanthus*, *Tristania*, *Elaeocarpus*, *Neonauclea*, and *Casuarina*. One of the other conspicuous differences between this forest and mid-height forest with an irregular canopy is the richness in ferns and mosses. Tree ferns are present to common; the recorded species include *Cyathea wengiensis* and the climbing tree fern *Cyathea biformis*. Palms are rare and normally confined to the shrub layer. Rattan, young or climbing, is absent.

Mid-height forest with a rather even canopy is found on crests and upper slopes of high ridges where clouds gather in the daily atmospheric rhythm. At lower altitudes where these situations are rather restricted this forest type is found only on the very crests. In the ranges it is more widespread and is very common in Atitau (33), Sulen (58), Daum (62), and Somoro (63) land systems. The total area covered is about 70 sq miles.

(*c*) *Low Forest*

Low forest (Fl) has an average canopy height of 50 ft or less. Two types were recognized on the air photos. One has an even, rather light-toned canopy of very small crowns and surrounds patches of herbaceous vegetation in Yambi (28) land system in the Sepik plains. It occurs in small patches totalling less than half a square mile.

The other type has an irregular canopy of small crowns, with groups of taller trees. It is found locally on scroll plains and along smaller rivers. Only one ground observation was made, which indicated a strong floristic resemblance to the seral stages of mid-height forest with a rather open canopy (Fmo). Probably this low forest type is a younger seral stage induced by destruction of tall forest after catastrophic floods. Therefore, its occurrences have been mapped as part of Nigia (12) land system. The total area of this low forest is about 2·5 sq miles.

Because of the minor importance of low forest in the survey area the types have not been mapped separately.

(*d*) *Woodland*

Woodland and savannah, both open tree communities with a herbaceous, often graminoid undergrowth, are uncommon and the areas involved are too small to warrant separate description or mapping with the exception of the following type.

(i) *Woodland with Tall Sedge* (Thoracostachyum) *Undergrowth* (WT; 2 observations; Plate 4, Fig. 1).—The photo image shows densely scattered trees over a blotchy grey-toned understorey. Crowns are of various sizes but predominantly very small, and have a medium-grey tone with one side lighter.

Observations for the open canopy gave a cover between 5 and 25% and heights up to 65 ft. Amongst the trees a species of *Campnosperma* or of *Timonius* was sometimes predominant and scattered sago palms occurred. Trunks were often clothed in climbing epiphytes, mainly *Stenochlaena* ferns.

The understorey is about 5 ft high and is dominated by the sedge *Thoracostachyum sumatranum*, with some *Scleria ciliaris*, *Phragmites karka*, and *Cyclosorus* ferns. Cover varies to a maximum 80%.

Between the tussocks is much organic debris, the most recent addition to the permanently waterlogged peat found under this type of woodland. Annual flooding up to 3 ft for several months is expected to occur.

Larger occurrences of woodland with tall sedge undergrowth are mapped as Kobar (7) land system, which covers 16·5 sq miles in the Sepik flood-plain. Some smaller areas totalling 2 sq miles are included in Pandamp (6) land system.

(*e*) *Palm and Pandan Vegetation*

The important structural characteristic of this group is that its dominants bear clusters of large leaves at the end of single or sparsely branched trunks. This produces an even-textured image on the air photos.

(i) *Sago Palm Vegetation* (M, Ml, Me; 9 observations; Plate 5).—The photo image is of a blotchy dark tone and an even, very fine texture. This blotchy pattern is caused at least partly by clumping of the palms, probably because of suckering. It seems to correlate with irregularities in height of the canopy, the clusters being slightly taller than the surrounding palms. Crowns and inflorescences very distinct on large-scale photographs can seldom be distinguished on the 1:50,000 photographs. An occasional emergent tree is normally present.

Ground observations show that sago (*Metroxylon rumphii*) forms an irregularly closed canopy, normally about 50–60 ft tall with emergent inflorescences. Trunks are about 35 ft, often in clumps, with younger palms amongst them. Epiphytic climbers, mainly *Stenochlaena* ferns, are present to abundant and small epiphytes are often conspicuous in the upper regions of the trunks. The ground cover is very scanty if present at all. Small pneumatophores project from the soil. Old leaves form a layer of organic debris. The soil is normally peaty and waterlogged and partly covered by puddles.

Under marginal conditions, e.g. when water-tables occasionally sink so deep as to cause drought stress, sago remains stunted, scarcely develops trunks, and does not flower, although it suckers strongly. Height is often not more than 20 ft. The photo image is like that of vigorous sago, but the tones are lighter. Stunted sago has been mapped with the symbol Ml.

Often an open storey of trees overtops the sago (Me). On the air photos these trees are very clearly visible, mainly because of one-sided illumination since the overall tone is often very similar to the dark tones of the sago. The density of the trees is quite variable and, as there are no distinct breaks in the distribution patterns of the trees, the boundaries are in fact rather arbitrary between sago vegetation and sago vegetation with emergent trees (M and Me) on the one hand and between Me and mid-height forest with an open canopy and with sago palms in the understorey (FmoM) on the other. Among the trees in the sago vegetation the following genera are represented: *Alstonia*, *Campnosperma*, *Horsfieldia*, *Ficus*, *Nauclea*, *Neonauclea*, *Planchonia*, *Timonius*. Average height of these trees is about 70 ft. Soil conditions under sago vegetation with emergent trees (Me) are similar to those under sago vegetation (M).

Sago vegetation (M) and stunted sago vegetation (Ml) have been combined into Kabuk (9) land system, which has scattered occurrences in the coastal plain (2 sq miles with M and 3 sq miles with Ml) but is extensive in the Sepik plain (15 sq miles with M and 9 sq miles with Ml). Sago vegetation with emergent trees (Me) occupies 22 sq miles in the coastal plain and 57 sq miles in the Sepik plain. Together with mid-height forest with an open canopy and with sago palms in the understorey (FmoM) it has been mapped as Pandago (10) land system.

(ii) Nypa *Palm Vegetation* (N; 1 observation; Plate 1, Fig. 2; Plate 2, Fig. 1).—The photo image of *Nypa* vegetation is very similar to that of sago vegetation; it is a little lighter in tone, often speckled rather than blotched, and height tends to be more regular.

Nypa fruticans is the single constituent of this vegetation type; its fronds, borne on an almost subterranean trunk, reach a height of 20 ft.

The largest *Nypa* stands are found east and west of the Sissano lagoon, they cover 3 sq miles and form part of Murik (3) land system. Other occurrences are scattered along tidal creeks in Nubia (2) land system.

(iii) *Pandan Vegetation* (P; no ground observations; Plate 3, Fig. 2; Plate 6, Fig. 1).—The photo image has a rather even grey tone and a fine texture. Small-crowned slightly emergent trees of the same tone are usually present in varying numbers. Trees with larger crowns are locally present and mark the ecotonal zone between pandan vegetation and mid-height forest with an open canopy and with pandans in the understorey (Fmop).

From the air it was seen that pandans about 20 ft high are dominant.

Pandan vegetation is limited to the Sepik flood-plain, where it is found in swales of Palimbai (11) land system (about 20 sq miles) and in adjacent back swamps mapped as Pandamp (6) land system (about 50 sq miles). These habitats appear wet.

(*f*) *Tall Grassland*

Grasses over 5 ft tall in the vegetative stage are classified as tall. On the air photo they have a medium to rather light grey tone.

(i) *Cane Grass* (Saccharum robustum), *with or without Reed* (Phragmites karka) (GtS; 3 observations; Plate 6, Fig. 1; Plate 9).—The photo image is very even-toned and has a rather rough, but fine, grain. The common parallel patterns are caused by the topography of low levees and swales, the former sometimes with a thin line of trees, the latter locally with clumps of pandan vegetation.

Cane grass reaches a height of 10–13 ft. On low levees and sand bars it grows in pure stands, but in swales it is mixed with reed which does not grow as tall (6–8 ft).

Because of its riverine habitats cane grass vegetation is virtually restricted to the following land systems: Palimbai (11), Screw (18), Papul (19), with smaller occurrences in Pandamp (6) and Nigia (12). The total area covered by cane grass is about 42 sq miles.

(ii) *Cane Grass with Seral Stages of Forest* (Gt′).—In Screw (18) and Papul (19) land systems cane grass vegetation occurs often in mosaic with woody vegetation, which forms an early successional stage of mid-height and tall forest with a rather open canopy (Fmo, Fo, Fod). The symbol, which should be GtS/Fl or GtS/Fmo, is shortened to Gt′ for convenience in mapping.

(iii) *Reed* (Phragmites karka) *with Other Grasses* (GtPh; 3 observations; Plate 3).—The photo image is of a blotchy medium and light grey tone and a texture varying from smooth to rather rough. In the rough texture a speckly very light-toned pattern, probably due to an illumination effect, is often superimposed. Scattered trees are often present, particularly near drainage channels and in zones transitional to pandan vegetation. Locally, trees are so dense that the vegetation should be classified as savannah or even woodland. These patches, however, are too small to be mapped out.

This grassland is rather variable in its floristic composition but reed is always present, often 13 ft tall and forming an open storey over other grasses, e.g. *Ischaemum polystachyum*, *Leersia hexandra*, and *Coix lacryma-jobi*, which are 5–8 ft tall. Some sedges, *Cyclosorus* ferns, and other herbs usually occur; *Cayratia* and *Merremia* bind the vegetation into an impenetrable mass.

This type of grassland covers seasonal swamps in the Sepik plain which are inundated up to a depth of 4 ft for 4 months a year or longer. In the dry season at least some parts of the grasslands are burnt, but no observations could be made on the effect of burning. It is likely, however, that it retards succession to woody vegetation quite considerably.

Reed grassland has been mapped as part of Sanai (5) land system, and covers about 35 sq miles of it. Where grassland occurs in mosaic with pandan vegetation it has been mapped as part (about 17 sq miles) of Pandamp (6) land system.

(g) *Mid-height Grassland*

In mid-height grassland (G, Gl; 41 and 15 observations, respectively; Plate 1, Fig. 2; Plate 10, Fig. 1; Plate 12, Fig. 2; Plate 13; Plate 14, Fig. 1) the grasses are 2–5 ft tall in their vegetative stage. A typical example of a mid-height grass is kangaroo grass (*Themeda australis*).

Mid-height grasslands are pictured in a medium-light to light grey tone often with streaks of a lighter tone. The texture is smooth. Because of the low vegetation, topographic features appear as if they were strongly sculptured. Tone differences do not necessarily correspond with different species, because burning history and soil moisture also influence tone. Therefore the constituent communities could not be mapped. Grassland dominated by *Imperata cylindrica* (GI) has been mapped not on image characteristics but on ground observations and circumstantial evidence, for it occurs in densely settled areas. Scattered shrubs or small trees are sometimes present; seldom, however, are they numerous enough for the vegetation to be classified as savannah.

The height of the grassland is commonly 3–5 ft, but as the grasses are often inclined the total length of the culms may be 6 ft. Inflorescences of some species may be borne up to 8 ft above the ground. Cover varies between 10 and 100%, but when the cover is low there is in most cases a ground layer of grasses and sedges with cover ranging between 5 and 75%.

About 10 communities can be distinguished on the dominance of *Alloteropsis semialata, Arundinella setosa, Coelorachis rottboellioides, Dimeria* sp., *Eulalia trispicata, Imperata cylindrica, Isachne confusa, Ischaemum barbatum, Ophiuros exaltatus, Polytoca macrophylla, Sorghum nitidum,* and *Themeda australis*. Some communities are clearly secondary, often dominated by *Imperata* or by *Imperata* and *Ophiuros, Coelorachis,* or *Polytoca*, but some by *Themeda* and *Sorghum*. These latter communities are also found elsewhere, where recent human interference, except for burning, is not obvious. *Ischaemum, Arundinella,* and *Ophiuros* develop a strong dominance in sites with poor drainage, whilst *Themeda, Dimeria,* and *Eulalia* occur more commonly in better-drained areas. However, no clear correlation between the communities and soil types or land forms was found. This and the fact that the communities cannot be distinguished on the air photos are the reasons why the communities will not be described in detail. A generalized account of them is given in the vegetation descriptions of the land systems mentioned in the next paragraph.

Mid-height grassland covers 4·7% of the survey area and, except for numerous small occurrences of *Imperata* grassland of which only the largest have been mapped, is largely in a zone of Pleistocene deposits north of the Sepik plain where it is found in five land systems: 38 sq miles in Nigre (27), 55 sq miles in Yambi (28), 53 sq miles in Burui (29), 41 sq miles in Kworo (30), and 13 sq miles in Yindigo (31) land systems. Groups of isolated grasslands, however, are also found just north of this zone, e.g. south-west of Nuku. Mid-height grasslands occur on a number of soil types for which the drainage status ranges from good to rather poor.

(*h*) *Mixed Herbaceous Vegetation*

In mixed herbaceous vegetation herbs other than grasses are dominant. On air photos it has light grey tones and often a rough texture.

(i) *Fern* (Dicranopteris) *Vegetation, Often with Sedges* (Scleria) *Common* (HD; 6 observations; Plate 12, Fig. 1).—The photo image is of a rather even or faintly blotched tone and rough texture.

Fern vegetation is normally two-layered. The upper layer, 3–6 ft high and with about 15% cover, consists of *Dicranopteris linearis, Scleria ciliaris,* some grasses, other sedges, and herbs. The ground storey covers about 75% and is formed by fine sedges, e.g. *Rhynchospora rugosa*, *Fimbristylis fusca;* fine grasses, e.g. *Sacciolepis indica*, *Isachne confusa*, *Ischaemum fragile;* club moss, *Lycopodium cernuum*; and ferns, e.g. *Schizoloma ensifolium*. Some climbers are usually present, e.g. a pitcher plant, *Nepenthes*, and a fern, *Lygodium*. Locally the upper storey is denser and the lower storey becomes shaded out. In extreme cases this leads to absolute dominance of *Dicranopteris*. Scattered shrubs are mainly *Fragraea racemosa*, *Commersonia bartramia*, and *Antidesma ghaesembilla*. Locally they are denser and the vegetation has the aspect of savannah.

Drainage lines have mid-height forest with an irregular canopy and with sago palms in the understorey (FmM), or remnants thereof. The larger ones have been mapped, but the smaller ones had to be included in the HD mapping type.

Dicranopteris–Scleria vegetation occurs on the lowest surfaces in the grassland zone, a total of 33 sq miles in Nigre (27) land system and 7·5 sq miles in Yambi (28) land system. Both are moderately to rather poorly drained.

(ii) *Tall Sedge* (Thoracostachyum) *Vegetation* (HT; 1 observation; Plate 3).—The photo image is rather similar to that of tall reed grassland (GtPh), but tones are a little more even and larger darker areas occur locally. The speckled patterns are present as well and often show a parallel arrangement. Scattered trees and transitions to woodland (WT) are common.

Only one observation was made: a dense 6-ft-high vegetation of *Thoracostachyum sumatranum* with scattered *Phragmites karka* and *Leersia hexandra*, covering 70%, with an open understorey of *Cyclosorus* ferns. The foot of the tussocks showed charred remnants of old leaves, revealing that even this vegetation can be burnt.

Tall sedge vegetation occurs in the back swamps of the Sepik flood-plain and locally in choked valleys in the grassland zone. Very long inundation is likely in these situations and the soil, mainly peat, stays waterlogged through the dry season. About 4·5 sq miles are in Sanai (5) and 12 sq miles in Pandamp (6) land systems.

(iii) *Herbaceous Vegetation, Often with Low Sedges Common* (H; 2 observations; Plate 2, Fig. 2).—All other herbaceous communities are combined in this mapping type, partly because the map scale does not allow their separate mapping, partly because their occurrence in the back swamps of the Sepik plain made ground observation difficult.

Most of the herbaceous vegetation has light to very light grey tones, the former of a rather rough texture, the latter smooth, in various intricate patterns, which reflect probably successional relationships but in some areas at least can be burn patterns. Areas of nearly black tone with numerous lighter specks and light grey-toned patches are open water with submerged and floating vegetation.

Two observations were made in the border zone of the swamps which are flooded up to 6 ft for 1–4 months annually and burnt during the dry. After burning, a meadow appears of 18-in.-tall sedges, e.g. *Fimbristylis podocarpa* or *Cyperus haspan*, with some scattered grasses and herbs. Some remnants of unburnt vegetation showed that grasses such as *Ischaemum polystachyum* become more common later. It was noticed from the air that part of the herbaceous vegetation is a floating mat.

Back swamps wholly covered by herbaceous vegetation (H) have been mapped as Chambri (4) land system (21 sq miles); back swamps partly covered by herbaceous vegetation and partly by reed (GtPh) as Sanai (5) land system. Herbaceous vegetation covers about 11 sq miles of this land system. Another 3 sq miles of herbaceous vegetation occurs in old oxbows in Palimbai (11) land system.

(*i*) *Secondary Vegetation*

The term "secondary vegetation" is applied to vegetation that replaces natural vegetation after interference by man. It comprises gardens, plantations, certain grasslands, and regenerating forest. On air photos secondary vegetation is readily recognizable by its chaotic pattern reminiscent of a quilt in the areas of densest population. This image is produced by gardens, by young regrowth with a multitude of lighter tones and sharp boundaries to adjacent vegetation, and by older regrowth, usually with darker tones and an array of textures.

As areas large enough to map are usually covered with more than one type of secondary vegetation, one will normally find a combination of symbols on the map, e.g. R-FRm/GtR, which means gardens and all stages of regrowth up to medium-aged secondary forest and local areas of regrowth dominated by cane grass.

Secondary vegetation is widespread and covers about one-third of the survey area. Land systems 80% or more covered by secondary vegetation are Nubia (2), Romei (22), Seim (46), Dreikikir (47), and Minatei (50). Only six land systems have no secondary vegetation: Murik (3), Sanai (5), Kobar (7), Pora (8), Daum (62), and Somoro (63); 10 others have only 1 or 2%: Chambri (4), Pandamp (6), Kabuk (9), Palimbai (11), Nigia (12), Misinki (14), Aiome (23), Nigre (27), Yambi (28), and Sulen (58). These land systems are mostly swampy or mountainous, but also include some dominated by grassland.

(i) *Gardens, Plantations, and Regrowth up to 25 ft* (R; 38 observations; Plate 1, Fig. 1; Plate 7, Fig. 1; Plate 14, Fig. 2).—These form the lighter-toned sharply defined patches on the air photos as described above.

Subsistence and cash crops are dealt with in Part VII.

After the gardens are abandoned herbaceous regrowth soon covers the ground and remaining stumps and logs. Woody regrowth soon follows and within two years forms a 13-ft-tall thicket. Species belonging to the genera *Alstonia*, *Althoffia*, *Artocarpus*, *Boerlagiodendron*, *Endospermum*, *Ficus*, *Geunsia*, *Macaranga*, *Melanolepis*, *Melochia*, *Villebrunea*, and *Wendlandia* shade out most of the original herbaceous invaders. Shade-tolerant species, e.g. several fern and *Selaginella* species, take their place. *Imperata* and *Saccharum*, however, seem to be able to maintain themselves for a number of years.

(ii) *Regrowth Dominated by Cane Grass* (Saccharum) (GtR; 3 observations; Plate 16, Fig. 2; Plate 21, Fig. 2).—In the eastern part of the survey area cane grass may dominate large tracts of regrowth, which can be recognized on the air photos by its even light grey tone and rough texture. Woody species are often present but scattered.

This dominance is probably caused by short fallow periods between cultivations which prevent the woody regrowth from shading out the cane grass.

(iii) *Exploited Natural Sago Stands and Planted Sago* (MR; 9 observations; Plate 1, Fig. 2; Plate 7, Fig. 1; Plate 13, Fig. 1; Plate 19, Fig. 1; Plate 23, Fig. 2).—On the air photos the first category is recognizable from unexploited sago vegetation, by irregularities due to selective cutting of palms. The second can be recognized among other secondary vegetation by its rather dark tone.

Natural sago is exploited where it is accessible and vigorous enough to come into flower. Sago is planted not only along stream courses and swamp margins, but also on slump terraces as found in Karaitem (41), Sengi (42), Asier (43), Flobum (44), Seim (46), Mambel (48), and Nuku (51) land systems, mainly in the western part of the survey area.

(iv) *Young Secondary Forest, up to 65 ft* (FR; 30 observations; Plate 20, Fig. 2; Plate 21, Fig. 2).—A pattern of larger but still rather small crowns replaces the rough-textured canopy image of regrowth thicket (in which the separate crowns are hardly visible), and the tone is slightly darker.

Young secondary forest develops from regrowth thicket as light-demanding shrubs are shaded out by the trees that need the protection of woody vegetation to germinate and develop. Genera represented in this category are *Albizia*, *Bombax*, *Celtis*, *Cryptocarya*, *Euodia*, *Horsfieldia*, *Mangifera*, *Octomeles*, *Pometia*, *Spondias*, *Sterculia*, and *Terminalia*. Some palms and epiphytes are usually found at this stage and rattan and other woody climbers replace the herbaceous ones common in the earlier stages.

In areas where cane grass regrowth is common, cane grass dominates the undergrowth of young secondary forest as well, and is often accompanied by gingers. The canopy is very open (up to 30% cover) usually with *Althoffia* dominant. The age of one of these forests was 7 years, the *Althoffia* trees being 45 ft tall. During the survey this forest was cut to be replaced by a coffee plantation.

(v) *Medium-aged Secondary Forest, 65–100 ft* (FRm; 22 observations; Plate 10, Fig. 2; Plate 17, Fig. 2; Plate 18, Fig. 1).—The photo image shows a canopy of rather small crowns, rather dark-toned and often with a lighter tone at the illuminated side. Crowns tend to be detached and of irregular height.

This type develops from young secondary forest through the replacement of woody regrowth species by forest species, e.g. of the following genera: *Aglaia*, *Canarium*, *Castanopsis*, *Dysoxylum*, *Myristica*, *Neonauclea*, *Pimelodendron*, *Sloanea*, and *Vitex*. The canopy becomes differentiated into a canopy and a subcanopy tree storey and emergent trees. Palms are usually present in the tree storeys and often common in the shrub layer, frequently with much rattan or *Licuala*. Epiphytes become well established. In short, the structure of the forest approaches that of mid-height forest.

(vi) *Medium-aged Secondary Forest with Sago Palms in the Understorey* (FRmM; 1 observation).—The photo image is similar to that of mid-height forest with an open canopy and sago palms in the understorey (FmoM), but the canopy is more irregular and the sago layer shows features of harvesting.

This type is the forest equivalent of exploited natural sago and planted sago (MR). It is rather restricted in its distribution; it is locally found on Nubia (2), Po (15), Nigre (27), and Burui (29) land systems. Probably the sago palms growing under forest conditions are usually not vigorous enough to warrant exploitation.

(vii) *Old Secondary Forest, over 100 ft* (FR; 17 observations; Plate 14, Fig. 2; Plate 17, Fig. 2; Plate 18, Fig. 1; Plate 19, Fig. 1).—The photo image is rather similar to that of medium-aged secondary forest (FRm), but crowns are larger. Scattered lighter-toned crowns occur. The image resembles that of tall forest with an irregular canopy (Fi, Fid).

Old secondary forest is the final stage in the regeneration succession. Structurally it is a tall forest type, but in floristics it still deviates from primary forest and there is sometimes predominance of certain species, e.g. *Pometia pinnata* or *Vitex cofassus*.

It is likely that not all forest mapped as FR is secondary forest but that some forest in which selective cutting has been carried out is included in this type as well.

III. Ecology

(*a*) *Influence of Rainfall*

The climate of the survey area has been treated in Part IV. It is classified as "wet tropical", but in the central eastern part of the area (around Bainyik and Dreikikir) it approaches the "subhumid tropical" class in the drier years. The annual average rainfall figure for this area is 66 in. and several weeks, exceptionally up to 14, of depleted soil moisture storage occur during the dry season. Rainfall increases to the north, west, and south and averages 81 in. per year for the Yambi–Nuku area whilst Ambunti, Lumi, and Aitape receive on average over 100 in. (Fig. 2).

The distribution of some types of secondary vegetation seems to reflect the rainfall pattern. Garden regrowth in which cane grass (*Saccharum*) is predominant (GtR) is confined to the eastern part of the survey area, reaching its western limit near Nuku (zone 4 (east), Fig. 4). The commonness of cane grass may be due to short rotation cycles as discussed in the description of this type, but climatic conditions could enhance this effect, directly by favouring the more drought-resistant species or indirectly through fires getting out of hand and burning into young regrowth under drought stress.

From Nuku westwards sago (MR) has been planted in slump floors, seepage areas, etc. (zone 4 (west), Fig. 4). Successful cultivation in localities as mentioned above is possible only when rainfall is sufficiently high and regular.

The seasonality seems also to be reflected in the distribution of forest types with light-toned crowns on the air photos. The likely cause of the light tone is flushing of leaves and/or flowers, and this could be linked with seasonality of climate. The number of light-toned crowns could be related to the degree of seasonality: north of the ranges in the relatively uniform coastal climate no forest types with light-toned crowns occur, with the exception of some small patches of tall forest with an open canopy with light-toned crowns and with sago palms in the understorey (FodM) south of Sissano lagoon. South of the ranges, however, tall forest with an irregular canopy with light-toned crowns (Fid) is extensive in the hilly country, tall forest with an open canopy with light-toned crowns (Fod) on levees and scrolls, and FodM on certain back plains. In the last two types the seasonal influence is probably not so much direct as indirect through the flooding regime of the rivers.

The likely cause for the relative commonness of trees with light-toned crowns in Fid as compared to their rarity in other tall forest types (Fi, Fos, Foi) under rather the same climatic conditions can probably be found in the soil conditions. Because of slow permeability imperfectly drained soils are twice as common under Fid as under the other types, and even some poorly drained soils were found. These together account for more than half the 21 observations in Fid. Such conditions may enhance the effect of dry spells and induce the occurrence of species with a seasonal rhythm in flowering and leaf-flushing.

(b) *Influence of Altitude*

If the survey area is divided according to the classification of van Steenis (1962), more than 99% belongs to the "tropical zone", which means it lies below 3300 ft. The rest comes into the "submontane zone", except for some peaks above 5000 ft which are in the "montane zone". The climax vegetation of the submontane zone is usually called "lower montane forest", which is characterized by a simple canopy structure, predominance of certain species, often oaks (*Castanopsis*, *Lithocarpus*), and abundance of smaller epiphytes such as mosses and filmy ferns (Hymenophyllaceae). Mid-height forest with a rather dark-toned even canopy (Fm) is one such lower montane forest type, whilst certain parts of mid-height forest with an irregular canopy (Fmi), especially where it occurs in mosaic with Fm, could also be regarded as lower montane forest. Together they cover 3·5% of the survey area, which means that a substantial part is in the tropical zone. This illustrates that the structure of the vegetation is not solely determined by a decrease in temperature of 3 degF for every 1000 ft but also by the cloudy conditions in areas with topographic barriers such as the Torricelli Mountains. Fm is found at altitudes as low as 1000 ft about 5 miles south of Sissano lagoon where a low range forms the first barrier for winds blowing from the sea, and at 1000–1500 ft on outliers on the northern side of the main ranges. Increased humidity already shows its influence as low as 400 ft, where epiphytic mosses are locally conspicuous in tall forest with a rather open irregular canopy (Foi). At the southern side the minimum altitude at which Fm occurs is about 2000 ft, and within the ranges 3000 ft, which comes close to the "traditional" boundary for lower montane forest.

Mid-height forests with small-crowned canopies (Fms in the grassland zone and Fmsv on the hills and low mountains in the Sepik plain) occur only below 1500 ft. That tall forest does not grow in these situations seems to be due to edaphic conditions and not to altitude. The soils on which they occur are poor and strongly acid; those under Fms are derived from Pleistocene sediments, and those under Fmsv from gneiss, quartzose sandstone, and mica-schist.

(c) *Influence of Soil Drainage, Flooding, and Inundation*

Swamps and plains of various kinds form about 50% of the survey area and constitute an environment in which soil drainage often becomes a critical factor. Moreover, half of this area is liable to flooding (overland flow of water) and/or inundation (ponding of water). The vegetation types found on these plains and swamps and for which field data are available are listed in Table 12 according to increasing impedance of soil drainage. After each vegetation type its flooding and/or inundation regime is given. These remarks, however, are tentative as evidence on these factors was obtained only indirectly from flood marks and by questioning the local population. The considerable overlap in amplitudes of the vegetation types with regard to these factors is probably partly due to unreliable information, partly also to the great variation in the incidence and interplay of these factors in different sectors of the survey area. During the survey it was not possible to ascertain these variables in any more detail.

The vegetation types can be arranged in sequences determined by environmental gradients.

(i) *The Plain Sequence:* Fo–FoM–FmoM–Me.—This sequence is characteristic of the alluvial plains (zones 1 and 6 in Fig. 4). Flooding increases from sporadic in tall forest with a rather open canopy (Fo) to twice a year in tall forest with sago palms in the understorey (FoM). Stagnation of flood-water causes inundation, which may last for 5 months in mid-height forest with an open canopy and sago palms in the understorey (FmoM) and for 8 months in sago palm vegetation with evergreen trees (Me). The drainage status of the soils deteriorates from well drained under Fo to swampy under Me.

(ii) *The Riverine Sequence:* GtS–Fmo–Fod–Fo–F.—This sequence comprises the vegetation from sand bars, scrolls, and lower banks to the higher terraces (mainly in zone 6, but also in zones 1 and 4 in Fig. 4). Flooding decreases from twice or more a year to sporadic or not at all. The current of the flood-water which is strong in the lowest situations diminishes accordingly. Under influence of soil development in the alluvial deposits the soil reaction changes from alkaline under cane grass vegetation (GtS) to acid and occasionally strongly acid under tall forests with rather open or closed canopies (Fo, F).

(iii) *The Flood-out Sequence:* FmoP–Fmop–FmPM–M.—Strong currents caused by flash floods and high rates of sedimentation seem to be the factors determining this series (occurs in zones 1 and 6 of Fig. 4). The velocity and depth of flood-water and the amount and coarseness of sediment decrease from mid-height forest with an open canopy with pandans (FmoP) to mid-height forest with an irregular canopy with pandans and with sago palms and pandans in the understorey (FmPM) and sago palm vegetation (M). Inundation increases from occasional to permanent and the drainage status deteriorates accordingly.

(iv) *The Valley Sequence:* FmM–FmCM–FmoM–Me–M–HT.—This sequence is confined to valleys in the grassland zone (zone 5 in Fig. 4). Inundation is caused by run-on and subsequent ponding. It increases from about one week per year in

TABLE 12

RELATIONSHIPS BETWEEN VEGETATION TYPES AND SOIL DRAINAGE, FLOODING, AND INUNDATION

Drainage Status	Vegetation Type	Flooding and/or Inundation Regime
Good, occasionally imperfect	F (tall forest with rather closed canopy)	Sporadically flooded or not flooded
Good to imperfect, occasionally poor	Fo (tall forest with rather open canopy)	Flooding varies from none to once a year, occasionally lasts longer than a fortnight
Good to poor	Fod (tall forest with open canopy with light-toned crowns)	Flooded once in every 5 yr to twice annually, occasionally inundated for longer than a fortnight
	Fmo (mid-height forest with rather open canopy)	Flooded once every 1–3 yr, usually with some deposition of sand and silt
	CK (*Casuarina* sp.–*Ficus* mid-height forest)	Flooded once every 1–3 yr, with deposition of coarser sediments
Imperfect to poor	FodM (tall forest with open canopy with light-toned crowns and sago palms in understorey)	Flooded once in 1–3 yr, or inundated for up to 3 months
	FmoP (mid-height forest with open canopy with pandans)	Flooded at least once a year; usually strong damaging currents; occasionally inundated for up to 3 months
	GtS (cane grass (*Saccharum*) vegetation)	Flooded twice or more a year; strong currents; deposition of sand and silt
	Cs (*Casuarina* sp. mid-height forest)	As above, but with deposition of coarser sediment
	FmM (mid-height forest with irregular canopy and sago palms in understorey)	Inundated for up to a fortnight per year
Imperfect to very poor	FoM (tall forest with open canopy and sago palms in understorey)	Flooded once in 2 yr to twice annually; inundation varies from shallow to 1½ ft and from a few days to 1½ months per year

Poor to very poor	FmCM (mid-height forest with *Campnosperma* predominant in canopy and sago palms in understorey)	Inundated annually from a few days to a few months
	Fmop (mid-height forest with open canopy and pandans in understorey)	Flooded twice or more a year, inundated up to 3 months
Poor to swampy	FmoM (mid-height forest with open canopy and sago palms in understorey)	Shallowly inundated from a few days to up to 5 months per year
	Me (sago palm vegetation with emergent trees)	Inundated up to 3 ft from 1 to 8 months annually
Very poor to swampy	M (sago palm vegetation)	Frequently flooded and/or inundated for at least 3 months per year
	GtPh (tall grassland of reed (*Phragmites*) with other grasses)	Inundated for at least 1½ months per year, often deeply for some months
	GtS,P (cane grass vegetation with reed, pandan vegetation)	Inundated for at least 1½ months per year, often deeply for some months; liable to strong currents
	H (low sedge and related herbaceous vegetation)	Inundated for at least 3 months per year, 4 ft or more during 2 months or longer
	HT (tall sedge (*Thoracostachyum*) vegetation)	As above, but inundated for at least 5 months
Permanent swampy	FmPM (mid-height forest with irregular canopy with pandans and with sago palms and pandans in understorey)	Frequently flooded
	FmoCM (mid-height forest with open canopy with *Campnosperma* and with sago palms in understorey)	Inundated up to 4 ft for at least 5 months per year
	WT (woodland with tall sedge undergrowth)	Inundated up to 4 ft for at least 5 months per year

mid-height forest with an irregular canopy and sago palms in the understorey (FmM) to at least 5 months per year in tall sedge vegetation (HT). The drainage status deteriorates from imperfect to permanently swampy. Peat accumulation may occur when inundation is longer than 3 months per year.

(v) *The Sepik Plain Sequence:* Fod–GtS–P–Fmop–GtPh–HT–WT–FmoCM (zone 7 in Fig. 4).—The influences of flooding and inundation are difficult to disentangle in the Sepik flood-plain for several reasons: firstly, because of the instability of the flood-plain the vegetation does not always reach equilibrium with a new situation before it changes again; secondly, man interferes by burning grass and other herbaceous vegetation in the dry season and in doing so may deflect the succession. Tall forest with an open canopy with light-toned crowns (Fod) occurs only on the highest scrolls which are flooded at most once a year and for only a short period. Cane grass vegetation (GtS) on low scrolls and, with reed, in swales between higher scrolls, and pandan vegetation (P) in swales and adjacent back plains are frequently flooded, subject to strong currents, and inundated up to several months a year. Mid-height forest with pandans in the understorey (Fmop) and reed land (GtPh) are inundated for longer periods, but experience only moderate currents. Tall sedge vegetation (HT), woodland with tall sedge undergrowth (WT), and mid-height forest with an open canopy with *Campnosperma* and with sago palms in the understorey (FmoCM) occupy the more quiet areas where water becomes stagnant and permanent swamp conditions make peat development possible.

(*d*) *Origin of the Mid-height Grasslands*

Most of the mid-height grasslands (G) together with fern vegetation, often with sedges common (HD), are found on the inland plains, with some northward extensions into the hill zone. In this belt the annual rainfall increases from nearly 70 in. in the east to over 120 in. in the west. Rainfall, therefore, is unlikely to be the primary factor in the origin and maintenance of the grasslands. Even the fern vegetation, mainly found in the western parts, is probably not a response to wetter climate, for similar topography and soils carry grassland in a zone north-west of its main area (both Nigre (27) land system). It is probably mainly the result of less regular burning in isolated positions, because a similar vegetation was seen at Yambi Agricultural Experiment Station in areas protected from burning.

The mid-height grasslands in the survey area are less extensive than those in the adjacent Wewak–Lower Sepik area. The origin of the grasslands in this latter area is discussed by Robbins (1968), Reiner and Robbins (1964), and Haantjens, Mabbutt, and Pullen (1965). The conclusion reached is that the grasslands are fire climax communities and Haantjens, Mabbutt, and Pullen (1965) put forward the hypothesis that clearing of large areas of forest and early abandonment of the gardens because of the poor physical environment have promoted grassland formation and that expansion of the grasslands in poor regrowth has been facilitated by droughts and level topography. Evidence in the present survey area supports this hypothesis. The original forest cover seems to have been mid-height forest with a small-crowned canopy (Fms) in better-drained situations and mid-height forest with an irregular canopy and sago palms in the understorey (FmM) in imperfectly drained areas.

Both types indicate a poorer condition on the Pleistocene deposits than on the adjacent country on Tertiary rocks which carries tall forest with an irregular canopy with light-toned crowns (Fid). Mainly on the highest surface of Pleistocene deposits large areas are still left under Fms. It is not unlikely that the establishment of grassland on the lower surfaces has been favoured by the rather poorer soil drainage conditions.

Scattered patches of grassland occur in country covered with the Fms type, and are also widespread in areas with the Fid type as well as in the secondary vegetation associated with these types. Unfortunately, nothing is known about the relative or absolute age of these patches. It appears significant, however, that the grasslands are still small in the country with the Fid type, notwithstanding the dense population in this area. It suggests that maintenance and enlargement of grasslands in this environment obviously require stronger interference than in the poorer Fms region.

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PART VI. SOILS OF THE AITAPE–AMBUNTI AREA

By H. A. Haantjens*

I. Introduction

This account of the soils is based on 360 observations made at an overall rate of 1 per 13 sq miles, but actually unevenly distributed and mostly clustered in groups of 2–5. Notwithstanding this very low observation density, it is thought that the great majority of soil types occurring in the area have been sampled. Sampling sites were carefully selected to cover the greatest possible range of land form and vegetation types discernible on the aerial photographs, and there are no obvious large gaps in the spectrum of soils described. Whilst the range of soils described may therefore be considered reasonably comprehensive, the remarks made on the distribution of the soils must be considered more tentative. Information on soil distribution is obtained almost wholly by means of air-photo extrapolation of observed relationships between kinds of soil and rock type, land form, and vegetation. Since these relationships are by no means constant, sometimes appear to be unsystematic, and in several cases could not be rationally interpreted, there is of necessity a rather strong element of conjecture in the statements made about soil distribution, including the soil map.

All observations were made from auger holes perpendicular to the slope to a standard depth of 6 ft, unless this was prevented by gravel, stones, rock, or caving-in of the soil below a water-table. In some cases the holes were made to depths of up to 13 ft for the purpose of finding the lower limit of peat, the lower limit of the weathering zone, the upper boundary of a suspected sandy substratum, or the water-table. Auger samples are of limited value for the pedological study of soil, mainly because they yield poor information on the nature of soil horizon boundaries, soil structure, and shape and distribution of such features as mottles, concretions, etc. These limitations made it difficult or impossible to classify some soil profiles with certainty.

Since the survey of the Aitape–Ambunti area was prepared, executed, and written up in a very different manner from that employed in the 1959 survey of the adjoining Wewak–Lower Sepik area, no attempt was made to extend any soil classes defined in the latter into the Aitape–Ambunti area. A generalized *a posteriori* attempt at soil correlation is presented elsewhere.†

II. Classification System and Nomenclature

The soils have been classified 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 author's

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† CSIRO Aust. Div. Land Res. tech. Memo. No. 71/1, Part I (unpublished).

system.* The problems encountered in the application of the 7th Approximation and the ways in which they were dealt with were essentially similar to those discussed in an earlier report (Haantjens 1967*b*). A serious problem with soils without texture B horizon on sedimentary rock and in some cases with soils on alluvium was to distinguish a cambic horizon† from a C horizon or unconsolidated D horizon. A cambic horizon is assumed to be present in soils with a transition to decreasingly weathered parent rock within 6 ft depth, even if the colour of the soil is only olive-brown; in all dark brown to yellow-brown soils, unless there are clear indications of colluvial displacement in the form of scattered or aligned fresh rock fragments and no transition to weathered rock within 6 ft depth, where this would normally be expected to occur; and in all red-brown to red soils that cannot be classified as oxisols. In several doubtful transitional cases a decision was made on the basis of land form.

All higher-category soil classes have been given 7th Approximation names, with newly coined names in brackets for classes not described in this system. The lowest taxonomic soil classes have been labelled with up to four capital letters, of which the first identifies the order, the second the suborder, the third the great group, and the fourth the subgroup. A few classes have no letter symbols for subgroup or for great group, and only the order letter symbol is used for the histosols. In most cases one letter symbol covers more than one lowest soil class, and further distinction is made by numerical suffixes. Many of the lowest soil classes appear to be taxonomically equivalent to soil families, some may be soil series.

III. Grouping and Description of Soil Classes

The soil profiles recorded in the field have been grouped into 7 orders, 15 suborders, 23 great groups, 54 subgroups, and 112 lower soil classes. In the following text, the soils are arranged to bring out their taxonomic relationships. The descriptions are kept as brief as possible and mainly concern the distinguishing properties of each soil class. It is hoped that this layout may also serve as a useful key for identifying soils in later surveys. The brief descriptions of the higher-category soil classes with 7th Approximation names are also to be regarded as explanatory notes for these names. More detailed descriptions of the lowest soil classes (including number of observations) are available upon request. Terms used in the soil descriptions are defined in Appendix I, Section II(*e*).

The descriptions are not necessarily exhaustive with regard to the whole spectrum of soils envisaged in a class in the 7th Approximation, but only with respect to the soils observed in the survey area. It should be noted that at any categorical level, the complete description of any soil class includes the description of all the higher-category classes to which the soil class in question belongs. For instance, the description of class EAY1 consists not only of the features mentioned for this class, but also

* Haantjens, H. A. (1965).—The classification of oxisols (latosols). CSIRO Aust. Div. Land Res. Reg. Surv. tech. Memo. No. 65/5 (unpublished).

† Called a structure or colour B horizon in Section III. It is not characterized by the absence of clay or iron and/or humus illuviation, the absence of the typical properties of a latosol (oxic horizon), but by the presence of structural organization and homogenization (loss of rock structure), *in situ* clay formation, and brown to red colour due to the redistribution of iron.

of the features mentioned for the hydraquents, aquents, and entisols. Where a soil class in a certain category is described as having mostly, or rarely, a certain property, this property is not repeated in the description of those component lower-category soil classes that conform to the general rule in the higher class, but is only mentioned in those lower classes that are exceptions to the rule expressed for the higher class.

(*a*) *Histosols* (H)

These are peaty organic soils, usually containing 30–40% organic carbon, and overlying clayey mineral substrata at depths of 4 to more than 12 ft. This order is not subdivided into suborders, great groups, and subgroups.

H1.—Acid raw peat of open fabric and/or organic mud, partly suspended in water.

H2.—Mostly fairly dense, well to poorly decomposed, acid peat.

H3.—Stratified acid peaty clay, clayey peat, and peat.

H4.—Well-decomposed neutral peat overlying clay at depths rarely over 4 ft.

(*b*) *Entisols* (E)

These mineral soils have not been subject to weathering *in situ* and do not show pedogenetic horizon differentiation, apart from the possible development of a thin dark topsoil and possible mottling and gleying due to excessive soil moisture.

(i) *Aquents* (EA).—Very strongly to moderately gleyed entisols.

(1) *Hydraquents* (EAY).—Very strongly to strongly gleyed aquents that are permanently water-saturated, plastic and sticky, and at least partly muddy.

EAY1.—Alkaline soils of suspended mud over stratified medium-textured substrata; slightly calcareous with depth.

EAY2.—Weakly alkaline soils of loamy peat and loam merging into sand.

EAY3.—Weakly acid to neutral soils of clay to heavy clay with thin dark topsoil.

EAY4.—Weakly acid to neutral soils of stratified silty heavy clay to sandy loam with thin dark topsoil, and overlying loamy sand to sand.

EAY5.—Weakly acid clay soils.

(2) *Haplaquents* (EAH).—Strongly to moderately gleyed aquents with textures other than sand or loamy sand, which are nearly permanently to commonly water-saturated but mostly not muddy.

(2*a*) *Hydric Haplaquents* (EAHY).—Nearly permanently wet strongly gleyed haplaquents with muddy surface horizons.

EAHY1.—Acid to weakly acid soils of organic or peaty clay over heavy clay to clay.

EAHY2.—Neutral soils of loam and clay loam merging into heavy clay.

(2*b*) *Orthic Haplaquents* (EAHO).—Generally wet strongly gleyed haplaquents.

EAHO.—Neutral soils of silty heavy clay to heavy clay with thin dark topsoil.

(2*c*) *Udic Haplaquents* (EAHU).—Commonly wet moderately (rarely strongly) gleyed haplaquents, having many brownish mottles and lacking the blue-grey or green-grey matrix colours characteristic of hydric and orthic haplaquents.

EAHU1.—Weakly acid soils of clay to heavy clay.

EAHU2.—Weakly acid to acid soils of stratified silty clay to loam.

EAHU3.—Weakly acid strongly gleyed soils of stratified heavy clay to fine sandy loam.

(2*d*) *Spodic Haplaquents* (EAHS).—Commonly wet moderately gleyed haplaquents having a brown-grey not mottled horizon above strongly greyish and brownish mottled lower horizons.

EAHS1.—Alkaline calcareous soils of stratified loamy sand to silty clay merging into sand, and with a thin dark topsoil.

EAHS2.—Neutral soils of silty clay merging into silty heavy clay.

EAHS3.—Weakly acid to neutral soils of clay loam over heavy clay, and with a thin dark topsoil.

(3) *Psammaquents* (EAP).—Very strongly gleyed aquents with sand to loamy sand texture.

(3*a*) *Orthic Psammaquents* (EAPO).—Greyish-coloured psammaquents with sandy textures to a depth of at least 30 in.

EAPO.—Weakly alkaline to alkaline soils; can have thin peaty loamy surface horizon.

(ii) *Udents* (EU).—Generally moist entisols, which are not strongly or very strongly gleyed and have textures finer than loamy sand.

(1) *Hapludents* (EUH).—Udents that are non-gleyed or slightly (rarely moderately) gleyed.

(1*a*) *Aquic Hapludents* (EUHA).—Slightly (rarely moderately) gleyed hapludents.

EUHA1.—Weakly alkaline to alkaline, slightly to moderately gleyed soils of stratified sand to silty clay loam, commonly calcareous.

EUHA2.—Weakly acid to neutral, slightly to moderately gleyed soils of stratified clay to silt loam.

EUHA3.—Weakly acid to neutral soils of clay loam to silty heavy clay over heavy clay.

EUHA4.—Acid soils of loam to silty clay loam; much gravel at depth.

EUHA5.—Neutral soils of silty heavy clay to heavy clay; few weathered rock fragments; thin dark topsoil.

EUHA6.—Neutral soils of clay to sandy clay loam, somewhat stratified; variable weathered rock fragments; thin dark topsoil.

EUHA7.—Weakly acid soils of clay loam over clay to silty heavy clay; few weathered rock fragments; thin dark topsoil.

(1*b*) *Orthic Hapludents* (EUHO).—Essentially non-gleyed hapludents, which are generally deep to very deep, more rarely moderately deep to moderately shallow.

EUHO1.—Alkaline mostly calcareous soils of stratified silty clay loam to fine sandy loam; commonly variable gravel with depth.

EUHO2.—Neutral to weakly alkaline soils of stratified clay loam to loamy sand; commonly variable gravel.

EUHO3.—Neutral soils of loam to silty clay over silty clay to silty heavy clay, at depth stratified with sandy loam.

EUHO4.—Weakly acid soils of stratified clay to sandy clay loam.

EUHO5.—Weakly acid to acid soils of stratified clay loam to loamy sand; commonly variable gravel.

EUHO6.—Weakly acid moderately deep to moderately shallow soils of silty heavy clay; very few to few weathered rock fragments.

EUHO7.—Weakly acid soils of clay to sandy clay loam, commonly stratified; commonly variable rock fragments.

EUHO8.—Weakly acid to acid moderately to very deep soils of loam to clay over loam to clay loam; commonly marked sand component; variable rock fragments.

EUHO9.—Acid moderately to very deep soils of loam to clay loam; variable rock fragments.

(1*c*) *Lithic Hapludents* (EUHL).—Shallow to very shallow hapludents, non-gleyed, and overlying hard rock.

EUHL.—Neutral to weakly acid soils of loam to clay loam; variable rock fragments.

(1*d*) *Thapto* (*Psammollic*) *Hapludents* (EUHT).—Shallow hapludents overlying slightly developed sandy soils with a neutral thick dark topsoil.

EUHT.—Neutral soils of silty clay loam over sandy loam merging into sand.

(iii) *Psamments* (EP).—Slightly gleyed or non-gleyed entisols of sand to loamy sand texture.

(1) *Orthopsamments* (EPO).—Psamments with minor quartz and consisting predominantly of feldspars and dark minerals.

(1*a*) *Aquic Orthopsamments* (EPOA).—Slightly gleyed orthopsamments.

EPOA.—Neutral over strongly alkaline soils of loamy sand over sand, and with a thin dark topsoil; calcareous at depth.

(1*b*) *Orthic Orthopsamments* (EPOO).—Very slightly gleyed to non-gleyed orthopsamments.

EPOO.—Alkaline calcareous soils of loamy sand stratified at depth with some non-calcareous silty clay.

(*c*) *Mollisols* (M)

These slightly to moderately developed soils have a weakly acid to weakly alkaline thick* dark topsoil (mollic epipedon).

(i) *Udolls* (MU).—Mollisols that are usually moist and not gleyed, or rarely slightly gleyed.

(1) *Hapludolls* (MUH).—Non-gleyed udolls without a texture B horizon.

(1*a*) (*Orthopsammentic*) *Hapludolls* (MUHP).—Slightly developed hapludolls with a very thin solum and with a sand to loamy sand texture containing little quartz but predominantly feldspars and dark minerals.

MUHP.—Neutral soils of sand with a moderately thick dark topsoil.

(1*b*) *Entic Hapludolls* (MUHE).—Slightly developed hapludolls with textures finer than loamy sand and with a very thin to thin solum without any B horizon.

* Relative to thickness of solum.

MUHE.—Weakly acid to neutral soils of clay loam to silty clay, with a moderately thick dark topsoil; commonly variable gravel at depth.

(1*c*) *Orthic Hapludolls* (MUHO).—Generally moderately developed hapludolls with a structure and/or colour B horizon (cambic horizon).

MUHO1.—Slightly to moderately developed, weakly alkaline soils with a moderately thin solum, sandy clay loam to silty clay texture and thick dark topsoil; calcareous in C_1 and C_2 horizons.

MUHO2.—Moderately developed, neutral over acid soils of clay to heavy clay with a moderately thick solum and thick dark topsoil.

(2) *Argudolls* (MUA).—Moderately developed udolls with a texture B horizon and a thick dark topsoil.

(2*a*) *Orthic Argudolls* (MUAO).—Argudolls with little or no gleying.

MUAO.—Weakly acid slightly gleyed soils of clay loam merging into silty heavy clay; moderately thick solum.

(ii) *Rendolls* (MR).—Mollisols with large amounts of calcareous material below the dark topsoil.

(1*a*) *Orthic Rendolls* (MR-O).—Non-gleyed rendolls without any B horizon.

MR-O1.—Slightly developed alkaline calcareous soils of gravelly loam with a very thin solum and a thin to moderately thick dark topsoil; overlie coral sand and/or rock.

MR-O2.—Slightly to moderately developed neutral to weakly alkaline soils of clay to clay loam, with a thin solum and a moderately thick to thick dark topsoil; overlie hard calcareous rock.

(1*b*) *Eutrochreptic Rendolls* (MR-E).—Non-gleyed moderately developed rendolls with a colour or slight texture B horizon and a moderately thick dark topsoil.

MR-E.—Weakly alkaline to alkaline, in some cases calcareous soils of clay to silty heavy clay, with a moderately thin solum; overlie hard calcareous rock.

(*d*) *Inceptisols* (I)

These slightly to strongly developed soils have a structure and/or colour B horizon (cambic horizon) and/or a weakly to strongly acid thick* dark topsoil (umbric epipedon).

(i) *Aquepts* (IA).—Moderately to strongly gleyed inceptisols.

(1) *Umbraquepts* (IAU).—Slightly developed aquepts with a weakly to strongly acid thick dark topsoil.

(1*a*) (*Orthopsammentic*) *Umbraquepts* (IAUP).—Umbraquepts of sand to loamy sand texture, with little quartz but predominantly feldspars and dark minerals.

IAUP.—Acid strongly gleyed soils of organic loam merging into sand; thin solum.

(1*b*) *Orthic Umbraquepts* (IAUO).—Umbraquepts with textures finer than loamy sand, and with a thin solum.

IAUO1.—Acid to weakly acid moderately gleyed soils of clay overlying heavy clay lower in the subsoil.

* Relative to thickness of solum.

IAUO2.—Acid strongly gleyed soils of heavy clay with thin clay loam surface horizon.

IAUO3.—Acid to strongly acid moderately to strongly gleyed soils of clay loam to sandy clay loam.

(ii) *Umbrepts* (IU).—Non-gleyed inceptisols with a weakly acid to acid thick to moderately thick dark topsoil.

(1) *Haplumbrepts* (IUH).—Umbrepts of warm climates.

(1*a*) (*Orthopsammentic*) *Haplumbrepts* (IUHP).—Slightly developed haplumbrepts of loamy sand to sand texture, with little quartz but predominantly feldspars and dark minerals.

IUHP.—Weakly acid soils of loamy sand over sand; thin to moderately thin solum; thick dark topsoil.

(1*b*) *Entic Haplumbrepts* (IUHE).—Slightly developed haplumbrepts of textures finer than loamy sand and without any B horizon.

IUHE.—Weakly acid soils of loam merging into fine sand; thin solum; thick dark topsoil.

(1*c*) *Orthic Haplumbrepts* (IUHO).—Slightly to moderately developed haplumbrepts with a structure and/or colour B horizon (cambic horizon) and a solum thicker than 20 in.

IUHO1.—Acid soils of clay loam over sandy clay loam; moderately thin solum; moderately thick dark topsoil.

IUHO2.—Acid soils of loam merging into sand; moderately thin solum; thick dark topsoil.

(1*d*) *Lithic Haplumbrepts* (IUHL).—Slightly developed haplumbrepts overlying dense weathered or hard fresh rock at very shallow to shallow depth.

IUHL.—Weakly acid soils of clay loam to clay without B horizon, with thin to very thin solum and a moderately thick to thick dark topsoil; very many rock fragments below solum.

(iii) *Ochrepts* (IO).—Slightly gleyed or non-gleyed inceptisols without a thick* dark topsoil but having a structure and/or colour B horizon (cambic horizon).

(1) *Eutrochrepts* (IOE).—Non-gleyed alkaline ochrepts with calcareous substratum.

(1*a*) (*Lithic*) *Eutrochrepts* (IOEL).—Eutrochrepts overlying hard rock at shallow depth.

IOEL.—Slightly developed soils of clay loam, with thin solum and thin dark topsoil; increasing rock fragments with depth.

(2) *Dystrochrepts* (IOD).—Non-alkaline ochrepts.

(2*a*) *Aquic Dystrochrepts* (IODA).—Slightly gleyed moderately developed dystrochrepts.

IODA1.—Acid to weakly acid soils of silty heavy clay to heavy clay; moderately thin to moderately thick solum.

IODA2.—Acid soils of clay loam, silty clay loam, clay, silty clay; moderately thin to moderately thick solum; thin dark topsoil.

* Relative to thickness of solum.

(2*b*) *Eutric Dystrochrepts* (IODE).—Weakly acid, rarely neutral, non-gleyed, mostly moderately developed dystrochrepts with solum thicker than 20 in.

IODE1.—Slightly developed neutral soils of clay or silty clay, with a moderately thin to moderately thick solum and increasing weathered rock fragments with depth; lower solum and substrata can be calcareous.

IODE2.—Sandy clay loam, clay loam, sandy clay soils with moderately thin to moderately thick solum; commonly weathered rock fragments with depth.

IODE3.—Clay to clay loam soils with moderately thin to moderately thick solum; increasing weathered rock fragments with depth.

IODE4.—Silty heavy clay to heavy clay soils with moderately thin to thick solum; variable weathered rock fragments at depth.

IODE5.—Clay soils with a thick solum.

(2*c*) (*Lithic*) *Dystrochrepts* (IODL).—Non-gleyed dystrochrepts overlying hard compact weathered rock at shallow depth.

IODL1.—Slightly developed weakly acid to neutral soils of silty clay or clay, with a very thin to thin solum and many rock fragments with depth.

IODL2.—Moderately developed acid to strongly acid soils of sandy clay loam to silty clay, with a very thin solum and increasing weathered rock fragments with depth.

(2*d*) *Orthic Dystrochrepts* (IODO).—Acid to strongly acid non-gleyed moderately to strongly developed dystrochrepts.

IODO1.—Moderately developed acid soils of silty clay to clay, with a moderately thin to moderately thick solum and increasing rock fragments with depth.

IODO2.—Moderately developed acid soils of clay loam, with a moderately thin solum and rapidly increasing weathered rock fragments with depth.

IODO3.—Strongly developed acid soils of silty clay loam to clay loam, with a moderately thick to thick solum and variable gravel at depth.

IODO4.—Strongly developed acid soils of somewhat stratified clay to sandy clay loam, with a moderately thin to thick solum.

IODO5.—Moderately developed strongly acid soils of clay loam, silty clay loam, silty clay, with a moderately thin to moderately thick solum and variable (mostly many) weathered rock fragments.

(2*e*) *Oxic Dystrochrepts* (IODX).—Strongly developed dystrochrepts resembling oxisols, but containing too many weatherable minerals.

IODX.—Strongly acid soils of clay loam, sandy clay loam, sandy clay; moderately thin to moderately thick solum; commonly few, but increasing strongly weathered rock fragments with depth.

(*e*) *Alfisols* (A)

These mostly moderately developed soils have a minimum pH in the B horizon of 5·5 and have a texture B horizon (argillic horizon), as deduced from the presence of a clearly coarser-textured (at least one textural class) surface horizon at least 5 in. thick.

(i) *Aqualfs* (AA).—Mostly moderately gleyed alfisols.

(1) *Umbraqualfs* (AAU).—Aqualfs with a thick dark topsoil.

AAU1.—Weakly acid to acid soils of clay loam merging into heavy clay; moderately thick to thick solum; can have few weathered rock fragments or concretions in lower B horizon.

AAU2.—Acid moderately to strongly gleyed soils of loam to sandy loam merging into clay; moderately thin to moderately thick solum; can have increasing quartz gravel with depth.

AAU3.—Acid soils of clay loam over clay; thin solum; concretions increasing with depth in B horizon and increasing weathered rock fragments with depth.

(2) *Ochraqualfs* (AAO).—Aqualfs without a thick dark topsoil.

(2*a*) *Umbric Ochraqualfs* (AAOU).—Ochraqualfs with a moderately thick dark topsoil.

AAOU.—Weakly acid soils of clay loam over clay and heavy clay; moderately thick solum.

(2*b*) *Orthic Ochraqualfs* (AAOO).—Ochraqualfs without or with a thin dark topsoil.

AAOO.—Weakly acid to neutral soils of clay to clay loam over silty heavy clay to clay; moderately thick solum; variable weathered rock fragments at depth.

(ii) *Udalfs* (AU).—Slightly gleyed or non-gleyed alfisols of moist warm climates.

(1) *Typudalfs* (AUT).—Udalfs without a bleached A_2 horizon tonguing into the B horizon.

(1*a*) *Aquollic Typudalfs* (AUTQ).—Slightly gleyed typudalfs with a moderately thick dark topsoil.

AUTQ.—Weakly acid soils of clay to clay loam over heavy clay; moderately thin to moderately thick solum.

(1*b*) *Aquic Typudalfs* (AUTA).—Slightly gleyed typudalfs without or with a thin dark topsoil.

AUTA1.—Weakly acid to acid soils of loam to clay loam over clay; moderately thick solum.

AUTA2.—Moderately to strongly developed acid soils of clay loam or silt loam merging into silty heavy clay to heavy clay; moderately thick to thick solum.

AUTA3.—Weakly acid to acid soils of clay loam merging into silty heavy clay to heavy clay; moderately thin to thick solum.

(1*c*) *Mollic Typudalfs* (AUTM).—Non-gleyed typudalfs with a moderately thick dark topsoil.

AUTM.—Weakly acid to acid soils of clay loam over clay; moderately thick solum.

(1*d*) *Orthic Typudalfs* (AUTO).—Non-gleyed typudalfs with a thin dark topsoil.

AUTO1.—Slightly to moderately developed alkaline soils of clay loam to clay over silty heavy clay over silty clay; moderately thick solum that can be calcareous in its lower part; variable rock fragments at depth.

AUTO2.—Weakly acid to neutral soils of loam to clay over silty clay, clay, silty heavy clay, or heavy clay; moderately thin solum; commonly increasing rock fragments with depth.

AUTO3.—Weakly acid to acid soils of clay loam over clay; moderately thin to moderately thick solum; commonly variable gravel or rock fragments at depth.

(*f*) *Ultisols* (U)

These are moderately to very strongly developed acid to strongly acid soils (maximum pH 5·5 in B horizon) with a texture B horizon (argillic horizon), as deduced from the presence of clearly coarser-textured (at least one textural class) surface horizons at least 5 in. thick. In very strongly developed soils the textural B horizon must have low friability and is mostly very firm to very plastic when moist.

(i) *Aquults* (UA).—Ultisols that are gleyed immediately below or already within any dark topsoil present, or in at least part of the A_2 horizon if no dark topsoil is present.

(1) *Umbraquults* (UAU).—Aquults with a thick dark topsoil and lacking the bright mottling specified for plintaquults.

UAU1.—Strongly developed acid moderately to strongly gleyed soils of loam merging into heavy clay; thick solum; few black concretions in B horizon.

UAU2.—Strongly developed acid to strongly acid moderately gleyed soils of loam to clay loam merging into silty heavy clay and heavy clay; moderately thick solum; can have very few concretions in lower B horizon.

(2) *Ochraquults* (UAO).—Aquults without a thick dark topsoil and lacking the bright mottling specified for plintaquults.

(2*a*) (*Umbric*) *Ochraquults* (UAOU).—Ochraquults with a moderately thick dark topsoil.

UAOU.—Moderately developed acid moderately gleyed soils of clay loam over clay to silty heavy clay; moderately thin solum; variable weathered rock fragments in C horizon.

(3) *Plintaquults* (UAP).—Mostly very strongly developed aquults with prominent red, brown, and light grey mottling (considered to be plinthite) in the subsoil.

(3*a*) (*Umbric*) *Plintaquults* (UAPU).—Plintaquults with a thick dark topsoil.

UAPU1.—Strongly acid moderately gleyed soils of loam merging into silty heavy clay to heavy clay; very thick solum; may have few concretions in B horizon.

UAPU2.—Acid to strongly acid slightly gleyed soils of loam to clay loam merging into silty heavy clay; moderately thin to thick solum.

(3*b*) (*Umbraquultic*) *Plintaquults* (UAPB).—Plintaquults with a moderately thick dark topsoil.

UAPB1.—Strongly developed acid moderately gleyed soils of loam merging into heavy clay; moderately thick solum.

UAPB2.—Strongly to very strongly developed acid to strongly acid moderately to strongly gleyed soils of loam to sandy clay loam merging into silty heavy clay to heavy clay; moderately thin to thick solum; mostly few to moderate concretions in B horizon.

(3*c*) (*Ochraquultic*) *Plintaquults* (UAPA).—Strongly gleyed plintaquults without a dark topsoil.

UAPA.—Strongly acid soils of silt loam merging into silty heavy clay; probably very thick solum.

(ii) *Ochrults* (UO).—Ultisols without a thick dark topsoil and without gleying beginning at shallow depth as specified for the aquults.

(1) *Typochrults* (UOT).—Ochrults without the bright mottling specified for plintochrults.

(1*a*) (*Umbraquic*) *Typochrults* (UOTB).—Moderately developed slightly to moderately gleyed typochrults with a moderately thick dark topsoil.

UOTB1.—Weakly acid slightly gleyed soils of clay loam merging into heavy clay; moderately thick solum.

UOTB2.—Acid moderately gleyed soils of clay loam over silty heavy clay; moderately thick solum.

(1*b*) (*Lithaquic*) *Typochrults* (UOTH).—Moderately developed slightly gleyed typochrults without a dark topsoil and overlying hard rock at shallow depth.

UOTH.—Acid soils of sandy clay loam over sandy clay; thin solum.

(1*c*) *Aquic Typochrults* (UOTA).—Slightly gleyed typochrults without or with a thin dark topsoil and a solum thicker than 20 in.

UOTA1.—Moderately developed acid soils of sandy clay loam to clay loam merging into silty clay to heavy clay; thick solum; can have variable concretions and gravel in B horizon.

UOTA2.—Strongly developed acid to strongly acid soils of fine sandy loam to loam over sandy clay to clay; moderately thin solum; can have variable gravel in subsoil.

(1*d*) *Orthic Typochrults* (UOTO).—Non-gleyed typochrults without or with thin dark topsoils and a solum thicker than 20 in.

UOTO1.—Moderately developed acid soils of sandy loam to clay loam over sandy clay to clay; moderately thick solum; thin dark topsoil; mostly variable weathered rock fragments in C horizon.

UOTO2.—Moderately to strongly developed acid soils of loam to clay loam over silty clay to clay; moderately thin to thick solum; variable gravel and weathered rock fragments, increasing with depth.

UOTO3.—Strongly developed acid soils of loam to clay loam merging into clay, silty heavy clay, heavy clay; moderately thick to thick solum; commonly variable gravel and in some cases concretions; can be slightly gleyed.

UOTO4.—Strongly developed acid soils of clay loam merging into heavy clay; thick solum; thin dark topsoil.

UOTO5.—Very strongly developed strongly acid soils of loam to clay merging into silty heavy clay to heavy clay; moderately thick to thick solum; can have few strongly weathered rock fragments.

(2) *Plintochrults* (UOP).—Ochrults with prominent red, brown, and light grey mottling (considered to be plinthite) in the subsoil.

(2*a*) (*Umbraquic*) *Plintochrults* (UOPB).—Very strongly developed slight to moderately gleyed plintochrults with a moderately thick dark topsoil.

UOPB.—Acid soils of loam to sandy clay loam merging into silty heavy clay to heavy clay; moderately thick to thick solum; can have concretions in A_2 and upper B horizons, decreasing with depth.

(2*b*) (*Aquic*) *Plintochrults* (UOPA).—Mostly slightly gleyed plintochrults without or with a thin dark topsoil.

UOPA1.—Strongly developed acid slightly to moderately gleyed soils of clay loam over clay, silty heavy clay, heavy clay; moderately thin to thick solum; can have few concretions in upper B horizon.

UOPA2.—Very strongly developed acid to strongly acid soils of sandy loam to loam over sandy heavy clay, silty heavy clay, heavy clay; moderately thick to very thick solum; little to moderate quartz gravel.

UOPA3.—Very strongly developed strongly acid soils of loam to clay loam merging into silty heavy clay and heavy clay; thick solum; can have few concretions in upper B horizon.

(2*c*) *Typic Plintochrults* (UOPT).—Very strongly developed non-gleyed plintochrults without or with a thin dark topsoil.

UOPT.—Acid soils of clay loam merging into silty heavy clay and heavy clay; thick solum; commonly has variable concretions in A and upper B horizons.

(iii) *Umbrults* (UU).—Ultisols with a thick dark topsoil and without gleying beginning at shallow depth as specified for the aquults.

(1) *Plintumbrults* (UUP).—Strongly to very strongly developed umbrults with prominent red, brown, and light grey mottling (considered to be plinthite) in the subsoil.

UUP.—Acid to strongly acid slightly gleyed soils of loam, sandy clay loam, and clay loam, merging into clay; moderately thin to thick solum; can have variable quartz gravel; can have few concretions in A_2 and upper B horizons.

(*g*) *Oxisols* (O)

These are very strongly developed strongly acid soils with a B horizon of minimal structure but high friability in relation to clay content (oxic horizon), and not overlain by a bleached A_2 horizon or any horizon with an abrupt texture change.

(i) (*Argox*) (OA).—Oxisols with a texture B horizon (argillic plus oxic horizon), as deduced from the presence of a clearly coarser-textured (one textural class) surface horizon at least 5 in. thick.

(1) (*Normargox*) (OAN).—Non-gleyed argox without a thick dark topsoil.

(1*a*) (*Umbric Normargox*) (OANU).—Normargox with a moderately thick dark topsoil.

OANU.—Soils of loam to clay loam merging into clay loam to clay; moderately thick to thick solum; mostly very low to moderate quartz gravel in B horizon; commonly few concretions above B horizon.

(1*b*) (*Typic Normargox*) (OANT).—Normargox without a dark topsoil.

OANT1.—Soils of loam to sandy clay loam merging into silty clay; thick to very thick solum; few very strongly weathered rock fragments, increasing with depth; can have little quartz gravel.

OANT2.—Soils of silty clay loam over clay; moderately thick solum; few very strongly weathered rock fragments in C horizon.

IV. Soil Distribution

(*a*) *Introduction*

The land system map can be used as a map of associations of the lowest category soil classes, as listed in the weathering and soils section of the detailed land system descriptions (Appendix III); or as a map of associations of soil subgroups, as listed in the synoptic land system descriptions (Part III). The distribution of great soil groups is shown on a separate map. In the reference to this map, the first 13 associations of undeveloped soils are arranged in order of decreasing hydromorphic soils. The other soil associations are arranged in order of increasing soil development. In this section soil distribution is discussed entirely in terms of orders and great groups and with reference to the associations on the soil map and to the air-photo illustrations of land systems in Part II. Points of interest concerning subgroups and lowest category soil classes are discussed in Section V of this Part. Areas given for soil orders and great soil groups are highly tentative estimates of the relative abundance or scarcity of the various kinds of soil in the area.

(*b*) *Histosols*

Most of the 160 sq miles of peaty soils occur in the back swamps of the Sepik River flood-plain (associations A to C1). Their presence supports other evidence for low rates of sedimentation in this plain, such as the fine texture of all alluvial deposits, the incapability of the river to build proper levee banks, and the absence of major bars in the river mouth (Reiner and Mabbutt 1968). Whilst histosols have been observed with many kinds of swamp vegetation, they appear to be most common under *Campnosperma* forest and swamp woodland (Plate 4). These combinations of soil and vegetation probably reflect permanently wet stable conditions with a minimum of sedimentation. Histosols are rarest under pandan vegetation (Plate 3, Fig. 2), which commonly appears to be indicative of unstable flood-plain conditions with greater movement of sediments. These soils are also less common in the grassland back swamps (Plate 2, Fig. 2; Plate 3, Fig. 1) which are characterized by great fluctuations in water level over the year.

Histosols are also an important component of the soils of swampy valleys (Plate 5, Fig. 2) along the edges of weathered surfaces in the inland plains. Included in soil associations A, B1, B2, C1, and E1, these valleys have a very low rate of sedimentation and thus have become blocked by the alluvia of streams in adjoining larger valleys.

In those parts of associations B2 and E1 that form the lowest wettest portions of alluvial plains and fans (Plate 5, Fig. 1) histosols occur much more rarely, because these are clearly more vigorously aggrading environments. This applies particularly to the coastal plains, where histosols appear to be restricted to a few small areas behind beach-ridge complexes.

The many different vegetation types found on peat soils would suggest a variety of plant residue sources for these soils. This is confirmed by the very limited field evidence. Some soils contain wood fragments and are derived from forest vegetation, with sago palms probably as the major producer of organic residue. Others appear to be derived solely from herbaceous vegetation, with *Phragmites* as the likely main supplier.

(*c*) *Entisols*

With an estimated total area of 2200 sq miles, this order of soils with pedologically undeveloped profiles is the largest in the area. This reflects not only the wide distribution of alluvial soils on youthful swamps, plains, and fans, but is due even more to the widespread occurrence of undeveloped colluvial soils on unstable hill slopes.

(i) *Hydraquents.*—These typical mineral swamp soils, characterized by strong gleying and a very low bearing strength due to saturation with water, occupy about

270 sq miles. They occur very largely in freshwater swamps in the alluvial plains, but also on tidal flats (Plate 2, Fig. 1), where they are saline (association C2). In the wettest parts of the swamps they occur in association with histosols (see previous section), whilst in less swampy areas they are associated with haplaquents, hapludents, and other soils (associations C1 to E1). In soil associations H, O, and P the hydraquents occur in minor tracts of low-lying swamp land dispersed among higher ground with quite unrelated soils. The hydraquents are associated with essentially the same variety of vegetation types as the histosols.

(ii) *Haplaquents.*—Having greater bearing strength than the hydraquents, these moderately to strongly gleyed soils occur extensively in those parts of swamps and alluvial plains where the water-table is very high in the wet season but recedes several feet below the land surface during the dry. Such areas include the meander plain (Plate 6, Fig. 1) and the higher parts of the back plains of the Sepik River (associations B2, B3, D1), as well as extensive low-lying alluvial plains (associations D2, E1, E2) and small low parts of flood-outs, fans, terraces, and valley floors in associations C3, F1, G, N, Q3. The alluvial haplaquents are mostly associated with sago palm vegetation and with forests with sago palms in the understorey (Plate 5, Fig. 1; Plate 7; Plate 8, Fig. 1), but occur also under grassland in the Sepik flood-plain.

A significant proportion of the 640 sq miles of haplaquents does not occur as alluvial soils, but as colluvial soils on the floors of slumps and in seepage zones on unstable hill slopes on sedimentary rocks such as mudstone and siltstone in associations F5, J2, L1, and M (e.g. Plate 20, Fig. 2; Plate 22, Fig. 1; Plate 23, Fig. 2). In these associations the haplaquents occur as small scattered pockets, under a natural vegetation of forest but often used for native gardens and planting of sago palms. As is to be expected, the haplaquents are associated with quite different soils in these associations than on the alluvial plains and swamps.

(iii) *Psammaquents and Orthopsamments.*—With a total area of less than 20 sq miles these sandy soils are very rare, a fact that reflects the general lack of sand in the rock-weathering products that are the source of the alluvia in the area. Occurring locally in soil associations C2, C3, E1, and H, these soils are confined partly to beach deposits along the coast, partly to the upper parts of unstable flood-outs and scroll plains (Plate 6, Fig. 2). Mangroves, sago palm, and pandan vegetation cover the poorly drained psammaquents; pandan vegetation and *Casuarina* forest cover the better-drained orthopsamments.

(iv) *Hapludents.*—Covering nearly 1300 sq miles these slightly gleyed or non-gleyed undeveloped soils are the largest great group in the area, and occur in 23 of the 43 soil associations. Probably more than anything else, this underlines the youthful condition of much of the land from the pedological point of view. This is due to very recently completed or still continuing aggradation of sediments in the plain sectors. In the hill sectors it is caused by slope instability as a result of surficial mass movement (Plate 18, Fig. 2), earth flow (Plate 19, Fig. 2), or rotational slumping (Plate 21, Fig. 2) on sedimentary rocks that are not very hard even when fresh.

The alluvial hapludents are dominant in associations D2, F1–F4, and G, where they are associated mostly with equally undeveloped but more gleyed soils. In association L2 rather acid alluvial hapludents have been observed on terrace surfaces up to 300 ft above stream level (Plate 11, Fig. 2), a fact that suggests an extraordinarily rapid rate of stream incision in this part of the area.

The colluvial hapludents are dominant only in association F5, but subdominant in many other soil associations of the hills (J1–J3, K1, L1, L2, M, N). In these cases they are associated with a great variety of more developed residual soils.

The natural vegetation on hapludents is tall to mid-height forest, but the types occurring in the plains (Plate 8, Fig. 2) are quite different from those in the hills and mountains (Plate 21, Fig. 1). These soils, particularly those on hill slopes, are commonly cleared for native shifting cultivation (Plate 10, Fig. 2; Plate 21, Fig. 2).

(*d*) *Mollisols*

With about 70 sq miles, this order of soils with neutral thick dark topsoils is of very minor importance in the area. Most mollisols are associated with rather specific environmental conditions.

(i) *Hapludolls*.—On alluvial deposits the development of a thick dark topsoil (the only attribute distinguishing most of the hapludolls from hapludents) is commonly the first clear expression of horizon differentiation. This is the case on some 30 sq miles of higher and no longer aggrading river terraces in association F3, but particularly F4 and G (Plate 9, Fig. 2; Plate 10, Fig. 1), and on young beach ridges in association H, just inland from the coastal ridges with orthopsamments. Near the coast these hapludolls are mostly under grassland, but on the river terraces they are covered with tall forest.

Hapludolls with B as well as A_1 horizons appear to occur very rarely as residual soils on hill slopes of sedimentary rock (associations K4 and N).

(ii) *Argudolls*.—These rare soils (3 sq miles) with coarser-textured surface horizons and rather poor drainage have been observed only in soil association Q3, where they occur on dissected plains of Pleistocene sediments (Plate 13, Fig. 1), apparently in places where the original weathering zone has been partly stripped off by denudation. These soils are closely related to umbraqualfs occurring in similar situations (subsection (*f*)(i)), and have a vegetation of grassland.

(iii) *Rendolls*.—These shallow dark soils probably occupy 30 sq miles and are associated with limestone, particularly in associations I1 and I2 of coral platforms (Plate 1, Fig. 1), coastal hills, and massive low mountains (Plate 27), but also wherever limestone forms a minor rock type in other soil associations (F5, J1, R1). The correlation between rendolls and pure or tuffaceous limestone is very close and virtually independent of land form. The rendolls are normally covered with tall forest, but locally cleared for native gardens and coconut plantations.

(*e*) *Inceptisols*

This second largest soil order covering nearly 1300 sq miles includes several different kinds of slightly to strongly developed soils that, however, never have coarser-textured surface horizons. It includes the dominant soils on erosional hill slopes throughout the area.

(i) *Umbraquepts and Haplumbrepts.*—Soils in both great groups are characterized by acid thick dark topsoils but little or no other profile development. Most of the 50 sq miles of strongly gleyed umbraquepts occur in soil associations B3 and H4. In the first of these they are very fine-textured soils under grassland in the Sepik River back swamps (Plate 3, Fig. 1), where they are associated with other very poorly drained soils such as haplaquents, hydraquents, and histosols. In the second association they are sandy soils found under sago palm vegetation in swales separating beach ridges with mostly haplumbrepts that are also very sandy and largely covered with grassland (Plate 1, Fig. 2). As typical soils of the older beach ridges, haplumbrepts occur also as minor soils in association G of coastal fans.

The umbraquepts in associations P, Q2, and Q3 are colluvial soils that occur in small grassed valley floors and slump alcoves formed by the dissection of weathered surfaces on Pleistocene sediments in or near the inland plains (Plate 13, Fig. 1). Similar soils were observed in large slumps on dip slopes in association P (Plate 22, Fig. 2).

In addition to the alluvial types, shallow residual haplumbrepts were observed locally under forest and regrowth on hill slopes and ridge crests on sedimentary rocks in the higher-rainfall parts of the area (associations J2, K4, and K7). The total area of haplumbrepts appears to be less than 30 sq miles.

(ii) *Eutrochrepts.*—These rare (less than 20 sq miles) alkaline shallow residual soils on calcareous sedimentary rocks appear to be restricted to local very steep erosional slopes and spur crests in the central hill zone (associations J2, L1). They have been observed mainly under regrowth and garden vegetation and represent the least-developed non-colluvial hill slope soils in the area.

(iii) *Dystrochrepts.*—With nearly 1200 sq miles this second largest great soil group includes shallow to deep weakly to strongly acid slightly to strongly developed soils. These are the dominant soils on erosional hill slopes on all consolidated parent rocks (except limestone) and on dissection slopes in Pleistocene sediments. They occur in 25 of the 43 soil associations and are dominant in 8, subdominant in 13. The only associations in which these soils do not occur are those consisting wholly of young alluvial deposits or limestone and, in addition, one association (Q1) on undissected very poorly drained Pleistocene alluvium.

As residual soils the dystrochrepts are much more common on straight erosional slopes than on irregular slopes with colluvial mantles and slumps. Such straight slopes tend to predominate in areas of igneous and metamorphic rock (Plate 28, Fig. 2; Plate 30, Fig. 2) and in areas of harder sedimentary rock (Plate 19, Fig. 2; Plate 28, Fig. 1), but also occur together with colluviated slopes in hilly areas on softer mudstone and siltstone (Plate 16). In all these situations (associations K1–K8), the dystrochrepts more than any other soils are the product of the interaction between weathering and soil formation on the one hand and slope denudation on the other hand. They range from slightly developed soils where denudation is rapid (Plate 29, Fig. 2) to strongly developed soils where it is slow (Plate 30, Fig. 1).

The hill slope dystrochrepts are commonly associated with undeveloped colluvial hapludents (particularly on sedimentary rocks) and with more developed other great soil groups occurring locally on weathered crests and shoulders. The association of dystrochrepts with more developed alfisols and ultisols on dip slopes in associations K4, L1, L3, and M is further discussed in subsections (*f*) and (*g*).

Dystrochrepts are commonly found on the exposed lower parts of dissected weathering zones that developed on originally stable surfaces. This is the case with dissected mountain plateau surfaces of associations R1 and R2 (Plate 15, Fig. 1); with dissection slopes in Pleistocene fanglomerates of association O (Plate 11, Fig. 1) and in Pleistocene alluvial deposits of associations L2, P, Q2, and Q3 (Plate 13, Fig. 2); and with upper slopes of hills on low sedimentary rock that are related to the lowland weathered surface (associations K7 and N; Plate 16, Fig. 1). On the slowly permeable mudstone and clay of the surfaces in the south, such dystrochrepts are commonly rather gleyed. In all these soil associations they occur together with more-developed soils on the intact parts of the weathered surfaces: mainly ultisols, also alfisols, and (particularly in the case of mountain summit plateaux) also oxisols. The only major occurrence of dystrochrepts on the weathered surfaces themselves concerns strongly developed soils on the fan surfaces of association O in the coastal region (Plate 11, Fig. 1), where they are associated with ultisols of a rather similar nature but possessing coarser-textured surface horizons.

Dystrochrepts are mostly covered with various types of tall and mid-height forest which appear to be related more to slope stability, altitude, rainfall, and drainage than to soil differences *per se*. In particular, the less developed less acid dystrochrepts have been cleared for native gardens over considerable areas in the east. Grassland occurs locally on dystrochrepts on the weathered surfaces in the south.

(*f*) *Alfisols*

Although small in extent (probably only 275 sq miles) this order of mostly moderately developed weakly acid to weakly alkaline soils with coarser-textured surface horizons is widespread through the area, occurring over a large range of rock types and land forms.

(i) *Umbraqualfs and Ochraqualfs*.—With areas of less than 60 and less than 20 sq miles respectively, these strongly gleyed soils are largely restricted to fine-textured Pleistocene sediments and Pliocene mudstone of dissected weathered lowland surfaces in the south (associations N, P, Q2). Both great groups are found locally on high-level plains and surface remnants, on terrace benches, and on moderate slopes (Plate 12, Fig. 2; Plate 13, Fig. 2; Plate 14). Since these soils occur as minor associates of more strongly developed acid ultisols, it would appear that they are related to partially stripped sectors of the weathering zone, in a similar manner to that suggested in subsection (*d*) for the closely related argudolls. In other cases these soils occur on surfaces and terraces at lower levels, which appear to be younger than the main Pleistocene plains.

Umbraqualfs also occur locally on moderate dip slopes in soil associations J2 and L1, where they are the most poorly drained members of a set of soils with coarser-textured surface horizons.

Umbraqualfs with their thick dark topsoil occur mostly under grassland; ochraqualfs with thinner dark topsoils are found under grassland, regrowth, and forest.

(ii) *Typudalfs.*—Although occupying only 200 sq miles, these well to imperfectly drained alfisols are widespread, occurring in 14 soil associations. On rare occasions they are associated with the more poorly drained aqualfs on slopes of the weathered surfaces in the south (associations N, Q1, and Q3) and on the weathered fans in the north (associations K5 and O). They are more common on the dissected fan terraces of association L2 (Plate 11, Fig. 1).

Probably the most interesting correlation of the typudalfs is with the moderate to gentle dip slopes of associations L1 and L3 in the central hill zone (Plate 23, Fig. 1; Plate 24, Fig. 1), where they are mostly somewhat gleyed and rather shallow and are associated with some more strongly developed ultisols and even oxisols. Thus the soil pattern of these dip slopes is quite different from that of other hill slopes. It resembles more closely the soil pattern of the Pleistocene weathered land surfaces, although the overall degree of soil development is less.

Shallow weakly alkaline typudalfs appear to be common on argillaceous limestone and marl on slopes and crests in soil association I2 (Plate 26, Fig. 2). These are closely related to the rendolls (subsection (*d*)(iii)), but are less dark, more clayey, and slightly deeper. Elsewhere in the hilly and mountainous areas typudalfs are found locally on various rocks and land forms (associations F5, J2, K5, and K6). In many of these situations their presence is difficult to explain. Locally, surficial soil movement may be the cause of the textural differentiation rather than pedological horizon differentiation.

Various kinds of forest are undoubtedly the natural vegetation types associated with typudalfs, but commonly the forest has been cleared and is replaced by garden regrowth.

(*g*) *Ultisols*

This order comprises the great majority of the most strongly developed soils in the area and is the third largest in size with 600 sq miles. The ultisols are acid to strongly acid soils with coarser-textured surface horizons and commonly compact very firm to plastic subsoils which are often mottled. It thus appears that under most conditions of drainage and parent rock in the area, ultisols rather than oxisols represent the final stages in soil formation.

(i) *Umbraquults, Ochraquults, and Plintaquults*—With only one exception, these strongly gleyed ultisols occupying 45, 50, and 140 sq miles respectively are restricted to soil associations N, P, Q1, Q2,* and Q3 of the weathered plains and dissected lowland surfaces. They are most common on the least dissected plains of Pleistocene sediments (Plate 12) and rarest on dissected surfaces on mudstone (Plate 14). The three great groups, which differ mainly by having thick dark topsoils in the umbraquults and bright mottles resembling plinthite (United States Soil Conservation Service 1960) in the plintaquults, all occur under similar conditions: mainly level plains and crestal surface remnants, occasionally upper dissection slopes within the weathering zone. There is a tendency for the most weathered soils, the plintaquults, to be more common on the highest, oldest surfaces and for the umbraquults to occur

* The minor plintaquults in association F3 are on areas similar to, but unmappable as, association Q2.

most often on the wettest plains. Grassland (and fern–sedge land) is the normal vegetation on these soils but they are also found under forest with sago palms. Surprisingly, some plintaquults were observed under tall forest that showed no sign of excessive wetness in structure and composition.

The exception referred to at the beginning of this section concerns the minor occurrence of ochraquults on dip slopes of association L1. This is further evidence for the basic similarity between dip slopes and weathered surfaces from a pedological point of view.

(ii) *Plintochrults and Plintumbrults.*—These two great groups of imperfectly to well drained ultisols with brightly mottled subsoils resembling plinthite are also very largely restricted to the weathered surfaces. Occupying nearly 130 and 30 sq miles respectively, they are most common on the slightly to moderately dissected surfaces on Pleistocene sediments (soil associations Q2* and Q3; Plate 12, Fig. 2; Plate 13, Fig. 1), where they occur on plains and crestal surface remnants as well as on upper dissection slopes within the weathering zone. These soils are rare on both the undissected wet plains of association Q1 (Plate 12, Fig. 1) and the fully dissected surfaces of association P (Plate 13, Fig. 2). Plintochrults, which lack the thick dark topsoil of the plintumbrults, are also common on the moderately to strongly dissected weathered surface on Pliocene mudstone (association N), where they occur typically on interfluve surfaces and high terrace benches (Plate 14, Fig. 2). Locally they occur on similar surfaces in association L2, but appear to be extremely rare in hilly areas on consolidated rock (see association J2).

Whilst the plintumbrults are associated with grassland vegetation, the plintochrults occur mainly under forest and regrowth but also under grassland.

(iii) *Typochrults.*—Whilst a few imperfectly drained typochrults occur on the weathered surfaces in the south and east (associations N, P, and Q1), this great group is much more important on the weathered fans and terraces of association L2 in the western hills (Plate 11, Fig. 2) and of association O† in the coastal area (Plate 11, Fig. 1). They are further common on the dip slopes of associations L3 and M in the central hill zone (Plate 23) and on the weathered dissected plateau surfaces of associations R1 and R2 (Plate 15). In all these cases the occurrence of the strongly developed, acid, and mostly well-drained typochrults is related to relatively stable weathered land surfaces, at least moderately permeable parent materials, and relatively high rainfall. Associated soils (to which the typochrults are in places transitional) include dystrochrepts (particularly on fan surfaces), typudalfs (particularly on dip slopes), and normargox (particularly on dissected plateaux in the mountains).

Typochrults are a minor component of the soil pattern of various hilly and mountainous areas on sedimentary and igneous rocks (associations F5, I1, J2, J3, K4–K7), where they occur on local relatively stable sites, mainly crests, shoulders,

* The minor plintochrults in association F3 are on areas similar to, but unmappable as, association Q2.

† The minor typochrults in association F4 refer to high river terraces with similar properties to the fan terraces of association O.

dip slopes (Plate 24, Fig. 2), and upper slopes cut within old weathered zones (Plate 16, Fig. 1; Plate 17, Fig. 2).

The typochrults occur under a vegetation of different kinds of forest, as do the dystrochrepts. They have been relatively rarely cleared for gardening in the area.

(*h*) *Oxisols*

This smallest of all soil orders (just over 40 sq miles) comprises very strongly developed friable acid to strongly acid soils, which could develop only in a few localities with the right combination of drainage, parent rock, and land surface stability. The oxisols have much in common with the most strongly developed classes of the dystrochrepts and typochrults.

(i) *Normargox*.—This great group, characterized by having coarser-textured surface horizons, is the only one observed in the area. Normargox are most commonly developed on basic igneous rocks. They are most conspicuous on deeply weathered dissected plateau surfaces of association R2, which are probably remnants of the oldest land surface in the area (Plate 15, Fig. 1); and on complexes of low and high hill ridges of igneous rock of associations K8 and R1 (Plate 15, Fig. 2). In these associations the normargox occur mainly on crests and upper slopes. This is also the case in associations J3 and K6, where the normargox are a minor component of the soil pattern of two land systems on igneous rock but with predominantly unstable erosional slopes (Plate 28, Fig. 2; Plate 29, Fig. 1). Normragox have also been sporadically observed on lower dip slopes in association L1 (Plate 24, Fig. 1).

In contrast to these occurrences in hard rock landscapes, the normargox are also a minor component of the soil pattern of the little-dissected weathered plains on weathered Pleistocene sediments (associations Q1 and Q2) and an apparently more important great group on the strongly dissected weathered surface of association P along the southern margin of the hill zone (Plate 13, Fig. 2). In the latter case, the normargox occur mainly on very low convex hill ridges of the oldest part of the surface, which appears to have undergone a second cycle of weathering after dissection of the original surface. The fact that the sediments in association P are commonly more coarse-textured than those in associations Q1 to Q3 could also have promoted the more frequent development of oxisols in P. This effect of drainage and texture is also demonstrated by the occurrence of the normargox on narrow meandering sandy slight rises in the otherwise very wet association Q1. These rises strongly resemble former river courses which now lie slightly above the level of the plains as a result of differential compaction and weathering (Plate 32, Fig. 2).

Because of their widespread distribution from the inland plains to the main mountain range, the normargox occur under a range of forest types as well as under grassland.

V. Soil Formation

The influence of the principal soil-forming factors—parent rock, land form, time, climate, and vegetation—on the formation of the different soils in the area is generally complex, as is evident from Haantjens's detailed account* of these relationships as observed in the field. Only rarely does one of these factors strongly dominate the others, and in many cases their interactions cannot be properly unravelled in a reconnaissance survey. Of the many lowest-category soil classes, less than 10 were found to be associated with exactly the same combination of rock type, land form, and vegetation at all sites observed. On the other hand, some relationships, such as those of the histosols and hydraquents with organic and mineral sediments in swamps, several very sandy soils with beach ridges, and the rendolls with limestone, are so obvious that they need not be discussed. This section is concerned with summarizing the overall influence and highlighting some special effects of various factors on soil development.

(*a*) *Parent Material*

Specific correlations between soil and parent material occur mainly at the lowest soil class level. Apart from the very obvious correlations between soil classes and young alluvium and between organic residues and limestone, 47 out of 74 lowest soil classes appear to be confined to either sedimentary rocks, basement rocks, or Pleistocene alluvium, whilst only 2 out of 23 subgroups that consist of more than one lowest soil class are so related. More lowest soil classes occur on both sedimentary rocks and old alluvium than occur on both sedimentary rocks and basement rocks (14 against 10). The greater similarities between sedimentary rock and old alluvium as a soil parent material emerge more clearly from the fact that 8 subgroups consisting of more than one lowest soil class are common to sedimentary rock and old alluvium, against only two that are common to sedimentary and basement rock. If young alluvium is included in the first category the ratio becomes 14 to 2. Soil subgroups that commonly occur on all three kinds of parent materials are the orthic dystrochrepts, orthic typudalfs, orthic typochrults, and typic normargox. These soils can be considered as stages in the development of zonal soils in the area which are not subject to any dominant influence of parent material. In these subgroups the old alluvium parent material consists of fanglomerates, derived mainly from basement rock, and the sedimentary rocks comprise mainly the coarser-textured members of the sequence. Thus the real contrasts in parent materials of these subgroups are relatively small.

Mudstone is the sedimentary rock with the greatest contrast to the basement rocks. It is therefore not surprising to find that 16 lowest soil classes are wholly or nearly confined to this type of sedimentary rock, although five of these also occur on Pleistocene clays. On the other hand, mudstone is hardly ever a parent material for those soil classes that occur on both sedimentary and basement rock.

Two factors lead to differences in soil formation on sedimentary and basement rock: drainage and rock weathering. No poorly drained soils were observed on basement rocks but very many were on sedimentary rocks. This is probably due largely to the slow permeability of the sedimentary rocks as a result of compact

* Haantjens, H. A. (1970).—The relationships between soil classes and rock type, land form, and vegetation in the Aitape–Ambunti area, Territory of Papua and New Guinea. CSIRO Aust. Div. Land Res. tech. Memo. No. 71/1 (unpublished).

bedding, and to the trend of basement rocks to be more jointed and to develop permeable regoliths. This last point seems to be borne out by the fact that, where weathering and earth movement have produced a thick mantle of colluvial detritus on slopes, poor drainage is much less common on sedimentary rocks. Again mudstone stands out amongst the sedimentary rocks by being very slowly permeable, and as a result soil gleying is twice as common on mudstone as on siltstone and four times as common as on sandstone and conglomerate. Similarly, colluvium derived from mudstone has more poorly drained soils, including the only colluvial haplaquents observed, than the colluvium from other rocks.

Comparable differences in permeability of the parent material are likely to be the main reason for the differences between soils of the weathered surfaces on Pleistocene to sub-Recent alluvium in the south and of the fan surfaces of similar age in the north, the materials of the fans and terraces of Lumi (26) land system occupying an intermediate position. Aquults, aquic typochrults, and aquic plintochrults are the main soils developed in the clayey alluvial deposits in the south that are largely derived from sedimentary rocks. The more gravelly sediments in the north have a large component of basement rock detritus in which there is a dominant development of orthic typochrults and orthic dystrochrepts.

Whilst soils can only form on the hard basement rocks after significant weathering of these rocks, both chemical and physical, only softening of the sedimentary rocks by hydration is required to permit soil development. Thus the immature eutric dystrochrepts occur predominantly on sedimentary rock, and such rather alkaline soil classes as MUHO1, AUTO1, and IOEL could also develop only on these rocks which may be softened even before being leached of all carbonates. This ease of softening by hydration is probably the major reason for the widespread slumping, surficial earth movement, and deeper earth flow observed on these rocks, and these in turn have given rise to much larger areas of colluvial entisols on sedimentary rocks than on basement rocks.

Another difference between weathering on crystalline basement and sedimentary rocks is that all clay is newly formed in the former, whilst much residual clay is normally already present in the latter. Even if the chemical composition of both kinds of rock is very similar, as it commonly is in New Guinea (cf. Ruxton 1969), this circumstance could result in differences in clay composition, size, and aggregation, which may be a major cause of the greater texture contrast usually found in soils on sedimentary rocks and alluvia derived from them, as compared with soils of similar maturity on basement rocks and alluvium derived therefrom. The same factors may underlie the fact that oxisols appear to be most common and best developed on basement rocks and some relatively coarse-textured sedimentary rocks and alluvium.

One effect of parent material on the alluvial entisols appears to be the common presence of carbonates in soils on locally derived alluvium (particularly in Nigia (12), Screw (18), and Papul (19) land systems) and their complete absence in the alluvia derived from extraneous sources and laid down by the Sepik River, even when they are as young as those of Palimbai (11) land system. This is accompanied by relatively low pH values in all soils of the Sepik plain, as compared with those of young soils elsewhere in the area. Whilst carbonates occur in nearly all very young river sediments in the rest of the area, they are surprisingly absent from the apparently extremely recent alluvium covering part of the beach ridges of Nubia (2) land system to form the thapto psammollic hapludents. This is probably because this alluvium was deposited during a catastrophic flood after a serious earthquake (Part II, Section I(*d*)), and consists mainly of leached material washed down from hill slopes rather than of the unleached material supplied gradually by the rivers as a result of normal down-cutting and lateral erosion.

Parent material also influences the alluvial entisols in that it largely controls texture. Fine-textured deposits commonly lead to aquic hapludents and even aquents with impeded drainage because of slow permeability rather than high water-tables and flooding. The soils of Misinki (14) and Nagam (16) land systems appear to be examples of this.

(*b*) *Land Form and Time*

Since the influence of these factors is often difficult to separate, they are best discussed together. The influence of slope steepness on degree of soil development is generally recognized and very obvious also in this area. It accounts largely for the differences in soil maturity between the many strongly denudational hills and mountains on the one hand and the weathered surfaces on the other. With increasing dissection of these surfaces there is generally an increase in the area of less mature soils, but also an increase in maturity of the most developed soils, attesting to the probable greater age of the more dissected surfaces. The most dissected surfaces have either relatively little-developed soils, when denudation has removed much of a shallow weathered zone as in Panakatan (25) and Yindigo (31) land systems, or many strongly developed soils, even on steep slopes, when dissection has taken place largely within a thick weathering zone as in Kworo (30), Atitau (33), and Dossett (34) land systems. In some areas, as in parts of Kworo land system and in Yindigo land system, there is also evidence that strongly developed soils on slopes are the result of renewed weathering on slopes that have become stable after preceding denudation.

Apart from being found on the weathered surfaces, strongly developed soils are also common in the hills of Kumbusaki (60) and Maio (64) land systems. In these cases, which represent probably deeply weathered masses of old basement rock, there is no obvious relationship between soils and land forms.

Compared with the dissected lowland weathered surfaces discussed above, there is further progressive decrease in soil development in the sequence of low hilly land systems (Sandri (35), Emul (36), and Kaugiak (37)) which are geographically and genetically related to these surfaces but where vigorous dissection and denudation have left few or no traces of the weathering zone and have brought about a predominance of steep slopes.

The ultimate stage in the reduction of the degree of soil development on erosional hill slopes is either the occurrence of colluvial entisols in areas affected by slumping and earth movement or the presence of lithic subgroups, particularly lithic hapludents, on the very steepest slopes. The colluvial entisols appear to indicate that denudation processes are still very active in many parts of the area. Further evidence for this comes from the scarcity of thick dark topsoils on hill slope soils. This is in marked contrast to findings in the adjoining Wewak–Lower Sepik area (Haantjens, Reiner, and Robbins 1968). Even though mollisols are probably not as common in that area as suggested, the difference appears to be a real one and supports geomorphic evidence (Reiner and Mabbutt 1968) pointing to a greater stability of the land forms further east.

The lithic soil subgroups on very steep or precipitous slopes usually carry secondary vegetation, although there is little evidence of actual gardening. Such vegetation may be largely seral and reflect the instability of such slopes. Curiously, lithic subgroup soils are also common on crests. Not uncommonly, they appear to mark former village sites where much of the existing soil was removed during habitation.

Another marked and expected effect of slope steepness on soil formation is that soil gleying decreases rapidly in frequency of occurrence and intensity as the slope steepness increases. As mentioned in the previous section, this effect can be modified by the permeability of the rock. Thus soils on dissection slopes on the piedmont surface are usually gleyed, even if they are rather steep. On the other hand, the commonness of gleyed soils on mudstone is due not only to the slow permeability of this rock but also to the fact that slopes are usually less steep here than on other types of rock. On slumped slopes the poor drainage of soils on the slump floors can be caused by lack of run-off, or by ground-water seepage, which is common on such slopes.

In contrast to the hill slopes discussed above, dip slopes on sedimentary rock have soils similar in nature to the soils on weathered plains and lowland surfaces. Both sets of soils have coarser-textured surface soils and are commonly gleyed, but these features are less pronounced on dip slopes, where the soils are also less thick and less acid, although some soils on gentle dip slopes are as strongly developed as soils on weathered surfaces.

The influence of time appears to be quite important to two sets of young soils. In the alluvial aquic and orthic hapludents of narrow flood-plains and river terraces, there is a clear trend for those of the present flood-plains to be alkaline and calcareous and for those of the terraces to become progressively more acid and rapidly non-calcareous, due to leaching, as the frequency of flooding diminishes on higher and older terraces. Where flooding becomes very rare or ceases altogether, the first visible profile development is the formation of a thick dark topsoil (entic hapludolls). These changes in leaching and flooding correspond to changes in vegetation, from seral communities on present flood-plains to tall forest with a rather closed canopy, and even forest types that are normally associated with hilly landscapes, on the non-flooded terraces. Both Salisbury (1925) and Hissink (1938) found that $CaCO_3$, initially present at levels of 0·5–9%, was leached out in about 270 years, respectively from English dune sands and Dutch marine heavy clays. Although these authors do not state this specifically, their data probably apply only to surface soils. The leaching of $CaCO_3$ from deeper subsoils, as observed in the Aitape–Ambunti area, may take substantially longer. Nevertheless, the data quoted above suggest that the flights of alluvial terraces along major rivers in the area are quite young and have probably evolved during the last one or two thousand years, or even less.

On the beach ridges there is a clear sequence of soils from the coast inland. Fresh alkaline sands on the beach merge into neutral sands with a strongly alkaline deeper substratum and with a thin dark loamy sand to sand topsoil on the frontal beach ridges. On slightly older ridges similar soils occur, but with a thicker dark topsoil and lacking the alkaline subsoil. The majority of the beach ridges, farther inland, have sandy soils that are weakly acid in the upper part, neutral in the subsoil, have a thick dark topsoil, and, farther inland, also a browner incipient B horizon. On the farthest inland ridges the soil becomes a sandy loam and the browner B horizon a loamy sand. Weathering, however slight, results in the formation of inceptisols, rather than of spodosols as is commonly the case on sands with water-tables in the tropics (Andriesse 1969; van der Voorde 1956). This appears to be due to the large amount of weatherable minerals and the small amount of quartz in the sands.

(*c*) *Climate and Vegetation*

Because of the great variability in land form, parent rock, and weathering in the area, it is difficult to isolate any differences in soils that are caused by variations in climate, especially since local differences in rainfall and temperature are by no means dramatic. The main effect of the wetter climate in the western and northern parts of the area, and particularly in the mountains, would tend to be an increase in the removal of solutes by leaching (Ruxton 1968). Indeed, there appears to be a concentration of more acid lower soil classes of normally less acid subgroups in these wetter areas, notably the soil classes EUHO5, EUHO9, IODE3, and IODL2. Similarly, the more acid orthic dystrochrepts appear to be more common in the wetter parts and the less acid eutric dystrochrepts much more common in the drier water balance zone 1 (Fig. 2). Yet there appear to be noticeable exceptions to this trend (e.g. Yassip (38) land system, with mainly eutric dystrochrepts in the wetter areas) and it is clear that the nature of the parent rock and the degree of weathering are often more important factors. There is also a tendency for organic A_0 horizons and root mats to be more commonly present under forests in the wetter, higher mountain regions, and a similar effect may have caused the prevalence of lithic haplumbrepts in such environments. However, since forest clearing quickly disposes of such horizons, their rare occurrence in the drier, lower parts of the area may be related to the predominance of secondary forests in these parts.

The relative scarcity of gleyed soils in the wetter areas, although undoubtedly due to a higher proportion of steep slopes, could also be caused by the absence of any significant dry season. Remaining always moist, soils in the wet areas cannot become compacted and slowly permeable as a result of repeated shrinkage and swelling. Some confirmation for this can be found in the linear shrinkage tests. Very high values have unexpectedly been recorded for apparently halloysitic clays from the wet mountains. Such values could result from an almost complete lack of seasonal shrinkage and thus the maintenance of low bulk density and maximum water content.

The effect of vegetation on soil development is largely unknown and nowhere obvious, except for the apparent development of thick dark topsoils under man-made disclimax grassland. Similarly, as reported elsewhere (Haantjens 1967*a*), there are enough exceptions to this rule to conclude that grassland is not essential for such development, unless one assumes that every thick dark topsoil under forest is a relict formed under a previous grass vegetation. In some instances this is a possibility, in most cases it seems highly unlikely. Topsoils thick and dark enough to influence the order, great group, or subgroup classifications were found in 49 cases under grassland, in 20 cases under forest or other woody vegetation.* Conversely, grassland† was observed on soils with thin topsoils or without dark topsoils in only 9 out of 58 cases. In several of these there is reason to believe that the grassland had not been established sufficiently long to produce a dark topsoil. The production of charcoal by annual grass fires appears to be one reason for the dark colour of the topsoil, whilst a great concentration of roots may also help to produce a dark topsoil relatively high in organic matter.

VI. Soil Properties and Land Use Capability

In a separate report‡ all lowest soil classes are rated for the following properties important to agricultural and/or engineering land use: agricultural soil depth, available soil water storage capacity, drainage status, permeability, soil reaction, nitrogen content, available phosphate content, potash content, unified soil classification, linear shrinkage, and engineering soil depth. The estimated distribution of these soil attributes, except linear shrinkage, is shown on five unpublished special maps, available upon request from the Division of Land Research, CSIRO, Canberra.

Readers wishing to ascertain, in the greatest detail possible for this reconnaissance survey, the distribution over the land systems of any lowest soil class with certain favourable or undesirable properties, can do so by consulting Part V of the separate report mentioned above.

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* Not counting rendolls, in which the dark colour is directly related to the limestone parent material.

† Not counting *Phragmites* and *Saccharum* tall grassland on aggrading swamp and flood-plains.

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PART VII. POPULATION AND LAND USE OF THE AITAPE–AMBUNTI AREA

By R. H. FAGAN* and J. R. MCALPINE†

I. POPULATION

(*a*) *Melanesians*

(i) *Numbers, Settlement, and Distribution.*—The Melanesian population of the area has been calculated as approximately 94,300 in 1966. This figure is derived from the quasi-annual census of villages listed in the Village Directory‡ and located within the survey area. Settlement throughout the area is nucleated, in near-permanent villages, even though this is frequently associated with additional temporary housing in food gardens, particularly when these are far away from the village.

The distribution of the population by census villages is shown on an accompanying map, together with the boundaries of administrative units and census divisions. In compiling this map, named villages from the directory have been identified with village sites observed on aerial photographs by means of the use of uncontrolled district village maps. In some instances listed village names were found to apply to a number of smaller hamlets rather than to a single village (Plate 31, Fig. 2). Conversely (Lea 1964), a number of named census villages may in reality form a single large settlement that has become socially segmented by clan separations and splits. The average settlement possesses 20–30 houses and a population of 150–200 persons. However, as the population map shows, there is great variation in village size. Settlements with less than 100 inhabitants are common; at the other extreme, the largest single village has over 1100 people.

The uneven distribution of the population is clearly demonstrated by the population map. Thus, the overall population density of 20 per sq mile has little significance other than to indicate that the area is densely populated in comparison with other large areas in the New Guinea lowlands.

Three-quarters of the population lives in the central hill lands and on some adjoining and similar land extending into the southern flank of the Torricelli Mountains. Within this general area there is a major concentration in the east, and smaller ones around Lumi in the west and east of Nuku in the centre. In these populous areas population densities on land used for subsistence cultivation§ are generally 100–180 per sq mile. Calculated locally on land owned by social and culture groups, they exceed 400 per sq mile in parts of the Wosera area in the east (Lea 1964). The

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‡ "Village Directory, 1960." (Department of Native Affairs, Port Moresby, T.P.N.G.)

§ This land is further referred to as "used land", and comprises any land mapped in one of the land use intensity classes discussed in Section II(*b*).

remainder of the hill zone is moderately to sparsely populated, with population densities of 30–80 per sq mile on used land.

A great concentration of people is also found on a narrow strip of land along the coast, including beach ridges, coral islands, and some coastal plains and hills. With about 10,000 inhabitants this area has a population density on used land of nearly 200 per sq mile, and considerably higher in the Sissano and Malol lagoon area in the north-west.

In contrast to these crowded areas most of the mountain range is uninhabited, as are large parts of the inland plains. Scattered villages occur on the coastal plains, on fans and hills behind the coastal strip, and in the Sepik flood-plain and Ambunti hills. Population densities on used land are high (100–250 per sq mile) in the inland plain and Sepik River area.

The high population densities on used land along the coast and near the Sepik River are made possible by a great reliance on fish and sago in the diet, although they locally also lead to highly intensive land use for cultivation. On the inland plains the high population densities on used land are a result of sago being the staple diet. In the hills and mountains there is a more general tendency for high population densities to be associated with intensive use of land for cultivation. Nevertheless, even here the high population densities are partly sustained by reliance on sago (see Section II(*a*)).

The distribution of the population over the land systems is given in Appendix IV, as well as in the land system descriptions.

(ii) *Population Growth*.—Population growth has been calculated from census division totals for 1960 and 1968. It is expressed as crude rates since reliable migration figures are unavailable. The overall growth rate is approximately 2% per annum, varying between subdistricts from 1·5% for Lumi to 3% for Aitape. While the accuracy of the census figures does not allow reliable detailed comparative comment between census divisions, it is interesting to note that the greatest population increases, indicating a growth rate of 4% per annum, occurred in the densely populated Wosera census division. This figure is confirmed and discussed in some detail by Lea (1964, 1965). The lowest growth rate recorded was 0·5% per annum for the Lumi local census division.

(iii) *Employment*.—The Melanesian population is almost wholly engaged in deriving subsistence from agriculture, gathering, and collecting. This is supplemented by some cash cropping (see Section III). Labour data for the East and West Sepik Districts reveal that less than 1% of the population is engaged in employment for wages within the Districts, whilst a further 2–3% are employed outside the Districts. The number of workers in the area from outside the Sepik Districts is extremely small.

(iv) *Social and Culture Groups*.—Melanesian societies are minute in scale (Hogbin and Wedgwood 1953). Hence, despite the possession of a common language and culture by larger groups, the widest effective social group is commonly only of clan or village size and usually contains less than 300 persons. Yet membership of wider culture groups is indicated by the existence of culture group names. Such groups usually have a common social culture, religion, technology, and language

(Fortune 1939). A language distribution map for the area is presented by Capell (1962), and the reader is also referred to the work of Laycock (1965) on the Ndu language family for greater detail in the heavily populated eastern part of the area.

On the basis of language distribution and subsistence systems there appear to be five broad culture groups, which here have been given those names most commonly used in the area. The Siau people dwell along the coast and on the off-shore islands. They alone in the area speak an Austronesian language. The Wapei culture group is centred around Lumi, but has an outlier extending into the western coastal hills and plains. East of the Wapei occurs the Au-Palei culture group, also known as the Maimai people. They are centred on Nuku. To the east again lies the land of the Abelam culture group, extending south to the Sepik River. The river people are related to the Abelam and like the latter speak a Ndu language. By contrast, the people on the hills rising from the Sepik flood-plain speak a quite separate language and are referred to as the Kwoma-Meio (Whiting 1941).

These broad groups are subdivided into 50 distinct languages, each of which comprises a multitude of yet smaller social groups, and only at this level is social cohesion effective. The recent superimposition of elected local government councils over this bewildering pattern is in part intended to overcome this social fragmentation.

Ethnography is outside the scope of this report. The reader is referred to the exhaustive Ethnographic Bibliography of New Guinea (Anon. 1968) to cover this aspect.

(*b*) *Europeans*

The non-indigenous population of approximately 150 persons consists entirely of Europeans, most of whom are transients. The figure given is an estimate, since exact data are available only for the two Sepik Districts as a whole. The Europeans are engaged in governmental and mission activities, and to a much smaller degree in commercial pursuits. Aitape has the largest European population.

II. Land Use for Subsistence

With few exceptions, present land use in the area serves the purpose of subsistence for the indigenous population. Most of this subsistence is gained from agricultural pursuits (subsistence cultivation). Virtually everywhere this is supplemented by sago collecting. In the south on the inland plains and Sepik flood-plain the situation is reversed, and subsistence cultivation is subsidiary to sago collecting (Henry and Muia 1959). Domestic pigs and fowl, together with the yield of hunting and gathering, are the main sources of protein over most of the area. Fishing is a major source of subsistence along the coast and is also important near the Sepik River.

(*a*) *Subsistence Cultivation*

As practised in the area, this form of agriculture may be generally described as bush fallowing or shifting cultivation. Nowhere does cultivation follow a nomadic pattern with temporary settlements and frequent shifts from cleared land to ever new areas of virgin bush. On the contrary, there appears to be a preference for a cyclic rotation of clearing and cultivation within rather well-defined areas of secondary vegetation. On the other hand, settlement and land use have never been static.

The wide distribution of old secondary forest and man-induced grassland points to considerable population movements in the past (Reiner and Robbins 1964). Other evidence of mobility is provided by the many old overgrown village sites found in many parts of the area. Such shifts of villages were probably caused by social–religious upsets and territorial changes due to tribal warfare. Since European contact, movement of villages has been largely restricted to within tribal areas representing the *status quo* at the time of contact, and has been guided mainly by administrative and economic motives.

The length of the bush fallow period varies widely within the area, apparently mainly in relation to population density but in some cases also in relation to natural conditions. In large parts it is over 20 years (Plate 32, Fig. 1), whilst at the other extreme it is only 2–3 years, and here the system approaches permanent cultivation with fields bounded by "hedges" of banana trees and other plants and by small ditches or banks (Plate 31, Fig. 1).

The chief cultivated staple crop is yam (*Dioscorea* spp.), of which one species with very large tubers is of great ritual importance in the east of the central hill zone. Other crops grown are taro (*Colocasia esculenta*), sweet potato (*Ipomoea batatas*), bananas (*Musa* spp.), taro "kongkong" (*Xanthosoma sagittifolia*), cassava (*Manihot esculenta*), sugar-cane (*Saccharum officinarum*), edible pit-pit (*Saccharum edule*), papaw (*Carica papaya*), and winged beans (*Psephocarpus tetraglobus*). In addition, maize, tomatoes, pineapples, peanuts, cucurbits, and various other recently introduced crops are planted in small amounts, Coconuts (*Cocos nucifera*) and breadfruit (*Artocarpus atilis*) are planted in villages.

Apart from the few vegetables and fruits mentioned above, protein is provided from fish, domestic pigs, and fowl.

As mentioned earlier, sago processed from mature stems of the sago palm (*Metroxylon sagu*) contributes to the diet throughout the area. Its significance varies regionally, locally, and seasonally, as shown by Lea (1964) and quoted in McAlpine (1968). In the western part of the central hill zone particularly, sago is more or less a part of the subsistence cultivation system in that the palms are commonly planted in suitable wet spots, particularly slump floors. Largely untended and left to natural propagation, these sago groves are a conspicuous element in the garden and regrowth pattern.

(*b*) *Land Use Intensity*

By its very nature bush fallow cultivation leads to very complex patterns of gardens and secondary vegetation in varying stages of development. These are commonly interspersed with areas of mature forest and other kinds of natural vegetation. The elements are not always easily distinguished on the aerial photographs at 1:50,000, and are generally too small to be shown on the 1:250,000 maps accompanying this report. In order to present a generalized map of land use intensity in subsistence cultivation, all these vegetation elements were placed in three groups: land in current use,* bush fallow vegetation,* and any other vegetation. The five

* See Appendix I, Section II(*f*) for more precise definitions. The land use intensity classes are also defined in the map reference.

land use intensity mapping units, of which the 1964 distribution is shown on an accompanying map, are simply arbitrary classes with different proportions of these three kinds of vegetation. The classes are defined firstly in terms of the percentage of bush fallow vegetation present, which is a broad measure of the area used during the cultivation/fallow cycle. They are then defined on the percentage of land in current use, which indicates the actual intensity of use.

The five land use intensity classes are illustrated in Plate 31 and Plate 32, Figure 1. In all, nearly 1300 sq.miles, or 28% of the area, is used at some level of intensity for subsistence cultivation. This percentage is more than three times that found in the adjoining Wewak–Lower Sepik area (McAlpine 1968). Since the population of the Aitape–Ambunti area is not more than 1·25 times that of the Wewak–Lower Sepik area, there is in general much less pressure on used land in the former. This is confirmed by the fact that there is nearly five times as much land of very high and high use intensity in the Wewak–Lower Sepik area, although the total area of used land is only one-third of that in the Aitape–Ambunti area.

Details of the distribution of the five land use intensity classes over the land systems are presented in Appendix IV and in the detailed land system descriptions.

(c) *Land Use Intensity and Land Use Capability*

A detailed comparison of land use capability and present land use intensity of the land systems is presented in Appendix IV. This serves mainly to indicate the degree to which land of a certain capability is already being used. In this comparison it is not valid to use the intensity of present land use as an indicator of land use capability. In the first place, the criteria used in the assessment of the agricultural potential of the area are not the same as those used by the present subsistence cultivators. In the second place, the uneven distribution of population has apparently been caused mainly by factors other than capability evaluation of the land, a conclusion similar to that reached by Spencer (1966) for south-east Asia in general when he writes: "It is culture and culture history, rather than physiography, which dictates the broad environmental location of shifting cultivation as a cropping system". In the present area the same kind of land, whether it has low or high capability, is commonly populated and used in one area, uninhabited and untouched in another.

Nevertheless, a statistical comparison has been made for the land systems between their land use intensity index and their land use capability indexes for arable crops, tree crops, and improved pastures. These indexes are given in the land system descriptions in Part III, and are explained in Appendix I. Spearman's rank correlation coefficients between land use intensity and the three kinds of land use capability were 0·44, 0·50, and 0·53 respectively. For the 65 land systems present all three coefficients are significant at the 1% level. This may be interpreted as indicating that greater use tends to be made of land of higher capability but that despite this, individual variation is great.

III. Land Use for Cash Cropping

Data presented in Table 13 show that cash cropping by indigenous persons is generally of minor importance. In addition to the figures given, 4 tons of tobacco were produced, mainly from the Nuku area, and 2 tons of copal gum from Lumi. This latter industry has been discussed by Cooper (1967). The discrepancies between acreage and production of coffee are caused by the large proportion of immature trees in most areas.

TABLE 13

PRODUCTION OF CASH CROPS BY INDIGENOUS PERSONS IN 1965–66*

Subdistrict†	Robusta (ac)‡	Coffee (tons)	Upland Rice (tons)	Copra (tons)
Maprik	1200	35	500	N.a.§
Aitape	30	$\frac{1}{4}$	—	128
Lumi	60	1	3	—
Ambunti	60	$\frac{1}{2}$	—	N.a.
Total survey area	1350	37	503	?

* Source: Department of Agriculture, Stock and Fisheries, Wewak, T.P.N.G. Although all four subdistricts extend beyond the survey area, the data have been compiled from census division figures which approximately cover the actual survey area.

† See map of Administrative Divisions.

‡ Calculated from data on tree numbers on the basis of 500 trees/ac.

§ Data exist but were not available.

Nearly all cash cropping by indigenous persons is closely associated with subsistence cultivation, and hence is on a small lot basis and restricted to areas mapped as used land. This is illustrated by the distribution of *Leucaena glauca* stands (Plate 31) as shown on the land use intensity map by black dots. Although shown as a measure of the distribution of indigenous coffee blocks, they present an exaggerated picture, since in several cases the growing of the shade trees is not followed by the planting of coffee, whilst in others the planted coffee has failed. The great predominance of coffee plots in the Maprik District is partly the result of active promotion by agricultural officers. It also provides a small cash income in an area where excessive land pressure makes this particularly necessary. Moreover, the denser road net in this area makes it easier than elsewhere to market the produce. The scarcity of coffee plots in the densely populated area north of Lumi appears to be partly due to failure of the crop. It would seem that the zone between 2000 and 3500 ft above sea level is rather unsuitable for either lowland or highland coffee.

Most of the copra production comes from the beach ridges along the coast, and includes two small native-owned plantations, shown as a separate category on the land use intensity map. The only non-indigenous plantation is situated on the coast at Aitape, and produces cocoa as well as copra.

IV. Resettlement Schemes

A resettlement scheme has been initiated to alleviate the population pressure in the subsistence sector among the Wosera people in the east of the survey area.

This Wosera Resettlement Scheme is discussed by McCarthy (1967). It entails short-distance migration of people to a block of 3200 acres of land purchased in 1962 in the Gawanga area on the inland plains, which is to be connected by road to the Wosera and Maprik.

A second scheme, only recently commenced, covers an area in the coastal plains around Pes, Aitape. Parts of this area have been and are being occupied by Wapei squatters, who are related to the present light population in the area. The scheme envisages formalization of the *de facto* situation, and will be based on development of both subsistence and cash crop agriculture.

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PART VIII. FOREST RESOURCES OF THE AITAPE–AMBUNTI 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.

The forest types are the same as those described in Part V, except for limitations on timber volume. These limitations require that a commercial forest contains 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). The only exception to the above definition is "mangrove", because of its possible value in the cutch industry.

Commercial forest (hereinafter referred to as forest) covers 48 % of the area, occurring in a wide range of environments from sea level to approximately 6000 ft. Within this range the forests exhibit a discontinuous distribution pattern, due largely to clearing prior to cropping and to swampiness and, in parts of the main range, to landslides.

At present there are no large-scale sawmills exporting timber from the area. Many mills associated with Government Stations and Missions are currently producing sawn timber for local consumption, the largest of these being located at Aitape.

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 topographic position, pure or nearly pure stands, recognizable species, and canopy characteristics such as height, closure, evenness, crown size, and occurrence of emergents.

Where possible in the field, the forest was sampled by three circular plots, each $\frac{1}{3}$ 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, taking care to remain on the same type of land.

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TABLE

MEASURED AND ESTIMATED PRODUCTIVITY

Numbers in parentheses are estimated values

Class of Forest	Forest Type	Area (sq miles)	Sample (ac)	Trees/Ac Range	Trees/Ac Av.	Reject (%)	Bole (ft) Range	Bole (ft) Modal Class
High productivity								
Forest on plains	F	45	6	5–15	10	11	15–70	50–60
	Fo	360	17	4–15	9	12	15–80	50–60
	Fod	50	7	4–11	7	12	10–70	50–60
Forest on uplands	Fos	35	4	9–10	10	0	20–60	50–60
Moderate productivity								
Forest on plains	Fow	11	—					
	FoM	260	8	0–10	6	15	15–70	50–60
Forest on uplands	Fi	70	13	4–12	7	8	10–75	50–60
Low productivity								
Coastal forest	Cq	1	—		8		10–40	25
Swamp forest	FmoM	100	2	3–7	5	10	20–50	30–50
Forest on plains	FodM	16	—		(7)	(15)	(15–70)	(50–60)
	Fmo	15	1		8	25	10–50	40–50
Forest on uplands	Foi	115	7	5–8	7	4	20–70	50–60
	Fms	115	12	1–10	6	13	5–70	30–50
	Fid	460	18	1–11	7	9	10–75	30–60
Secondary forest	FR	155	13	1–10	6	18	5–70	20–60
Very low productivity								
Swamp forest	FmoCM	45	—		(5)		(10–40)	
Forest on uplands	Fmi	260	11	0–8	5	14	10–65	40–50
	Fmio	20	3	4–8	5	19	20–65	40–50
	Fm	18	2	8–10	9	6	15–65	40–50
Secondary forest	FRm	19	15	3–12	7	17	5–70	5–70
Nil productivity								
Coastal forest	B	5	—				(20–50)	(<4)
Forest on uplands	Fmsv	55	5	2–8	6	3	15–65	40–60

* Indices: SI, slope; DI, drainage/inundation; F, flooding; AI, access; SR, stocking rate; FP, forest

14

PARAMETERS OF FOREST TYPES

no field observations being available

Girth (ft) Range	% in 7 ft+	Usage Group (%) 1	2B	3	4A	4B	5	Stocking Rate (super ft/ac) Max.	Est. Av.	SI	DI	Indices* F	AI	SR	FP
5–10	22	1		16	9	37	37	13,750	7700	0	8	1	92	77	70
5–10	27	4		1	23	42	30	12,930	7800	0	14	1	85	78	66
5–10	43				12	55	33	11,440	7600	0	26	2	71	76	54
5–15	33	7			53	29	11	15,420	10,000	24	8	0	68	100	68
							(100)		5100	0	30	0	70	51	36
5–10	28	1		1	50	29	19	10,650	5100	0	31	2	67	51	34
5–12	39				59	17	24	17,970	8100	46	8	0	46	81	37
5–6	0				100				3000	0	8	0	92	30	28
5–7	11			5	33	5	57	3760	3000	0	55	0	45	30	14
(5–10)	(28)				(50)	(30)	(20)		5100	0	55	3	42	51	21
5–6	0				55	15	30		3400	0	40	3	57	34	19
5–10	23			7	32	23	38	10,790	7000	54	8	0	38	70	26
5–9	11	4		7	41	30	18	7510	3900	27	12	0	61	39	24
5–10	23	4		3	34	26	33	10,890	6000	47	14	0	39	60	23
5–10	17	1			8	26	65	9430	4200	47	11	0	42	42	18
(5–7)							100		3000	0	65	0	35	30	11
5–9	30	3		3	31	37	26	7880	4100	76	8	0	16	41	7
5–8	8				18	43	39	7190	3200	70	8	0	22	32	7
5–7	12		17		10	27	46	7590	4500	78	8	0	15	45	7
5–12	24	1		1	13	34	51	11,710	3000	65	9	0	27	30	8
										0	80	0	20		
5–8	7				22	25	53	6950	4000	80	8	0	12	40	5

productivity.

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. 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.

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 a form factor of 0·5 and no allowance for bark or internal defect was made.

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 220 ac approximately. 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, 22 forest types 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 14): 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 composite map (scale 1:250,000) showing forest types and population/land use 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.

IV. Access

(a) *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 11 broad access categories as shown in Table 15 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 15, together with its area, forest cover, and component land systems. The access categories, the distribution of which is shown on an accompanying map, are briefly described below.

Access category S consists of swamps, unstable flood-out splays and scroll plains, and tidal flats. 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 the dry season. This category covers most of the Sepik flood-plain and substantial areas of the inland and coastal plains. It covers an area of 702 sq miles including 158 sq miles of forest.

Access category W consists mainly of alluvial fan and flood-out 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 inland plains and covers a total area of 636 sq miles of which 318 sq miles are forested.

Access category Iw land consists of alluvial and colluvial plains and fans, and low gently undulating surfaces. 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 northern part of the inland plain with smaller areas along the coast and scattered throughout the inland hills. Access category Iw covers a total area of 447 sq miles of which 319 sq miles are forested.

Access category IFw consists of flood-plains including levees, 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 good. It occurs as scattered areas throughout the coastal and inland plains and covers a total area of 109 sq miles of which 77 sq miles are forested.

Access category IF consists of terraces and flood-plains which receive damaging floods at least once a year. Except for this hazard it is comparable with access category I. It occurs mainly along larger rivers in hilly country. Of a total area of 62 sq miles, 36 sq miles are forested.

Access category I land consists mainly of better-drained alluvial plains, fans, and low 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 foothills at the inland edge of the coastal plain, stretching towards but rarely reaching

TABLE 15

NATURE OF ACCESS CATEGORIES AND DISTRIBUTION OVER LAND SYSTEMS

Access Category	Area (sq miles)	% Forest	Indices* SI	DI	F	AI	Accessibility	Land Systems
S	700	23	0–1	75–100	0–2	0–22	Nil to very poor	Murik (3), Chambri (4), Sanai (5), Pandamp (6), Kobar (7), Pora (8), Kabuk (9), Pandago (10), Palimbai (11), Nigia (12)
W	630	50	0–11	37–67	0	31–59	Poor to moderate	Yilui (13), Misinki (14), Nigre (27), Yambi (28), Burui (29)
Iw	450	71	0–18	22–30	0	54–76	Moderate to good	Nubia (2), Nagam (16), Ambunti (20), Yindigo (31), Musendai (32), Ningil (49)
IFw	110	71	0–2	24–25	2–3	71–73	Good, subject to flooding	Po (15), Screw (18)
IF	60	58	4	12	3	81	Very good, subject to flooding	Papul (19)
I	180	80	2–10	8–21	0	76–90	Very good, rarely good	Madang (1), Pes (17), Kabenau (21), Romei (22), Aiome (23)
II	650	38	21–40	8–21	0	41–58	Moderate	Paiawa (24), Lumi (26), Atitau (33), Kaugiak (37), Karaitem (41), Sengi (42), Seim (46), Minatei (50)
IIw	310	54	31–38	28	0	34–45	Poor to moderate	Kworo (30), Nuku (51)
III	910	53	45–70	8–21	0	27–44	Poor to very poor, rarely moderate	Panakatan (25), Dossett (34), Sandri (35), Emul (36), Yassip (38), Morumu (39), Numoiken (40), Asier (43), Flobum (44), Dreikikir (47), Aitape (55), Barida (part) (56), Nopa (57), Maio (64)
IIIw	280	46	45	24	0	31	Poor	Mambel (48)
IV	380	43	73–87	8	0	5–19	Nil to very poor	Om (45), Musak (52), Wuro (53), Imbia (54), Barida (part) (56), Sulen (58), Wanabutu (59), Kumbusaki (60), Mup (61), Daum (62), Somoro (63), Waskuk (65)

* Indices: SI, slope; DI, drainage/inundation; F, flooding; AI, access.

the coast. Access category I covers a total area of 177 sq miles of which 142 sq miles are forested.

Access category II land consists mainly of moderately dissected alluvial and colluvial fans, dip slopes, low hilly country, and small 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 to the south of the main range extending to the inland plain, but also in patches along the inner edge of the coastal plain and as scattered areas through the main range. It covers a total area of 650 sq miles including 248 sq miles of forest.

Access category IIw land consists of low to high hills often with moderately steep dip slopes and some scarps. The dip slopes and slump floors may be imperfectly to very poorly drained causing moderate to poor access. It is distributed throughout the inland hills covering a total area of 306 sq miles of which 164 sq miles are 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 main range and stretches southwards to the inland plain. Small scattered occurrences are found protruding from the coastal plain and larger occurrences on the Ambunti hills. It covers a total area of 908 sq miles including 478 sq miles of forest.

Access category IIIw land is similar to category III in all respects except drainage, which creates increasing difficulties of access. It occurs throughout the inland hills but mainly in the western half. Access category IIIw covers a total area of 280 sq miles of which 129 sq miles are forested.

Access category IV land consists mainly of very high hilly and mountainous country with very steep slopes and relief varying from moderate to 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 main range but scattered occurrences are found elsewhere, notably near Ambunti. It covers an area of 383 sq miles of which 166 sq miles are forested.

(*b*) *General Conclusions*

Any future exploitation of forests on the coastal side of the main range will be hindered by the almost continuous band of swampy and poorly drained land along the coastal edge. At some points near Aitape well-drained land does touch the coast. Elsewhere, it would be necessary to construct all-season roads through poorly drained land to reach the coast direct. Alternatively, a road along the foothills of the main range, with access roads to adjacent forests, could link up with an existing road on well-drained land giving access to the coast at Aitape. The main problem in a road along the foothills would be the fording of rivers that flood suddenly every time heavy rains occur on the main range. None of the rivers in the coastal plain is suitable for floating timber downstream as they generally have braided beds and in many cases end in swamps.

From inspection of the land system map, access roads across the main range are feasible in some places but difficult in all cases.

Much of the hilly country to the south of the main range could be accessible by roads confined as far as possible to category II land. The general grain of the country here is NW. to SE. and possibly the easiest outlet would be to the south-east linking up with a road along the foothills edge of the inland plain, then proceeding east towards the Maprik–Pagwi road.

Access from the inland plain to the Sepik River is seriously hindered by the swampy nature of the Sepik flood-plain. Thus access to the better-drained areas of the plain would be from the north, linking up with the foothills road mentioned above. One possible access route from the inland plain to the Sepik River is via the levees of the Yimi and Screw Rivers. These, however, are subject to flooding. Most rivers of the inland plain are unsuitable for floating timber as they all end in swamps. The Yimi and Screw Rivers are the only ones that could possibly be used for this purpose.

Existing road systems in the area are not designed to carry heavy logging traffic and therefore would require improvements to cater for this. All except the Aitape–Yalingi River road generally serve areas of high population density and therefore low forest resources. It may be possible, however, to exploit some areas by constructing access roads to link areas of good forest resources with these systems.

The only existing outlets from the area as a whole are via the Maprik–Wewak and Maprik–Pagwi road system, the Sepik River, and coastal shipping. Unfortunately there are no harbours available and cargoes must be either loaded off shore or towed to Vanimo where harbour facilities will be available.

V. Description of Forest Types

(*a*) *General*

Two coastal forest types are recognized, each occupying its own restrictive habitat. The two swamp forest types are separated mainly on a floristic basis. Seven forest types are recognized on plains, the habitat of each being dictated mainly by soil drainage, inundation, and flooding. Nine 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 ones involved being climate as reflected in the proportion of deciduous trees (Fid forest), climate and altitude (Fm forest), and parent material (Fmsv forest). The two secondary forest types result from interference by man, and in this area may be found in any habitat except in swamp 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, the parameters both measured and estimated applying to each forest type are listed in Table 14. Species recorded for each type are given in Table 16. The general descriptions are restricted to points of forestry interest, and for full descriptions of each forest type Part V should be consulted.

TABLE 16

TREES RECORDED AND THEIR FREQUENCY OF OCCURRENCE IN FOREST TYPES

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

Botanical Name	Local Name	F	Fo	Foi	Fos	Fow	FoM	Fi	Fid	Fod	Fmo	FmoM	Fmi	Fm	Fmio	Fms	FR	FRm	FodM	FmoCM	B	Cq	Fmsv
Aglaia	Kasia	R	R	O			R		R			R	R			R							
Ailanthus	Man'nak							R															
Albizia	Balau							R	R					R									
Alseodaphne	Molil								R														
Alstonia scholaris	Der	R						O	R	R			R			R	R	R					
Alstonia	Tawal		R					R	R						(V)			R					
Anisoptera polyandra	Nipinib							R															
Anthocephalus			R																				
Artocarpus	Onil												R		R								
Artocarpus	Tse'el	R						R	R				R				R	R					
Artocarpus	Udidi							R															
Artocarpus	Uti								R														
Artocarpus	Ye									R													
Bischofia	Sabal									R													
Bombax	Suwale		R														R	R					
Bridelia	—																						
Bruguiera																					D		
Buchanania	Utul	O	R				R		R	R		O	R			R		R					
Calophyllum	Nawal				R																		
Campnosperma	Utul		R	R			R					O								P			
Campnosperma	—						R																
Cananga odorata	Mate		R				R										R						
Canarium	Enal	R	R				R	R	R	O						R							O
Canarium	Enalketiket		R	R				R					R	O		R	R						R
Canarium	—																	R					
Castanopsis	Aikulkul													S		R	R	R					R
Casuarina equisetifolia																						P	
Celtis nymanii	Baigup		R	R	R		R	R	R	R							O	R					
Celtis philippensis	Sui	R	O	O	R			R	R				R	R		R	R	R					
Celtis	Suigolof		R					R										R					
Celtis	Uri															R							
Cerbera floribunda	Esilpipito															R	R						
Chisocheton	Lili'o												R										
Chisocheton	Tope																R						
Chisocheton	—													R									
Chrysophyllum	Kitikit	R		R																			
Cordia dichotoma	Mal																	R					
Cryptocarya	Bagibag		R																				
Cryptocarya	Bosabos																						R
Cryptocarya	Gor		R																				
Cryptocarya	Mew		R	R						R						R							R
Cryptocarya	Urumna				R			R								R							S
Dillenia	Nawal		R	R	O		R	R					C		C	R	R						
Diospyros	Ali'es								R		R			R									
Dracontomelum	Fa		R		R								R				R						
Dracontomelum	Failela	R	R		R		R		R				R			R		R					
Drypetes	Solkat			R																			
Dysoxylum	Damasewa	R							R				R				R	R					
Dysoxylum	Kanan															R	R	R					
Dysoxylum	Toamek	R															R						R
Dysoxylum	Uluka								R								R						
Dysoxylum	Wali									R								R					

TABLE 16 (*Continued*)

Botanical Name	Local Name	F	Fo	Foi	Fos	Fow	FoM	Fi	Fid	Fod	Fmo	FmoM	Fmi	Fm	Fmio	Fms	FR	FRm	FodM	FmoCM	B	Cq	Fmsv
Dysoxylum	—								R														
Elaeocarpus	Alata								R														
Elaeocarpus	Sila								R														R
Elaeocarpus	— J47												R										
Elaeocarpus	— J49																	R					
Endospermum	Suhumal								R							R	R	R					
Endospermum	— J60		R																				
Euodia	Boban								R									R					
Ficus (strangler)	Kurum	O	O	R			C	R	O	C	O	O	R	C		R	R	O					
Ficus	Bambam	R						R	R				R										
Ficus	Bameso								R			R					R	R					
Ficus	Duelbik																	R					
Ficus	Go	R																					
Ficus	Mai																R						
Finschia																		R					
Flindersia	—															R							
Galbulimima belgraveana	—			R																			
Ganophyllum falcatum	Kanen'anak			R				R															
Garcinia	—													R									
Garuga floribunda	Selamek		R													R	R						
Gonocaryum	Ulumo								R														
Hernandia	Bolat									R													
Homalium	Ebel		O	O			R	R	R							R	R	R					
Hopea cf. *iriana*	—							R								O							
Hopea cf. *papuana*	—								R														
Horsfieldia	Hokol	R						R									R	R					
Ilex	—							R															
Intsia bijuga	Mep		O	O			O	C	O	O			O		C	V	R						
Lithocarpus	—													R									
Litsea	Babelia																						R
Litsea	Batebate							R	R														
Litsea	Halihal							R	R														R
Litsea	— J14												R										
Kingiodendron	—		R						R							R							
Macaranga	Giraeme		R															R					
Mangifera	Atita							R															
Mangifera	Mohihil								R														
Maniltoa	Falef	R	R	R				R								R		R					
Microcos	Ota'aut																	R					
Myristica	Ba'al																	R					
Myristica	Dahol															R							
Myristica	Kasia			R																			
Myristica	Matamata									R													R
Nauclea	Duadu		R							R													
Neonauclea	Wa'aul									R													
Neonauclea	Yau	R	R				S	R	R		C	V	R			R	R	R					
Neonauclea	Yau													R	R								
Neoscortechinia	Him												R										
Neuburgia																	R						
Octomeles sumatrana	Katul		R						R	R								R					
Opocunonia	Asisiv												R										
Palaquium	Kilius	R																					
Palaquium	—																	R					
Pangium edule	Metun	R															R						
Papuodendron lepidotum	—												R					R					

TABLE 16 (*Continued*)

Botanical Name	Local Name	F	Fo	Foi	Fos	Fow	FoM	Fi	Fid	Fod	Fmó	FmoM	Fmi	Fm	Fmio	Fms	FR	FRm	FodM	FmoCM	B	Cq	Fmsv
Parartocarpus venenosus	Segolof		R	R					R								R						
Parinari	—								R									R					
Pimeleodendron	Basal	R														R	R	R					
Planchonella	Bali															R							
Planchonella	Gusis																						O
Planchonella	Kinakin														R	R	R						
Planchonella	Kukus		R					R	R														
Planchonia	Tali		R				C		R	R							R	R	S				
Podocarpus	Kosikos													O									
Polyalthia	Bisipis		R													R							
Polyalthia	Kugulu		R																				
Polyalthia	—																R						
Pometia pinnata	Bam	S	S	O	R		O	O	C	V	V	O	O		C	O	S	S					
Pometia tomentosa	Bamara		R	O	D			V	O				O			O	R	R					
?Pouteria	—											R											
Pterocarpus indicus	Nara	O	R					R									R	R					
Pterocymbium	O								R									R					
Randia	Maniman													O	R			R					
Rhizophora																						D	
Sloanea	Ata'al	R		R			O	R									R	R					
Sloanea	Hal	R	R						R								R						
Sloanea	— J17 J13												R										
Spondias dulcis	Hunek	R	R				R		R								R	R					
Sterculia	Biri						R		R														
Sterculia	Iri							R	R	R								R					
Sterculia	Metutun	R	R																				
Sterculia	Sahotot								R			R					R	R					
Sterculia	Wasiwas																R						
Symplocos	—													R									
Syzygium	Arahumaik			O				O	R				R										S
Syzygium	Asisiv												R		R								
Syzygium	Nawal		R	R				R	R			R	R	O	R								
Syzygium	Yawan										R						R						
Terminalia kaernbachii	Is	R						R	R	R						R		R					
Terminalia	Huan'oh	R								R													
Terminalia	Oh			O			O	R		R							R						
Terminalia	Oh'huan								R							R		R					
Terminalia	Samanak		R			P	R						R					R					
Teysmanniodendron	Oktur		O	R				R	R	R								R					
Timonius	Sebil														R								
Tristania	Turirik													R									
Tristiropsis	Kunalkosi	R	R							R				R		R	R	R					R
Vitex cofassus	Kari		R	O				R	O	R	O		R			C	R	R					
Wrightia	Ambil		R					R	R														
Xanthophyllum	Mepkotot			O				R	R														
Xanthophyllum	Baiyaka																						O
Sapotaceae	—													O		R							
?	Ifelhulu																						O
?	Malakbaiya	R	R	R				R	R								R						R
?	Tolonamek	R		R												R							
?	Bali								R														
?								R			R												
Total recorded		57	168	46	25		46	105	137	50	8	10	57	29	16	85	90	99					31

(*b*) *High Productivity Forest*

(i) *Forests on Plains*

(1) *Tall Forest with a Rather Closed Canopy* (F).—This forest has a 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 moderately large and the estimated stocking rate is moderately high to high.

The forest occurs on alluvial terraces which are not subject to flooding or receive only minor rare floods.

The access index is very good and the forest is found scattered throughout the area from the coast to the northern edge of the inland plain.

F forest is the dominant forest type on Papul (19) land system but does occur on several others.

(2) *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 boles are long, straight, and clear. Girths are moderately large and the stocking rate is moderate to 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 inland and coastal plains with isolated occurrences along the larger rivers in hilly areas. Although it occurs on many land systems it is the predominant forest on Pes (17) and Nagam (16), and the dominant forest on Ambunti (20). 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*.

(3) *Tall Forest with an Open Canopy with Light-toned Crowns* (Fod).—This forest has a high productivity index and is of mixed species composition. *Pometia pinnata* is very common and deciduous trees are conspicuous. Boles are generally straight, long, and clear. Girths are moderately large to 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 along the larger rivers flowing southward from the main range and along the Sepik River.

Fod forest is the dominant forest type on Screw (18) land system but also occurs on Papul (19) and on higher parts of Palimbai (11).

* These species together with *Vitex cofassus* generally have a poor stem form and are the main contributors to the reject percentage.

(ii) *Forest on Uplands*

(1) *Tall Forest with a Rather Open Small-crowned Canopy* (Fos).—This forest has a high productivity index and is of mixed species composition. Locally, however, *Pometia tomentosa* can be dominant. Boles are generally long, straight, and clear and girths moderate to large. The estimated stocking rate is high and locally very high.

The forest is found mainly on remnant fan plains, fan terraces, and hills at low altitudes and has a good access index, slope being the local hazard. It is confined to the northern foothills of the main range and although present on several land systems it is the predominant forest on Aitape (55).

Locally the forest has been severely damaged, presumably by wind.

(*c*) *Moderate Productivity Forest*

(i) *Forests on Plains*

(1) *Tall Forest with a Rather Open Canopy with Groups of Woolly-textured Crowns* (Fow).—This forest, although not visited in the field, is assumed to have a moderate productivity index. Probably it is a pure stand of *Terminalia* and the estimated stocking rate is considered to be moderate.

It occurs on recent fan plains and, though subject to inundation hazards and poor drainage, has a good access index. It is found on the coastal and inland plains and occurs exclusively on Yilui (13) land system.

(2) *Tall Forest with an Open Canopy and with Sago Palms in the Understorey* (FoM).—This forest has a moderate productivity index and is of mixed species composition, although *Neonauclea* is often subdominant and *Planchonia* and *Ficus* spp. are common. Boles are generally long, straight, and clear and girths moderately large. The estimated stocking rate is moderate.

The forest occurs on imperfectly to poorly drained alluvial plains often subject to short periods of inundation. The access index is nevertheless good. The forest is found throughout the inland and coastal plains.

FoM forest occurs on several land systems but is the predominant forest on Misinki (14) and the dominant forest on Po (15).

(ii) *Forest 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 and *Intsia bijuga* common. No single remaining species contributes more than 10% of trees present. Boles are straight, clear, and long and girths generally large. The estimated stocking rate is high, locally very high on areas of gentle slope.

The forest occurs on dissected fan plains, terraces, and hills, generally at altitudes below 2000 ft, and has a moderate access index. It is scattered throughout the area but is mainly associated with the main range.

Fi forest is found on a large number of land systems.

(d) *Low Productivity Forest*

(i) *Coastal Forest*

(1) Casuarina equisetifolia *Mid-height Forest* (Cq).—This forest has a low productivity index. *Casuarina equisetifolia* with short boles and small girths is predominant. The estimated stocking rate is low.

The forest occurs on the outermost beach ridges on well-drained soils and the access index is very good. However, the intervening swales are poorly drained and frequently inundated, presenting some problems of access. It occurs as small stands scattered along the coast, the largest single occurrence standing at the western end of the area.

Cq forest occurs exclusively on Nubia (2) land system.

(ii) *Swamp Forest*

(1) *Mid-height Forest with an Open Canopy and with Sago Palms in the Understorey* (FmoM).—This forest has a low productivity index, and although of mixed species composition *Neonauclea* is very common. Boles are straight and short to moderately long with girths 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 index is only moderate. It occurs throughout the inland and coastal plains.

FmoM forest is the dominant forest type in Pandago (10) and Nigre (27) land systems but does occur in several others.

(iii) *Forests on Plains*

(1) *Tall Forest with an Open Canopy with Light-toned Crowns and with Sago Palms in the Understorey* (FodM).—This forest, although not sampled in the field, is considered to have a low productivity index. It is similar in most respects to FoM forest but has a large proportion of deciduous trees, notably *Planchonia*. The estimated stocking rate is moderate.

Like the FoM forest it occurs on imperfectly to poorly drained alluvial plains subject to frequent flooding or moderate inundation. The access index is moderate. It occurs mainly on the inland plain and to a minor extent on the coastal plain.

The forest is found on Misinki (14) and Po (15) land systems in association with FoM forest, and also on Yilui (13) land system.

(2) *Mid-height Forest with a Rather Open Canopy* (Fmo).—This forest has a low productivity index. Species composition is mixed but *Pometia pinnata* is very common. Boles are straight and moderately long and girths are small. The estimated stocking rate is low.

The forest occurs on imperfectly to poorly drained alluvial terraces subject to frequent and serious flooding, but the access index is good. It is found along rivers flowing southward from the hills to the inland plain.

Fmo forest occurs on Screw (18) and Papul (19) land systems.

(iv) *Forests on Uplands*

(1) *Tall Forest with a Rather Open Irregular Canopy* (Foi).—This forest has a low 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 and remnant fan plains at low altitudes and has a moderate access index due to slope. It is confined to the hills of the coastal plain and the northern foothills of the main range. Although found on many land systems, it is the dominant forest type on Panakatan (25), Paiawa (24), Yassip (38), and Nopa (57).

(2) *Mid-height Forest with a Small-crowned Canopy* (Fms).—This forest has a low productivity index. Species composition is mixed with *Intsia bijuga* and *Vitex cofassus* contributing up to 20% each, and *Pometia* spp. and *Hopea* spp. up to 10% each. Boles are moderately long and girths moderately large. The estimated stocking rate is low.

The forest is found on low hilly country and has a good access index despite slumping and resultant poor drainage conditions. It occurs on the hilly country adjacent to the northern edge of the inland plain.

Fms forest occurs on a large number of land systems.

(3) *Tall Forest with an Irregular Canopy with Light-toned Crowns* (Fid).—This forest has a low productivity index. Species composition is mixed and similar to Fi forest but with a greater proportion of deciduous trees. *Pometia pinnata* is common and is generally associated with secondary vegetation, particularly as a local dominant on slumped areas. Boles are generally straight and clear. Girths are moderately large and the estimated stocking rate is moderate.

The forest occurs on dissected fans, terraces, and hilly country up to an altitude of 2000 ft. The access index is moderate, due partly to steep slopes and partly to poor drainage on slump floors. It is found mainly south of the main range, particularly in the western half of the area.

Fid forest occurs on a wide range of land systems and is the dominant forest type on Lumi (26), Seim (46), Dreikikir (47), Sengi (42), Nuku (51), Mambel (48), and Ningil (49).

(v) *Secondary Forest*

(1) *Old Secondary Forest* (FR).—This forest has a low productivity index. Species composition is usually mixed but *Pometia pinnata* is often subdominant. Boles are generally moderately long and girths moderate to large. The estimated stocking rate is low.

The forest has a moderate access index.

(*e*) *Very Low Productivity Forest*

(i) *Swamp Forest*

(1) *Mid-height Forest with an Open Canopy with* Campnosperma *and with Sago Palms in the Understorey* (FmoCM).—This forest has a very low productivity index.

Campnosperma is predominant. Insufficient observations were made in the better parts of this forest, but from estimation boles should be straight and short with small girths and a low estimated stocking rate.

The forest occurs on swampy alluvial plains subject to long periods of inundation and thus has a poor access index. It is found mainly on the Sepik flood-plain with some patches occurring on the coastal plain.

FmoCM forest occurs mainly on Pora (8) land system.

(ii) *Forests on Uplands*

(1) *Mid-height Forest with an Irregular Canopy* (Fmi).—This forest has a very low productivity index. Species composition is very mixed and the only species contributing more than 5% of the trees present are *Dillenia* spp., *Pometia pinnata*, *P. tomentosa*, and *Intsia bijuga*. *P. pinnata* is often locally dominant on secondary sites, e.g. slump features. Boles are mainly moderately long and girths moderate in size. The estimated stocking rate is low.

The forest is found on steep hilly country and has a very poor access index. It is associated mainly with the main range and adjacent hills.

Fmi forest occurs on a wide range of land systems.

(2) *Mid-height Forest with a Very Irregular Canopy* (Fmio).—This forest has a very low productivity index. Although species composition is mixed, the common occurrence of secondary species indicates a large degree of disturbance, no doubt due to slumping and probably wind damage. In most respects it is similar to Fmi forest but has a lower estimated stocking rate.

The forest occurs on steep hilly country and has a very poor access index. It is associated with the lower parts of the main range.

Fmio forest occurs on a number of land systems but has no particular association.

(3) *Mid-height Forest with a Rather Dark-toned Even Canopy* (Fm).—This forest has a very low productivity index. Species composition is mixed but *Castanopsis* is subdominant and may locally predominate on ridge crests. Boles are generally moderately long and girths small to moderately large. The estimated stocking rate is low.

The forest occurs on the main range mainly at altitudes above 2500 ft and has a very poor access index due to steep slopes.

Fm forest occurs on several land systems.

(iii) *Secondary Forest*

(1) *Medium-aged Secondary Forest* (FRm).—This forest has a very low productivity index. Species composition varies from single species dominance to mixed, depending on the stage attained by the forest. *Pometia pinnata* is generally subdominant. Bole lengths and girth are extremely variable due to the mixture of secondary and remnant trees. The estimated stocking rate is low.

The forest has a poor access index.

(*f*) *Nil Productivity Forest*

(i) *Coastal Forest*

(1) Rhizophora–Bruguiera *Mid-height Forest and Other Mangrove Vegetation* (B).—The mangrove forest is not well developed in this area. The trees are not of commercial size but the forest type is included because of its possible value to the cutch industry.

For this reason the forest has not been separated from the allied vegetation. *Rhizophora* and *Bruguiera* with short boles and small girths are codominant.

The forest occurs on coastal flats subject to tidal inundation and has a low access index. It is found mainly around the Sissano lagoon with a small patch near the mouth of the Yalingi River.

B forest occurs exclusively on Murik (3) land system.

(ii) *Forest on Uplands*

(1) *Mid-height Forest with a Small-crowned Rather Even Canopy* (Fmsv).—This forest has a nil productivity index. *Cryptocarya* and *Syzygium* are both subdominant but the associated species are mixed. Boles are mainly moderate to long and girths small to moderate in size. The estimated stocking rate is low.

The forest occurs on steep to very steep hills on schist and gneiss and consequently has a very poor access index. It is found on both sides of the Sepik River near Ambunti.

Fmsv forest is restricted to Maio (64) and Waskuk (65) land systems.

PART IX. LAND USE CAPABILITY OF THE AITAPE–AMBUNTI AREA OTHER THAN FOR FORESTRY

By H. A. HAANTJENS*

I. AGRICULTURAL LAND USE

(*a*) *Method of Capability Assessment*

The land use capability of the area has been assessed by a method described by Haantjens,† which involves two distinct steps that are briefly discussed below. Although the method is based on arbitrary decisions in establishing classes and on generalizations and assumptions in making assessments, it is internally consistent and can be applied objectively. The limitations mentioned above are the result of the present inability to predict crop performance and farming costs in New Guinea accurately by the application of analogue or process-model techniques.

It should be emphasized that the assessment of land use capability in this Part is exclusively concerned with modern techniques of commercial farming involving permanent land use. For New Guinea conditions this does not necessarily imply large-scale mechanized agriculture, but may equally well involve labour-intensive farming methods on small plots. Because of this the assessment does not take directly into account the size of areas with a uniform capability.

(i) *Rating of Land Attributes*.—The first step in the assessment is a rating of physical land attributes that could influence and normally limit land use capability. Some information on the rating procedure is given in a separate report.‡ The following 16 attributes were rated at all field observation sites: l, altitude; e, slope and erodibility; b, cobbliness; s, stoniness; r, rockiness; f, short-duration river flooding; i, long-duration inundation; w, soil drainage status; p, soil permeability; d, agricultural soil depth; m, available soil water storage capacity; t, tillage problems; a, soil reaction; c, soil salinity; u, land surface unevenness; and j, topographic irregularity. In addition, all land under 6° slope was rated with respect to its suitability for irrigation of rice, taking into account slope, topographic position, and soil permeability.

The attributes and their ratings occur in very many different combinations, even on similar types of land. This is evident from the list of "limiting factor formulae" presented elsewhere.‡ This great complexity prevented the inclusion of such formulae in the detailed land system descriptions of Appendix III. This lack of information is partly compensated for by identifying the relevant land system by number for each listed formula in the separate report and by preparing maps showing the estimated distribution of important attributes that commonly limit land use capability in the area (see Section I(*d*)).

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† Haantjens, H. A. (1969).—Agricultural land classification for land resources surveys in New Guinea. 2nd Ed. CSIRO Aust. Div. Land Res. tech. Memo. No. 69/4 (unpublished).

‡ CSIRO Aust. Div. Land Res. tech. Memo. No. 71/1, Part VI (unpublished).

(ii) *Rating of Agricultural Suitability of Land.*—The second step in the assessment is concerned with rating the effect of the combined attributes of a type of land on limiting its suitability for agriculture. Since it was impracticable to consider the suitability of land for all crops that might conceivably be grown in the area, suitabilities have been rated only for four kinds of agricultural land use: arable (annual) crops involving regular land cultivation; perennial tree crops involving little or no cultivation; improved (sown) pastures, either permanent or as leys; and irrigated rice. Ratings fall into six capability classes, from very high to nil.

These ratings are on a much more subjective basis than the ratings of the physical land attributes. In the absence of factual data about the influence of the land attributes on agricultural productivity and production costs, the ratings are based on a number of assumptions based on general experience in New Guinea or in tropical agriculture generally. The main assumptions underlying the suitability assessments are:

(1) Cultivated land (arable crops) is more susceptible to erosion than land under tree crops or improved pastures.

(2) Level land is essential for irrigated rice and is of greater advantage with cultivated arable crops than with tree crops or improved pastures.

(3) Poorly drained soils are a very serious limitation for tree crops, less serious for arable crops, even less serious for improved pastures, and virtually no disadvantage for irrigated rice.

(4) The effects of inundation of long duration are similar to those of poorly drained soils, but more serious, also for irrigated rice.

(5) Flash floods by rivers are likely to affect arable crops and irrigated rice most and tree crops more than improved pastures.

(6) Surface stones, cobbles, and rocks cause land development and management problems that decrease in the following order: irrigated rice, arable crops, improved pastures, tree crops.

(7) The greatest soil depth and water storage capacity are required by tree crops, followed by arable crops, which generally require deeper soils than improved pastures. These factors are of virtually no importance for irrigated rice.

(8) Acid soils are either an advantage or less of a limitation for tree crops than for the other three kinds of agriculture.

(9) Neutral to alkaline soils and soil salinity are a greater limitation for tree crops than for arable crops or improved pastures, and affect irrigated rice least.

(10) Soils that are difficult to till present the greatest problems for cultivation of arable crops. Such problems are less for improved pastures and play only a minor role or do not affect tree crops and irrigated rice.

Whilst the above assumptions appear to be valid for the four kinds of agricultural crops as a whole, they may affect individual crops within these groups to different degrees or not at all. Thus it is advisable, when the suitability of land for a specific crop is considered, to check the general capability of a land system with the specific information given for the relevant land attributes, either in the land system descriptions or on the special maps.

(iii) *Water Stress and Soil Fertility*.—Variations in rainfall and evapotranspiration and in chemical soil fertility (N, P, K contents) have not been used directly in determining the land use suitability.

Indirectly, water stress has had some influence on the land use capability assessment through the factor of soil depth. Nowhere in the area does soil water stress appear to be an important limiting factor on usable land. Water stress risks (see Appendix I, Section II(*g*) for definitions) have been assessed by applying rainfall and evapotranspiration data from the four water balance zones (Part IV, Section III) to a range of soil water storage capacities.

Although there is great variation in the nitrogen, phosphate, and potash contents of soils of different kinds and in different parts of the area, it is held that nutrient deficiencies can be rectified comparatively easily under modern agricultural management and, therefore, do not greatly affect the basic land use capability. Extreme deficiencies of P and K occur only in strongly acid soils and hence have indirectly influenced the capability assessment through the factor of soil reaction. In addition, the N, P, K contents of the lowest soil classes are listed elsewhere.*

(*b*) *Agricultural Assessment of Land Systems*

The agricultural land use capability of each land system is shown in detail in a separate report† by the estimated percentages of land with different levels of suitability for arable crops, tree crops, and improved pastures, as assessed in the manner discussed earlier. These fractional assessments (and also those for irrigated rice) have been used to derive land use capability indexes for the whole of each land system, as described in Appendix I. The indexes, one for each of the four broad kinds of agricultural activity, are given in the synoptic land system descriptions in Part III, as well as in Table 23 in Appendix IV. The average of the indexes for arable crops, tree crops, and improved pastures is taken as a measure of the overall land use capability of the land systems. It is presented in the same places in the report. Although given as two-digit figures, the indexes merely represent "best estimates" and serve mainly to rank the land systems with respect to each other. On the basis of the indexes the land systems have been placed in six land use capability classes (Appendix I, Section II(*g*)), which are given in the detailed assessments in Appendix III and have been used in compiling the map of agricultural land use capability (Section I(*e*)).

The detailed assessments of the land systems in Appendix III contain in addition the following information on land use capability: notes on the chances of occurrence of soil water stress; data on the N, P, K contents of soils; information, where needed, on the degree of variation of land quality and on the distribution and size of areas of relatively good land; and information on the possibilities of land reclamation in land systems where poor drainage and overflow on level land are the main limiting factors.

* CSIRO Aust. Div. Land Res. tech. Memo. No. 71/1, Part IV (unpublished).

† CSIRO Aust. Div. Land Res. tech. Memo. No. 71/1, Part II (unpublished).

It should be noted that the assessment of the overall land use capability of the land systems has not in any way been influenced by either the size of a land system or its location and accessibility from outside.

(*c*) *Land Use Capability and Present Land Use*

To determine the possibilities of agricultural development in existing centres of population or the needs and possibilities for resettlement and new agricultural ventures, it is necessary to compare the land use capability of land systems as assessed in this report with the use being made of them at present. Information on this subject has been tabulated in Appendix IV.

(*d*) *Special Maps*

The estimated distribution of a number of terrain and soil features of importance to agricultural development is shown on five unpublished maps at a scale of 1 : 250,000, available upon request to the Division of Land Research, CSIRO, Canberra. The references of these maps are compiled directly or indirectly from the ratings of land attributes discussed in Section I(*a*). The boundaries of the mapping units are derived from land system boundaries.

The subjects of the maps are: ruggedness and relief; soil drainage status and overflow hazards; agricultural soil depth and soil permeability; potential for land reclamation and available soil water storage capacity; soil reaction and N, P, K contents of soil. The last two maps deal with features that have not been used directly in the preparation of the agricultural land use capability map discussed below, and can therefore be considered complementary to it.

(*e*) *Agricultural Land Use Capability Map*

(i) *Introduction*.—The aim of this map is to give an impression of regional differences in land use capability, by showing groups of land systems with similar overall levels of land use capability and with similar suitabilities for arable crops, tree crops, and improved pastures. The map reference is arranged in order of decreasing land use capability. Since this reference states only the levels of suitability of the groups, it is desirable to outline briefly, in this section, the nature of the limiting factors that control these suitability levels. These factors can differ greatly for different land systems in the same capability group. The distribution of each group in the survey area is shown in Figure 17.

It should be noted that chemical soil fertility (N, P, K contents) and chances of soil moisture stress have not directly influenced the land use capability groupings, but complementary information on these subjects is available on special maps discussed in the previous section. Similarly, the unpublished special map of potential for land reclamation provides complementary information for those groups of land systems in which the land use capability is depressed by poorly drained soils and overflow hazards.

Land use capability for irrigated rice has not been used as a criterion in the grouping and thus varies irregularly within and between groups. The land systems belonging to each land use capability group are listed in Table 23 in Appendix IV, together with all their land use capability indexes. This information has been used to estimate the total areas with different levels of suitability for arable crops, tree crops, improved pastures, and irrigated rice given in Table 2.

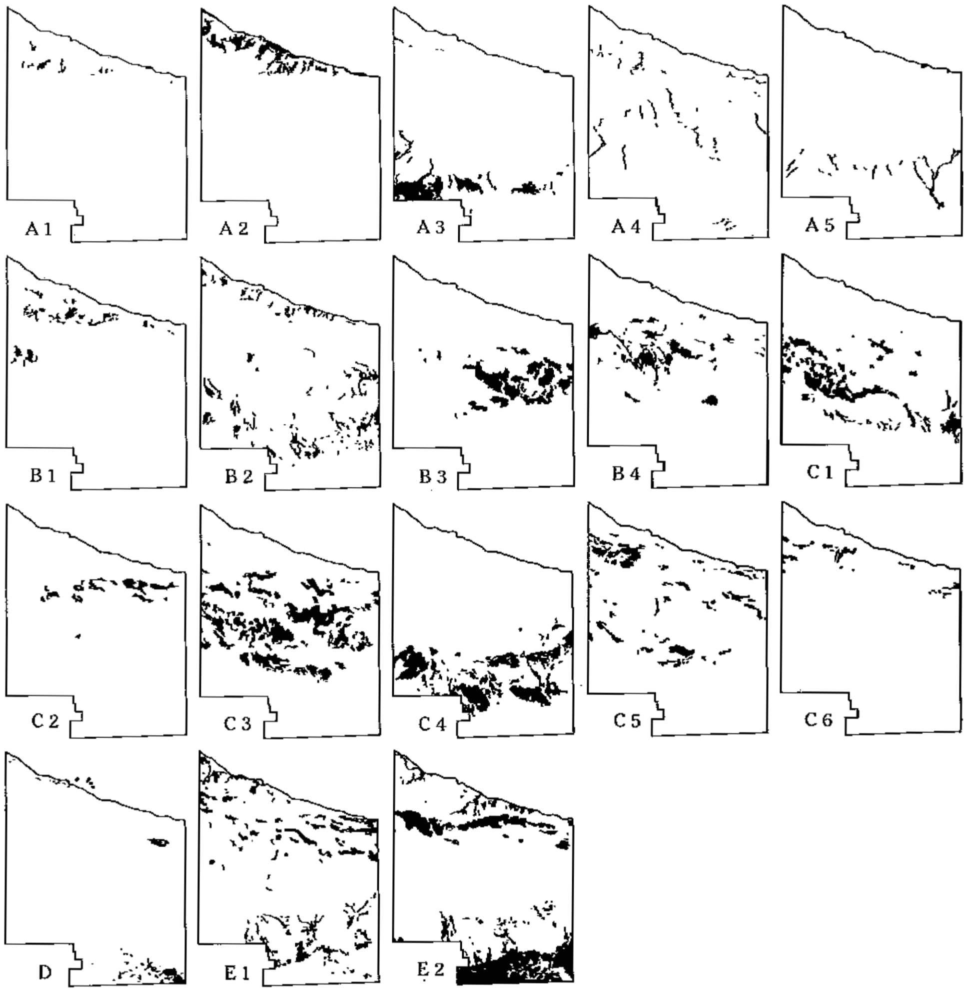

Fig. 17.—Distribution of land use capability groups. Groups A1–A5, overall high capability; groups B1–B4, overall moderate; groups C1–C6, overall low; group D, overall very low; groups E1–E2, overall nil.

(ii) *Groups with High Overall Capability* (*565 sq miles*).—These groups nearly always have a high capability for arable crops. The capability for tree crops is high to moderate, but very high in group A1. The suitability for improved pastures is high, and very high in groups A2 and A3. There is a more consistent potential for irrigated rice than in any other set of groups.

A1.—On the slightly dissected fans of this group the capability for arable crops is affected by slight erosion and topographic hazards, that for improved pastures by high soil acidity. The land is generally too high and uneven for irrigated rice.

A2.—On the plains and beach ridges of this group occurs what is probably the best land in the area, although care may have to be exercised in regular cultivation of the sandy beach ridge soils. Soil pH may often be too high for optimal tree-crop growth. In low-lying parts of this land impeded drainage and local overflow hazards reduce its suitability for arable crops, and particularly for tree crops. These same areas have the highest potential for irrigated rice. Drainage improvement of low-lying plain sectors appears to be relatively simple and worth while.

A3.—Large plains in this group have imperfectly drained slowly permeable soils of neutral reaction that are least suitable for tree crops and somewhat difficult to cultivate because of high clay and silt contents. The capability for irrigated rice would be greater if it were not for likely difficulties in bringing water onto the land. Drainage improvement of the plains appears to be relatively simple and worth while. Small fans in this group have soils that are too alkaline for many tree crops and somewhat stony for cultivation.

A4.—Terraces along major rivers are subject to varying degrees of flooding that would affect arable crops and irrigated rice most, improved pastures least. Some terraces are flooded rarely or not at all and include some of the best land in the area, but always as small lots. Other land, near the rivers, is virtually unusable. On small fans in this group, impeded drainage of the lower sectors affects improved pastures least, whilst rather cobbly acid soils on the upper sectors are most suitable for tree crops. Both types of land appear suitable for cultivation.

A5.—Land in this group is essentially of the same nature as that of the previous group but suitability levels are lower, particularly for arable and tree crops, because of the greater incidence of impeded drainage.

(iii) *Groups with Moderate Overall Capability* (*905 sq miles*).—In these groups the capability for arable and tree crops varies from moderate to low, although it is high for tree crops in part of group B1. The suitability for improved pastures is high to moderate, but for irrigated rice it is nil except in most of group B2.

B1.—On the dissected fan surfaces of this group land use capability is reduced by topographic obstacles and erosion hazards on steep slopes and ridges of little or no agricultural value surrounding rather small areas of reasonably level land of good quality. These hazards are particularly limiting for arable crops. The suitability for tree crops is locally decreased by soil drainage deficiencies and rather shallow soils, while the capability for improved pastures is reduced by soil acidity.

B2.—Most of this group consists of plains with poorly drained soils, because of high water-tables and overflow or slow soil permeability. These limitations, together with rather high soil pH on low-lying plains, reduce in particular the capability for tree crops but hardly affect the suitability for irrigated rice. Acid soils and slight dissection are further limitations for cultivation of arable crops and for improved pastures on the higher-lying plains. Whilst most plains are uniform, some consist of very wet back plains and drier levees with land of high capability. Drainage improvement and control of overflow appear to be moderately difficult, but seem worth while where soils are not too clayey. On the higher-lying plains slow permeability of the very infertile soils may allow improvement only of the surface drainage.

The remainder of this group consists of partly dissected upland surfaces and low hills, where the land use capability is reduced by a number of factors. Of these, erosion hazards are most important for arable crops, soil drainage and soil depth deficiencies for tree crops. These factors do not seriously reduce the suitability for improved pastures. Some soils have a rather high pH for tree crops, whilst others are rather too acid for pastures.

B3.—In this group of low hills the slopes are commonly too steep for arable crops, but not steep enough to seriously affect the capability for improved pastures. The irregularity of the slopes is also less of a limitation for pastures, and results in the presence of small pockets of land that could be cultivated. The suitability of this land for tree crops is often reduced by impeded soil drainage, rather shallow soils, and/or relatively high soil pH.

B4.—The hills and colluvial slopes of this group have generally well-drained rather deep and commonly acid soils favourable for tree crops. These advantages are partially offset by the fact that some of this land occurs above 2000 ft in a climate unfavourable for tree crops. The very great irregularity in detail of the slopes strongly reduces the suitability of this land for arable crops, and together with the acid soils also limits its suitability for improved pastures.

(iv) *Groups with Low Overall Capability (2035 sq miles)*.—In these groups the suitability for arable crops ranges from low to nil, whilst for tree crops it is usually low or very low, but moderate in group C2. The suitability for improved pastures is moderate to low and for irrigated rice usually nil, except in group C4.

C1.—This group consists partly of dissected plains with very infertile soils, where erosion hazards and poor soil drainage strongly reduce the capability for arable crops and tree crops. Erosion hazards and high soil acidity affect the capability for improved pastures to a lesser degree. Small valleys and depressions have some potential for irrigated rice.

The largest part of this group comprises high hills with considerable topographic limitations for agricultural development. Only small areas on the irregular slopes are suitable for cultivation of arable crops. Soil drainage deficiencies, rather shallow soils, and rather high soil pH occur in many places and keep the capability for tree crops low. Since these factors are less limiting for pastures, this land still has a moderate capability for grazing.

C2.—This group of high hill ridges has serious topographic limitations. The slopes are too steep and irregular for arable crops, except when terraced or in small pockets with gentler slopes. With its rather high relief the terrain is very rough for grazing on improved pastures. Since the soils are generally deep and rather acid and the slopes not too steep, the greatest capability of this land is for tree crops, except where it lies above 2000 ft in a climate unfavourable for both lowland and highland tree crops.

C3.—This group includes a variety of terrain, from very low hills to low mountains. Topographic limitations and erosion hazards make cultivation of arable crops very difficult or impossible, except in pockets of gentler slopes. Whilst topographic conditions would still allow the planting of tree crops in many areas, various other limitations such as soil drainage deficiencies, shallow soils, or altitudes above 2000 ft would further reduce the capability for tree crops to low. These factors have little effect on the suitability for improved pastures. Pasture management is only moderately hampered by topographic limitations because the terrain is either of very low relief or consists of very long irregular but not very steep slopes of hills and mountains.

C4.—The limitations of this group are of the same nature as those in group B2, but more serious. Land reclamation of the poorly drained plains in this group, which over large areas are quite suitable for irrigated rice, would be rather simple to moderately difficult, although only partial drainage improvements may be feasible because of the slow permeability of the heavy clay soils. The higher-lying plains and hills in this group have generally very infertile soils.

C5.—Topographic and erosion hazards due to steep slopes and rough terrain are the main and very serious limitations in this group of low hill ridges. Only very small pockets of land on upper slopes could be cultivated. The suitability for tree crops is further limited by local shallow soils and very locally by impeded soil drainage. Soil acidity is a common additional limitation for improved pastures, which would be the most suitable form of land use if any development were desirable.

C6.—The limitations in this group of hills and low mountains are largely similar to those in the previous group. In rather large areas above 2000 ft the suitability for tree crops is further reduced by unfavourable climatic conditions. Shallow soils of rather high pH on limestone appear to be little suited to tree crops but offer moderate possibilities for improved pastures.

(v) *Groups with Very Low (65 sq miles) or Nil (1560 sq miles) Overall Capability.*— Land in these groups has no suitability at all for arable crops. The groups usually have no capability, but in some cases a very low or, in group D, even a low capability for tree crops. Their suitability for improved pastures is generally nil to very low, but it is low in parts of group D. Some land in groups E1 and E2 has a greater (but nevertheless mostly low) capability for irrigated rice than for any other agricultural use.

D.—Most of this group consists of rugged hill ridges with very steep slopes as the main limitation. Their acid and rather deep soils tend to favour tree crops above improved pastures, but this advantage is partly offset by unfavourable climatic conditions for tree crops on land above 2000 ft. In the remainder of this group, a combination of erosion hazards and shallow or very shallow soils with high pH causes the land to have a low capability for improved pastures, and to be even less suitable for arable and tree crops.

E1.—About half this group consists of very rugged high hills and mountains, where erosion hazards and terrain conditions result in a very low capability, either for tree crops and pastures where the soils are relatively deep and acid or only for improved pastures in areas above 2000 ft or on shallow soils that can also have a rather high pH.

The other half of this group comprises sago swamps that appear to have a moderate suitability for irrigated rice, although in their present state they are virtually unsuitable for other forms of agricultural land use except sago collecting and planting. Reclamation of most of these swamps appears to be only moderately difficult, and could produce good land except for tree crops.

E2.—More than one-third of this group comprises mountains and hills too rough and steep to have any agricultural potential. The remainder consists of swamps that are virtually unusable in their present state, except for a very low to low capability of parts of the group for irrigated rice. The best prospects for rice within this group are in the grass swamps of the Sepik flood-plain. Reclamation of the swamps would be technically difficult or very difficult, and would often result in land of doubtful capability, particularly for tree crops but also for arable crops.

II. Engineering Land Use

(a) *General*

Some general problems in the evaluation for engineering of small-scale reconnaissance surveys, with particular reference to the manner in which these have been approached in the present survey report, are discussed by Haantjens (1968).* It has not been possible to produce a comprehensive engineering land use capability map of the area equivalent to the agricultural land use capability map discussed in the previous section. In general terms it can be stated, however, that large parts of the area present formidable engineering problems as a result of difficult terrain and heavy vegetation, dense stream nets, poor land drainage and overflow hazards, shortage or inaccessibility of suitable engineering construction materials including rock and soil, difficult climatic conditions, or combinations of these factors. The aim of this section is merely to direct the reader to those parts of the report and those maps that are relevant to engineering land use.

(b) *Information Relevant to Engineering Works*

(i) *Individual Land Systems*.—Each detailed land system description in Appendix III includes a section on engineering assessment that summarizes in a qualitative manner the favourable and unfavourable aspects of the land system for engineering, with emphasis on the construction of minor and major roads. The assessment takes into account such factors as rock type, topographic conditions (including slope stability), stream pattern and stream properties, soil drainage status, flood and

* Haantjens, H. A. (1968).—The relevance for engineering of principles, limitations and developments in land system surveys in New Guinea. Proc. 4th Conf. Aust. Road Res. Bd, 1968. Vol. 4, pp. 1593–612.

inundation hazards, and the suitability of soil materials for engineering purposes. Soil depth and classification in the Unified Soil Classification System* are mentioned separately. The advantages and disadvantages of certain land systems relative to adjoining land systems are discussed where desirable, together with the probable significance of land systems for local development or regional communications. Brief notes on airfield construction are included in land systems 1, 2, 16, 17, 19–21, 23, 24, 26–28, 31, 32, 36, and 49. Some engineering aspects of harbour development are mentioned in land systems 2 and 3. Brief notes on engineering problems in land reclamation are included in the agricultural assessment sections of land systems 3–15, 18, 19, 21, and 27.

A first impression of the nature of the land systems is best obtained by reading their synoptic descriptions in Part III, Section II, and by viewing their air-photo stereograms (Plates 1–30) and their stream pattern plans (Figs. 9–15). Much additional information relevant to engineering can be obtained from the sections on land forms, streams and drainage, geology, and weathering in the detailed land system descriptions. Information presented on timber resources and vegetation may also be of some value, but probably little useful information can be extracted from the soils section over and above that already given in the engineering assessments. All terms and ratings used in the descriptions are defined or explained in Appendix I.

(ii) *The Survey Area as a Whole.*—Whilst the land system descriptions and map are suitable media for obtaining integrated information for particular parts of the area, other methods have been used to present relevant topical information for the area as a whole. Attention is also drawn to the brief discussion of earthquakes in Part I.

(1) *Maps.*—Several unpublished maps at a scale of 1:250,000 and derived from the land system map have been prepared which can be significant for engineering. They are available upon request from the Division of Land Research, CSIRO, Canberra. The subjects of these maps are: engineering materials (including lithology, USC soil classes, soil depth, and information on gravel); ruggedness and relief; and soil drainage status and overflow hazards. Qualitative information on soil permeability, presented on another map, is also available. The independently prepared maps on forest resources and vegetation included with the report could also be of some value, mainly the vegetation map if studied together with the listings† of some vegetation properties relevant to clearing, line surveying, etc. The altitude map could also be useful.

(2) *Soil Data.*—Some properties of the lowest soil classes that are important for the engineering use of soils are listed in a separate report.‡ In relating this information to the area as a whole, it is necessary to consult Part V of that report and the land system map.

(3) *Climatic Data.*—Of the climatic data presented in Part IV, Tables 7, 10, and 11 have the greatest significance for engineering projects since they give informa-

* The assistance of the Public Works Department, Port Moresby, in testing 100 soil samples is gratefully acknowledged.

† CSIRO Aust. Div. Land Res. tech. Memo. No. 71/1, Part III (unpublished).

‡ CSIRO Aust. Div. Land Res. tech. Memo. No. 71/1, Part IV (unpublished).

tion on wet and dry spells, soil moisture regimes, and rainfall surplus. They can be roughly extrapolated across the area by means of Figure 2. In the absence of any measured data, the information of Table 11 could probably be used for rough computation of stream flow, if it is used in conjunction with catchment areas and the qualitative information on surface run-off/through drainage ratios given in the streams and drainage sections of the detailed land system descriptions. The catchments of the major rivers and other drainage divisions are shown on an accompanying map. The distribution of the A and B type catchments shown on this map over the water balance zones and land systems is presented in a separate report.*

(c) *Information Relevant to Terrain Trafficability*

Many of the sources of information discussed in the previous sections are equally applicable to problems of cross-country movement. The map of terrain access categories, although prepared for forestry purposes and not taking account of the vegetation, provides a general picture of regional differences in terrain trafficability. It is obvious that the possibilities for cross-country movement, even for tracked vehicles, are usually very small or non-existent due to topographic conditions, vegetation, or both. Reasonable prospects seem probable only in Nubia (2), Yambi (27), and Burui (28) land systems. Data on tree spacing† are particularly relevant for the effect of vegetation on mobility.

The difficult terrain renders it necessary to make as much use as possible of existing roads, tracks, waterways, and airfields. Information on transport facilities is provided in Part I, Section I(*c*), and on an accompanying map. It is impossible, in the context of this report, to indicate the location of the numerous foot tracks in the area. Since these tracks link villages either with each other or with areas of shifting cultivation, the population map and the land use intensity map accompanying this report indirectly give an idea of the density of this network of tracks. In addition, several tracks across the main mountain range link the interior with the coast. It should be kept in mind that the information presented reflects the 1964–67 situation. Subsequent changes due to construction of new or closure of old roads and airstrips, and to relocation or agglomeration of native villages, are likely to occur.

III. Tourism and Hunting

(a) *Scenery and Cultural Aspects*

The area appears to be less endowed with scenic features than many other parts of New Guinea. This is due to the absence of high mountains, and to the large areas of monotonous forested alluvial plains and hill country on sedimentary rock. The Sepik flood-plain area, particularly where it is broken by hills and mountains near Ambunti and in the Chambri Lakes area just east of the Aitape–Ambunti area, constitutes a rather unusual landscape centred upon a truly impressive river which is likely to appeal to at least certain groups of more sophisticated tourists. Sepik River tourist cruises are already taking place on a modest scale from Angoram. The

* CSIRO Aust. Div. Land Res. tech. Memo. No. 71/1, Part VII (unpublished).

† CSIRO Aust. Div. Land Res. tech. Memo. No. 71/1, Part III (unpublished).

attraction of this area is enhanced by the skill of the local people in wood-carving and in places also in pottery. Some villages, situated mainly further east in the Wewak–Lower Sepik area, have interesting ceremonial men's houses (haus tambaran), and in places remnants of an older "megalithic" culture. Revival and upholding of the traditional arts would be an asset to any tourist trade in this area. The uncomfortably hot climate is a disadvantage, although the heat is felt less on the water.

The artistic skill of the people near Maprik, as expressed in their unique haus tambaran, wood carvings, and other craft, is already attracting tourists to this area which extends into the central eastern part of the Aitape–Ambunti area. The environs of Lumi and Anguganak are probably the most scenically attractive south of the mountains. Given basic facilities, scenic drives and walks could be made in a pleasant though rather wet climate, with added interest provided by the numerous native villages on hill tops.

Along the coast, Aitape could be the focal point for various attractions. The beautiful coral islands of Tumleo, Ali, and Selio have good living coral, pleasant small beaches, and an interesting, different type of native inhabitants, who use large decorated sea-going canoes and beautifully carved and painted garamut drums. A boat trip along the tidal channels behind the fore-dune to Sissano lagoon, with its large prosperous villages, mangroves, sand spits, and intricate fish traps, would be in pleasant contrast to a visit to one of the spectacular gorge-like valleys, where major rivers emerge from the rugged mountain front. Already Aitape is the centre of the kind of development that may interest tourists; for instance, the extensive Roman Catholic Mission complex, the leprosary, the coconut/cocoa plantations, and the minor industries of brick-making and sago-mat weaving on real looms.

Since the New Guinea landscape is impressive and most comfortably viewed from the air, aerial scenic tours could be an important feature of the tourist industry in any of the places mentioned above.

(*b*) *Recreation*

The usual sporting facilities normally expected by tourists still have to be built up from the ground, except for some rather unusual golf links on airstrips. The natural attractions of the area with respect to recreation are to be found mainly in its water features. Several lakes, caused by landslides in the past in the southern foothills of the mountains between Maprik and Dreikikir (see toponymy map), would be suitable for swimming, canoeing, and probably also water-skiing. Ideal conditions for these sports would also exist in the Sepik River area, were it not for the presence or suspected presence of crocodiles. If some of the oxbow lakes could be kept free of them, they could be turned into attractive water-sport areas during the dry season. More immediately realizable appear opportunities for duck shooting as a tourist sport. Data are lacking for the assessment of the value of this area for the angler. It appears to have at least some potential, but development may involve stocking with fish and some control of fishing. Fishing, sailing, boating, water-skiing, swimming, skin-diving, and, to a lesser degree, surfing are all sports that could be pursued in pleasant surroundings and under good conditions near Aitape and the off-shore islands if the essential facilities were provided.

(c) *Crocodile Hunting*

Whilst unattractive to most people as a recreational holiday activity because of the discomforts of the night-time hunts, crocodile hunting for the skin industry is one of the few sources of cash income for the indigenous population of the Sepik River flood-plain. According to Dr. H. R. Bustard (unpublished data), who investigated the industry in 1967, the selective killing of large breeding specimens has decimated the crocodile population, particularly the larger and most sought-after "saltwater" crocodile (*Crocodylus porosus*). At present the volume of the skin trade is being kept static by the ever-increasing killing of smaller specimens. The result is that most of the more accessible parts of the Sepik River swamp lands have become almost "shot out", even with respect to the more numerous, smaller, freshwater crocodile (*C. novaeguineae*).

Although there is no danger of either species becoming extinct, Dr. Bustard considers that protective and stimulating measures are urgently needed to prevent the collapse of the crocodile skin industry and, conversely, to promote its expansion. Considerable increases in the controlled harvest of crocodile skins are biologically possible in the vast areas with favourable conditions along the Sepik River. They are economically desirable in view of the increasing world demand and prices for crocodile leather. The main measures proposed by Dr. Bustard to stimulate the industry are:

(1) Establishment of ownership title of crocodile territory for indigenous communities.

(2) Introduction of minimum and maximum skin sizes to foster both acceptable growth and breeding rates.

(3) Prohibition of netting and hooking as hunting methods that are indiscriminate as to size of catch.

(4) Establishment of crocodile hatcheries.

(5) Improvement of skin treatment to ensure a uniformly high quality of marketed skins.

APPENDIX I

Definition or Explanation of Descriptive Terms and Classes of Land Attributes

By H. A. Haantjens,* P. C. Heyligers,* J. R. McAlpine,* 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 17. 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.

(ii) *Slope Index* (SI).—This index is calculated for each land system from: $0 \times$ (% slopes $<10°$) $+ 0 \cdot 33 \times$ (% slopes 10–17°) $+ 0 \cdot 66 \times$ (% slopes 17–30°) $+ 1 \times$ (% slopes $>30°$).

(iii) *Ruggedness*.—This is expressed as seven ruggedness classes based on slope index (SI): non-rugged, SI 0–3; very slightly rugged, SI 4–9; slightly rugged, SI 10–19; moderately rugged, SI 20–41; rugged, SI 42–68; very rugged, SI 69–84; extremely rugged, SI 85–100. Note that land consisting exclusively of slopes $<10°$ is non-rugged, slopes 10–17° moderately rugged, slopes 17–30° rugged, slopes $>30°$ extremely rugged.

(iv) *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 18.

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† CSIRO Aust. Div. Land Res. tech. Memo. No. 69/4 (unpublished).

‡ This term is not used in an absolute sense but in relation to the conditions prevailing in each land system.

(v) *Ridge Spacing Density*.—This pattern property, equivalent to twice the grain, is qualitatively described from air-photo observations. For land systems with noticeable relief it can be more quantitatively assessed from the stream pattern plans (Figs. 9–15), since generally the ridge density is similar to the stream density.

TABLE 17

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°		

* All called level (<0°30′) if no gradient can be specified.

(vi) *Crest Width*.—Based on field measurements and estimates from air photos, 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.

TABLE 18

RELIEF CLASSES

Class	Relief (ft)	Terrain Type
Nil	<20	Level to undulating plain
Ultra low	20–50	Undulating, rolling, or dissected plain
Very low	50–150	Very low hills or deeply dissected plain
Low	150–300	Low hills
Moderate	300–750	High hills
High	750–1500	Low mountains
Very high	>1500	High mountains

(*b*) *Streams and Drainage*

(i) *Stream Gradient*.—See slope steepness classes under subsection (*a*)(i).

(ii) *Stream Width*.—Either this is qualitatively described or estimates or measurements (field measurements for small streams, air-photo measurements for large rivers) are given in yards. These data apply to the whole of the bare or sparsely vegetated stream bed, not necessarily to the channel alone.

(iii) *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 (*d*)(x)), 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.

Swampy.—Permanent excessive soil moisture throughout the profile; water-tables at or near the surface during the dry season.

(iv) *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.

(v) *Surface Run-off in Relation to Through Drainage.*—This is purely qualitatively classed for each land system as nil, very low, low, moderate, or high. It seems possible that in the high class 60–80% of the annual run-off (difference between precipitation and evapotranspiration) will be in the form of surface run-off, the remainder contributing to ground-water storage and discharge. The assessment of the ratio is based on slope index, apparent permeability of soil and rock, and agricultural soil depth.

(*c*) *Vegetation*

(i) *Mapping Symbols.*—These are built up as follows. The first capital letter or combination of capital letters indicates the major structural group to which the

* For drainage and inundation index see subsection (*f*)(i).

† For flooding index see subsection (*f*)(i).

vegetation type belongs: F, forest; W, woodland; G, grassland; H, mixed herbaceous vegetation; R, gardens and young regrowth; and FR, secondary forest. Exceptions to this rule are several cases in which the vegetation types could be recognized on their floristics. These types have been tagged with a capital letter from the scientific name of a dominant genus. They are: mangrove vegetation (B, from *Bruguiera*); stands of *Casuarina* (C); sago palm vegetation (M, from *Metroxylon*); *Nypa* palm vegetation (N); and pandan vegetation (P, from *Pandanus*).

The capital F or G is, as a rule, followed by a lower-case letter expressing the height: l, low; m, mid-height; and t, tall. To keep the symbols as short as possible one in a group is left out: F is *tall* forest, G is *mid-height* grassland.

For woodland, grassland, and mixed herbaceous vegetation a second capital letter is then used, taken from a scientific name or indicating the secondary nature of the vegetation (R).

In symbols for forest more lower-case letters are added to indicate air-photo characteristics of the canopy: o, open; i, irregular; s, small-crowned; w, woolly-textured crowns; v, even-textured crowns; d, crowns of a very light tone. An exception is p, which means that pandans are common in the understorey. The capital letters which follow refer to *Campnosperma* (C), sago (M), and pandan in the canopy (P). Secondary forest (FR) has been split into young (y), medium-aged (m), and old (without lower-case letter).

(ii) *Frequency*.—The number of times a particular characteristic or plant was observed in a certain vegetation type in comparison with the total number of observations of 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 is more than 50%; often, mostly, or generally is more than 75%.

(iii) *Cover*.—In woody communities, canopy cover, or crown cover if subcanopy strata are dealt with, is expressed as the proportion of sky obscured by foliage. Cover of herbaceous communities is expressed as the proportion of ground overshadowed by foliage. Cover has been estimated in steps of 5% up to 40% and in steps of 10% for higher values.

(iv) *Density*.—The closeness with which plants or parts of plants, e.g. tree crowns, grow together is expressed on relative scales as follows: dense, rather dense, scattered, very scattered, odd individual; or closed, rather closed, rather open, open.

(v) *Commonness*.—This pertains to the number of individuals present in a certain area. The following relative scale is used: abundant, very common, common, rather common, present, rare.

(*d*) *Weathering and Soils*

(i) *Degree of Weathering*.—The terms skeletal, immature, and mature are used qualitatively to indicate the apparent abundance, commonness, or paucity, respectively, of rock fragments and unstable minerals in the weathered debris relative to their proportion in the underlying hard or unconsolidated rock (Haantjens, Paijmans, and Ruxton 1967). The term hydration is used for the softening of sedimentary rocks under the influence of the wet climate, which can be evident to a depth of several tens of feet, without any marked effects on chemical weathering except the leaching of carbonates (Ruxton 1969).

(ii) *Depth of Weathering.*—This is indicated as: very shallow, <5 ft; shallow, 5–10 ft; deep, 10–50 ft. It should be noted that these terms are directly linked to the associated degree of weathering. Thus shallow mature weathering generally implies the presence of additional underlying zones of immature and skeletal weathering, about which little or no information is available. These underlying zones tend to be relatively thin or very thin on clastic sedimentary rocks (apart from hydration) and on alluvium, particularly if fine-textured, and are virtually absent on limestone.

(iii) *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.

(iv) *Thickness (Solum).*—This refers to the combined thickness of A and B horizons: very thin, <10 in.; thin, 10–20 in.; moderately thin, 20–30 in.; moderately thick, 30–45 in.; thick, 45–60 in.; very thick, >60 in. Note that for undeveloped soils that have a minimal solum or no solum at all, agricultural depth notations (see (viii) below) replace solum thickness notations in the pedological descriptions.

(v) *Thickness (Dark Topsoil).*—This is indicated as: thin, 1–5 in.; moderately thick, 6–10 in.; thick, >10 in. Note that where the term "thick" is used in the description of higher-category soil classes, it is differently specified in a footnote relating the term to the thickness of the solum. In these cases, thick means 6 in. (15 cm) or more in deep undeveloped soils; >4 in. if resting directly on rock; more than one-third of the thickness of the solum where the solum is less than 30 in. thick; >10 in. in soils with a solum thicker than 30 in.

(vi) *Dark Topsoil.*—This term indicates A_1 horizons having moist soil colour with a Munsell value of less than 3·5 and in nearly all cases a chroma of less than 4.

(vii) *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.

(viii) *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,

* For engineering soil depth and engineering soil depth index see subsection (*h*)(i, ii).

since this is accounted for in drainage status. The depth classes arrived at in this manner have the same limits as the solum thickness classes (see (iv) above).

(ix) *Soil Drainage Status.*—See subsection (*b*)(iii).

(x) *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 grey 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.

(xi) *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.

(xii) *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 (*h*)(iv).

(xiii) *Linear Shrinkage.*—This is based on sample tests carried out by the Department of Public Works, Port Moresby, and on extrapolation of these data to untested soils by correlation with field texture and soil type. It is expressed in seven classes: nil, 0–1; very low, 2–3; low, 4–5; moderate, 6–8; high, 9–14; very high, 15–20; extremely high, >20.

(xiv) *Available Soil Water Storage Capacity.**—This has been estimated from agricultural soil depth, field texture, and consistency and is expressed in six classes: very low, <2 in.; low, 2–3·9 in.; moderate, 4–5·9 in.; moderately high, 6–7·9 in.; high, 8–10 in.; very high, >10 in. The figures apply to the whole soil profile to its agricultural depth limit.

(xv) *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.

(xvi) *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% N (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

* For soil water stress see subsection (*g*)(iii).

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, $<0\cdot2$ 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, $>1\cdot5$ m-equiv. % K (maximum recorded 3·26 m-equiv. %).

(xvii) *Soil Distribution*.—The estimated proportions of lowest category soil classes in the land systems are expressed in the detailed descriptions of Appendix III as predominant, >80 %; dominant, 51–80 %; subdominant, 20–50 %; common, 8–19 %; minor, <8 %. Parentheses around soil classes indicate that the class was not observed in the land system but its presence is inferred.

(e) 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.

(iii) *Bush Fallow Vegetation*.—This term is used to encompass all secondary vegetation as described in Part V, Section II(*i*), except for old secondary forest (FR) and some secondary vegetation occurring on slumps, rock slides, and scarps. The old secondary forest is excluded because it is not related to present cultivation cycles, the seral secondary vegetation because it is the result of natural processes rather than of clearing by man.

(iv) *Land Use Intensity Classes*.—Indigenous land use has been mapped on the aerial photographs according to the following classes.

Very high.—Land in this class is covered for more than 75 % by anthropogenous vegetation, of which 10–20 % is in current use.

High.—Land in this class is covered for more than 50 % by anthropogenous vegetation, of which 5–10 % is in current use.

Medium.—Land in this class is covered for 20–50 % by anthropogenous vegetation, of which 1–5 % is in current use.

Low.—Land in this class is covered for 20–50 % by anthropogenous vegetation, of which less than 1 % is in current use. Exploitation of sago palm stands is a significant element of the land use pattern.

Very low.—Land in this class is covered for 10–20 % by anthropogenous vegetation, of which <1 % is in current use.

(v) *Land Use Intensity Index* (II).—This index is calculated for each land system by weighting each land use intensity class and adding up the weighted percentages of each class in a land system as follows: II = 1 × (% very high) + 0·75 × (% high) + 0·4 × (% medium) + 0·25 × (% low) + 0·1 × (% very low land use intensity).

(*f*) *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 widely from 4 days per year at Bainyik to 48 days per year at Aitape (Table 19). Generally it can be expected that shorter periods occur in the south-eastern part of the area and longer periods elsewhere. An average figure of 30 days per year is used over the whole area in assessing the DI index.

TABLE 19

NUMBER OF DAYS WHEN SOIL WATER STORAGE EQUALS 4 IN. AND RUN-OFF IS MORE THAN 3 IN.

	Bainyik	Yambi	Lumi	Aitape
May–Oct.	0	7	11	12
Nov.–Apr.	4	11	34	36
Annual	4	18	45	48

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 20.

Thus:

$$DI = 0{\cdot}08(W0)+0{\cdot}22(W1)+0{\cdot}44(W2)+0{\cdot}71(W3)+0{\cdot}85(W4)+0{\cdot}27(i1)+0{\cdot}41(i2)+0{\cdot}55(i3)+0{\cdot}82(i4)+1{\cdot}0(i5),$$

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 hazard (according to Table 20) 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 wheeled vehicles (see previous section).

Although all 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 (see subsection (*a*)(ii)), the soil

TABLE 20

PERIODS OF INACCESSIBILITY ASSOCIATED WITH VARYING DEGREES OF HAZARDS DUE TO WETNESS

Nature and Class of Hazard	Expected Max. 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 ⩽ 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 year (f3)	15	0·04
More than once every year (f4)	> 30	0·08

drainage and inundation index, and the flooding index for each mapping unit, subtracted from 100. In three land systems (Kworo (30), Sandri (35), Aitape (55)) the terrain access index is upgraded because of very low relief or favourable location. Terrain access index classes are: nil, 0–9; very poor, 10–29; poor, 30–39; moderate, 40–59; good, 60–79; very good, 80–100.

(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, 8000–12,000 super ft/ac; moderate, 5000–8000 super ft/ac; low, 3000–5000 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, 6–12; low, 13–28; moderate, 29–50; high, 51–80; 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.

(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). Five more access categories (Iw, IIw, IIIw, 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, T.P.N.G., as at March 1, 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 21.

(*g*) *Agricultural Assessment*

(i) *Land Use Capability Indexes.*—The method of assessing the capability of land for arable crops, tree crops, improved pastures, and irrigated rice, using six levels of suitability ranging from very high to nil, is briefly discussed in Part IX, Section I(*a*).

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 × (% land with very high suitability) + $\frac{3}{4}$ × (% land with high suitability) + $\frac{1}{2}$ × (% land with moderate suitability) + $\frac{1}{5}$ × (% land with low suitability) + $\frac{1}{12}$ × (% land with very low suitability) + 0 × (% land without suitability).

TABLE 21

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

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) *Soil Water Stress*.—Slight soil water stress is considered to occur when the available soil water is depleted to 3·99–1·00 in. in soil with very high available water capacity (AWC) (see subsection (*d*)(xiv)), to 2·99–1·00 in. in soils with high AWC, to 1·99–0·01 in. in soils with moderately high AWC, to 0·99–0·01 in. in soils with moderate AWC. Severe soil water stress is considered to occur when available soil water is depleted to 0·99–0·01 in. in soils with very high or high AWC, and to full depletion in soils with lower AWC.

The expected frequency of soil water stress is indicated as: rare, once in 8–15 yr; rather rare, once in 4–7 yr; rather frequent, once in 2–3 yr; frequent, about once each year.

(iv) *N, P, K Contents*.—See subsection (*d*)(xvi).

(*h*) *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) *Soil Depth Index* (*Engineering*) (EI).—The soil depth index is calculated for each land system from: 0 × (% very shallow soils) + 0·25 × (% shallow soils) + 0·5 × (% moderately deep soils) + 0·75 × (% deep soils) + 1 × (% very deep soils).

(iii) *Soil Depth* (*Engineering*) *Distribution.*—The proportion in each land system of soils in different engineering depth classes is indicated as: predominant, >80%; dominant, 51–80%; subdominant, 20–50%; common, 8–19%; minor, <8%. Within each division depth classes are placed in apparent order of decreasing dominance.

(iv) *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.

(v) *Linear Shrinkage.*—See subsection (*d*)(xiii).

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APPENDIX II

Survey Procedures

By H. A. Haantjens*

I. Aerial Photographs and Maps

(a) *Aerial Photographs*

Three sets (see Section II(*a*)) of double-weight mat and glossy 9 × 9 in. prints of panchromatic aerial photographs, taken from an altitude of 25,000 ft with a 6-in. focal length lens with a minus-blue filter, were used on the survey. The photos had been taken by Adastra Airways Pty. Ltd. during May to October 1964. Although some photos are partially obscured by cloud, it was generally possible to circumvent this problem by using overlapping photos taken at different times. The only unavoidable cloud areas are shown on the vegetation map. The flight lines and numbers of the photos used, and which provide the best possible coverage of the area, are shown in Figure 18.

(b) *Maps*

No suitable topographic maps were available before and during field work. Eight uncontrolled photomosaics at an approximate scale of 1:63,000 were used for survey planning and for the compilation of information. Several months after the survey topographic map compilations were obtained from the Royal Australian Army Survey Corps for the western half of the area, at a scale of 1:100,000, and from the Division of National Mapping, Department of National Development, for the eastern half, at a scale of 1:50,000. These maps were used to compile a base map at 1:250,000 in the drawing office of the Division of Land Research. Whilst ground control, particularly in the western half of the area, is appreciably better than that available for most base maps prepared for earlier surveys, the topo-compilations suffered the usual lack of contour lines. The information in this report on hypsometric zones and on the altitudes of land systems is derived largely from the contours (at 250-ft, 500-ft, and subsequent 500-ft intervals) shown on the Aitape sheet of the U.S.A.F. aeronautical approach chart at 1:250,000.

II. Survey Preparation and Field Work

(a) *Preliminary Photo Interpretation*

Preliminary photo interpretation took about three months. Preliminary vegetation and commercial forest types were delineated and labelled on separate sets of aerial photographs and the mapping units subsequently correlated and integrated. Attempts at the customary mapping of preliminary land form patterns on the third set of photos were not successful, because of the complex and often apparently

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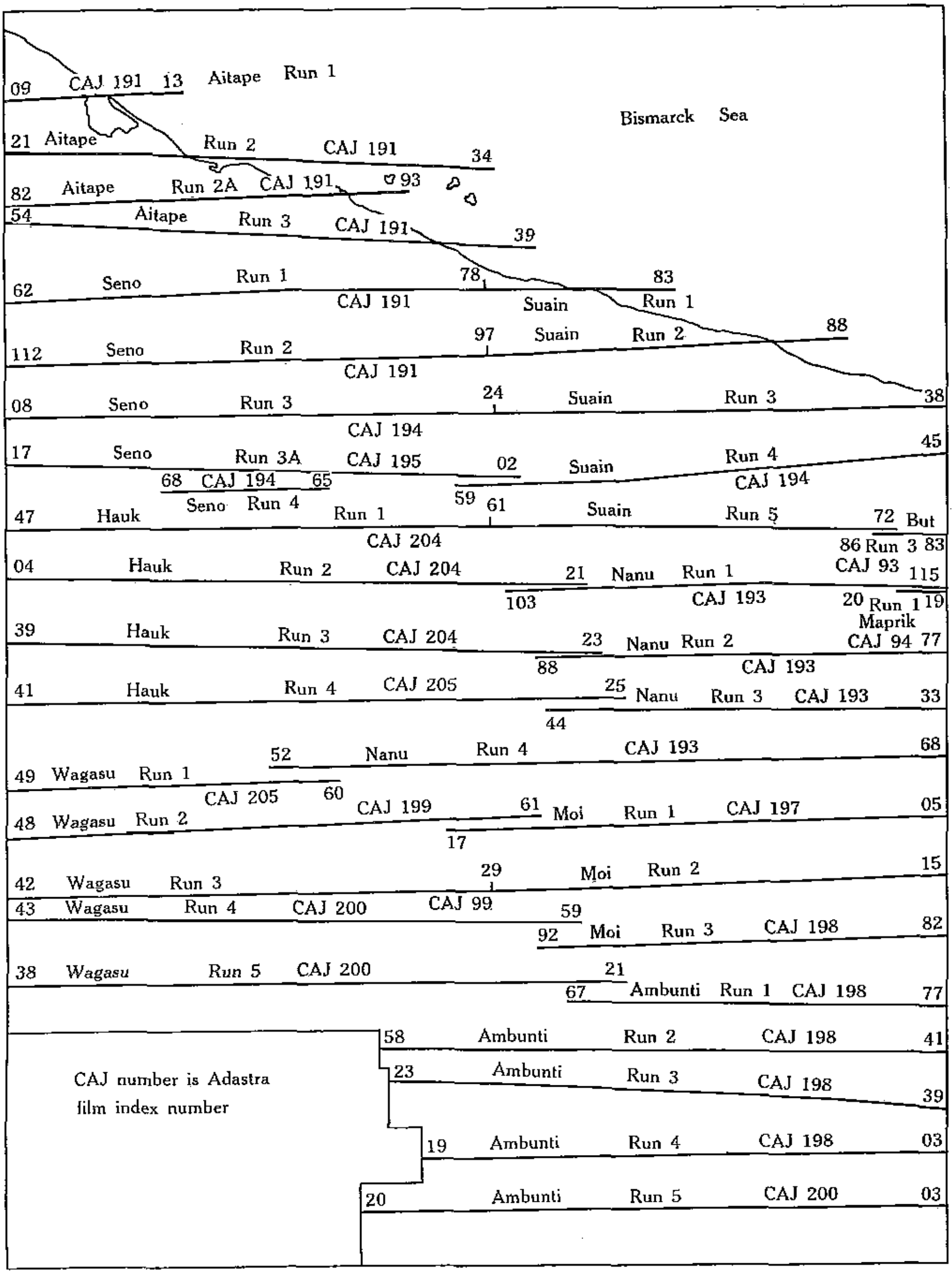

Fig. 18.—Minimum Adastra Airways aerial photography required to obtain the best possible coverage of the Aitape–Ambunti area. The end-of-run photo numbers are shortened from 4-digit numbers beginning with 50 or 5.

irregular variations in the patterns and the common lack of clear and consistent pattern boundaries. Useful information on photo interpretation of some geological aspects was derived, however, from discussions with Mr. S. Marchant, of the Bureau of Mineral Resources and Geophysics, who at that time was engaged in the preparation of a photo-geological map of north-west New Guinea.

(*b*) *Planning of Field Observations*

During a final round of examination of the air photos by the team, using paired Old Delft scanning stereoscopes, 519 potential sampling areas were marked on the photos and mosaics. They were selected on the basis of accessibility by helicopter or vehicle and on their significance either as typical examples of familiar land form and vegetation patterns, or as useful sites for investigating the nature of unfamiliar or doubtful features or for obtaining clues about the genesis of the landscape. For each sampling area a card was made out listing the nature and likely quality of the helicopter landing site, the different land forms and vegetation types that could be visited from the landing site, and the expected maximum number of site observations. The total number of these potential observations was probably more than 1500.

After selecting suitable base camp sites, located at airstrips or vehicular roads for logistic purposes, daily helicopter flight schedules were drawn up centred upon these base camps. More than 300 of the original 500 sampling areas were included in these daily programmes. About one-third of these were considered as spares or alternatives, to be used only if landing on the priority sites proved to be impossible. In the selection of the 300 areas emphasis was placed on achieving a good scatter, avoiding undue repetition, and on good-quality landing spots. Some road traverses in the central eastern part of the area were less rigidly planned.

(*c*) *Field Work*

The survey team spent 62 days in the field, from July 20 to September 20, 1966, and including 8 rest days. Operations were conducted from base camps at Bonahoi on the road from Maprik (21 days, including 13 days of vehicle traverses), Ambunti (7 days), Nuku (15 days, including 3 days of vehicle and walking traverses), Lumi (5 days, including one day of vehicle traverse), and Aitape (14 days, including 3 days of vehicle traverses). A proposed temporary camp on the coast east of Aitape could not be arranged, with the result that no observations were possible in the north-east corner of the area.

The detailed flight programmes proved to be very useful in conducting the helicopter programme, even though alterations often had to be made because of unforeseen circumstances and, particularly, as a result of delays and groundings of the helicopter which necessitated the substitution of improvised ground traverses on several occasions. Whilst the number of 167 sampling sites visited was not too far below expectation, the total number of 365 actual observations (including three from the air only) was considerably lower than hoped for. Field days were often short owing to morning fog and afternoon rain, and on occasions much time was lost in reaching observation sites from landing spots through trackless country.

The location of the observation sites is shown on the land system map. Details of these sites were recorded on 5 × 8-in. pro-forma cards for vegetation, forest resources, soils, and land use capability factors, and recorded on Fortran data sheets for land forms and geology during the first half of the survey. Integrated summaries of each day's observations were recorded each night in camp on a separate set of cards.

The survey team consisted of Mr. H. A. Haantjens, leader and pedologist, Dr. P. C. Heyligers, plant ecologist, Mr. J. C. Saunders, forest botanist, and Mr. V. G. Dawson, who was in charge of transport, logistics, and the 14 native field and camp assistants. Mr. J. R. McAlpine described the land forms at observation sites and collected information on population and land use until September 5. Mr. B. P. Ruxton joined the team as geomorphologist on August 29. Flying 132 hours, pilots G. Treat, W. Mayo, and W. Dossett, assisted by engineers W. Spence and J. Hislop, transported the team to and from occasionally difficult landing spots in a Bell 473 GB 1 helicopter. Three trips were needed to position a full team, but only two flights were possible to landing spots beyond 25 miles from base camps because of the time involved.

III. Final Mapping

After the return from the field, and aided by knowledge and experience gained during field work, the team adjusted the vegetation mapping where necessary and made a fresh attempt at the interpretation and mapping of the land forms. The final land system mapping was carried out on odd-numbered photos viewed stereoscopically with even-numbered photos on which the vegetation had been mapped. After completion, the mapping was checked and adjusted for consistency. In areas of noticeable relief on the air photos (20 ft or more) vegetation differences, although often important, were subordinated to land form differences in land system mapping. In flat areas land system boundaries were very largely based on vegetation differences. Both vegetation and land system mapping were based as much as possible on morphometric rather than morphogenetic or regional differences (Haantjens 1968). In the case of vegetation, use was made of structural (stereo-parallax) characteristics and tonal and textural variations (Heyligers 1968). In the case of land forms, mapping was based on relief, slope form, slope steepness, grain, and on peakedness, width, length, and patterns of ridge crests. A deliberate attempt was made to keep the mapping units as uniform as possible, commensurate with their reduction to 1:250,000 on the final map. On the other hand, the objective in land system mapping remained throughout to map landscape *patterns* rather than individual landscape *elements*.

Land system and vegetation boundaries, drawn with Omnichrom pencils on the air photos, were transferred onto transparent overlays of 1:100,000 base maps, using a Grant projector and relating boundaries by eye to streams and central photo points shown on the base maps. Forest resources map overlays were prepared from the vegetation overlays by marking the necessary adjustments in boundaries. When the base map at 1:250,000 became available in 1968, the existing boundary overlays were reduced in scale and new overlays prepared at the final scale.

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APPENDIX III

Detailed Descriptions of the Land Systems of the Aitape–Ambunti Area

By H. A. Haantjens,* P. C. Heyligers,* J. C. Saunders,* and R. H. Fagan†

I. Introduction

The land systems are described in the same order as on the land system map. Synoptic descriptions given in Part III contain information on water balance zones and various indexes, which is not repeated in the detailed descriptions. Details about the occurrence in each land system of classes on which the indexes are based are given by Haantjens (unpublished data)‡ for slope classes, soil drainage classes, engineering soil depth classes, and land use capability classes for arable crops, tree crops, and improved pastures.

Virtually all descriptive terms and symbols are explained in Appendix I. The plates and figures quoted under land form refer to stereo pairs of aerial photographs in Part II. The figures quoted under streams and drainage refer to stream pattern plans, shown in Part III. In the "probable soil composition" summaries, soil classes have been placed in brackets if their presence is inferred but has not been observed in the field.

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‡ CSIRO Aust. Div. Land Res. tech. Memo. No. 71/1, Part II.

II. Land System Descriptions

(1) Madang Land System (1 sq mile)

Land Forms (Plate 1, Fig. 1).—Raised coral platforms, 10–20 ft a.s.l., form four off-shore islands. Land surface partially flat, partially undulating with 3–8-ft relief and slopes up to 5°. Small steep coral beaches occur on south-eastern (leeward) margins. Elsewhere low (6–12 ft) very steep margins lead down to narrow to wide submerged fringing reefs.

Streams and Drainage.—No surface drainage. Surface run-off probably nil. There are a few wells, which apparently become brackish in the dry season. The land is well to excessively drained.

Vegetation.—Virtually no original vegetation; land system is covered by coconut groves, gardens, and regrowth communities. Usually a fringe of large *Calophyllum* trees along the coast.

Geology.—Recent coral limestone locally covered with thin coral sand.

Weathering and Soils (1 obs.).—Virtually no weathering. Probable soil composition is MR-O1 predominant. Soils consist of slightly to undeveloped, alkaline, very shallow, very dark, very friable gravelly or sandy loam, tonguing into hard coral rock or having an intermediate layer up to 18 in. thick of yellow-white gravelly coarse coral sand (MR-O1). Rock outcrop common, particularly on low rises.

Population and Land Use.—Population of 1060 distributed over four villages. Present land use covers whole area, 75% in land use intensity class 2, 25% in class 3. Population also uses some land in Nubia (2) west of Aitape. Fishing and sago are an important part of subsistence.

Transitions to Other Land Systems.—None.

Forest Resources.—Nil. Access category I.

Agricultural Assessment.—In terms of permanent commercial agriculture, land use capability restricted to very low potential for arable crops and low capability for improved pastures. Coconut palms are adapted to this type of environment, but are unlikely to be highly productive. Soil contents of N, P, and K appear to be moderate. Probably rather frequent severe soil water stress.

Engineering Assessment.—No special difficulties, but no need for civil engineering works. Airstrip constructed on Selio Island during World War II. Islands are potential source of limestone for use in road surfacing, stabilization, and building materials on the mainland. Soils are SW to SC; probably all are very shallow.

(2) Nubia Land System (28 sq miles)

Land Forms (Plate 1, Fig. 2).—Very low flat to very gently undulating beach ridges, probably occupying about 70% of the land system and 150–800 yd wide, separated by swales 50–300 yd wide and not more than 4 ft below the ridges. Ridges interrupted in places by narrow (50–100 yd) flood-plains. Assuming groundwater-table in beach sands is close to horizontal, there is little difference in height between coastal and inland ridges, and the furthest inland ridge is probably only 12–15 ft above mean sea level. Possibly the beach ridge complex in extreme east of area is higher above sea level.

A rather narrow gently to moderately shelving beach is backed by a short steep slope to the youngest frontal beach ridge which is 5–9 ft above mean sea level (normal tidal range probably about 4 ft), and generally more undulating than older ridges inland.

East of Nigia River, characteristic ridge and swale relief has been almost obliterated by very young fluviatile deposits, possibly originating from the 1935 earthquake. Ridges here also appear slightly lower.

Streams and Drainage (Fig. 9(*a*)).—Dense to rather open pattern of parallel very small unincised channels in the swales, with virtually no gradient, which are merely drainage lines fed by ground water since run-off is probably nil in relation to through drainage; some swales have no channels. Channels are intercepted by meandering small (5–8 yd wide) streams that drain the plains behind ridges and break through to reach the sea in 30–60-yd-wide brackish to salt-water tidal creeks running parallel to the coast for some distance and with bars at their mouths.

Beach ridges are generally well drained, locally imperfectly drained with dry-season water-tables between 4 and about 8 ft (soil colours indicate wet-season water-tables probably rarely rise more than 1–1·5 ft above these figures). Swales and flood-plains are very poorly drained and at least partly inundated for 1–3 months, or have moderate to minor flood hazards.

Vegetation.—Little original vegetation remains because about 90% of area is used for some form of production (coconut plantations, gardens, sago) or bears secondary communities: partly woody garden regrowth (R-FRm), partly mid-height grassland dominated by *Imperata cylindrica*, with some *Coelorachis rottboellioides* and *Sorghum nitidum*, with weeds common (GI). *Casuarina equisetifolia* (Cq) occurs on frontal beach ridges, often as a single line of trees, in places as larger stands up to 90 ft high. Sago is found in swales, occupying about 15% of the land system. Most of it is exploited (MR). Scattered trees are commonly present (Me) and form locally an open canopy (FmoM). Locally, in inland areas tall forest with an open canopy and sago palms in the understorey (FoM, 3%) is found. *Nypa* palms line tidal creeks with low banks.

Geology.—Recent beach sands, well sorted and mainly fine. Minor alluvial clay along traversing streams and in some swales.

Weathering and Soils (10 obs.).—Slight increase in weathering from fresh beach sands along the shore to very shallow skeletal weathering on furthest inland ridges.

Probable soil composition is: IAUP, IUHP subdominant; EAY4, EUHT, MUHP common; EAPO, EPOA, IUHO2 minor.

On the ridges is a sequence of soils from the coast inland. Undeveloped, neutral, very dark grey loose sands with strongly alkaline deeper substratum and a thin darker loamy sand to sand topsoil (EPOA) on frontal ridges become slightly developed similarly textured soils with a moderately thick darker topsoil and without alkaline subsoil (MUHP) on still very young ridges. Further inland, majority of ridges have slightly developed weakly acid soils (neutral at depth) of similar texture but with a thick dark topsoil and (more inland) an incipient browner-coloured B horizon (IUHP). On furthest inland beach ridge over 2 miles from the coast, a slightly to moderately developed acid (at depth weakly acid) soil was observed with a thick very dark very friable sandy loam topsoil and a weakly developed brownish loamy sand B horizon overlying the normal very dark grey loose sand (IUHO2). East of the Nigia River sandy soils are covered by very young, neutral, friable silty clay loam, probably varying in thickness from 0·5 to 2 ft (EUHT).

The swales have slightly developed, acid to weakly acid, strongly gleyed sandy soils with thick dark very friable organic loam to loamy sand topsoils (IAUP). On flood-plains and in swales in which fluviatile deposition has taken place occur undeveloped, neutral to weakly acid, very deep, strongly gleyed alluvial soils of stratified (slightly) plastic and (very) sticky silty clay loam to silty heavy clay with occasional sandy layers, becoming sandier below 2·5–3-ft depth, with sand or loamy sand below 4–6 ft (EAY4). Saline muds or sands (EAPO) occur along edges of tidal creeks.

Population and Land Use.—Population of 7540 distributed over 25 villages. Present land use covers 23·2 sq miles (83% of area), 34% in land use intensity class 2, 47% in class 3, 5% in class 4, and 2% in class 5. Remaining 12% consists of non-indigenous coconut plantations. Beach ridge use is typically found in a littoral belt a few hundred yards wide. Ridges are gardened or planted with coconuts, whilst sago is exploited in the swales. Fishing forms an important part of subsistence, particularly around lagoons in west. Plantations are near Aitape and in the east, near Suain.

Transitions with Other Land Systems.—Although it normally has a very characteristic pattern, the inland boundaries are commonly rather vague, with gradual transitions to Po (15), Pandago (10), or Nigia (12). Pattern and boundaries are least distinct in the alluvium-covered area east of the Nigia River.

Forest Resources (1 obs.).—Only 7% under forest; nil forest resources. Low stocking rate *Casuarina* forest (Cq, 1 sq mile) occurs on frontal dunes, best stand in north-west corner of area. Along inland edge occurs some forest of moderate stocking rate (FoM, 1 sq mile). Access category Iw because of waterlogged nature of swales, although beach ridges provide good access.

Agricultural Assessment.—Apart from possible limitations inherent in sandy nature of the soils, there is high capability for arable and tree crops, very high capability for improved pastures, and low capability for irrigated rice. Whilst swales are unsuitable for tree crops, have very restricted capability for arable crops, and only low to moderate capability for improved pastures, they are the most suitable areas for rice-growing, together with alluvially covered beach plains east of the Nigia River. Crop rotation with green manuring or ley farming is essential if beach ridges to be used for arable crops. Variations in soil acidity between youngest and oldest ridges could influence selection of both arable and tree crops. Also, parts of beach ridges are difficult to use for agriculture because they were turned into sealed or matted airstrips or dug over during World War II.

Nitrogen contents increase inland, are generally low but very low on frontal ridges and recently covered areas, and moderate on most inland ridges and in swales. Phosphate contents are generally high but decrease to moderate on inland ridges, and are very high in alluvium-covered areas. Potash contents are generally low, very low on inland ridges, but moderate on covered plains. Probably rare slight soil water stress for shallow-rooting crops in IUHP, MUHP, and EPOA soils.

Engineering Assessment.—No great problems for road-building other than construction of causeways with culverts across swales. Sealing roads with coral and gravel or admixtures of clay, all or some of which are usually nearby, will be necessary to prevent bogging of vehicles when sand occasionally dries out in the surface. Organic surface horizons should be removed. Although sand is poorly graded, Nubia could be a valuable source in an area where it is generally in short supply. Soils are dominantly SP with minor MH, SM; all are very deep, although coral may locally be present at shallow depth near Aitape.

Very suitable for airfield construction, with runway directions varying from E.–W. to SE.–NW. At relatively small cost a well-protected harbour in the lee of the coastal hills could be dredged out from Nubia and adjoining Pandago (10) at the present site of Aitape, with additional shelter provided in the lee of nearby coral islands.

(3) MURIK LAND SYSTEM (9 SQ MILES)

Land Forms (Plate 2, Fig. 1).—Tidal flats at approximately sea level, and including two small delta flats in Sissano lagoon. Occurring exclusively near the lagoon, this land system probably exists because of the very recent subsidence of this area (Part I).

Streams and Drainage.—Widely spaced tidal streams up to 80 yd wide with intermittent and tidal flow of fresh to brackish water in wet season, brackish to salt water in dry season. Those tidal streams directly behind and parallel to beach ridges are navigable for motor launches. Because of small tidal range (probably 4 ft), Murik is neither deeply inundated nor deeply drained at any time.

Vegetation.—Mangrove, mainly *Rhizophora–Bruguiera* mid-height forest, lines inland margins of Sissano lagoon and covers two-thirds of land system. *Avicennia* colonizes some mud bars but occurs also in the zone only covered by salt water during spring tides. Vegetation mainly consisting of *Acrostichum* ferns grows in this zone, probably in places with stagnant water. Dense *Nypa* palm vegetation making up the remaining third backs beach ridges at both sides of the lagoon and is particularly extensive towards the east. Air photos and aerial observation indicate it is rather stunted in that area, probably due to stagnant water and increasing freshwater influence.

Geology.—Recent estuarine sediments, probably clay and sand.

Weathering and Soils (no obs.).—No weathering. Probable soil composition is (EAY1) dominant, (EAPO) subdominant. Soils are probably saline soft mud (EAY1) with saline sand (EAPD) near beach ridges of Nubia (2).

Population and Land Use.—No population. Present land use at intensity class 2 confined to 0·2 sq mile (2% of area) of land that can be regarded as inclusions of Nubia (2). This land used by people in Nubia west of Malol lagoon.

Transitions to Other Land Systems.—Although Murik has unique characteristics, boundaries with Pandago (10) and Kabuk (9) are indistinct in places. This suggests no clear demarcation between fluviatile and marine deposition and most sediments are probably fluviatile-derived, acquiring their saline estuarine character by subsidence.

Forest Resources (no obs.).—Mangrove forest (B) covers 56% (5 sq miles); no forest resources. Small girths render forest non-commercial for milling but perhaps of some importance as poles or in a cutch industry. Access category S.

Agricultural Assessment.—No agricultural land use capability. Small tidal range makes reclamation difficult and pointless. No data on nitrogen, phosphate, and potash contents of soils.

Engineering Assessment.—To be avoided for road-building. Soils probably MH with some SM; all are very deep.

Poor harbour facilities along this part of New Guinea coast could make it worth while to investigate the possibility of developing such facilities in Sissano lagoon which is very shallow. Suspended clay enters the lagoon mainly from small channels draining swamps to the south-east (Nigia (12)) and is deposited mainly on mud banks just inside opening of lagoon. These mud banks had clearly grown in September 1966 when compared with aerial photographs from May 1964. Since no proper rivers debouch in the lagoon, the rate of sedimentation is likely to be small. There is a sand bar below low sea level outside opening of lagoon. Any use of lagoon as harbour would involve dredging a channel and the harbour proper, whilst breakwaters would have to be built into the sea. Channel maintenance would appear to require little effort. Sediments drained from the channel and harbour could be used to raise the site for harbour facilities and construction of a road inland. Most suitable site would be on most stable western shore of lagoon. Rock suitable for fill and road construction and probably for cement brick-making is available in Aitape (55) not far west.

(4) CHAMBRI LAND SYSTEM (21 SQ MILES)

Land Forms (Plate 2, Fig. 2).—Level flood-plain back swamps, probably 5–18 ft below bank level of Sepik River and 160–180 ft a.s.l. Very faint scroll and swale pattern visible in a few small occurrences around cut-off meanders of Sepik River. Levees 10–30 yd wide and 1 or 2 ft high along a few waterways.

Streams and Drainage.—No streams, but areas of open water are common, ranging from 100 to 1200 yd in diameter. Narrow waterways, partly stable, partly unstable, are present in some occurrences and may link patches of open water. The larger lakes, which include some partly in-filled oxbows of the Sepik River, contain rounded floes of matted floating vegetation moving under the influence of weak currents and wind. Same factors cause minor and sometimes major changes in the shore configuration of lakes and the position of some waterways. Including the open water, but with the possible exception of some levees along waterways, the land system is permanently inundated, water levels probably ranging from 0·5 to 8 ft during dry season and reaching heights of 5–15 ft for 1–2 months during flooding of Sepik River.

Vegetation.—Herbaceous vegetation (H) covers almost the whole land system, but communities ranging from aquatic vegetation via floating grasses to sedge and fernlands have not been investigated in any detail. Scattered patches of tall grass (GtPh, GtS) cover 7%.

Geology.—Recent paludal clay and organic material.

Weathering and Soils (no obs.).—No weathering; probable soil composition is (H1, EAY3) subdominant. Over most of the area there is no soil in the generally accepted sense of the word. Undeveloped silty clay to silty heavy clay soils, soft underfoot and possibly with thin or thick peaty surface layers (EAY3), are expected to be found on the few higher levee areas and shallowly inundated parts. Elsewhere semi-suspended organic mud mixed with roots (H1) may be found below fairly stable grass vegetation, merging into sloppy heavy clay at depths below 3–8 ft.

Population and Land Use.—Nil.

Transitions to Other Land Systems.—Boundaries with Sanai (5) and in a few cases Palimbai (11) are gradual and rather arbitrary.

Forest Resources.—Nil, access category S.

Agricultural Assessment.—No agricultural land use capability and land reclamation does not appear to be feasible, or would not produce good land. Should large-scale reclamation in the Sepik flood-plain be contemplated, areas could be either used as reservoirs for temporary storage of excess water or incorporated within polders and transformed into permanent lakes suitable for stocking with fish. Soil nitrogen contents are probably very high in organic mud and raw peat, low in mineral soils. Phosphate contents probably vary from very low to moderate. Potash contents probably high in mineral soil, low in peat.

Engineering Assessment.—Unsuitable for road construction. Soils are Pt and CH; all are very deep. See agricultural assessment for engineering aspects of land reclamation.

(5) SANAI LAND SYSTEM (55 SQ MILES)

Land Forms (Plate 3, Fig. 1).—Level flood-plain swamps in Sepik plain, probably 3–8 ft below bank level of Sepik River and about 170–200 ft a.s.l. Levee banks, 1–4 ft high and 10–40 yd wide with low- to high-gradient back slopes, occur along waterways.

Streams and Drainage.—Many occurrences have slightly to moderately branching waterways, either near their centre or curving around near their edges, which tend to have long straight and gently curving sections with occasional sharp bends and meander loops. The largest are 10–30 yd wide. During the dry season the water level drops to 6–12 ft below the level of the levee bank, leaving a depth of probably 4–10 ft above a muddy channel bottom. Banks are steep to very steep. Smallest tributaries are 2–4 yd wide and 3–5 ft deep, and may fall almost dry in dry season. These waterways appear to function as drainage channels of the swamps when Sepik River flood waters recede after the wet season. Conversely, at the beginning of the Sepik flooding they carry river water into the swamps. Thus direction of flow is probably reversed during the year, with almost complete stagnation at the end of dry season and total disappearance of channels below water level at the height of seasonal flooding. There are rare small patches of open water.

Surface run-off is nil. Land system is very poorly drained to swampy and seasonally inundated by flooding of Sepik River probably to 4–6 ft in lower parts and 1–2 ft in higher parts for 1–2 months, after which water levels gradually recede. Higher parts probably fall dry soon after the flood season with water-tables descending to depths of 2–3 ft at end of dry season, whilst water-tables on lower parts are never lowered significantly below land surface. Water-tables in low levee banks remain very close to the surface, only a few yards away from water levels up to 10 ft lower in the channels.

Vegetation.—Tall reed (*Phragmites*) grassland (GtPh) covers about 75%, herbaceous vegetation the rest. The latter comprises some tracts of tall sedge (*Thoracostachyum*) vegetation (HT), but normally is of the mixed type (H) and found in most poorly drained parts. Area of aquatic vegetation is negligible. Where tall grassland has been burnt, a vegetation of low sedges dominates the aspect before taller grasses take over later in the season.

Geology.—Recent paludal clay and peat.

Weathering and Soils (6 obs.).—No weathering. Probable soil composition is H3, EAY3, EAHY1, IAUO2 subdominant. Many soils are undeveloped to slightly developed, weakly acid to acid (pH increasing with depth), moderately shallow heavy clay soils with thin peaty or organic clay topsoils. They are either very strongly gleyed and rather soft underfoot (EAY3) or strongly gleyed with soft very sticky upper horizons and very plastic stronger subsoils, and have a thin (EAHY1) or a thick (IAUO2) dark topsoil. Also common, but possibly restricted to lower areas, are acid, stratified peaty clay, clayey peat, and peat soils which are soft underfoot and overlie soft sticky heavy clay or organic clay at 5–8 ft (H3).

Population and Land Use.—Nil.

Transitions to Other Land Systems.—Boundaries are often clear and distinct, in other cases gradual. Gradual boundaries as well as transitional patterns occur with Pandamp (6) where proportion of tall sedge vegetation increases; with Kobar (7) where number of low swamp trees increases; with Chambri (4) where proportion of open water increases;* and with Palimbai (11) where small linear flood-plain scrolls begin to appear. Where Burui (29) merges with Sanai, the latter strongly resembles Nigre (27) on air photos.

* Where grass burn patterns occur in Sanai, they can be very difficult to distinguish from open water on aerial photos.

Forest Resources.—Nil. Access category S, although higher parts may be accessible during part of dry season.

Agricultural Assessment.—Low potential for irrigated rice-growing. Semi-swamp rice varieties could be planted before and harvested during or after the flooding season on parts of area not too deeply flooded. Small areas could also be used for rough cattle grazing in the dry season. Land reclamation problems are very similar to those for Pora (8), but reclaimed land with clay soils would have very high capability for irrigated rice, high or very high capability for improved pastures. The capability of reclaimed land for arable crops and tree crops is more difficult to assess but could be moderate to high and low to moderate respectively. Upon reclamation the land surface is likely to be lowered about 1 ft through compaction of the water-saturated clay soils. Possibly these soils will develop many permanent cracks, increasing their permeability and capability to produce crops. Where peat soils occur, much greater lowering of land can be expected unless water-tables are artificially kept at shallow depths. The productive capability of these soils is difficult to forecast (see Pora (8)). Soil nitrogen contents are high to very high in organic or peaty topsoils, low to very low in mineral topsoils. Phosphate contents are generally low, but probably vary from very low to moderate. Potash contents are high to moderate in essentially mineral soils, low in peat soils.

Engineering Assessment.—For all practical purposes, unsuitable for road construction. However, were it essential to connect the Sepik River with its hinterland and no route using higher ground was available, it would be simpler to construct a road on a built-up causeway here, provided with many culverts to prevent banking up of flood waters, than in Pora (8), Pandamp (6), or Kobar (7). Present waterways are extensively used for canoe traffic, and it might be useful to investigate the possibility of enlarging and straightening one or two of them to carry larger vessels from the Sepik to a roadhead on higher ground. Such canals would need to be beaconed to be tractable when area is inundated. Soils are dominantly CH, subdominantly Pt, OH; all are very deep. See agricultural assessment of Pora (8) for engineering aspects of land reclamation.

(6) Pandamp Land System (96 sq miles)

Land Forms (Plate 3, Fig. 2).—Level back plain swamps in Sepik River flood-plain and along southern margin of alluvial plains to north. Also valley floor swamps, associated with dissected higher grassland plains and blocked by more strongly aggraded alluvial plains. Altitude 170 ft to probably 210 ft. Isolated scrolls or levee banks a few feet high occur locally in Sepik flood-plain area.

Streams and Drainage.—Either no streams or single or slightly branched waterways of similar nature and dimensions as described for Sanai (5).

Surface run-off nil. Land system is swampy and much is probably permanently inundated, with water levels 0·5–1 ft in dry season and reaching 5–7 ft for 1–2 months during flooding of Sepik River. Locally water-tables may descend to about 1 ft below surface in dry season. Smaller fluctuations in water levels (probably between surface and 2 ft above) are likely to occur in areas north of Sepik flood-plain proper.

Vegetation.—Vegetation consists of two major components. One is tall sedge (*Thoracostachyum*) (HT) which, together with patches of woodland with tall sedge undergrowth (WT), covers 27%. The other comprises vegetation types with pandans: mid-height forest with an open canopy and pandans in the understorey (Fmop) covers 13%. Remaining 60% is under pandan vegetation (P) in places interspersed with tall grass vegetation, mainly reed and associated grasses (GtPh) and some cane grass and reed (GtS).

Geology.—Recent paludal clay and, probably minor, peat.

Weathering and Soils (no obs.).—No weathering. Probable soil composition is (EAY3) dominant; (EAY4) subdominant; (H1) common. Soils probably mostly undeveloped, weakly acid to acid, very strongly gleyed silty clay and silty heavy clays which are soft underfoot. Acid raw peat and organic mud soils likely to occur, particularly, in valley-floor swamps, overlying soft clay at depths up to 7 ft. Partly decomposed acid peat soils overlain by or interbedded with organic clay or silty clay may occur locally in Sepik flood-plain in east of area.

Population and Land Use.—*Population of 210 in a single village* along an oxbow of the Sepik River. Present land use negligible and mainly restricted to levees of the Sepik River which are to be considered as inclusions of Palimbai (11).

Transitions to Other Land Systems.—Commonly gradual and somewhat arbitrary boundaries with Sanai (5) where tall grass becomes more conspicuous; with Kobar (7) where there is a *strong increase in woodland trees;* and with Pandago (10) where sago palms become frequent. Boundaries with Pora (8) and Palimbai (11) are usually more distinct.

Forest Resources.—Nil. Access category S.

Agricultural Assessment.—No capability for agricultural land use. Land reclamation problems appear to be intermediate between those for Sanai (5) and Pora (8). It may be feasible to develop some valley-floor occurrences, associated with higher grass plains further north, for use as fish ponds. Soil nitrogen contents appear to be low, but very high in peat and organic mud. Phosphate contents probably mostly low to moderate, very low in peats. Potash contents may range from high to low.

Engineering Assessment.—Unsuitable for road construction. A small area might have to be traversed if a road link were made between Ambunti and alluvial plains to the north, using the hills of Maio (64) and Waskuk (65) as the main approach. This would involve building about 2·5 miles of causeway with some culverts through this land system and Sanai (5), using earth fill and rock materials from isolated hills for earth works. Soils are dominantly CH, subdominantly MH, and minor Pt; all are very deep. See Pora (8) for engineering aspects of land reclamation.

(7) Kobar Land System (17 sq miles)

Land Forms (Plate 4, Fig. 1).—Level back plain swamps in Sepik River flood-plain and valley-floor swamps associated with dissected higher grassland plains and blocked by more strongly aggraded alluvial plains. Altitude is 170 to probably 210 ft.

Streams and Drainage.—No streams. Surface run-off is nil. Swampy and inundated by flooding from Sepik River to probably 2–4 ft for 1–2 months, after which water levels slowly decline to the surface or slightly below towards end of dry season. In small northern occurrences inundation levels probably do not exceed 1–2 ft.

Vegetation.—*Woodland with tall sedge* (*Thoracostachyum*) undergrowth (WT) with some patches of reed and other grasses (GtPh).

Geology.—Recent paludal clay and peat.

Weathering and Soils (2 obs.).—No weathering. Probable soil composition is H1, H3 subdominant. Acid organic soils consist of either open-structured raw peat and organic mud (H1) or denser, little to well decomposed peat (H3) which near present or former courses of the Sepik River can be covered by 0·5–1·5 ft of organic clay and plastic silty clay sometimes overlain by a layer of litter and roots 0·5–1 ft thick.

Population and Land Use.—Nil.

Transitions to Other Land Systems.—Gradual boundaries with Pora (8) where there are denser stands of trees and sago; transitional to Kabuk (9) where there is more stunted sago and fewer trees; and gradual boundaries with Pandamp (6) where pandan palms are common and emergent trees scarce.

Forest Resources.—Nil. Access category S.

Agricultural Assessment.—No capability for agricultural land use. *Land reclamation problems similar to those for Pora (8).* Valley-floor swamps associated with higher grass plains could be turned into fish ponds. Soil nitrogen contents very high in peat soils, moderate in clay layers. Phosphate contents range from moderate to very low in peat soils, appear very high in clay layers. Potash contents low to very low in peat soils, moderate in clay layers.

Engineering Assessment.—Unsuitable for road construction. Soils are dominantly Pt, subdominantly OH, with a CH substratum at depth; all are very deep. See agricultural assessment of Pora (8) for engineering aspects of land reclamation.

(8) Pora Land System (49 sq miles)

Land Forms (Plate 4, Fig. 2).—Level flood-plain swamps, approx. 170–200 ft a.s.l., probably lying 2–5 ft below bank level of Sepik River. Two small occurrences north of Sepik plain are swamps partly enclosed by high ground and blocked by slightly higher flood-plains.

Streams and Drainage.—No streams. Surface run-off nil. Swampy and inundated by flooding from Sepik River to probably 2–4 ft for 1–2 months, after which water levels decline to the surface or recede slightly below towards end of dry season. In small northern occurrences inundation levels probably do not exceed 1·5 ft.

Vegetation.—Mid-height forest with open canopy with *Campnosperma* and sago palms in understorey (FmoCM) covers 98%. Mid-height forest with open canopy and pandans in understorey (Fmop) occurs on the rest.

Geology.—Recent paludal clay and peat.

Weathering and Soils (2 obs.).—No weathering. Probable soil composition is H1, H2 subdominant. Soils are of peat ranging from very open-textured raw peat mixed with roots and soft mud (H1) to denser, poorly decomposed, but in upper part rather well decomposed peat (H2). The peat is acid underlain at 4 ft to probably more than 10 ft by very strongly gleyed, weakly acid, soft clay and silty heavy clay.

Population and Land Use.—Nil.

Transitions to Other Land Systems.—Pora has a characteristic very uniform photo pattern that cannot be mistaken, but in places has gradual boundaries with Pandago (10) and Kobar (7).

Forest Resources (1 obs.).—Forest covers 86%; low forest resources. Only one forest type with a low stocking rate (FmoCM, 42 sq miles) occurs. Access category S.

Agricultural Assessment.—Land use capability nil. Land reclamation possible only at great cost, involving complete empoldering for protection against flooding from Sepik River as well as complete water control, largely by mechanical means since water-tables would have to be maintained at a constant high level for the more decomposed peat soils to prevent undue oxidation and shrinking. Raw peat and organic mud soils, however, are so soft underfoot that to be usable they would require compaction and shrinkage by lowering the water-table to below the surface of the underlying clay. Construction of stable levee banks could be very difficult in peat and soft clays. Agricultural suitability of such reclaimed peat soils is difficult to assess, but cattle-grazing would possibly lead to trampling problems, regular cultivation to rapid oxidation of the peat, and stability problems could arise with tree crops. Investigation of peat quality for fuel, potting soil, or compost and mulch, could indicate the value of exploitation. Soil nitrogen contents very high in peat, low in mineral horizons. Phosphate contents probably range from very low to moderate; potash contents low to very low in peat, high in mineral horizons.

Engineering Assessment.—Unsuitable for road construction. Soils are Pt, with CH at depth; all are very deep. See agricultural assessment for engineering aspects of land reclamation.

(9) Kabuk Land System (30 sq miles)

Land Forms (Plate 5).—Flood-plain swamps, 5–260 ft a.s.l., form the lowest parts of large alluvial fan plains. Valley floors are confined between high plains or hills with drainage blocked by more vigorously aggrading alluvial plains. Gradients are about 1 : 4000 or less.

Streams and Drainage.—No developed stream channels. Surface run-off appears to be nil. Dry season water-tables are at the surface; the land is swampy and inundated 0·5–2 ft up to 8 months of the year.

Vegetation.—Complete cover of sago palm vegetation, 42% stunted (M1), remainder without or with few scattered emergent trees (M).

Geology.—Recent clay and peaty materials overlying clay.

Weathering and Soils (2 obs.).—No weathering. Probable soil composition in H1 dominant, (EAY3) subdominant, (EAHY1) common, (EAY2) minor. Soils observed in blocked valleys are acid raw peat and/or organic mud (H1), partially suspended in water and very soft underfoot. In two observations no solid substratum was reached at 7 ft and 13 ft respectively. Soils in alluvial plains probably undeveloped, weakly acid to weakly alkaline (near the coast), deep, very strongly gleyed clay loam to heavy clay alluvial soils, commonly soft underfoot, and possibly locally associated with peat soils.

Population and Land Use.—No population. Land use negligible. Some occurrences seem to be used for sago exploitation.

Transitions to Other Land Systems.—Associated with and in places transitional to Pandago (10) (particularly in alluvial fan plains), and Pandamp (6) and Kobar (7) (particularly in blocked valleys). Distinguished from last two only on basis of vegetation differences. In a few places Kabuk has gradual boundaries with Nigia (12).

Forest Resources.—Nil. Access category S.

Agricultural Assessment.—No capability at present for agricultural land use, except possibly for growing swamp rice varieties. Much blocked valley land appears suitable for construction of fish ponds. Reclamation would probably involve lowering water level by 8–15 ft to reach firm substrata because overlying raw peat and organic mud would be lowered with water-table. Pumping out of water and protection of open valley ends by levee banks to prevent flooding would be necessary. This land, with its heavy clay soils, would probably be suitable for irrigated rice and moderately suitable for arable crops and improved pastures. Reclamation in the fan plains would be easier, but again slow permeability of soils might limit its suitability for agricultural use. Soil nitrogen contents high in peaty soils, probably very low to moderate in mineral soils. Phosphate contents very low in peaty soils and probably vary from high to low in clayey soils. Potash contents mostly moderate to high, but low near the coast.

Engineering Assessment.—Should, and generally can, be avoided for road construction. For a road through land in a blocked valley large quantities of earth fill, easily obtainable from nearby high ground, will be required to provide a firm foundation and raise the road surface above maximum inundation level. Culverts are essential since much run-off and seepage water from high ground is discharged through these valleys, despite lack of proper stream channels. Feasible to develop some valleys as water reservoirs for agricultural use, but weed control will be necessary. Soils are subdominantly Pt, CH, and minor OH, SP; all are very deep. See agricultural assessment for engineering aspects of land reclamation.

(10) Pandago Land System (215 sq miles)

Land Forms (Plate 5).—Flood-plain swamps, 5–300 ft a.s.l., mainly lower parts of alluvial fan plains, including stabilized parts of flood-out fans, and of small fans and aprons along margins of hills in the south-east; also alluvial plains behind beach ridges or semi-enclosed by dissected higher older plains and low hill ridges. A few areas comprise lower parts of levee splays of the Sepik River. Two small areas (total about 1 sq mile) occur on older fan surface of Aiome (23), where drainage is disorganized by recent warping of fan surface. Land gradients probably 1 : 1000 to 1 : 4000.

Streams and Drainage.—No organized stream net, or at most widely spaced small shallow channels of draining streams with a sluggish flow.

Surface run-off probably nil. Dry-season water-tables observed ranged from the surface to more than 6 ft depth, but mostly at 3 ft or higher, and will rise considerably during wet season, probably resulting in inundation to 0·5–1·5 ft for 2–3 months in most areas. River flooding, probably annual, seems restricted to areas in Sepik River flood-plain and some narrow blocked valleys. Very poorly drained to swampy.

Vegetation.—Sago palm vegetation with emergent trees (Me) and mid-height forest with open canopy with sago palms in understorey (FmoM) cover 38% and 54%. Sago palm vegetation without emergent trees (M) and mid-height forest with irregular canopy with pandans and with sago palms and pandans in understorey (FmPM) are very restricted, as are patches of exploited sago palms (MR).

Geology.—Mainly Recent alluvium; probably stratified clay, silt, and minor sand. Littoral sand and lagoonal clay present in some occurrences near the coast. Peat common locally.

Weathering and Soils (7 obs.).—No weathering. Probable soil composition is EAHO, (EAHY1), EAHU2 subdominant; H2, H3, H4, EAY2, (EAY5), EAPO minor. Large areas associated with fan plains not sampled, but are probably undeveloped, neutral to weakly alkaline, deep to moderately deep, strongly gleyed alluvial soils, mainly clays but ranging in texture from sandy clay loam to heavy clay. A very plastic soil of the last kind, with thin dark topsoil (EAHO), observed in blocked valleys in east. Soils of Sepik flood-plain likely to be weakly acid and very silty and to lack any dark topsoil. In the blocked swamps organic soils of moderate to slow permeability appear common. Acid, very deep, rather dense peat soils or soils with stratified peat, clayey peat, and peaty clay layers (H2, H3) were observed in the south (underlain by heavy clay at 5 ft in one case). A weakly alkaline well-decomposed peat soil overlies strongly alkaline lagoonal clay at 4·5 ft (H4) in the north near the coast. Here also occur weakly alkaline very deep sandy soils with a thin organic loamy topsoil (EAPO), and similar soils with a thicker slightly plastic and very sticky rather organic loam to sandy loam surface soil (EAY2). Soils on older fan surfaces may be similar to one observed in a small depression of Paiawa (24): undifferentiated weakly acid deep strongly gleyed plastic and very sticky clay soils (EAY5).

Population and Land Use.—Population of 80 in a single village on the Sepik River on an inclusion of Palimbai (11). Present land use covers 3·8 sq miles (2% of area) near Aitape of which 39% is in land use intensity class 2, 28% in class 3, and 33% in class 5. Land system commonly a source of sago for nearby villages in adjoining land systems.

Transitions to Other Land Systems.—Fairly abrupt differences implied with Po (15) and Misinki (14), but boundaries with them are commonly gradual on aerial photographs. Boundaries with Kabuk (9) are even less distinct and apparently accompanied by equally gradational differences in land characteristics, Kabuk (9) appearing more swampy. Distinction between Pandago and Nigia (12) is based mainly on vegetation and stream pattern differences indicative of more stable conditions in Pandago, and boundaries are commonly indistinct. Whilst mapping of Pandago is based on the distinction on aerial photographs between sago communities and other swamp communities without sago or with stunted sago, some small areas of communities normally included with Pandago have been mapped as Nigre (27), since it is clear that they occur on an older, weathered land surface, not on young alluvial plains.

Forest Resources (2 obs.).—Forest covers 44%; very low to low forest resources. Forest of low stocking rate (FmoM) covers 95 sq miles. Access category S.

Agricultural Assessment.—Poor drainage, inundation, and locally also flooding indicate no capability for arable crops and tree crops, very low capability for improved pastures (dry-season grazing during 3–5 months, except in very swampy areas), but moderate capability for irrigated rice-growing. Under natural inundation annual yields of this crop are likely to vary strongly because of poor water control. Problems in land preparation, harvesting, etc., may arise on peat soils. The wettest parts of Pandago appear to have no agricultural capability. Nearly all the larger well-developed stands of sago palms are in the area, which appears capable of sustained sago production, particularly if stands are improved by selective planting and removal of emergent trees. Land use capability for irrigated rice may be raised to high by the application of relatively simple measures to control inundation and drainage in large parts of the land system. Further reclamation by drainage improvement would be more expensive, involving construction of large drainage channels and, locally, the pumping out of excess water and protection against flooding by levee banks. Both organic soils and some very slowly permeable alluvial soils may be difficult to drain or require maintenance of shallow water-tables. Full reclamation would result in high capability for arable crops, very high capability for improved pastures, but only low to moderate capability for tree crops because of the rather alkaline reaction and slow permeability of many soils. Soil nitrogen contents are low to moderate, but very high in peat soils. Phosphate contents are probably mostly high to moderate, but vary from very high to very low. Potash contents probably range mostly from moderate to very high, but are low to very low in peat soils, sandy soils near the coast, and small occurrences associated with Aiome (23).

Engineering Assessment.—Road construction should be avoided. Where short traverses are necessary roads should be built up well above inundation levels, but roadside ditches by themselves would serve little purpose. Culverts would be required to prevent banking up of water. Trafficability of unmade roads will be poor even at the height of the dry season. The softness of organic and many clayey soils could cause sagging of earth structures for built-up roads. Soils are dominantly CH, subdominantly MH, Pt, and minor SM; all are very deep. See agricultural assessment for engineering aspects of land reclamation.

(11) Palimbai Land System (102 sq miles)

Land Forms (Plate 6, Fig. 1).—Scroll plains and minor splay plains of the Sepik River flood-plain at about 170–200 ft a.s.l. Scrolls consist of long, gently arcuate, low flat ridges, 20–100 yd wide and 0·5 to over 2 miles long, with very gentle side slopes and standing 2–8 ft above interlying swales or surrounding swamp land. Where freely developed they form feathery or fan-shaped bundles, with width of interlying swales increasing from narrow to wide end of bundle. In many cases, criss-cross patterns arise where the river has cut through existing bundles and built up new scroll systems at a different angle. Actively aggrading scrolls occur in many inner bends of the Sepik River. Swales vary in width from 10 to 400 yd and probably occur at a height of 2–8 ft below bank height of the Sepik River. When very wide they form inclusions of Sanai (5) and Pandamp (6), rather than having the characteristic swale character of Palimbai. Splay plains occur in two places just downstream from points where the Sepik River is wedged between hills of Maio (64). They are narrow and highest (up to 10 ft above surrounding swamps) at their upstream end and wide and lowest (probably 3–6 ft above surrounding swamps) downstream. They owe their existence to more vigorous sedimentation below narrows in the river and consist essentially of coalescing scroll ridges, with very shallow (1–2 ft) swale depressions.

Streams and Drainage.—Closely associated with the Sepik River, which it surrounds almost completely west and north-east of the Ambunti hill region. The river has an average width of about 320 yd, with extremes at 520 and 220 yd and a gradient of <1 ft per mile. Shifting mud banks occur along most inner banks, but the talweg depth is likely to be normally more than 20 ft* even at low water level. Outer banks are mostly precipitous, with tops 15–18 ft above low water level. Bank erosion is visibly active in many places. The river carries clay in suspension and has a current of probably 3 knots at low water level. The bedload probably consists of clay, silt, and small amounts of fine sand. Many oxbow lakes occur, and in places shallower and narrower channels form short cuts in the meander loops or occur on the inner side of low scroll plain islands. Slow gradual changes in the river bed occur in many places, due to erosion along outer and sedimentation along inner banks. Major shifts in river course occur rarely and appear to be restricted to certain sections.

During annual floods, occurring in wet season but not necessarily in relation to local rainfall pattern, river level will normally rise up to 17 ft, flooding the land system to depths from 1 to probably 10 ft depending on height and nearness of the land to the river. The very highest parts are flooded to 1–2 ft in exceptional years only, e.g. March–April 1966. On higher parts and close to the river, flooding may last from a few weeks to two months, with water-tables descending to 7–9 ft or more during dry season. On lower scrolls away from the river inundation may last from 4 to 7 months, many swales are permanently inundated, water levels of 0·5–1 ft above the surface having been observed towards end of dry season. Surface run-off nil. Drainage status varies from poorly drained on most higher scrolls and splay plains to swampy in swales and on lowest scrolls.

Vegetation.—Tall forest with open canopy with light-toned crowns (Fod) occurs on higher scrolls and one of the splay plains. Large tracts are rare because of the form of the scrolls. On the smaller scrolls only narrow bands of trees are found, often breaking up into scattered clumps where these scrolls fade out. All occurrences together account for about 25% of the land system. Tall forest with open canopy and sago palms in the understorey (FoM) is found on the other splay plain, about 2%. In the swales and on the lowermost scrolls, tall grassland (GtS) with cane grass (*Saccharum*) and reed (*Phragmites*) covers about 48%; pandan vegetation (P) covers about 20% and is confined to swales. Along and in oxbow lakes is herbaceous vegetation (H), often consisting of floating grasses, covering about 3%. On higher mud banks and aggrading scrolls along the river is tall cane grass vegetation (GtS), covering about 4%.

Geology.—Recent alluvium; silty clay to silt loam.

* Depths ranging from nearly 20 to more than 130 ft were recorded during a trip of naval patrol boats up the river well beyond Ambunti in February 1969. Naval Public Relations, Canberra, Navy News Information Sheet 15/69.

Weathering and Soils (3 obs.).—No weathering. Probable soil composition is EAY3, (EAHY1), EAHU2 subdominant. All are undeveloped alluvial soils and, apparently and surprisingly, acid to weakly acid. They range from very deep moderately gleyed rather stratified soils with textures of firm silty clay, friable silty clay loam, and some silt loam (EAHU2) on the highest scrolls and splay plains, to very strongly gleyed, slightly plastic and very sticky clay soils which are soft underfoot (EAY3) in low-lying swales. Transitions are likely to occur but heavy clay soils are noticeably absent.

Population and Land Use.—Population of 1390 distributed over five villages. Present land use covers 1·1 sq miles (1% of area), all in land use intensity class 1, and occurs on higher Sepik River levees. Sago collecting is principal form of subsistence, supplemented by fishing and gardening.

Transitions to Other Land Systems.—Where the scroll pattern becomes vague, with only small grass-covered scrolls, there is transition to Sanai (5) and, if open water also present in pattern, to Chambri (4). Where scrolls become widely spaced, Palimbai becomes transitional to Sanai (5) or Pandamp (6). Boundaries with these range from very distinct to gradual and arbitrary. Where splay plains become very low, there is a rather gradual boundary between Palimbai and Pandago (10).

Forest Resources (1 obs.).—Forest covers 16%; very low resources. Moderate stocking rate forests (Fod, 15 sq miles; FoM, 1 sq mile) occur on the rarely to commonly flooded higher parts. Access category W, but highest parts may be accessible most of the year.

Agricultural Assessment.—Overall, very low capability for irrigated rice. About 25% of the area, comprising higher parts of scroll ridges and splay plains, has low to very low capability for arable crops and moderate to very low capability for improved pastures, whilst about 15% has low to very low capability for tree crops. Prolonged flooding and inundation would prevent intensive land development except on very highest ground, unless crops were planted on high built-up ridges, a practice used locally in indigenous land use. These factors, moreover, seriously limit the periods available for cropping and grazing. Silty topsoils, lacking in organic matter and structure, are readily compacted and sealed by rain, thus posing problems in land tillage and seed-bed preparation. Poor drainage further limits capability for tree crops even on high-lying land. Rice-growing would have to depend on either natural irrigation by inundation or irrigation with pumped-up river water in dry season. A large proportion of land system, which is almost permanently under water, has no land use capability. Soil nitrogen contents are, surprisingly, moderate. Phosphate contents appear to be very low, but may be much higher in places. Potash contents probably range from very high to moderate, being apparently lowest on the highest scrolls. Land reclamation, particularly of higher parts, would produce land with high capability for arable crops and moderate capability for tree crops. Because of the relief inherent in the scroll–swale pattern, land grading would be required before reclaimed land reached high or very high capability for irrigated rice.

Reclamation involving empoldering by levee banks and discharge of excess water by pumping, required during the flooding season only for higher parts but throughout the year for lower parts, would be very costly, even though foundation problems for levee banks would be smaller than in other land systems of the Sepik flood-plain. On the other hand, the proximity of Palimbai to the Sepik River would make protection of the dikes against flood scouring essential, whilst some areas along the river might have to be left unprotected to prevent too great a rise in water level in a confined channel between dikes. One favourable circumstance in this part of the Sepik plain is that stone for construction purposes is close at hand in Maio (64) and Waskuk (65).

Engineering Assessment.—The large lower parts are unsuitable for road construction. Since traffic can be expected to be by ship on the Sepik River, there is no need for road construction other than small feeder roads on highest ground, if and when any development takes place. These could be surfaced with stone from Maio (64) or Waskuk (65), and would probably require regular maintenance after floods. Soils are dominantly MH, subdominantly CH; all are very deep. See agricultural assessment for engineering aspects of land reclamation.

(12) Nigia Land System (107 sq miles)

Land Forms (Plate 6, Fig. 2).—Actively aggrading unstable distributary fans (flood-out splays), as well as scroll plains (unstable flood-plains) of the Nigia and Wagasu Rivers (about 12% of total area). Altitude ranges from 5 to 260 ft; gradients probably range from 1 : 500–1 : 1000 in upper parts to 1 : 2000–1 : 3000 in lower parts; relief is up to 5 ft. The Nigia scroll plain commonly has flood scouring and channelling microrelief of 1–3 ft and two terraces with a 2–3-ft break were observed. They appear to have an appreciable back slope so that the present river bed occupies an elevated position. Terrace edges, 4–6 ft high, separate the scroll plains from surrounding alluvial plains. Similar sharp breaks may be present in upper parts of the distributary fans but gradually disappear in lower parts.

Streams and Drainage.—Distributary fans have unstable unincised distributary streams at the upper ends where main braiding or meandering streams enter the land system. The greater part of these fans, including also upper sectors of fans near southern margin of southern alluvial plains, have no organized drainage, but small draining creeks may originate in the lowermost parts. Scroll plains have a 40–130-yd-wide main stream throughout, which is braided or anabranching in its upper reaches, meandering in its lower reaches, with cut-off meanders particularly frequent near the point of change.

Surface run-off appears to be nil. Most of land system is subject to frequent flooding with scouring and sedimentation, whilst lowest areas of distributary fans are inundated probably up to 2 ft for 3–9 months. Drainage status of distributary fans ranges from poor in upper parts to very poor to swampy in remainder. Scroll plains are poorly to imperfectly drained. Dry-season watertables in distributary fans appear generally close to the surface whilst in the scroll plains they range from <4 ft to nearly 6 ft in depth.

Vegetation.—Vegetation types with pandans are characteristic. Their distribution pattern reflects the severity of the flooding current: mid-height forest with an open canopy with large heavily stilt-rooted pandans (FmoP) occurs in flood-out parts of fans and on terraces along braiding rivers (18%). In middle sections of fans and on back slopes of scroll plains pandans are less common in canopy, but other species still feature in understorey (Fmop, 49%); small patches of low forest (Fl, 7%) occur here in mosaic with mid-height forest. In farthest quietest parts sago comes in and vegetation changes into mid-height forest with an irregular canopy with pandans and with sago palms and pandans in the understorey (FmPM, 20%). On higher gravel beds in northern rivers an as yet undescribed *Casuarina* (*Gymnostoma*) species (Cs) forms pure stands, characteristic in photo pattern but generally too small to map out. Tall cane-grass vegetation (GtS) is found in some of the southern flood-out areas (3%).

Geology.—Recent alluvium: stratified sand, silt, and clay, with gravel in upper parts of occurrences, where main streams enter land system (at least in coastal plains); commonly calcareous.

Weathering and Soils (5 obs.).—No weathering. Probable soil composition is EAY1, (EAY4) subdominant; EAHS1, EAPO, EUHA1 common; (EAY2), EPOO minor; all are completely undeveloped alluvial soils. No observations in inland plains, but soil conditions appear fairly similar to those in coastal plain, although textures are likely to be finer. The only soil observed in the distributary fans is an alkaline, very deep, very strongly gleyed, slightly calcareous, stratified silty clay loam to sand with soft muddy upper layers (EAY1). Similar but finer-textured soils also expected to be common. Upper parts of fans appear to have sandy and gravelly "soils" (?EAY2). Soils of Nigia River scroll plain appear mainly alkaline, very deep, moderately gleyed, predominantly loamy soils, but with stratification from fine sand to silty clay, and strongly calcareous in upper part becoming slightly or non-calcareous with depth (EUHA1, EAHS1). A slightly gleyed, very sandy and wholly calcareous soil with thin less sandy bands (EPOO) observed on youngest scroll terrace.

Population and Land Use.—Population nil; present land use negligible.

Transitions to Other Land Systems.—Scroll plains and upper parts of distributary fans have unique and sharply bounded photo patterns, but lower parts are often difficult to distinguish from Pandago (10) or even Kabuk (9), and, where there has been much interference with the vegetation by man, also from Po (15). It is likely that land of transitional characteristics has been included in these three land systems. Mapping is based largely on distinguishing pandan vegetation from sago and other swamp communities, but its recognition is often difficult. In several places Nigia is associated with Yilui (13), thought to consist of similar but older and now stabilized distributary fans; sometimes these two land systems are not clearly distinguishable.

Forest Resources.—Nil. Access category S.

Agricultural Assessment.—Only low capability for irrigated rice due to great risk of crop failure through excess flooding. Any development of land as it is would be most hazardous. Reclamation would require construction of large channels to harness the rivers. Maintenance of such channels might present problems because of the apparently large sediment loads in the rivers. The method would, however, be very effective in mitigating flood control and improving land drainage, giving very high capability for improved pastures or irrigated rice and high suitability for arable crops, with choice of crops or varieties limited mainly by alkalinity of calcareous soils. This factor could be a more serious limitation for tree-crop growing, even on reclaimed land. Soil nitrogen contents are generally low to very low, locally moderate; phosphate contents are mostly high to very high, locally moderate; potash contents appear to vary from high to low.

Engineering Assessment.—High flood hazards and poor drainage make road construction difficult and hazardous. The need to avoid this land system is probably main obstacle to construction of east–west roads in the coastal plain and, to a smaller degree, in inland plains. Particular problems arise in crossing the Nigia River scroll plain, necessary in any road between Aitape and Dagua, unless a bridge is constructed on the beach. The scroll plain is narrowest (360–400 yd) 4–5 miles inland, but would have to be wholly bridged since long abutments would cause banking up of flood waters. Upper parts of distributary fans in coastal plain could be minor but useful sources of sand and gravel. Soils are CH, CL, ML, SM, with minor SP; all are very deep. See agricultural assessment for engineering aspects of land reclamation.

(13) Yilui Land System (48 sq miles)

Land Forms (Plate 7, Fig. 1).—Alluvial plains and fan plains of stabilized flood-out splays. Altitude ranges from 10 to 220 ft. Alluvial plains have very low gradients or are level (maximum gradient probably 1 : 1000) and consist of narrow (60–100 yd) low levee banks along streams, separated by back plains 3–9 ft below the levees and 400–1000 yd wide. Levees probably account for 20%, back plains for 40%, and fan plains for 40% of the area. Fan plains are flat with very low gradients but in places slightly dissected by small channels. Some areas are transitional in character between the levee/basin and fan plains.

Streams and Drainage.—Alluvial plains have rather widely spaced small meandering streams that commonly divide into branches as in deltas. Streams are in various stages of degradation, being disconnected from major stream pattern of which they originally were a part. They range from streams 10–30 yd wide with 10–15-ft-high precipitous banks to concave channels 10–20 yd wide, 4–8 ft deep, and with relatively gentle bank slopes. Larger streams have a very sluggish flow in dry season and never appear to flood above bank-full height. Small channels probably have surface flow only after heavy rains. Similar channels 8–15 ft deep, with or without perennial flow, drain parts of fan plains.

Surface run-off is probably nil to very low in relation to through drainage, and streams largely fed by ground-water seepage would tend to rise and fall gradually. Levee banks are imperfectly drained, flood-out plains poorly drained, and back plains very poorly drained to swampy. Dry-season water-tables observed in levees range from 3 ft near very degraded channels to deep near little-degraded channels and are likely to rise to about 2 ft in the wet season. Dry-season water-tables in back plains are between 0·5 ft and probably 2 ft; such land is inundated in wet season mainly by rain water and probably to about 1·5 ft for periods of two months. The dry-season water-table on a fan plain was at 4 ft, and might rise to 2 ft and occasionally to near the surface in the wet season.

Vegetation.—Secondary vegetation (R-FRy, R-FR) covers about 30% on levees and parts of fan plains. Levees frequently used as village sites and for gardens and coffee plantations. Sago commonly exploited (MR) on adjacent back plains. Tall forest with rather open canopy with groups of woolly-textured crowns (Fow, 22%) seems typical for fan plains, whilst some tall forest with open canopy and sago palms in the understorey (FoM) and much similar forest with light-toned crowns (FodM, 20%) occur on lower parts of fan plains, particularly on back plains. The most poorly drained back plains carry several types of mid-height forest, mainly with an irregular canopy with pandans and with sago palms and pandans in the understorey (FmPM, 15%), and with an open canopy and pandans in the understorey (Fmop, 7%).

Geology.—Recent alluvial clay and clay loam.

Weathering and Soils (4 obs.).—No weathering. Only undeveloped alluvial soils. Probable soil composition is EAY3, (EAHY1), EAHS2, EUHA2 subdominant. On levees, weakly acid, very deep, slightly gleyed, slightly stratified soils with textures varying from very friable loam and fine sandy loam to friable clay loam or silty clay loam to firm to plastic silty clay and clay (EUHA2). Significantly, one of these soils near a strongly degraded channel has developed a thin dark topsoil. On back plains are neutral, moderately deep, heavy clay soils that can be very strongly gleyed and soft underfoot (EAY3) or possibly also somewhat less gleyed and of greater bearing strength. On a flood-out fan, a neutral, deep, moderately gleyed, slightly stratified soil was observed with a texture ranging from friable silty clay loam to very plastic silty heavy clay (EAHS2).

Population and Land Use.—Population of 1380 distributed over six villages. Present land use covers 11·8 sq miles (25% of area), 12% in land use intensity class 3, 38% in class 4, and 50% in class 5. Gardens occur on levees. Chief subsistence is sago collected on back plains. Occurrences near coast are unused.

Transitions to Other Land Systems.—Distinction in mapping between Yilui and Nigia (12) based on different vegetation and land use patterns, there being no land use in Nigia (12). Since these differences are commonly vague, mapping of Yilui is somewhat tentative and gradual boundaries are common. Similar difficulties exist in separating it from Nagam (16), Misinki (14), Po (15), and locally Pandago (10). The tendency is to include in Yilui all those patterns that are more heterogeneous than or do not fit in well with these three. This is therefore probably the most complex and variable land system in the inland plains.

Forest Resources (2 obs.).—Forest covers 60%; low to moderate resources. Forests of moderate stocking rate (Fow, 11 sq miles; FodM, 9 sq miles) and low stocking rate (FR, 6 sq miles; FoM/FR, 3 sq miles) occur. Access category W, although fan plains and levees may locally provide better access.

Agricultural Assessment.—High capability for improved pastures and irrigated rice, moderate capability for arable crops, and low capability for tree crops. Strong contrast between land use capability of levees, which is very high for pastures, high for arable crops, and moderate for tree crops (because of imperfect drainage), and that of the very poorly drained back plains which mostly are suitable only for rice-growing. The fan plains occupy an intermediate position. Varied agricultural development adapted to local conditions is indicated. While adequate water control for paddy rice growing on the back plains might be a simple matter, full reclamation might be difficult; firstly, it might involve pumping out of excess water and secondly, the heavy clay soils might not respond to drainage, although this would require further testing. After reclamation these fine-textured neutral soils might be little suited to many tree crops and also present tillage and root development problems with arable crops. Thus it might be advisable to develop this land system only as far as its present condition will allow. Soil nitrogen contents are low to moderate; phosphate contents high to low; and potash contents very high to moderate.

Engineering Assessment.—Levees appear quite suitable for road construction and could be used to advantage in any road system linking the plains south of the hill zone with the Sepik River. Unmade roads on levees would probably stand up to low traffic density in dry season only. Direction of levees renders them of little value in east–west connections. Back plains should be avoided for road construction because of very poor drainage, inundation, and the low bearing strength of many soils. If good roadside drainage was provided and roads built up in some places, the fan plains would not present great problems. There are, however, no road-surfacing materials and soils, particularly when very silty, appear to be of poor quality as subgrade. Nearest road-building materials are in the hills of Maio (64). Soils are dominantly CH, subdominantly CL, and minor MH, ML; all are very deep. See agricultural assessment for engineering aspects of land reclamation.

(14) Misinki Land System (238 sq miles)

Land Forms (Plate 7, Fig. 2).—Alluvial back plains of very low gradient at altitude of 180–250 ft. Locally slightly dissected by narrow shallow channels. Commonly, slight microrelief of gentle rises 6–12 in. high and about 20 ft in diameter.

Streams and Drainage.—Probably widely spaced small meandering drainage channels, 8–10 ft deep and 8–10 yd wide, with small (1–4 yd wide) streams in the bottom. Flow may vary from bank-full in wet season to almost nil at end of dry, with gradual rather than sudden variations in flow.

Surface run-off probably very low in relation to through drainage. Largely because of ponding of rain water but locally stream overflow, parts of land system, probably not more than 50%, are flooded up to 2 ft for a few days once in 2–5 years and/or inundated for 1–2 months to depths up to 1·5 ft. Dry-season water-tables observed at depths from 3 to 7 ft, but where land is not actually inundated wet-season water-tables are expected to rise to 6–12 in. below surface. Poorly to very poorly drained.

Vegetation.—Tall forest with an open canopy and sago palms in the understorey (FoM) covers 98%. Another 2% is covered by similar forest with light-toned crowns (FodM).

Geology.—Recent alluvial clay.

Weathering and Soils (4 obs.).—No weathering. Probable soil composition is EAHU1 predominant, EAHU2 common. Undeveloped, weakly acid to neutral, moderately deep to moderately shallow, moderately gleyed, very plastic heavy clay or silty heavy clay alluvial soils, which may have firm to plastic clay upper horizons (EAHU1); and similar, but very deep, more stratified, predominantly friable to slightly plastic silty clay loam to firm to plastic clay soils (EAHU2). Latter soils probably occur mainly near boundaries with Yilui (13) and Nagam (16). Locally subsoils are slightly calcareous.

Population and Land Use.—Nil.

Transition to Other Land Systems.—Boundaries with drier Nagam (16) and wetter Pandago (10) are commonly gradual and somewhat arbitrary. Similarly, they are commonly indistinct between Misinki and Yilui (13), although the latter is characterized by a more heterogeneous photo pattern. Pattern of Misinki very similar to Po (15), although fan features and regrowth patterns are lacking in former. Distinction between these two land systems largely based on properties other than photo pattern.

Forest Resources (4 obs.).—Forest covers 100%; moderate to high resources. Mainly forest of moderate stocking rate (FoM, 230 sq miles; FodM, 6 sq miles); very minor stands of low stocking rate (FmoM, 1 sq mile). Access category W.

Agricultural Assessment.—High capability for irrigated rice, moderate capability for improved pastures, and low capability for arable crops. Most land sufficiently low-lying for irrigation for rice-growing, soils appear very suitable for this crop, and water control easily achieved by drainage channels, whilst flood protection only locally necessary. Only distance from suitable water-supplying rivers prevents a very high capability for this form of land use. Suitability for pastures and arable crops varies with drainage and inundation risks, as well as soil texture, and is highest on the probably small areas of less clayey soils near margins with Yilui (13) and Nagam (16). Technically, reclamation appears quite feasible, requiring mainly surface drainage improvement by ditches and discharge of excess water via drainage canals into adjacent swamp land. Locally, levee dams might be needed but drainage by gravity would usually be possible. Whilst such reclaimed land would have high to very high capability for improved pastures, the very clayey nature of most of the soils might restrict the depth of adequate drainage, limiting the number of arable crops that could be grown successfully and restricting even more the capability of reclaimed land for many tree crops, although rubber and oil palm would probably thrive. Tillage and seed-bed problems may commonly occur in heavy clay topsoils. Soil nitrogen contents are probably low to moderate; phosphate contents probably vary from low to high; and potash contents are probably high to moderate.

Engineering Assessment.—No topographic limitations for road construction, but poor drainage and risks of inundation and locally flooding necessitate adequate roadside drainage including many culverts and, commonly, raising the road body above the land surface. There is no road-surfacing material and soils are probably of poor quality as subgrade, although the heavy clays could be reasonably stable if dried out. Unmade roads will be boggy and slippery even after light rains. Nearest source of road-building materials is hills of Maio (64), separated from Misinki by swamp land. Soils are CH with minor MH; all are very deep.

(15) Po Land System (49 sq miles)

Land Forms (Plate 8, Fig. 1).—Flood-plains and some poorly drained alluvial plains, consisting for the greater part of lowermost sectors of alluvial fan plains. Altitude ranges from 5 to 250 ft, gradients probably from 1 : 500 to 1 : 1500 but mostly more than 1 : 1000. Commonly microrelief of 1–2 ft, at least partially due to flood scouring.

Streams and Drainage.—Ill-defined pattern of small shallow wash courses with intermittent flow in upper parts, and of meandering small streams up to 6 ft incised and largely fed by ground-water seepage from Pes (17) in lower parts.

Surface run-off probably nil in relation to through drainage. Dry-season water-tables appear mostly between 6 and 7 ft but likely to rise considerably during wet season. Large parts subject to flooding at least twice a year to probably 1–3 ft; small areas rarely flooded or not flooded. Flooding generally caused by combined effect of high rainfall and increased seepage and run-on from Pes (17), but in area just east of the Yalingi River it appears to be caused by direct overflow. Land system largely imperfectly drained, rarely poorly drained, with inundation up to 1 ft for short periods in some parts.

Vegetation.—Tall forest with open canopy and sago palms in understorey (FoM) is characteristic, covering just over 50%. Species composition usually very mixed, but locally *Terminalia* and *Planchonia* predominate, recognizable on air photos by their light-toned crowns (FodM). Mid-height forest covers about 12%, represented mainly by two types having an open or irregular canopy and a dense sago understorey. *Campnosperma* common in canopy of one (FmoCM), pandans common in the other (FmPM). These types, especially FmPM, are indicative of wetter and frequently flooded areas. Half remaining 35% covered by exploited stands of sago (MR), the other half consists of gardens, garden regrowth, and secondary forest (R-FR).

Geology.—Recent alluvium: stratified sand, silt, and clay, overlying alkaline probably lagoonal clays at shallow depths (4–8 ft) near the coast.

Weathering and Soils (3 obs.).—No weathering. Probable soil composition is EUHA2 dominant, EUHA1 subdominant, (EUHA3) common. Undeveloped, neutral to locally alkaline, very deep, slightly to moderately gleyed, stratified alluvial soils with textures varying within the profile from friable silt loam to slightly plastic and sticky clay or from loose sand to friable to firm clay loam (EUHA1, EUHA2). Since soils are moderately permeable, gleying appears due to high water-tables in wet season. Probably slowly permeable, more clayey soils also occur.

Population and Land Use.—Population of 200 in two villages. Present land use covers 10·9 sq miles (22% of area), 5% of it in land use intensity class 2, 57% in class 3, 5% in class 4, and 33% in class 5. Parts of Po used by people in Nubia (2) for gardening as well as sago exploitation.

Transitions to Other Land Systems.—As mapped, gradual boundaries with drier Pes (17) and wetter Pandago (10). Very difficult in places to distinguish from less stable and more actively aggradational Nigia (12). Boundaries between the two are gradual and transitional areas may have been included in either. See also Misinki (14) for a discussion on similarities and differences.

Forest Resources (3 obs.).—Forest covers 65%; moderate forest resources. Forest of moderate stocking rate (FoM, 25 sq miles; FodM, 1 sq mile) dominant; also smaller areas of forest of low stocking rate (FmoCM, 3 sq miles; FR, 3 sq miles), the secondary forest generally occurring on drier parts. Access category IFw.

Agricultural Assessment.—Flood hazards, and for tree crops deficient drainage and soil alkalinity, give Po low capability for tree crops, moderate capability for arable crops and irrigated rice, but high capability for pastures. Land use capability varies according to differences in flood hazard and alkalinity. Because of low topographical position and probable seepage problems, land reclamation (flood control and drainage) would involve major works including construction of local levee banks and drainage channels and probably pumping out of excess water in some areas. Reclamation for irrigated rice would only be concerned with flood control and land grading. Complete land reclamation would raise land use capability to very high for arable crops and improved pastures and to high for tree crops and irrigated rice. Soil nitrogen contents are generally low, locally probably moderate; phosphate contents appear to be very high, locally high; but potash contents are generally moderate, commonly low, rarely high.

Engineering Assessment.—Road-building should be avoided if possible. Where needed, roads should have wide roadside ditches and in many places be well built up to prevent flooding. Culverts may be required to prevent banking up of flood water. Road-surfacing materials are commonly obtainable nearby in Aitape (55). Unmade roads would tend to be untrafficable for up to 8 months due to the low strength of the commonly wet soils. Soils are CH, MH, CL, with minor ML, SM; all are very deep.

(16) Nagam Land System (233 sq miles)

Land Forms (Plate 7, Fig. 2).—Alluvial plains of generally very low, locally in northern parts low, gradient. Altitude from 180 to 300 ft, with 88% below 250 ft. Gradients probably nowhere lower than 1 : 2000. Plains probably sparsely dissected by small channels. Short very gentle slopes occur locally towards channels or near margins with Yambi (28); some have wash courses 2 ft deep and 12 ft wide, without banks. Three terraces 6, 12, and 15 ft above stream level occur in most northerly part of Nagam along the Yula River; the lowest two are only 40–150 yd wide. Similar terraces possibly occur east of the Nopan River and occupy not more than 5% of land system. Small areas of older plain (probably <5% of area) contiguous to weathered surfaces of Yambi (28) and Nigre (27) have been included because of their vegetation.

Streams and Drainage.—Apart from a 1½-mile stretch of the 60–80-yd-wide Yula River there are no major streams. Drainage in many parts is by rather widely spaced meandering channels, 3–5 yd wide, with 4-ft steep lower banks and gently to very gently sloping convex upper banks. Channels probably about 10 ft below plain surface and probably more frequent near margins of Po close to higher ground of Yambi (28), Burui (29), and Nigre (27). Similarly shaped but larger (up to 10 yd wide and 10 ft deep) channels, in places dendritically branching, occur locally in south-western part of area; some appear to be degraded old courses of larger rivers and may have narrow low levee banks, others appear to be locally originating drainage channels. Since surface run-off appears very low in relation to through drainage and streams appear to be fed mainly by ground water, only gradual rises and falls in water levels of streams are likely, with maximum flow only rarely exceeding the height of the steep lower banks. Most streams appear perennial, but discharge is strongly reduced and flow very sluggish after long rainless periods.

Most of Nagam appears imperfectly drained, but terraces along major northern rivers are well drained. A dry-season water-table at 5 ft was observed once, but water-tables probably rise generally to 1·5–2 ft in wet season except on terraces and old plains. Lower terrace along the Yula River is probably rarely flooded.

Vegetation.—Tall forest with a rather open canopy (Fo), apart from a few areas (<3%) which are gardened or under secondary vegetation (R-FR).

Geology.—Predominantly Recent alluvium, mainly clay, but some clay loam with gravel in narrow upper parts along major rivers. In east and west small areas of Pleistocene alluvial clay adjacent to or surrounded by Yambi (28) and Nigre (27).

Weathering and Soils (5 obs.).—Great contrast between lack of weathering in most of Nagam and shallow mature weathering on small parts contiguous to Yambi (28) and Nigre (27).

Probable soil composition is EUHA3 predominant, (EUHO3) common, MUHE, UAPU2, (UOPA1) minor. Young alluvial plains have mostly undeveloped, neutral to weakly acid, deep to moderately deep, slightly gleyed, slightly stratified, firm to plastic silty clay or clay, and very firm to very plastic silty heavy clay (rarely heavy clay) alluvial soils, virtually without dark topsoils (EUHA3). On upper terrace along Yula River is a slightly developed, weakly acid, deep to very deep, friable or slightly firm clay loam soil with a moderately thick dark topsoil (MUHE) and much gravel below a depth from 1·5 to 6 ft. On the weathered surface is a strongly developed, strongly acid, thick, slightly gleyed, firm silty clay merging into very firm silty heavy clay soil, with 18-in.-thick coarser-textured surface soil of very friable clay loam and silt loam. Subsoil is prominently light grey, red, and brown mottled and bleached silt is conspicuous in silty clay (UAPA2).

Population and Land Use.—Population of 360 in two villages. Present land use covers 7·4 sq miles (3% of area), 22% in land use intensity class 3, 78% in class 5. Gardening in only a few areas, near streams. Sago exploited in adjoining land systems is important in subsistence. Some land used by people in adjacent Nigre (27) near Yula River.

Transitions to Other Land Systems.—Mapped solely on forest vegetation characteristics. Where tall forest with open canopy occurs on old weathered surfaces, Nagam is clearly transitional to Yambi (28) or Nigre (27); where it occurs on alluvial terraces, transitional to Papul (19); where long open patches occur in the forest, commonly along streams, Nagam is locally transitional to Yilui (13). Boundary with wetter Misinki (14) nearly always gradual and somewhat arbitrary. Pattern similar to Pes (17) but lacking the fan plain characteristics; the distinction is based more on other properties than on photo pattern.

Forest Resources (4 obs.).—Forest covers 99%; high forest resources. Moderate to high stocking rate forest (Fo) covers 230 sq miles, with minor stands of low stocking rate forest (FR, 2 sq miles). Access category Iw.

Agricultural Assessment.—Very high capability for improved pastures, high capability for arable crops, moderate capability for tree crops and irrigated rice. Small areas of strongly leached, strongly acid, and physically rather poor soils of the old surface are the worst land; small areas of terrace land along Yula and probably Nopan Rivers are the best. Imperfect drainage is the major limitation, but does not affect capability for improved pastures. Soils not ideal physically for tree crops and high pH might adversely affect their suitability for some tree crops. Capability for irrigated rice somewhat reduced by commonly great distance from water-supplying rivers, relatively high position of the land, channels, and some surface unevenness. All pose problems in bringing and distributing irrigation water onto the land and would necessitate some land grading. Possibilities for tree crops, but mixed development for arable crop (permanent cultivation) and improved pastures best suited to the conditions. Tillage and seed-bed preparation might be difficult on land with very clayey topsoils. Soil nitrogen contents moderate, probably rarely low; phosphate and potash contents high to moderate and very high to high respectively on young alluvial plains, very low and very low to low on old weathered plains.

Engineering Assessment.—Topographically ideal for road construction; only a few small bridges required, mainly for east–west roads. Good roadside drainage should be provided. Major problem is lack of road-surfacing materials and probable poor quality of soils as subgrade. Unmade roads will become very boggy in wet season. Only source of road-surfacing materials is river gravels, commonly of igneous rock, in terraces of Yula and possibly Nopan Rivers. Soils are CH, with minor MH and CL; all are very deep. Topography suitable, but drainage deficiencies and lack of surfacing materials would limit airfield construction

(17) PES LAND SYSTEM (143 SQ MILES)

Land Forms (Plate 8, Fig. 2).—Fan plains and alluvial back plains and levees, with minor flood-plains, scrolls, and flood-plain terraces. Altitude from 10 to 300 ft, very rarely above 250 ft. Fan plains associated with wide slightly braiding river courses occupy mostly inland portions; gradients probably vary between 1 : 250 and 1 : 500 and tend to slope down very slightly from river courses. They range from about 1 to 5 miles wide and occupy probably 70%. Back plain and levee tracts occur along meandering streams, mainly close to coast. Levees (commonly indistinguishable on aerial photos) are probably 100–300 yd wide and a few feet above back plains. Narrow but high and distinct levee or degraded old beach ridge observed along a former river course (? Yalingi River) near the coast. Levee gradients similar to those of fan plains but back plain gradients are lower (probably 1 : 500–1 : 1500); width from <1 to 3 miles. Minor flood-plains, low terraces, and scrolls found along meandering rivers.

Streams and Drainage.—Largest streams traversing land system are very widely spaced and flow in a northerly to north-easterly direction. They have wide gravelly (but not very bouldery) beds 60–400 yd wide with many shifting channels and 4–8-ft-high banks. Widest river beds not included in land system and have been left blank on land system map. Braided rivers commonly merge into narrower meandering single channels nearer the coast, but many smaller rivers disappear in flood-out fans of Nigia (12). Distance from the coast at which braided streams change into meandering rivers varies greatly. Meandering channels have many sandy to gravelly scrolls and sand bars and very steep banks 8–12 ft high. In lower parts of fan plains small (8–15 yd wide) widely spaced streams arise, 7–10 ft incised and fed largely by ground water from seepage from braided river beds and through drainage of precipitation. Back plains in many places have widely spaced (probably 200–400 yd) shallow (3–8 ft) channels and very small streams 8–16 yd wide, commonly with rounded profiles. These are mostly intermittent in flow, probably largely fed by run-off from slowly permeable soils of back plains.

Overall surface run-off is probably very low in relation to through drainage. Regular flooding is very rare (apart from scrolls and flood-plains) and restricted to small parts of back plains and very local overflow spots along braiding rivers. Fan plains and levees are well drained but back plains are imperfectly to poorly drained. Water may commonly lie on the surface of back plains after heavy rains but is rarely of sufficient depth and duration to be a serious limitation. Dry-season water-tables appear to be mostly below 7 ft on fan plains and levees and between 5 and 8 ft on back plains, but here water-tables are likely to rise considerably during wet season. Anomalous water-tables between 3 and 4 ft were observed in an overflow area of the Yalingi River near Po (15), and just south of the Nigia River where ground water is probably banking up against the high-lying, aggrading scroll plain (see Nigia (12)).

Vegetation.—Tall forest with a rather open canopy (Fo) occurs throughout and covers 77%. Locally on back plains scattered sago occurs in the understorey (FoM). Tall cane grass (GtS) and successional stages leading to tall forest occupy scrolls and lower flood-plain terraces. The rest (18%) is cultivated (coconut plantations locally interplanted with cacao, gardens, and some coffee) or in different stages of regrowth.

Geology.—Recent alluvium: stratified clayey, sandy, and gravelly beds. Material derived from basic igneous rocks and Tertiary sedimentary rocks; either can be locally dominant as a source or both have contributed in about equal proportions, depending on nature of catchment of each contributing stream. Locally limestone has also contributed to the alluvial sediments. Soil observations indicate that alluvium near the coast may overlie (weakly) alkaline lagoonal sand and clay (locally with coral debris) at depths as shallow as 4–5 ft.

Weathering and Soils (15 obs.).—No weathering; nearly all soils are undeveloped. Probable soil composition is EUHO2, EUHO4, subdominant; EUHA2, EUHA3 common; EUHO3, EUHO5, IUHE minor. Fan plains and levees have neutral to weakly acid (rarely acid), very deep to deep, alluvial soils, strongly stratified but mostly very friable and loamy, more rarely firm silty clay in top 4 ft (EUHO2, EUHO3, EUHO4, EUHO5). Textures range from gravelly loam to silty heavy clay and deeper substrata vary similarly. A similar soil but slightly developed with a thick dark topsoil (IUHE) observed on higher, steeper, and apparently older levee or beach ridge close to mouth of Yalingi River. Back plains have neutral to weakly acid, very deep to moderately shallow, slightly to moderately gleyed alluvial soils that are less stratified and generally silty clay to silty heavy clay in texture, but can also be mainly (sandy) clay loam (EUHA2, 3). Finer-textured soils particularly are very firm to very plastic. Below 6–7 ft the substratum is commonly very sandy and gravelly.

Population and Land Use.—Population of 1160 distributed over eight villages. Present land use covers 20·9 sq miles (15% of area), 19% in land use intensity class 2, 64% in class 3, and 12% in class 5, whilst 5% consists of non-indigenous plantations near the Raihu River. Land use concentrated near Sissano lagoon and lower reaches of Yalingi and Raihu Rivers.

Transitions to Other Land Systems.—Land system mapped mainly on vegetation characteristics and likely to include small areas transitional to more poorly drained plains of Po (15) and to older, weathered, but undissected fans of Aiome (23). Boundary with fringing calcareous fans of Romei (22) very arbitrary and probably unreliable. Some boundaries with Papul (19) are arbitrary. Differences with coastal fans of Kabenau (21) not investigated and could be minor. See also Nagam (16) for discussion of similarities and differences.

Forest Resources (10 obs.).—Forest covers 83%; high forest resources. Forest with moderate to high stocking rate (Fo, 110 sq miles) predominant; moderate stocking rate forest (FoM, 3 sq miles) on wetter parts of back plains; secondary forest (FR, 5 sq miles) with low stocking rate occurs locally on fan plains and levees. Part of original forest has been felled and milled for local consumption. Access category I.

Agricultural Assessment.—High capability for arable crops, tree crops, and irrigated rice, and very high capability for improved pastures. Limiting factors mainly poor drainage and slowly permeable soils on back plains and local minor inundation and very local flood hazards. Many soils appear slightly too alkaline for optimal tree-crop growth and land unevenness could be a minor problem for arable crops and improved pastures. Tree crops have by far the greatest capability on fan plains and levees, irrigated rice best suited to back plains. Improved pastures and arable crops could be successfully grown over most of Pes, but improved surface drainage needed on back plains. Soil nitrogen contents mostly low, locally moderate; phosphate contents range from very high to moderate; and potash contents from high to moderate.

Engineering Assessment.—Major problem in road construction, particularly from west to east, concerns bridging of larger rivers. River beds appear fairly stable but are usually wide and foundation problems could arise. Land system poor in road-surfacing materials and unmade roads tend to become untrafficable in wet season, particularly on back plains, because of low bearing capacity of soils when wet. Road-surfacing materials fairly simply obtained from larger river beds and from quarries in Aitape (55) and Barida (56). Soils are CL to CH with minor MH, ML, SM; all are very deep. Area generally suitable for airfield construction, particularly fan plains and levees since construction on back plains will involve drainage improvement.

(18) Screw Land System (60 sq miles)

Land Forms (Plate 9, Fig. 1).—Narrow scroll flood-plains and small discontinuous low flood-plain terraces along major and smaller rivers south of hill zone. In northern upper parts these are bounded by two or three river terraces, of which the uppermost is the most continuous. These merge in southern lower parts into levee banks and levee back slopes. Altitude ranges from 180 to 280 ft. Scroll plains, best developed along largest rivers, are only a few feet above low water level and may have small parallel swales. Lowest flood-plain terraces about 4–7 ft above low river level and may have very gentle back slopes to filled-in old river channels. Together these elements occupy about 12% of area but are virtually absent along small streams. Terraces 8–25 ft above low river level with very steep to precipitous marginal slopes; they can be flat to slightly undulating with local slopes up to 4°, and can have filled-in old meander loops up to 30 yd wide and 5 ft deep. Lower terraces usually 30–80 yd wide but upper terraces vary from 100 to 600 yd; they occupy probably 53% of area. Levees, comprising about 35%, are about 15 ft above low water level and 30–100 yd wide, with low or high gradient to very gently sloping back slopes 50–400 yd long.

Streams and Drainage.—Long meandering streams with few small tributaries. Most streams are 30–60 yd wide but only 10–20 yd wide in some small occurrences. Gradients mostly 1 : 2000 to

1 : 3000 but may approach 1 : 1000 in some upper parts. Cut-off meander loops occur commonly, particularly in southern parts. Streams have very steep or precipitous banks 5–15 ft high. Sand and silt bars commonly visible at low water level but decrease in size downstream. Some small gravel present in stream beds only in upper parts of land system. At low water level, rate of flow ranges from moderate in upper parts to slow in lower parts and suspended sediment is present in lower courses. River levels tend to rise rapidly after heavy rain in upper catchments, but flood spates that cover sand bars and scroll plains last only a few days.

During the wet season, low flood-plain terraces and some levee back slopes are flooded at least once a year to up to 3 ft. Higher terraces and levee banks are subject to short floods on the average probably once every five years, once in every ten years, or more rarely, depending on local conditions and height of the terrace. Surface run-off is probably very low in relation to through drainage. Levee banks and most lower flood-plain terraces are well drained, higher terraces imperfectly drained, and levee back slopes poorly drained.

Vegetation.—Tall cane grass (*Saccharum*) vegetation and young forest (Gt′) on scroll plains and lowest terraces (11 %). The rest bears tall forest with an open canopy with light-toned crowns (Fod, 50 %) or mid-height forest with a rather open canopy (Fmo, 24 %), the latter mainly in narrow valleys probably due to less favourable drainage conditions. Parts of Screw River terraces (15 %) are intensively cultivated. Rotation cycle appears short as often young secondary forest (FRy) is already cleared for gardens. Part of the gardens seems almost permanent as field boundaries are marked by low earth banks.

Geology.—Recent alluvium: clay, clay loam, and some fine sand. Flood-plain deposits are mostly calcareous.

Weathering and Soils (9 obs.).—No weathering. All undeveloped alluvial soils. Probable soil composition is EUHA3 subdominant; EUHO1, EUHO3, EUHA2, EAHU1 common; EUHO2, EUHO4 minor. Soils on scrolls are of stratified silt loam to sand and are calcareous, as are the weakly alkaline to alkaline, very deep, stratified friable silty clay loam to very friable sandy loam and loamy fine sand soils (EUHO1) of lowermost flood-plain terraces. Neutral, very deep, non-gleyed to slightly gleyed, somewhat stratified firm silty clay loam to clay soils (EUHO3) on lower terraces, and neutral to weakly acid, deep, slightly gleyed, somewhat stratified friable silty clay loam to firm to plastic clay soils with very plastic silty heavy clay subsoils (EUHA3) observed on higher terraces; these soils can have thin dark topsoils on virtually flood-free terraces. Weakly alkaline to weakly acid, very deep, stratified soils with textures of firm to friable silty clay, clay, silty clay loam, or clay loam to very friable silt loam and fine sandy loam (EUHO2, EUHO4) found on levee banks, with neutral to weakly acid, very deep to moderately deep, moderately gleyed, slightly stratified soils with textures of firm to very plastic silty heavy clay, firm silty clay, or clay to friable silty clay loam and clay loam (rarely silt loam) (EAHU1, EUHA2) on levee back slopes.

Population and Land Use.—Population of 100 in two villages near mouth of Screw River. Present land use covers 9·9 sq miles (17 % of area), 14 % in land use intensity class 1, 28 % in class 2, 27 % in class 3, 3 % in class 4, and 27 % in class 5. Most intensive land use on terraces along middle reaches of Screw River and its tributaries (Plate 31, Fig. 1); all used by people living in adjoining land systems.

Transitions to Other Land Systems.—Photo pattern commonly similar to that of Papul (19) and where there is a common boundary it is rather arbitrary. Levee tract patterns absent in Papul (19), and meandering of rivers more pronounced in Screw. Distinction between the two land systems further based on differences in vegetation photo pattern. Areas of Screw with very small streams can be transitional to either Misinki (14) or Pandago (10) and wider areas along large streams can be transitional to Nagam (16). The few boundaries with Nigia (12) are generally distinct, whilst the major distinction from Yilui (13) lies in the latter's lack of clearly active streams.

Forest Resources (6 obs.).—Forest covers 75 %; moderate forest resources. Main forest of moderate to high stocking rate (Fod, 30 sq miles) occurs on levees and terraces. Forest of low stocking rate (Fmo, 15 sq miles) occurs mostly in rather narrow valleys. Access category IFw.

Agricultural Assessment.—High capability for improved pastures, moderate capability for arable crops and irrigated rice, and low capability for tree crops. Flood hazards and drainage deficiencies are main limitations, the first for irrigated rice, the latter for tree crops. Since flood hazards are particularly difficult to assess, land use capability could be somewhat higher or lower than indicated. Some wider terraces and levees might be protected against flooding by low levee banks, which would increase the possibilities of drainage improvement. The commonness of neutral to alkaline soils has contributed to the low rating for tree crops. Slight to moderate engineering problems in bringing and distributing irrigation water for paddy rice growing have influenced the capability rating for this crop. Land use capability varies considerably, the best land occurring on levee banks and flood-free high terraces and unusable land on river scroll plains and steep terrace edges. Mixed development, based largely on improved pastures and arable crops, with tree crop plantations on better-drained weakly acid soils, appears to be most suitable. Soil nitrogen contents are low to moderate; phosphate contents mostly high to very high, although a few low to very low values were obtained on levee soils. Potash contents are mostly high, locally very high or moderate.

Engineering Assessment.—No great problems for road construction parallel to the rivers. Where surrounded by either more poorly drained or more hilly land, this land system might offer the most suitable location for roads. However, any reasonably level higher adjacent land systems might be preferable, in order to avoid flood hazards. Such hazards can be partly avoided by aligning roads on highest terraces, but building up and culverting of roads will be required locally. Road-building materials are scarce, mainly very small quantities of hard stream-bed gravel in the north and sand in the south. Major problem in road construction is the need for small to rather large bridges in roads traversing from west to east. Foundation problems could arise, and shifting of the river bed within its scroll plain must be anticipated. Unimproved fording places will require constant maintenance because of bank erosion during floods. Vehicles also tend to become bogged in the soft sandy stream beds. Concrete causeways would provide a reasonably cheap, durable, and efficient means of crossing these rivers. Soils are dominantly CH, subdominantly MH, and minor CL, ML; all are very deep. See agricultural assessment for engineering aspects of land reclamation.

(19) Papul Land System (62 sq miles)

Land Forms (Plate 9, Fig. 2).—River terraces and flood-plains along larger streams in confined valleys in hilly areas north and south of mountain ranges. Altitude ranges from 150 to 900 ft; 46% below 250 ft. Active flood-plains more extensive south of mountains, particularly in east and south-west, than in the north where they consist mainly of braided river beds, mostly not included in the land system but kept blank on the land system map. Flood-plains (25% of area) occur as scrolls with parallel minor swales and ridges or as flat scroll terraces up to 8 ft above mean low water level, and are 32–200 yd wide. A higher flood-plain terrace usually 10–13 ft above low water level and commonly 50–150 yd wide generally present south of mountains, together with a higher terrace 15–30 ft above low water level and probably 100–300 yd wide. North of the mountains there appears to be only one terrace, 10–20 ft above low water level. Flood-plain terraces cover probably 15% and higher terraces 50% of area; all tend to be discontinuous. The land system includes remnants of still higher sub-Recent terraces and a few benches cut into bed-rock, together probably occupying <5%. Terraces have slopes ranging from low gradient to gentle slope (commonly back slopes) and are smooth or with slight microrelief or have channels or gullies 5–10 ft deep.

Streams and Drainage (Fig. 10(c)).—Except for a few small first- or second-order tributaries, streams (6% of area) are large to rather small and have braided (particularly in the north), semi-braided to angular point bar or meandering courses with 5–10-ft-high very steep to precipitous banks. Apart from minor shifts in sand bars and occasional breaches of meander loops, the streams appear stable. Width of stream beds (apart from those left blank on the map) ranges from 40 to 50 yd. Stream flow in generally shallow channels is fast or moderately fast, never sluggish, so gradients in low gradient slope class, very locally high gradient. Bed loads generally gravel and sand, with cobbles in upper reaches and mainly silt and sand in lower reaches, particularly in the south-eastern half of area where river gravel is generally scarce. Outcrops of bed-rock scarce in areas mapped as Papul.

Scrolls and scroll terraces are flooded several times a year to well over 2 ft; flood-plain terraces on average flooded once or twice a year and in some instances not every year, mostly to less than 2 ft; higher terraces only rarely flooded or not at all. Surface run-off probably nil to very low in relation to through drainage. Generally well drained with only local areas of imperfect drainage.

Vegetation.—Tall cane grass vegetation (GtS) covers scrolls and lower terraces (30%). Invasion of woody plants leads via mid-height forest with a rather open canopy (Fmo) to tall forest with a similar canopy (Fo, Fod, 13%) on larger flood-plain terraces and to tall forest with a rather closed canopy (F, 42%) on high rarely flooded or not flooded terraces. Several low terraces in braided streams carry *Casuarina* (*Gymnostoma*) sp. vegetation (Cs) or *Casuarina* sp.–*Ficus* mid-height forest (CK) (total cover about 1%). About 14% is under secondary vegetation (R-FR).

Geology.—Recent, very locally sub-Recent stratified alluvium: mainly mixtures of sand, silt, and clay and some gravel, with local beds of more pure gravel, sand, or clay. Most recent sediments are commonly calcareous. Thin alluvium veneers sedimentary rock on a few cut terrace benches.

Weathering and Soils (13 obs.).—Almost no weathering. One observation north of mountains showed very shallow immature weathering of the terrace. Shallow skeletal to immature weathering may also be found on remnants of highest terraces and benches south of mountains.

Probable soil composition is MUHE subdominant; EUHO1, EUHO3, EUHO4, EUHO5, EUHA2 common; EUHA1, UOTO3 minor. Mostly undeveloped alluvial soils. Scrolls and scroll plains and lowermost flood-plain terraces have deep to very deep, strongly stratified soils with textures of loose sand to friable silty clay loam, usually within one profile. These are weakly alkaline to alkaline and probably mostly calcareous (EUHO1). Gravel lenses may also occur. Low-lying scroll soils can be slightly gleyed (EUHA1). Mostly weakly acid to neutral, very deep soils with slight stratification, but dominant textures from very friable loam to firm clay, with occasional sandy or gravelly layers (EUHO3, EUHO4), appear to occupy all higher flood-plain terraces and a large part of non-flooded high terraces. Tendency to greater acidity (EUHO5) north of mountains and locally soils are slightly gleyed (EUHA2). Probably in places these undeveloped soils are still rarely flooded. Initial soil formation on high terraces consists of development of a thick dark topsoil in weakly acid to neutral, mostly very deep slightly stratified, friable to firm clay loam to clay soils, which may very locally contain much gravel (MUHE). Such soils appear common, indicating almost complete freedom from flooding. Absence of carbonates in soils of all but lowest terraces may be due to leaching. A shallowly but strongly developed, acid, firm silty clay soil with friable loam to clay loam surface horizon (UOTO3) observed on a sloping high terrace north of mountains, similar to soils normally found on fan surfaces in that area. No information on soils of small remnant highest terraces or rock-cut benches.

Population and Land Use.—Population of 320 distributed over three villages. Present land use covers 8·6 sq miles (14% of area), 45% in land use intensity class 3, 10% in class 4, and 45% in class 5. Only a few occurrences used, with land use mainly on higher terraces.

Transitions to Other Land Systems.—See Screw (18) for similarities and differences. Placement of boundaries between Papul and Pes (17) (north) and Nagam (16) (south) presents problems that have been solved rather arbitrarily. In the north boundaries have been drawn where valleys widen considerably, but this has resulted in some inclusion of forest typical for Pes (17) into Papul. In the south Nagam (16) has been mapped consistently on the basis of forest photo pattern, which has led to the inclusion of some areas with soils and land forms more characteristic of Papul. In places it is very difficult to distinguish between photo patterns of Papul and Musendai (32), resulting in locally tentative mapping of both.

Forest Resources (10 obs.).—Forest covers 58%; moderate forest resources. Forests of moderate to high stocking rate (F, 29 sq miles; Fo, 6 sq miles; Fod, 3 sq miles). Access category IF, scroll and flood-plain terraces being subject to frequent flooding.

Agricultural Assessment.—High capability for arable crops, tree crops, and particularly improved pastures. Flood hazards main limitation but do not seriously affect about half the area. Locally drainage deficiency in slowly permeable soils and problems due to irregular or dissected topography. Capability for tree crops would be higher, except that soils tend to have a relatively high pH. Small areas are suitable for irrigated rice. Flood control not really feasible, because naturally occurring peak flows must be accommodated. Locally small areas can be protected by levee banks or flood waters diverted through drainage channels. Because of the diverse possibilities and small size of most occurrences of Papul, development of small mixed farms is probably most appropriate. Soil nitrogen contents generally low, but moderate in soils with more developed topsoils. Phosphate and potash contents mostly very high to moderate. Low to very low phosphate and potash contents virtually restricted to more weathered soils on high terraces and benches. In water balance zone 1, rather rare slight soil water stress in the most sandy and gravelly specimens of EUHO1 and 5 soils, and for shallow-rooting crops in general.

Engineering Assessment.—Probably provides easiest terrain for road location in hill zone. Cuttings into valley side spurs necessary where rivers swing out to margins of their valleys. Lower terraces should be avoided because of flood hazards; these may locally require building up of roads above normal flood levels. Bridging main streams will be the largest engineering problem, and bridges normally are more easily constructed where rivers flow against bed-rock on margins of land system. Many river beds contain useful amounts of gravel for road surfacing, but gravel is generally very scarce in eastern occurrences south of the mountains. Soils are CH, MH, CL, with minor ML, SM; nearly all are very deep. Larger higher terraces suitable for construction of airstrips, but there is no choice in direction and approaches can be difficult due to surrounding hilly country.

(20) AMBUNTI LAND SYSTEM (5 SQ MILES)

Land Forms (Plate 30, Fig. 2).—Alluvio-colluvial fans 190–230 ft a.s.l., with concave slopes ranging mainly from high-gradient to very gentle slope. Uppermost parts may have gentle slopes, lowermost parts low gradients. Plains probably slightly and very shallowly dissected.

Streams and Drainage (Fig. 15(*a*)).—A few small streams 4–8 yd wide and with very steep 4–10-ft-high banks; at least some would have intermittent flow. Short bank-full or smaller flood spates caused by the high run-off on Waskuk (65) are likely to occur frequently.

Surface run-off appears virtually nil, nearly all rain water as well as some stream flow discharging as through drainage. Upper parts well drained, flatter lower parts imperfectly drained, locally poorly drained due to ground-water seepage.

Vegetation.—Tall forest with rather open canopy (Fo, 50%) covers well-drained parts. Tall forest with open canopy and sago palms in the understorey (FoM, 30%) covers poorly drained areas. Gardens and secondary vegetation up to medium-aged secondary forest (R-FRm) found in both situations. Sago (MR) exploited in poorly drained areas.

Geology.—Recent fanglomerate derived from metamorphic rocks, mainly schist, also gneiss and some sandstone.

Weathering and Soils (1 obs.).—No weathering. Soils undeveloped. Probable soil composition is (EUHO5) dominant; EUHA4 subdominant; (BAHU2) common. Profile observed on lower slope an acid, very deep, slightly gleyed, slightly stratified soil of friable to very friable silty clay, silty clay loam, and some silt loam texture, containing low to high but with depth generally increasing amounts of rather fresh rock fragments (EUHA4). Similar but non-gleyed and probably more gravelly or even slightly stony soils likely to occur on upper parts of fans and similar but moderately gleyed soils with few rock fragments on lowermost slopes.

Population and Land Use.—Population an unknown number o people at Ambunti. Present land use covers 0·7 sq mile (14% of area), 70% in land use intensity class 3, 30% in class 5. Some sago exploited by people in adjoining Maio (64) and Waskuk (65).

Transitions to Other Land Systems.—Photo pattern very similar to that of Romei (22); any distinction impossible had they occurred in close association. Locally rather gradual boundaries with Pandago (10).

Forest Resources (No obs.).—Forest covers 80%; high forest resources. Forests with moderate to high stocking rate (Fo, 3 sq miles) and moderate stocking rate (FoM, 1 sq mile), the latter on lower, more poorly drained parts. Access category Iw, because of wetness problems on lower parts.

Agricultural Assessment.—High capability for arable crops, tree crops, and improved pastures and moderate capability for irrigated rice. Capability for improved pastures clearly higher than for other forms of land use. Limitations are drainage deficiencies in lower parts, slight erosion hazards and cobbly soils in upper parts. Only lower parts suitable for irrigated rice, with water from local small streams and land grading. Although Ambunti is small, its development could be significant in an area where good land is very scarce. Soil nitrogen contents appear moderate; phosphate contents probably mostly very low to low; potash contents mostly moderate, but commonly low.

Engineering Assessment.—Suitable for road construction; soil materials appear suitable as subgrade and road metal can be quarried in nearby hills. Minor or scattered hard gravel. Best possibilities in a wide area for location of airstrips, but landings and take-offs possible in only one direction because of high backing hills. Soils are MH, CL, ML, with minor CH, SM; all are very deep.

(21) KABENAU LAND SYSTEM (5 SQ MILES)

Land Forms (Plate 10, Fig. 1).—Coastal fan plains of low to high gradient, with fan terraces, 200–600 yd wide, probably at two levels, 4–15 ft above low water level in main streams and probably up to 30 ft a.s.l. Shallow (<10 ft) deserted distributary channels on higher fan plains. Near the coast some distributary flood-plains and back plains of very low gradient and up to 500 yd wide, together with minor low beach ridges. Near Dandriudad River, a few narrow-crested ridges and hills with steep straight slopes rising 50–80 ft above plains.

Streams and Drainage.—Wide shallow braided streams with sandy to gravelly beds (mostly blank on land system map) maintain a rapid rate of flow right down to the coast. Probably a few small distributary channels, and very small draining streams in lower part, fed largely by ground-water seepage from fans.

Surface run-off probably nil, except on small hills. Appears largely well drained, with imperfect to poor drainage on back plains and excessive drainage on low hills in Dandriudad River area. Shallow inundation may occur on parts of back plains during wet season.

Vegetation.—Mostly covered by secondary vegetation; only 10% tall forest with a rather open canopy (Fo). Kunai grassland (Gl) on fan terraces as well as hills, occupying nearly one-third of land system. Sago growing in back plains exploited (MR). Remainder is garden or under various stages of regrowth up to medium-aged secondary forest (R-FRm).

Geology.—No field data. Recent sediments, probably fanglomerate and alluvium: stratified and mixed gravel, sand, and clay. The few low hills probably consist of Tertiary sedimentary rock.

Weathering and Soils (No obs.).—Probably no weathering except on low hills which could be shallowly skeletally or immaturely weathered. Probable soil composition (MUHE, EUHO5) subdominant; (EUHA2, EAHU2) common; (IUHP, IODL1) minor. Soils are probably similar to those described for this land system elsewhere:* slightly developed, weakly acid, deep, more or less gravelly friable clayey soils with thick dark topsoils (hapludolls) on higher fan surfaces; mainly undeveloped, neutral, deep, medium-textured, non-gleyed to moderately gleyed alluvial soils on flood-plains and back plains; sands on beach ridges and probably thin truncated soils on the small hills.

* Lands of the Gogol–Upper Ramu area, New Guinea (1957); Lands of the Lower Ramu–Atitau area, New Guinea (1959). CSIRO Div. Land Res. Reg. Surv. divl Reps. Nos. 57/2, 59/1 (unpublished).

Population and Land Use.—Population of 560 in two villages. Present land use covers 2·5 sq miles (50% of area), 88% in land use intensity class 3 and 12% in class 5. Nearly all land use near Dandriudad River. Sago exploited in swampy areas.

Transitions to Other Land Systems.—Distinguished from Pes (17) because of clear fan pattern and on basis of vegetation. Transitions to neighbouring Nubia (2), Po (15), Pandago (10), and Nigia (12) either gradual or difficult to detect on aerial photos.

Forest Resources (No obs.).—Forest covers 22%; no forest resources. Moderate to high stocking rate forest (Fo, 0·5 sq mile) and low stocking rate forest (FRm, 0·5 sq mile). Access category I, but minor areas subject to poor drainage and inundation.

Agricultural Assessment.—Probably high capability for arable crops and improved pastures, moderate capability for tree crops, mainly on higher fan surfaces, and low capability for irrigated rice for which only poorly drained back plains appear really suitable. Drainage improvement of back plains difficult because of their low position and local need for protection against flooding. On the plains, soil nitrogen contents probably moderate in soils with dark topsoils, low in others; phosphate and potash contents probably very high to moderate.

Engineering Assessment.—The wide braided rivers are considerable obstacles requiring construction of major bridges in any road link of the Aitape coastal plain with Wewak. Apart from this and small poorly drained areas, Kabenau is very suitable for road construction, and may even be a useful source of gravel. Soils are MH, CL, ML, with minor CH and SP; nearly all are very deep, but those on small hills probably very shallow. Suitable for airfield construction, but only in a roughly north–south direction.

(22) Romei Land System (3 sq miles)

Land Forms (Plate 10, Fig. 2).—Short gently undulating fans and aprons of locally derived materials. Altitude ranges from 230 to 280 ft; 85% below 250 ft. Slopes very gentle, locally gentle, and slightly or not dissected.

Streams and Drainage.—Few parallel to radial small streams and gullies 4–12 ft deep, commonly with intermittent flow. Surface run-off probably nil. Well drained.

Vegetation.—Large parts (80%) used for gardening and cash cropping (coconuts, coffee) or under various stages of regrowth. Remaining original vegetation classified as tall forest with rather open canopy (Fo).

Geology.—Recent fanglomerate, at least partly rich in limestone cobbles and gravel.

Weathering and Soils (1 obs.).—No weathering. Probable soil composition is EUHO1 predominant; (EUHO2) common. An undeveloped alkaline and calcareous deep but rather stony very friable loam to friable clay loam soil (EUHO1) observed in a fan at foot of a limestone hill. Where fans are farther from limestone, less or non-calcareous alluvial soils with few or no stones may also be found.

Population and Land Use.—Population of 440 in four villages. Present land use covers 2·4 sq miles (80% of area), 46% in land use intensity class 2, 21% in class 3, and 33% in class 5.

Transitions to Other Land Systems.—Hard to separate from Pes (17) on photo pattern. Mapped on positional evidence and from land use patterns. Pattern also very similar to that of Ambunti (20).

Forest Resources (No obs.).—Forest resources are low. Forest with a moderate to high stocking rate (Fo, 1 sq mile approx.) covers 20%. Access category I.

Agricultural Assessment.—Very tentatively assessed as having high capability for arable crops, very high capability for improved pastures, but only moderate capability for tree crops because the alkaline soils suitable for coconut palms are probably much less suitable for other tree crops. Only moderate capability for irrigated rice because of unevenness of terrain and local stoniness, although water supplies would be generally close. Soil nitrogen and phosphate contents generally low to moderate; potash contents probably high.

Engineering Assessment.—Few difficulties for road construction apart from need for culverts or small bridges. If stony limestone fanglomerate is extensive, it could be a useful source of subgrade for use elsewhere in the coastal plains. Soils are MH, ML, with minor CH; all are very deep.

(23) Aiome Land System (25 sq miles)

Land Forms (Plate 11, Fig. 1).—Flat to undulating slightly dissected higher fan surfaces. Altitude ranges from 100 to 900 ft; 48% below 250 ft. Fan surface slopes range from high gradient to very gentle slope. Surface east of Raihu River exhibits some very broad undulations, probably due to slight warping in Recent time. Some fan surfaces appear shallowly (10–30 ft) dissected by ill-defined gullies, which in places appear to be remnants of original channels. Fan surfaces stand 6–200 ft above present stream levels, height normally decreasing gradually from south to north away from mountain front. Marginal slopes steep to precipitous particularly near larger rivers. Along the margins occur few short dissection valleys 20–70 ft deep, with steep to moderately steep concave slopes commonly with small slump scars and alcoves.

Streams and Drainage (Fig. 9(*b*)).—Along the margins, moderately spaced very small first-order streams with high gradient to gentle slope. Stream flow probably almost perennial, with relatively small extremes in discharge probably due to very low surface run-off in relation to through drainage and to constancy of ground-water seepage towards streams. Stream beds rather gravelly to bouldery. Shallow gullies in some fan surfaces probably have very small channels with intermittent flow or no proper channels.

Generally well drained. Observation near lower margin showed a water-table of only 14 in., although soil was not gleyed; this possibly caused by seepage from a rapidly aggrading flood-plain nearby or by banking up of ground water against it. Other examples of imperfect drainage may occur elsewhere near boundary of low-lying fan surfaces and younger alluvial plains.

Vegetation.—Tall forest dominant; rather open and small-crowned canopy (Fos) forest most common (56%), rather open irregular canopy (Foi) forest (28%), and irregular canopy (Fi) forest (6%). Mid-height forest restricted and covers <10%. It is mainly forest with an open canopy and sago palms in the understorey (FmoM), which is locally common in valleys. Little secondary vegetation (1%).

Geology.—See Paiawa (24). Age of the beds appears to be late Pleistocene to sub-Recent.

Weathering and Soils (2 obs.).—Weathering probably mostly shallow and immature. Probable soil composition is UOTO3 dominant; IODO3 subdominant; AUTO3 common; IODO1 minor. Soils essentially similar to those for fan surface remnants of Paiawa (24), but generally appear slightly less acid and slightly less weathered. For instance, a moderately developed, acid to weakly acid, thick friable to plastic clay soil with more friable clay loam surface horizons (AUTO3) was observed on a low-lying fan surface with an anomalously high water-table.

Population and Land Use.—Population of 60 in one village. Present land use negligible.

Transitions to Other Land Systems.—See Paiawa (24). Mapping was difficult and is tentative in the east because of elusive boundaries with Pes (17) as well as Paiawa (24). With Pes (17) this appears due to the weathered surface dipping gradually below younger alluvium.

Forest Resources (2 obs.).—Almost totally forested (92%); high to very high forest resources. Main forest type (Fos, 8 sq miles) has a moderate to high stocking rate except in wind-damaged areas. In parts, further areas of this forest have been mapped as a complex forest (Fos/FmoM, 7 sq miles) with a moderate to low stocking rate; it is restricted to valley floors. Forest with a moderate stocking rate (Foi) covers another 7 sq miles and there are minor occurrences of high stocking rate forest (Fi, 2 sq miles). Access category I.

Agricultural Assessment.—Very high capability for tree crops and high capability for arable crops and improved pastures, with a slight general limitation of soil acidity and very local limitations due to steep slopes or imperfect drainage. Very low capability for irrigated rice, because of both the difficulties of getting irrigation water to the high surfaces and the necessity of much land grading due to local slope and general gradient. See Paiawa (24) for further details. Soil nitrogen contents are probably mostly moderate, locally low. Phosphate and potash contents are low to very low, but some high potash contents may occur on lower slopes.

Engineering Assessment.—Road-building problems very minor, except considerable cutting would be necessary for a road entering across one of the long very steep marginal slopes. Otherwise this land system appears the most suitable for road construction in the coastal plain area. Small to moderate amounts of gravel obtainable from upper parts but only insignificant amounts in lower margins. See Paiawa (24) for further details. The soils are dominantly MH, subdominantly CH, and minor ML; all are very deep. Very suitable for airfield construction.

(24) Paiawa Land System (72 sq miles)

Land Forms (Plate 11, Fig. 1).—Partially dissected alluvial and few colluvial fans. Altitude ranges from 40 to 1100 ft; 67% below 250 ft, 32% between 250 and 1000 ft. Relief mostly very low, but commonly ultra-low or low (extremes 10 and 250 ft). Remnants of original fan surface, usually long strips 100–400 yd wide, occupy about half the area (locally varying between 20 and 80%) and in a few places include younger lower terraces 200–500 yd wide. Fan surfaces normally have very gentle to gentle slopes, but moderate slopes occur on colluvial fan surfaces along southern foothills and gentle convex slopes where fans are slightly warped up against low sedimentary hills of Yassip (38) and Morumu (39) in the north. Remainder mostly occupied by slopes towards dissecting streams and gullies and along fan margins. These slopes vary greatly in steepness and are normally moderately steep to very steep, locally moderate or precipitous. Less steep slopes normally more strongly slumped and irregular than steepest slopes. Where strongest, dissection has produced short ridges with very narrow to narrow crests. Locally, particularly where relief is lowest, occur narrow alluvial valley floors 50–200 yd wide (not more than 2%).

Streams and Drainage (Fig. 9(*b*)).—Spacing of streams varies from wide to close, depending on degree of dissection. Pattern is generally dendritic, but subparallel to radial in some more steeply sloping occurrences at foot of mountains. Local streams are very small, commonly have sinuous courses, low to high gradients, and probably rather gravelly to bouldery beds. Since streams appear largely fed by ground-water seepage and run-off is probably low in relation to through drainage, flood spates would tend to be minor and residual flow large, only the smallest gullies having intermittent flow. Only some larger streams have narrow (40–100 yd) flood-plains, whilst some wider valleys in lowest parts have no proper streams. A few trunk streams, mainly with braided beds, traverse land system.

Generally well drained; imperfect drainage on some lower fan terraces, probably due to seepage. Many valley floors are poorly drained to swampy, probably mainly due to blocking by coastal plain alluvium; some are probably inundated 1–2 ft for 1–3 months in wet season.

Vegetation.—Tall forest covers 85%. Same types as in Aiome (23), but in different proportions: forest with a rather open and small-crowned canopy (Fos) covers only 22%; forest with a rather open irregular canopy (Foi), 49%; and forest with an irregular canopy (Fi), 14%. Mid-height forest, mainly with an irregular canopy (Fmi), covers 10% and is found on upper steeper part of fans. About 5% is gardened, used to supply sago, or under regrowth.

Geology.—Late Pleistocene (Recent on minor lower terraces) stratified fanglomerate and alluvium, predominantly silt and clay with low to high amounts of pebbles and cobbles, with some non-gravelly sandy silt to clay.

Gravels are mainly basic igneous rock and metabasalt, locally mixed with or replaced by siltstone and minor quartz. Thus these sediments are derived in locally varying proportions from igneous "basement" rocks and Tertiary sedimentary rocks. West of Raihu River these deposits in places shallowly and unconformably overlie Tertiary mudstone and siltstone.

Weathering and Soils (9 obs.).—Fan surface remnants have shallow immature weathering, locally tending to mature weathering. Upper dissection slopes are immaturely, lower slopes probably skeletally, weathered; a few lower fan terraces are unweathered.

Probable soil composition is UOTO3, IODO3, (IODO2) subdominant; EUHA4, EAY5, AUTA2 minor. Fan surfaces generally have strongly developed, acid, moderately thick to thick clay to silty heavy clay soils with coarser-textured (loam to clay) and more friable surface soils 0·5–2 ft thick (UOTO3). Subsoil tends to be friable to firm when soil is predominantly derived from igneous rock debris, firm to plastic where there is a large contribution of sedimentary rock debris in the parent material. Occasionally moderately developed acid, uniformly textured friable clay loam to silty clay soils of similar thickness (IODO3) are found. Moderately to strongly weathered gravel occurs in varying amounts, but rarely in large quantities within the first few feet. Soils of upper dissection slopes are probably mainly similar to these last soils although an acid, slightly gleyed clay soil with friable clay loam surface horizon and very plastic silty heavy clay deeper subsoil (AUTA2) was also observed, apparently developed in an exposed clay lens in the fanglomerate. No data available for soils on lower dissection slopes; they would tend to be less thick, generally less clayey and less acid, and more gravelly and stony. An undeveloped, acid, slightly gleyed but gravelly and stony friable loamy soil (EUHA4) was observed on a younger lower terrace, and a weakly acid, very deep, but strongly gleyed, slightly plastic and very sticky alluvial clay soil (EAY5) in one of the poorly drained narrow valley floors.

Population and Land Use.—Population of 390 distributed over four villages. Present land use covers 1·9 sq miles (3% of area), 84% in land use intensity class 3, 16% in class 5. Land use occurs only in the western occurrences. Some villages also use land in adjoining Panakatan (25).

Transitions to Other Land Systems.—Clearly transitional to both Panakatan (25) and Aiome (23). Boundaries are commonly gradual and mapping is arbitrary in places. Some occurrences are complexes of Panakatan (25) and Aiome (23) that are not individually mappable.

Forest Resources (9 obs.).—Forest covers 93%; high forest resources. Principal forest type (Foi, 35 sq miles) has a moderate stocking rate. Associated is forest with a moderate to high stocking rate (Fos, 17 sq miles), which has been wind-damaged in parts, and a high stocking rate forest (Fi, 10 sq miles). Minor occurrences of other forest types, all with low stocking rates, are also found (Fmi, 2 sq miles; Fmi/Fmi′, 2 sq miles; Fmio, 1 sq mile). Access category II, with minor problems on poorly drained valley floors.

Agricultural Assessment.—High capability for tree crops and moderate capability for arable crops and improved pastures, the last occupying an intermediate position between tree crops and arable crops. Tree crops rated highest because acid soils with poorly developed topsoils are probably more suitable for most tree crops than improved pastures. These overall land use capabilities encompass a strong contrast between high suitability of fan surfaces and very low suitability of dissection slopes. Whilst there are some areas in which good or poor land dominates, the two types are commonly intermingled. This is a limitation to organized development and tends to favour tree crops, and to a lesser degree improved pastures, above arable crops. Some poorly drained valleys have moderate capability only for irrigated rice. Soil nitrogen contents are low to moderate; phosphate and potash contents generally low to very low, although higher potash contents occur on some slopes.

Engineering Assessment.—Dissection is main obstacle to road construction; otherwise there are advantages of well-drained high ground, broad flattish crestal surfaces, commonly interconnected, moderate suitability of soil materials for fill, ease of road-cut construction, and a probably minor but significant supply of gravel. Gravel in upper layers is commonly too weathered to be usable. Bridges can normally be small and of simple construction, whilst culverts are sufficient in gullies. Overall this land is better suited for road construction than the surrounding hills, flood-plains, and swamps. Depending on density and direction of dissecting valleys, suitable sites for small airstrips appear common. Soils are dominantly MH, subdominantly CH, and minor ML; all are very deep.

(25) Panakatan Land System (26 sq miles)

Land Forms (Plate 11, Fig. 1).—Strongly dissected alluvial fans, now forming dendritic and, locally near mountain front, subparallel to radial patterns of closely to moderately spaced very short to rather long ridges. Altitude ranges from 50 to 1600 ft; 70% below 250 ft and 25% at 250–1000 ft. Relief generally very low, but in strongly spurred western occurrences low and locally moderate (extreme range 50–500 ft). Local remnants of original fan surface occupy <20% in any one occurrence. They are probably 100–300 yd in diameter and have very gentle to gentle convex slopes. East of Raihu River original fan surface appears undulating, probably due to slight Recent warping. Ridge crests are even and range from narrow and rounded to knife-edged. Dissection slopes mostly steep to very steep but in places moderate to moderately steep. Precipitous marginal slopes occur locally. Slopes are smooth and mostly concave, or clearly slumped with small to medium-sized slump alcoves, or spurred, particularly in higher-relief occurrences west of Nengo River. Strong slumping usually associated with less steep slopes. Particularly the upper slopes within the weathering zone commonly appear very irregular and uneven, possibly due to microslumping of the soft material after earthquakes. Small but relatively wide (probably 40–80 yd) flattish valley floors occur sporadically.

Streams and Drainage (Fig. 9(*b*)).—Generally a typically dendritic, but near mountain front subparallel to radial, pattern of closely to very closely spaced small streams of low to high gradient, except for some short steeper first-order streams. Stream characteristics appear similar to those of Paiawa (24). Well drained; surface run-off probably moderate in relation to through drainage.

Vegetation.—Tall forests, mainly with a rather open irregular canopy (Foi) but sometimes more closed (Fi) or with smaller crowns (Fos), cover 48, 4, and 8% respectively. Near mountain front the forest is lower, classified as mid-height forest with an irregular canopy (Fmi) or with a very irregular canopy (Fmio). Locally successional stages (Fmi′) occur, probably indicative of unstable slopes. These types together cover 17%. In some valleys is mid-height forest with an open canopy and sago palms in the understorey (FmoM). Remaining 23% is or has been cultivated and all stages of secondary forest are found (R-FR). Sago has been exploited (MR) in suitable situations.

Geology.—See Paiawa (24). Age of beds is probably mid to late Pleistocene and nowhere Recent.

Weathering and Soils (1 obs.).—Crests and upper slopes appear affected by shallow to deep immature to mature weathering, but lower slopes probably only skeletally weathered. Weathering probably least on strongly spurred slopes, particularly in the west. Colluvial displacement of weathered material down upper slopes appears common.

Probable soil composition is IODO3, (IODO2) subdominant; (UOTO3) common; (AUTA2) minor. Little information, but soils probably similar to those of dissection slopes of Paiawa (24); soils of few remaining fan surface remnants similar to those of fan surfaces in that land system. No information on soils of small valley floors.

Population and Land Use.—Population nil. Present land use covers 2·2 sq miles (8% of area), 86% in land use intensity class 3, 14% in class 5. Used by people in Paiawa (24) in the west, and by people in Pes (17) in the east.

Transitions to Other Land Systems.—See Paiawa (24). Difficult to distinguish on photo pattern from Yassip (38) or Morumu (39), and in the west even from Numoiken (40). Mapping is based on geographical position (adjacency to Aiome (23) and Paiawa (24) or nearness to large rivers). In particular, the area of Morumu (39) west of the Nengo River and north of Barida (56) could well be Panakatan, as could some areas of Yassip (38) and Morumu (39) in extreme north-east of area.

Forest Resources (1 obs.).—Forest covers 69%; moderate forest resources. Main forest type (Foi, 12 sq miles) has a moderate stocking rate. Others are moderate to high stocking rate forest (Fos, 2 sq miles), high stocking rate forest (Fi, 1 sq mile), and two low stocking rate forests (Fmio, 2 sq miles; FR, 1 sq mile). Access category III, but access problems commonly reduced by low relief.

Agricultural Assessment.—Because of steepness of slopes there is low capability for tree crops and improved pastures and no capability for arable crops. Nature of acid soils and local stoniness make development for tree crops preferable to that for improved pastures, but land probably best left under forest or used for forestry purposes. Soil nitrogen contents probably mostly low to moderate, phosphate contents probably low to very low, and potash contents may be high to very high on lower slopes and low to very low on upper slopes and crests.

Engineering Assessment.—Conditions for road construction similar to those of Paiawa (24), but limitations are greater and advantages smaller. Traverse roads should be built only if necessary or where they offer the best of a number of poor prospects. Some road gravel obtainable, when other sources are unavailable. Soils are MH with minor CH, CL; predominant soils are probably very deep, minor soils moderately deep.

(26) Lumi Land System (22 sq miles)

Land Forms (Plate 11, Fig. 2).—Little to strongly dissected fan surfaces and river terraces with narrow flood-plains along major streams. Altitude ranges from 600 to 1200 ft; 31% above 1000 ft. Relief generally 100–300 ft, locally up to 500 ft near major streams. Flattish terrace and fan surfaces probably occupy 40%, moderate to moderately steep erosional slopes 35%, steep dissection slopes and cliffs 20%, and flood-plains 5%. Commonly two terrace or fan levels, one 30–250 ft above stream level, the other 150–400 ft above. Lumi is on what appears to be a remnant of a still higher surface 500 ft above river level. Highest surfaces particularly subjected to erosion and dissection, resulting in undulating to rolling topography with slopes about 10° and local relief of 50–150 ft, and in more extreme cases flat-topped or rounded ridges with broad to narrow crests. At least one large surface, up to 1 mile wide and 300 ft above stream level, is not dissected and has remnants of original meandering stream courses 5 ft deep and up to 7 yd wide. One upper surface has uniform 10° slope probably due to tilting. Dissection slopes are broadly convex with commonly moderate to steep irregular upper slopes with small slump alcoves, and steep to precipitous lower slopes with rock outcrop cliffs. South of Yelbu River is a moderate foot slope on mudstone with igneous gravel and cobbles on the surface; this is probably a slip terrace. The flood-plains are 100–300 yd wide and include discontinuous flood-plain terraces 4–8 ft above stream level.

Streams and Drainage (Fig. 9(*c*)).—Several through-going third- and higher-order streams with meandering but shallow gravelly to stony beds 40–100 yd wide and with many sand and gravel bars. They have rapid flow and probably low to high gradients. Although flowing in narrow flood-plains, rivers are undercutting valley sides in many places. In places, main rivers have closely spaced short dendritic to subparallel first- and second-order tributaries, with perennial flow and rock-cut beds with gradients of very gentle to gentle slope. Run-off probably generally low in relation to through drainage and contributes little to flow of the main through-going rivers which, although continually fluctuating in discharge within narrow limits, probably have few major flood spates.

Most small flood-plain terraces probably flooded less than once a year. Mostly well drained, flattish upper surfaces commonly imperfectly drained.

Vegetation.—Largely secondary, ranging from gardens to old secondary forest (R-FR, 58%), with locally planted sago (MR). Remainder of land system under tall forest with an irregular canopy with light-toned crowns (Fid).

Geology.—Pleistocene and Recent fanglomerate and alluvium, mostly sandy clay to silty clay, commonly with igneous gravel, cobbles, or stones, some quartz gravel, rarely mudstone gravel; in places heavy clay. Sediments appear generally 20–150 ft thick and overlie Pliocene siltstone and mudstone, exposed on lower dissection slopes.

Weathering and Soils (8 obs.).—Shallow immature weathering common on flattish high surfaces and crests, but dissection slopes only skeletally weathered, even when rather gentle. Some intermediate terraces up to 150 ft above stream level and (surprisingly) a large flat high surface at 300 ft are not weathered or only slightly skeletally weathered. This freshness of alluvium so high above present stream level attests to a very high rate of subsequent stream incision. Mature weathering is found on very high surface remnant at Lumi.

Probable soil composition is IODA1, AUTO3 subdominant; UOPA1, UOTA2, UOTO3, EUHO5, EUHA2 common; IODO1, IODE3, EUHL minor. Soils on weathered upper surfaces include strongly developed, acid to strongly acid, thick to moderately thin, commonly slightly gleyed, firm clay to very plastic silty heavy clay soils with friable loam to clay loam surface soils and thin or no dark topsoils (UOTO3, UOTA2, UOPA1). On stripped surfaces and moderate dissection slopes moderately developed, weakly acid to acid, moderately thin, firm clay soils with friable loam to clay loam surface soils, with stones at surface and/or in subsoil (AUTO3), observed on fanglomerate; moderately developed, acid, moderately thick, slightly gleyed, uniform, very firm to very plastic silty heavy clay soil (IODA1) on mudstone. On intermediate terraces and on a large flat high surface were undeveloped weakly acid to acid, deep to very deep, partly slightly gleyed, slightly stratified friable to firm clay loam to clay alluvial soils that may have gravelly subsoils (EUHA2, EUHO5). No data on steeper dissection slopes which probably have slightly developed to undeveloped, weakly acid to acid, moderately thin to moderately thick, medium- to fine-textured soils, that may be stony, or on flood-plain terraces with probably undeveloped, weakly acid to neutral, deep, medium-textured alluvial soils.

Population and Land Use.—Population of 510 distributed over four villages. Present land use covers 13·4 sq miles (61% of area), 12% in land use intensity class 3, 68% in class 4, 20% in class 5. Some use apparently by people living in adjoining Mambel (48).

Transitions to Other Land Systems.—Photo pattern generally similar to Paiawa (24), but locally resembles Karaitem (41). Where dissection is close and deep, pattern is difficult to distinguish from Morumu (39). Some intermediate terraces along major streams akin to similar features in Musendai (32).

Forest Resources (8 obs.).—Forest covers 41%; low forest resources. There is one forest type with a moderate stocking rate (Fid, 9 sq miles). Access category II, but minor access problems could arise due to wetness on upper surfaces and flooding on low terraces.

Agricultural Assessment.—Moderate capability for arable crops, tree crops, and improved pastures; highest for pastures, lowest for arable crops. Erosion hazards are main limitation for arable crops and improved pastures, with soil acidity and stoniness as contributory factors. Erosion hazards, drainage deficiencies, and physical soil deficiencies are main limitations for tree crops. Flooding is main factor limiting land use capability on flood-plains. Since the land system forms enclaves of relatively good land in large areas of populated steep hilly country, its development on a mixed basis would be useful, each type of land being put to its most suitable use. Soil nitrogen contents are mostly low or even very low, but commonly moderate. Phosphate contents are variable, very high to moderate in alluvial soils and on slopes, low to very low on older surfaces, but also on some slopes. Potash contents are high to moderate in alluvial soils and on slopes, low to very low on older surfaces.

Engineering Assessment.—Topographically, this land system has fewer problems in road building than any surrounding land systems, and the road from Lumi to Anguganak is largely in it. Major problem is necessity of large bridges, and in some cases the construction of approaches, where valley sides are very steep or cliffed. Cuttings easily made in unconsolidated sediments, and present no serious problems in underlying mudstone. Many large streams a useful source of road metal in the form of crushed river stone. Possibility of finding useful beds of rather fresh rounded gabbro gravel in intermediate terraces. Soils are dominantly CH, subdominantly CL, and minor MH, ML; probable depths are very deep dominant, moderately deep subdominant, shallow or very shallow minor. Best locations for airfields in this part of area, although direction would tend to be NE.–SW. which is unfavourable for prevailing winds.

(27) Nigre Land System (132 sq miles)

Land Forms (Plate 12, Fig. 1).—Flat almost undissected plains occur exclusively at lowest of two or three regional depositional surface levels. Altitude ranges from 190 to 280 ft, 98% occurring below 250 ft. Relief is almost always < 10 ft. Local slope varies from low to high gradient. Calculated overall gradients range from 1 : 670 to 1 : 2500 (mostly 1 : 800–1 : 2000). Plains stand < 10–30 ft (mostly up to 10 ft) above level of nearby flood-plains. In the west are some very gently undulating areas with many very slight depressions, either rounded and 100–400 yd in diameter or long drainage depressions 60–120 yd wide. Characteristic of south-western occurrences are meandering slight rises about 5 ft high, 40–80 yd wide, and 0·7–1·5 miles long (Plate 32, Fig. 2). These are interpreted as former river beds now forming highs due to relief inversion by weathering and erosion. Occurrences closely associated with Burui (29) and Kworo (30) east of Wagasu River rather resemble Pandago (10). They are included on basis of vegetation and because location of some is compatible with normal position of Nigre. In grassland, usually slight microrelief of 6–9-in.-deep rounded depressions is common; locally longer depressions 12 in. deep. Under forest, either no microrelief or 18-in.-deep rounded depressions and 22-in.-deep trenches, up to 6 ft wide and about 30 ft long, together covering 50–70% of area.

Streams and Drainage (Fig. 9(*d,e*)).—Open to rather dense dendritic pattern with some subparallel and radial elements of mostly very poorly developed very small first- to third-order streams.

Except for the largest, which may be 10 yd wide, streams have poorly defined almost unincised narrow (2–5 yd) channels winding through ill-defined valleys only a few feet below plain surface. Several such valleys have no stream bed but are merely wide swampy drainage channels. Short but more clearly defined dissection gullies occur locally along margins of land system. Surface run-off probably nil to very low relative to through drainage, and streams mainly fed by lateral subsurface flow over slowly permeable subsoil layers. No flood spates, but streams may alternately gradually increase in width and depth and shrink to mere trickles and stagnating pools, depending on rainfall.

Plains poorly to very poorly drained, even swampy in slight depressions and some larger low-lying areas. Higher meander tracts are well drained. Dry-season water-tables mostly below 6 ft, but in one case 4 ft, whilst a perched water-table at 18 in. was also observed. Some depressions and low-lying areas have real or perched water-tables above or near land surface throughout dry season, whilst most of land system likely to have shallow water-tables or even ponded surface water in wet season.

Vegetation.—Mid-height grassland (G) and fern vegetation often with sedges common (HD) occupy 30% and 26%. Grasslands 3–5 ft high and dense to very dense have very mixed assemblage of grasses and sedges, with varying numbers of species common but none dominant.

Land along poorly defined drainage channels traversing grass and fern lands, and in some cases also larger stretches of plain, is covered by mid-height forest, mainly with an irregular canopy with sago palms in the understorey (FmM, 30%), in places with *Campnosperma* predominant in the canopy (FmCM, 4%), but also of the related type with an open canopy (FmoM, 6%). Sago palm vegetation with emergent trees (Me, 4%) occurs in swampy valleys.

Geology.—Pleistocene to locally sub-Recent alluvium, mainly clay, locally interbedded with sandy clay to sandy loam, with very minor gravel; clays at least locally calcareous. Recent alluvium may be present east of Wagasu River.

Weathering and Soils (10 obs.).—Weathering mostly shallow to very shallow mature or nearly mature. Clearly immature weathering observed east of Yimi (Bongos) River, corresponding with small degree of weathering in adjoining Yambi (28). Possibly some atypical occurrences east of Wagasu River are less weathered. On the whole weathering is less intensive than in Burui (29) and probably slightly less intensive than in Yambi (28).

Probable soil composition is UAPB2 subdominant; UAPA, UAU1, UAU2, UOTB2 common; AUTA2, OANU minor. Soils vary in detail, but over large areas comprise strongly to very strongly developed, strongly acid (less commonly acid), thick to moderately thick, strongly to moderately gleyed, very plastic to very firm silty heavy clay to heavy clay soils with 11–26-in.-thick coarser-textured surface horizons of very friable loam, silt loam, or sandy clay loam to friable to firm or plastic clay loam to clay, and commonly (UAPB2, UAPA, UOPA1) but not always (UAU2) with prominently red, brown, and light grey mottled subsoils. These soils have either few black to red concretions or bleached silt in subsurface horizons. A soil observed in sandy to gravelly material of a "meander rise" is in many respects similar but not gleyed, and consists of friable clay loam overlain by 9 in. of very friable loam (OANU). Soils where land system forms lowest of three surfaces and on lower-lying area east of Yimi (Bongos) River comprise moderately to strongly developed, acid, moderately thick to thick, moderately gleyed, very plastic to very firm silty heavy clay to heavy clay soils with 9–12-in.-thick very friable or soft loam to silty loam to friable to firm clay loam to clay surface horizons, and without prominent mottling, concretions, or bleached silt (UOTB2, UAU2, AUTA2). These less mature soils suggest slightly lower age of such surfaces. Possibly less or much less developed or strongly gleyed heavy clay soils occur on rather anomalous occurrences east of Wagasu River which were not examined in the field. Although not sampled, soils of swampy slight depressions, mainly in the west, are probably similar to Mindumo family of adjoining Wewak–Lower Sepik area, which are moderately developed, acid, moderately thick, strongly gleyed very plastic heavy clay soils overlain by approximately 1 ft of peaty clay. Such soils are similar to and may be associated with UAU soils. Soils under grassland have moderately thick to thick dark topsoils, generally lacking under forest with one surprising exception with a thick dark topsoil.

Population and Land Use.—Population of 190 in one village. No present land use; people use land, at low intensity, in neighbouring Nagam (16).

Transitions to Other Land Systems.—Rather similar to Yambi (28). Boundaries are commonly arbitrary and gradual, and in some cases it is very difficult to decide from air-photo interpretation whether an area should be Yambi (28) or Nigre. Also mapping problems in separating forested areas from Pandago (10). Normal sago forest (FmoM) is included with Pandago (10) except where it is clearly related to older weathered surface of Nigre. Other sago forest (FmM), commonly characteristic of areas obviously belonging to Nigre, was therefore always mapped as such, except for some small areas which clearly belong to Yilui (13), even where shape and location are rather similar to Pandago (10). Nigre, therefore, possibly includes some Recent alluvium with little or no weathering and less-developed soils. Boundaries of Nigre with Nagam (16) and Misinki (14) are based purely on vegetation differences but the vegetation does appear to reliably reflect differences in soils and drainage.

Forest Resources.—Nil. Access category W, with small parts virtually in access category S.

***Agricultural* Assessment.**—Moderate capability for improved pastures and irrigated rice, low capability for arable crops, and no capability for tree crops. Poor drainage is major limitation, combined with poor physical soil conditions for tree crops and high acidity for other forms of land use, for which microrelief is a minor other limiting factor, requiring grading or special care in land tillage. Although capability for pastures is rated as moderate in both Nigre and Burui (29), the latter appears more attractive because management of erosion and topographic limitations appears simpler than the major drainage improvement required in Nigre. Pastoral development of drier parts of Nigre appear possible; wetter parts probably most suitable for irrigated rice. Irrigation water can be brought from adjoining rivers without great difficulty, whilst ponding of rain water is generally easily achieved; it may be more difficult to drain off unwanted water than to obtain irrigation water. Drainage schemes on a larger scale could raise land use capability to moderate for arable crops, low for tree crops, and high for improved pastures, whilst major irrigation works could raise capability for irrigated rice to high. Soil nitrogen contents are mostly moderate, but tend to be low to very low under forest. Phosphate contents are very low. Potash contents are very low to low on most surfaces, but only low where the land system forms lowest and probably youngest of three surfaces.

Engineering Assessment.—Poor drainage and locally inundation, and the absence of good road-building materials are major limitations for road construction. Roads may have to be raised with material from roadside ditches. Weathered sandy to gravelly deposits of raised "meander strips" could be minor source of better-quality subgrade. Possibly, but not likely, brightly mottled subsoils will harden irreversibly upon thorough drying and may be used as low-grade laterite for road surfacing. Dark topsoils should be removed, but coarser-textured subsurface soils should be retained, particularly on unmade roads. Poor drainage renders this land system less suitable for airfield construction than Yambi (28). Soils are CH with a thin veneer of MH, CL, ML, OL; all are very deep.

(28) Yambi Land System (110 sq miles)

Land Forms (Plate 12, Fig. 2).—Flat to very gently undulating slightly dissected plains occur mostly at the lower of two regional depositional surface levels, but also comprise intact parts of the generally more dissected upper surface. Altitude ranges from 180 to 320 ft; 95% below 250 ft. Relief is mostly between 10 and 40 ft. Calculated overall gradients of lower depositional surface range from 1 : 500 to 1 : 3000 (mostly 1 : 600–1 : 2000), of upper surface from 1 : 380 to 1 : 2000 (mostly 1 : 500–1 : 1000). Gradients tend to become less from north to south. On lower surface, the plains stand <10–50 ft (mostly up to 30 ft) above level of nearby flood-plains; on higher surface, 10–150 ft (mostly 20–50 ft). Local slope of plains is mostly low to high gradient, rarely very gentle slope, with gentle convexities towards dissection slopes. Dissection slopes and valley floors occupy <20% (normally 5–10%) of any one occurrence. Dissection slopes mostly moderate to moderately steep towards incised small streams and gullies, but usually steep to very steep along margins with adjoining alluvial plains. Very gently sloping narrow (20–50 yd) bench terraces 10–20 ft below plain level occur locally along streams. Southern edges of land system mostly frayed, with narrower plain sections and wider valley floors. A slightly different type of plain occurs in south-western corner and is more undulating due to many very shallow (<15 ft) flat-floored long and narrow (30–50 yd) or wider rounded drainage depressions, bounded by very gentle to moderately steep slopes. Level ground in most cases has a microrelief of rounded depressions (rarely irregular trenches), 1–2 ft wide and 6–8 in. deep, covering 5–40% of area. Small gullies up to 30 in. deep can be present near margins.

Streams and Drainage (Fig. 9(*e,f*)).—Open pattern with dendritic, subparallel, or radial elements of very small second- to third-order streams, with irregularly spaced short first-order tributaries that are no more than back-cutting gullies. Stream beds 2–6 yd wide, commonly with 3–6-ft-high vertical banks separating them from very narrow (5–20 yd) discontinuous flood-plains. They have very little or no gravel and very low gradients, except in many first-order streams with gradients up to very gentle slope. Where streams are located in grassland there commonly is no proper channel, only a concave valley floor probably formed by colluviation. Such valleys have strongly intermittent flow, whilst normal streams, except for the smallest, appear perennial.

Surface run-off appears very low relative to through drainage and streams appear fed mostly by lateral subsurface flow over slowly permeable clays and by slow through-drainage seepage; flood spates are probably rare. Plains are mostly poorly drained, less commonly imperfectly drained, and rarely well drained or very poorly drained; dissection slopes are mostly imperfectly drained; and valley floors probably imperfectly drained to swampy.

Vegetation.—Mid-height grassland (G) covers 52% and fern vegetation, often with sedges common (HD), another 8%. Grasslands of better-drained areas are 3–4 ft high, dense, and of mixed species composition. Sedges generally less common than in Nigre (26). *Themeda australis* occasionally predominant. In more poorly drained areas height is 4–6 ft, *Ischaemum barbatum* is dominant, and *Arundinella setosa* common; other grasses and sedges still mixed with these except in drainage depressions. Mid-height forest, partly with an irregular canopy (Fmi) and partly a small-crowned canopy (Fms), occurs over about 25%, often in tracts surrounding grasslands but also on slopes fringing valley floors. Also some tall forest with an irregular canopy (Fi, 5%). In valleys is mid-height forest with an irregular canopy and sago palms in the understorey (FmM, 8%), in places with *Campnosperma* predominant in canopy (FmCM, 1%). It merges into an open canopy type (FmoM, 2%) in wider valleys.

Geology.—Pleistocene and minor sub-Recent alluvium, mainly clay loam, silty clay, and clay, with intercalated sandy clay loam to sandy clay beds, locally with low to high amounts of quartz and other gravel.

Weathering and Soils (27 obs.).—Low surface plains are generally shallowly to very shallowly maturely, more rarely immaturely, weathered. No observations on upper surface plains which are expected to be similarly or slightly more weathered. Low-lying plains along Yimi (Bongos) River appear skeletally to immaturely weathered, whilst immature weathering was observed on a bench terrace in the west. Weathering on dissection slopes varies from very shallow mature to skeletal.

Probable soil composition is UAPB2, UAPU2, UAOU, UOPB common; IAUO1, IODA2, AAU2, AAOU, AAOO, UAU, UAOO, UAPU1, UAPB1, UOPA1, UUP, OANU minor. Variety of soils with basically similar properties occurs on plains. Together these can be described as strongly to very strongly, more rarely moderately developed (AAU2, UAOO,* UAUOU), acid to strongly acid, moderately thick to thick (rarely moderately thin), mostly moderately to strongly gleyed (AAU2, UAU, UAOO, UAOU, UAPB1, 2, UAPU1, 2), more rarely slightly gleyed (UOPA1, UOPB, UUP), plastic or firm clay to very plastic or very firm heavy clay soils, with 6–18-in.-thick coarser-textured very friable loam to sandy clay loam or friable to firm clay loam surface horizons. Most have prominently red, brown, and light grey mottled subsoils (UAPB1, UAPB2, UAPU1, UAPU2, UOPA1, UOPB, UUP). Low to high amounts of brown and black concretions or bleached fine sand and silt common in subsurface horizons. A similar but only moderately developed soil (AAU2) observed on bench terrace along a stream. Very rarely and probably only on higher parts occur very strongly developed, strongly acid, moderately thick to thick, non-gleyed, friable clay to silty clay soils with very friable loam topsoils (OANU). With rare exceptions (UOPA1, UAOO), all have thick to moderately thick dark topsoils. On some low-lying plains, notably one along Yimi (Bongos) River, slightly to moderately developed soils were observed, consisting of weakly acid, moderately thick, moderately gleyed, very plastic to very firm silty heavy clay to heavy clay, with friable clay loam over firm to plastic clay surface horizons, up to 18 in. thick, and with moderately thick (AAOU) or thin (AAOO) dark topsoils. Similar moderately developed soils together with acid, moderately thick, slightly gleyed, uniformly textured clay loam to heavy clay soils (IODA1, 2) were observed on dissection slopes, but in some localities strongly developed soils (UAPB2 observed) may continue almost to bottom of valleys, where the profile may be exposed in small breakaways. No observations on forested valley floors, but concave or flat drainage depressions in grassland have slightly developed, acid, thin, moderately to strongly gleyed clay or clay loam soils overlying heavy clay substrata and having thick dark topsoils (IAUO1, IAUO2).

Population and Land Use.—Population of 560 distributed over three villages. Present land use covers only 1·1 sq miles (1% of area), 28% in land use intensity class 3, 72% in class 4. Most land use by population is on adjoining Screw (18) and on a small atypical area of Pandamp (6).

Transitions to Other Land Systems.—Rather arbitrary gradational boundaries with similar but more dissected Burui (29) and more similar but generally slightly lower and wetter Nigre (27). Many

* Derived from observations made during 1959 survey of Wewak–Lower Sepik area, not described in this report. It is very similar to UAOU soils but has only a thin topsoil or no dark topsoil.

boundaries with Nagam (16), Misinki (14), and Screw (18) based purely on vegetation differences (see discussion in Nagam (16)).

Forest Resources (2 obs.).—Forest covers 30%; very low to low forest resources. Low stocking rate forests (Fmi, 12 sq miles; Fms, 10 sq miles) and a high stocking rate forest (Fi, 6 sq miles) occur exclusively on the fan plains and dissection slopes. The alluvium carries low stocking rate forest (FmoM, 1 sq mile) on poorly drained areas. Another forest complex of low stocking rate (Fms/FmM, 5 sq miles) occurs on both land forms. Access category W.

Agricultural Assessment.—High capability for improved pastures and moderate capability for arable crops, but low capability for tree crops and irrigated rice. Poor drainage and poor physical soil properties are main limitations, except for rice, and are most serious for tree crops and least for improved pastures. Only partial improvement of drainage status probably attainable by construction of ditches or graded grassed watercourses but this should be sufficient for pastures and a limited range of arable crops. Erosion hazards on plains generally slight, but should be watched where soils with coarse-textured surface horizons over slowly permeable subsoils are to be permanently cropped. Soil acidity a contributory limitation, except for tree crops, as is surface unevenness of microrelief which necessitates grading for cropping and rice-growing and in some cases for improved pastures. Irrigated rice best grown on areas not too high above river levels in adjoining land systems, but even here irrigation water can only be brought by pumping or long channels from upstream weirs. Inundation by rain water feasible over large parts, but was not considered in assessing capability for irrigated rice. Terracing of rice bays will commonly be required. Soil nitrogen contents are moderate to low, generally higher on plain surfaces and in grassland valleys and lower on dissection slopes. Phosphate and potash contents generally very low (more rarely low) on old surfaces, whilst in grassland valleys low contents appear to dominate very low. Younger terrace surfaces tend to have low phosphate but high to very high potash contents. On dissection slopes phosphate and potash contents vary greatly from very low to high. In water balance zone I is rather rare to rather frequent slight soil water stress in most soils except the wettest.

Engineering Assessment.—Minor topographical limitations for road construction. Stream crossings require only culverts or small bridges and approaches are easily graded in the unconsolidated sediments. Roadside drainage needs attention and in slight depressions roads may have to be built up. No road-surfacing materials apart from probably very limited quartz gravel and iron concretion deposits. Brightly mottled subsoils unlikely to harden irreversibly upon thorough drying and be used as low-grade laterite for road surfacing. Subsoils probably poorly but underlying less-altered sediments moderately suitable for subgrade. For unmade roads a dark topsoil is best removed, but any coarser-textured soil between it and the clay subsoil should be preserved on road surface, because subsoils become very boggy and slippery in wet weather. Soils are predominantly CH with a thin veneer of MH, CL, ML, or OL; minor CH; and minor MH with a veneer of ML; all are very deep. Topography suitable for airfield construction, particularly in a roughly north–south direction, but drainage will require special attention. If airstrip surface is to remain in grass topsoils are best left intact, but careful grading necessary because of microrelief.

(29) Burui Land System (108 sq miles)

Land Forms (Plate 13, Fig. 1).—Undulating to flat dissected plains occur mostly at higher of two regional depositional surface levels, but also comprise dissected parts of the generally less dissected lower surface. Altitude ranges from 190 to 350 ft; 89% below 250 ft. Relief mostly between 20 and 80 ft. Calculated overall gradients range from 1 : 180 to 1 : 670 (mostly 1 : 220–1 : 600) at upper level, from 1 : 600 to 1 : 2500 (mostly 1 : 600–1 : 2000) at lower level. At higher level, plains stand 10–170 ft (mostly 20–100 ft) above level of nearby flood-plains; at lower level, $<$10–40 ft (mostly 10–40 ft). Plain sectors occupy 15–80% of any one occurrence; remainder consists of dissection slopes and valley floors. Thus individual plain sectors vary greatly in width, probably from 150 to 700 yd; local slope varies from low gradient to gentle slope. Gentle slopes of undulating plain sectors mostly straight or convex, but locally slumped and concave, backed by short (10–20 ft) steep slump walls. Slight microrelief of rounded depressions up to 9 in. deep and 36 in. wide occurs in places on nearly level plain sectors. Dissection slopes mostly moderate to moderately steep towards incised small streams and gullies, but steep to very steep along margins of Burui near adjoining alluvial plains. Valley floors probably 20–70 yd wide, but wider near strongly frayed southern margins of land system where proportion of plain sector is always relatively small. In a narrow occurrence in the east are two clearly separated alluvial terraces 20 and 40 ft above nearby flood-plain, which are probably related to an old course of Nanu River.

Streams and Drainage (Fig. 9(*f*)).—Stream pattern essentially similar but considerably closer than that of Yambi (28), and there are a few fourth-order and commonly longer first-order streams. Stream characteristics same as for Yambi (28) except largest streams are up to 10 yd wide.

Surface run-off low in relation to through drainage but can result in common flooding of narrow flood-plains along larger streams. Level plains are predominantly poorly, in some cases imperfectly drained; position reversed on gently sloping plain sectors and dissection slopes. Valley floors poorly drained to swampy.

Vegetation.—Mid-height grassland (G) covers 52%, tall forest with an irregular canopy with light-toned crowns (Fid) about 7%, and mid-height forest with a small-crowned canopy (Fms) another 8% on both plain sectors and dissection slopes. Grasslands about 3 ft high consist usually of an open layer of taller grasses and sedges over a denser ground cover of smaller species. Occasionally one or more species are especially common, e.g. the grasses *Themeda australis*, *Ischaemum fragile*, *I. barbatum*, *Eriachne squarrosa*, *Alloteropsis semialata* and the sedges *Rhynchospora rubra* and *Fimbristylis* spp. In more poorly drained areas grasslands are higher and denser and *Ischaemum barbatum*, *Arundinella setosa*, and *Ophiuros exaltatus* predominate.

Valley floors have mid-height forest with an irregular canopy and sago palms in understorey (FmM, 14%). Some mid-height forest with an open canopy, occasionally with *Campnosperma*, and sago palms in understorey (FmoM, FmoCM, 2%) found on wider valley floors. About 17% of land system covered by secondary vegetation that commonly includes exploited sago palm vegetation (R-FR/MR).

Geology.—Pleistocene alluvium, mainly clay and clay loam, locally sandy clay and sandy clay loam, and very locally with small amounts of quartz and other gravel. In northern upper parts these sediments are locally semi-consolidated, indicating a gradual transition to Pliocene sedimentary rocks of Yindigo (31).

Weathering and Soils (21 obs.).—Level and gently sloping parts of plains nearly always shallowly maturely weathered, on higher- as well as lower-level surface. Shallow skeletal weathering observed only on very low-lying, very gently sloping lower-level surface remnant near Sepik River. This agrees with other evidence of less weathering or partial stripping of weathered zone in Pagwi–Burui area. The few observations suggest steeper dissection slopes are shallowly immaturely to skeletally weathered.

Probable soil composition is UUP, IODA2, UAPB2, UOPA3, UAPU1 common; UOPA1, 2, UOPB, AUTA1, MUAO1, IAUO1, EAHU1 minor. Soils of almost level plain sectors are very strongly developed, rarely strongly developed (UOPA1), strongly acid (in some cases acid), moderately thick to very thick (mostly thick), moderately to slightly gleyed, very firm to very plastic silty heavy clay to heavy clay, with coarser-textured very friable loam to firm clay loam surface horizons 10–18 in. thick. All these soils have prominently red, brown, and light grey mottled subsoils (UAPB2, UAPU1, UOPA1, 3, UOPB). Soils on gentle slopes are generally similar but commonly not as strongly developed, apparently never very thick, and always only slightly gleyed. Coarser-textured surface horizons slightly thicker here and consist more of fine sandy loam to loam than of clay loam (UUP, UOPA2, 3). Black and brown concretions occur only sporadically in soils of plains but bleached silt common in subsurface layers. On a slumped gentle slope was a moderately developed, acid, moderately thick, slightly gleyed plastic clay soil with a 14-in.-thick almost loose loamy sand surface horizon (AUTA1). A very gently sloping low-lying occurrence near the Sepik River had a moderately developed, weakly acid, moderately thick, slightly gleyed, very firm to very plastic silty heavy clay soil with a more friable clay loam surface horizon and thick dark topsoil (MUAO1), which is similar to some soils described for lower plains of Yambi (28) near the Yimi (Bongos) River. Strong correlation between topsoil colour and vegetation; soils under grassland have a moderately thick to thick dark topsoil (except for soils on a slumped slope (UOTA3) and on a moderately steep dissection slope (IODA2)), soils under forest have no dark topsoil or only a thin one (UOPA1, 2, 3). Soils on dissection slopes include strongly weathered, moderately thick, acid, slightly to moderately gleyed, very plastic heavy clay soils, with 10–19-in.-thick very friable sandy loam to firm clay loam surface horizons and prominently red, brown, and light grey mottled subsoils (UAPB2, UUP) on moderate slopes and a moderately developed, moderately thin, weakly acid, slightly gleyed, friable to plastic, rather uniformly textured clay soil (IODA2) on a moderately steep slope. Two different valley floor soils were observed: in a concave, colluvially aggrading grassland valley occurred a slightly developed, weakly acid, moderately thin, moderately gleyed, plastic clay soil overlying a very plastic heavy clay substratum and having a thick dark topsoil (IAUO1); in a narrow forested flood-plain was an undeveloped, weakly acid, moderately deep, moderately gleyed, firm to plastic clay over silty heavy clay soil (EAHU1).

Population and Land Use.—Population of 1510 distributed over 10 villages. Present land use covers 17·1 sq miles (16% of area), 5% in land use intensity class 2, 21% in class 3, 50% in class 4, and 24% in class 5. Exploited sago important in subsistence, particularly in south-east. Land use only in eastern occurrences where many villages also use land in adjacent Screw (18).

Transitions to Other Land Systems.—Many boundaries with Yambi (28) and more rarely with Kworo (30) are arbitrary and gradational. Boundary with Musendai (32) near Nanu River arbitrarily placed to include grassland in Burui. Here the typical fan plain pattern of Burui merges imperceptibly into the terrace bench pattern along major rivers, characteristic of part of Musendai (32), showing the close relationship between the two land systems.

Forest Resources (3 obs.).—Forest covers 18%; very low forest resources. Low (Fms, 5 sq miles) and moderate (Fid, 1 sq mile; Fid/FR, 1 sq mile) stocking rate forests found exclusively on fan plains and slopes, while low (FmoM, 1 sq mile) stocking rate forest is found on alluvium. Forest complexes found on both are of moderate (Fid/FmM, 8 sq miles) or low (Fms/FmM, 6 sq miles) stocking rate. Secondary forest (FR, 1 sq mile) of low stocking rate also occurs. Access category W, whilst minor access problems from dissection slopes may also be experienced.

Agricultural Assessment.—Moderate capability for improved pastures and low capability for arable crops and particularly tree crops and irrigated rice. Generally lower rating than for Yambi (28) is largely attributable to higher erosion hazards in this more dissected terrain, which are only partly offset by lesser drainage problems. The fact that poor or imperfect drainage persists in soils on slopes indicates that it is mostly caused by inherent slow permeability and will therefore be difficult to rectify completely. Soil acidity appears a slightly greater limitation than in Yambi (28). Flooding is a hazard in narrow flood-plains. Steeper slopes and greater height above river levels mean only small areas can be irrigated for rice-growing without involving major works. These comprise some low-lying plains, flood-plains, and valley floors. A characteristic of Burui is uniformity of land capability over large areas. Development for pastoral activities appears the most appropriate. Soil nitrogen contents are mostly low but moderate on low-lying plains, valley floors, and more rarely on dissection slopes and upper surfaces. Phosphate contents nearly always very low but low values occur on small low-lying areas and alluvial valley floors. Potash contents mostly very low but low values not uncommon on upper surfaces and common on low-lying surfaces and dissection slopes; moderate values common on dissection slopes and high values on alluvial valley floors. In water balance zone 1 there is rather frequent slight soil water stress, particularly in UOPA3, UUP, UOPB, and UOPA2 soils, and possibly rather rare to rather frequent severe soil water stress for shallow-rooting crops.

Engineering Assessment.—Conditions for road construction mainly very similar to those in Yambi (28) except topographic limitations are greater, requiring more small bridges and culverts and more earth movement for road cuttings, or construction of more winding roads. Soils are predominantly CH (locally MH) with a thin veneer of MH, CL, ML, OL, or SC; minor CH, MH; all very deep.

(30) Kworo Land System (113 sq miles)

Land Forms (Plate 13, Fig. 2).—Very low, and in the south commonly ultra-low, finely to very finely branching accordant hill ridges with, in any one occurrence, up to 10% flattish crestal remnants of an original plain surface. Land system always occurs as upper of two or three regional depositional surface levels. Altitude ranges from 210 to 400 ft; 67% below 250 ft. Relief decreases from north to south and is mostly 40–120 ft with extremes of 20 and 150 ft. Calculated overall gradients, which may be indicative of original surface gradients but could locally have been increased by erosion, range from 1 : 170 to 1 : 1000 (mostly 1 : 180–1 : 500) and generally decrease from north to south. Some hill slopes are convex to straight and either smooth or with many very fine spurs and grooves; others are concave and strongly benched or slumped. Smooth convex slopes (probably 33% of area) appear stabilized and the result of a past phase of dissection. They include some rolling terrain on high interfluves, rather than branching ridges. The concave slumped slopes (probably 55%) appear essentially unstable and associated with present-day dissection. Transitional stages occur in the forms of the finely spurred convex slopes and smooth concave slopes. Overall hill slopes are moderately steep, less commonly moderate or steep. Local slope on slumped ridges varies from very gentle to moderate on slump and bench floors to steep to very steep on slump and bench walls. Slumping patterns consist of fairly regularly spaced slump benches extending along ridges for up to 0·5 mile, or of parabolical individual slumps commonly separated by low spurs, or of chaotic hummocky relief of 10–20 ft. Ridge crests are mostly knife-edged to very narrow, in places clearly rounded and narrow; they may be even, undulating, or somewhat peaked. Slumped ridges commonly have emergent crests with very short steep to very steep side slopes. Crestal surface remnants (probably 5%) mostly have very gentle slopes and are 30–160 yd wide. Microrelief depressions up to 12 in. deep found on some flat crestal surfaces. Where ridge patterns are dense, valleys are usually very narrow, but in many other cases there are 20–140-yd-wide valley floors (probably 8%) that in grassland areas are generally concave and normally very gently to gently sloping. Mounds 6 in. high or depressions 6 in. deep occur commonly in grassed valley floors.

Streams and Drainage (Fig. 10(*a*)).—Dense dendritic to subparallel pattern of very small mostly first- to third-order streams. In forested valleys the mostly perennial streams are 2–8 yd wide, 4–6 ft incised in discontinuous flood-plains, or cut directly into Pleistocene sediment. Stream beds have no gravel or very small amounts, and gradients probably vary from low gradient in larger streams to very gentle slope in some first-order tributaries. In lower parts of Kworo these streams commonly disappear in slightly wider unchannelled valleys of very low gradient or less. Grassland valleys (of first and few of second order) have no defined channels, and flow is intermittently overland after heavy rain and slow subsurface at other times. Surface run-off probably moderate in relation to through drainage, and minor flood spates probably common and will only rarely exceed bank level.

Swampy lower valley floors probably inundated for 3–5 months per year to a depth of 1–3 ft. Drainage status variable: convex or straight slopes well to imperfectly drained; slumped slopes imperfectly to poorly drained, locally well drained or very poorly drained; crestal flats well to poorly drained; grassland valley floors poorly drained and valley flood-plains imperfectly to very poorly drained.

Vegetation.—Some areas covered mainly by mid-height grassland (G, 29%), others by mid-height forest with a small-crowned canopy (Fms, 34%) or tall forest with an irregular canopy with light-toned crowns (Fid, 11%). Grasslands are 4–5 ft high, dense, with *Themeda australis* dominant and *Ischaemum barbatum*, *Ophiuros exaltatus*, *Sorghum nitidum*, and/or *Arundinella setosa* common or codominant. In areas with a thin dark topsoil or without a dark topsoil species composition is more mixed, with no species predominant and sedges common. In slump alcoves *Ischaemum barbatum*, *Arundinella setosa*, and *Scleria ciliaris* form an open to rather dense storey over a rather dense ground layer of small sedges, e.g. *Scleria caricina*, or fine grasses, e.g. *Isachne* sp., and of *Xyris pauciflora*, *Eriocaulon australe*, and *Lycopodium cernuum*. Valley bottoms are covered by very dense 4–5-ft-high grassland dominated by *Ischaemum barbatum* and *Arundinella setosa*, with *Ophiuros exaltatus* and *Scleria ciliaris* usually common, or carry mid-height forest with an irregular canopy and sago palms in the understorey (FmM, 9%) which merges into the open canopy type (FmoM, 2%) in wider valleys. Secondary vegetation only of minor importance (5%), mainly of secondary forest (FRy-FR) occurring as patches in undisturbed forest.

Geology.—Pleistocene alluvium and fanglomerate, predominantly clay loam and clay, commonly interbedded with sandy clay loam to sandy clay and locally containing small quartz and other gravel. In northern upper part these sediments are locally semi-consolidated, indicating a gradual transition to the Pliocene sedimentary rocks of Yindigo (31).

Weathering and Soils (19 obs.).—Weathering rather variable and difficult to assess precisely. The flat crestal surface remnants seem generally shallowly to deeply maturely weathered, the latter particularly in areas with predominantly convex slopes, on which shallow mature weathering is also evident, and initial slumping is taking place in the weathering zone, so that most slump benches and alcoves also consist of maturely weathered material. In contrast, in one area with common surface remnants but common concave slopes, shallow immature and even skeletal weathering was observed on the slopes. This indicates rather complex relationships between land form and weathering. As generally expected, only shallow immature weathering was found on slopes as well as on very small surface remnants in areas of strong and apparently active slumping. This suggests that in such situations surface stripping also takes place. Where smooth concave slopes appear to have resulted from slope stabilization after earlier strong slumping, shallow mature weathering was observed on lower slopes.

Probable soil composition is IODA2 subdominant; UOPB, UAOU, UOTO3, OANT1, AAU1 common; AAU3, OANU, IAUO1, IAUO3, EUHA3, EAY3 minor. In areas of essentially stable, very strongly weathered, predominantly convex slopes and surface remnants occur very strongly developed, strongly acid, thick (locally moderately thick on slopes), friable to firm clay loam, silty clay, or clay soils, with 5–10-in.-thick coarser-textured very friable to friable loam, sandy clay loam, or clay loam surface horizons, and commonly with moderately thick dark topsoils (OANU) that can be absent on steep slopes (OANT1). Such soils were observed on crests, slopes, and slump benches. Also observed on slopes was a strongly developed acid, moderately thick, hard to very firm sandy clay with a 10-in.-thick very friable sandy clay loam surface horizon (UOTO3). Since all these soils contained at least some quartz gravel, and some also much quartz sand, their formation may be related to relatively coarse-textured sediments, and similarly weathered but much more plastic and clayey and more mottled soils may occur in similar situations on finer-textured sediments. An example of the last soils is the very strongly developed, acid, moderately thin, slightly to moderately gleyed, very firm to very plastic silty heavy clay over plastic silty clay soils, with 9-in.-thick coarser-textured very friable to firm clay loam to clay surface horizons and moderately thick dark topsoils (UOPB), found on what appear to be originally slumped but now stabilized concave slopes. They have prominently red, brown, and light grey mottled subsoils. In areas being more actively denuded by slumping and erosion, common soils, occurring mainly on slopes but locally also on crests, appear to be moderately developed, acid, moderately thin to moderately thick, moderately gleyed, uniformly textured, friable to firm or hard clay loam, silty clay loam, silty clay, and clay soils (IODA2). All four observations of this soil family were under forest. Associated soils observed in grassland are moderately (to strongly) developed, acid, moderately thin to moderately thick, moderately gleyed, very plastic silty heavy clay or heavy clay to plastic clay soils, with a 9-in.-thick friable clay loam surface horizon and moderately thick (UAOU) to thick (AAU1, AAU3) dark topsoil. Soils observed in grassy colluvial valley floors and small slump alcoves were slightly developed, strongly acid to acid, thin, moderately to strongly gleyed, very dark, very friable to slightly plastic clay loam to sandy clay loam soils, overlying similarly textured substrata (IAUO3) in areas of very strong weathering; also similar but acid to weakly acid clay soils overlying very plastic clay to heavy clay substrata (IAUO1) in areas of less weathering and more active slumping. On forested flood-plains occur undeveloped, weakly acid, moderately deep clay to heavy clay alluvial soils, ranging from slightly gleyed soils (EUHA3) in upper valleys to very strongly gleyed soils, commonly with little cohesion in upper part due to over-saturation with water (EAY3) in swampy lower valleys.

Population and Land Use.—Population of 730 distributed over three villages. Present land use covers 4·7 sq miles (4% of area), all in land use intensity class 5. Although villages make some use of land in adjoining Sandri (35), low land use intensity is also caused by predominance of sago exploitation in subsistence.

Transition to Other Land Systems.—Very similar in pattern to Yindigo (31), and the two always merge gradually. They are separated mainly to indicate the approximate boundary between consolidated Pliocene and unconsolidated Pleistocene sediments, but there appears to be no sharp natural break there either. Kworo generally has slightly lower relief and a denser and more intricate ridge pattern than Yindigo (31). Where Kworo borders Sandri (35) there is usually a clear break in pattern, if not in relief. In many places Kworo merges gradually into Burui (29), and the boundaries simply separate areas with <10% from those with >15% of remnant flat crestal surfaces. These percentages seem to represent a fairly clear break as no occurrences were observed with 10–15% of remnant surfaces.

Forest Resources (6 obs.).—Forest covers 47%; low forest resources. Low stocking rate forests (Fms, 21 sq miles; Fms/FmM, 22 sq miles) cover much of forest area. In northern parts are moderate stocking rate forests (Fid/FmM, 10 sq miles; Fid, 3 sq miles; Fid/FR, 2 sq miles). Two types of complex forests (Fid and Fms) occupy hill sites and another two (F and FmM) valley floors. Secondary forest (FR) occurs on both sites. Access category IIw.

Agricultural Assessment.—Moderate capability for improved pastures, low capability for tree crops, and very low capability for arable crops. Erosion hazards are main limitation, particularly for arable crops. Equally significant limitations for tree crops are drainage deficiencies and insufficient effective soil depth, and apart from some small areas Kworo appears unattractive for tree crop plantations. Improved pastures seem most adaptable to these conditions although capability has been unfavourably influenced by high soil acidity. Scope for pastoral development, particularly since much of area is already in grassland and provision of stock water would not present problems. Careful management is required since over-grazing could lead to serious soil erosion. Poorly drained to swampy valley floors could be utilized for rice-growing, either with rain-water irrigation or under conditions of semi-controlled flooding. Soil nitrogen contents generally low, but usually moderate on valley floors and locally moderate on slopes. Phosphate contents very low, except on small alluvial valley floors where they are high to low. Potash contents low, in a few cases very low, on more weathered, more stable slopes; low to moderate on slightly less weathered slumped slopes; and mostly high on valley floors, but low where valleys are associated with strongly weathered slopes. In water balance zone I, rather frequent slight soil water stress for shallow-rooting crops on upper slopes.

Engineering Assessment.—Low relief and scarcity of steep slopes mean only moderate topographical problems in road building. North–south roads will require few, east–west roads many, small bridges or culverts. Earth-moving in road cuts will be a simple operation in the unconsolidated sediments. One of the biggest problems could be sagging of road surfaces by slow slumping in many parts of land system. Good roadside drainage with many culverts might largely solve this problem. Soil materials commonly more suitable as subgrade than those of adjoining Burui (29) and Yambi (28). Although quartz gravel and sand deposits appear larger than in these two land systems, road-surfacing materials could still be very scarce. Soils are CH, MH; and CH and some MH with a thin veneer of MH, CL, ML; all are very deep.

(31) Yindigo Land System (128 sq miles)

Land Forms (Plate 14, Fig. 1).—Very low generally accordant hill ridges that tend to be branching or have an irregular pattern, but are locally subparallel. Ridges are broad, or very broad if poorly expressed wide short spurs are included. Altitude ranges from 210 to 700 ft; 40% below 250 ft. Relief is generally 100–200 ft. Hill slopes range from gentle to moderately steep but are predominantly moderate. They are normally convex (probably 45% of area), but concave where slumped (probably 37%). Prominent small slump alcoves common in several areas; in other cases ridges have slump benches, which in rare cases lead to presence of emergent residual crestal ridges. Short steep slopes occur locally near incising rivers and very short precipitous slopes can be present above slumps. Ridge crests (probably 15%) are rounded or level and narrow to broad, rarely very broad; broad crests represent remnants of an old surface. Crests are somewhat peaked with very gentle to moderate crestal slopes. This locally results in individual very low hills. In some instances wide apparent valleys consist largely of ultra-low convex residual ridges with gentle slopes, probably remnants of a younger surface cut below normal ridge crest surface. Southern and eastern parts include alluviated valley floors (probably 3% of area) 40–200 yd wide, mostly inclusions unmappable as Pandago (10) or Kabuk (9).

Streams and Drainage (Fig. 10(*b*)).—Moderately dense dendritic to subparallel pattern of long and predominantly north–south-flowing small first- to third- (rarely fourth) order streams with few very short tributaries. Most streams of local or near-local origin, and only one or two larger through-going rivers. Streams flow in shallow beds 2–15 yd wide and mostly shallowly cut into narrow (10–30 yd) strips of alluvium. Except for smallest headwaters they have low to very low gradients; lower courses disappear in wider swampy valleys without channels and blocked by the more vigorous aggradation in adjoining Screw (18), Nagam (16), or Misinki (14). No gravel or sand in stream beds. Surface run-off probably moderate in relation to through drainage, so flood spates are fairly frequent and many small streams may cease to flow after long rainless periods.

Hill ridges appear more often imperfectly to poorly drained than well drained. Small valley floors are poorly drained to swampy and inundated for long periods in wet season.

Vegetation.—More than 50% covered by secondary vegetation including grassland. Regrowth dominated by cane grass (*Saccharum*) (GtR) forms an important element in secondary vegetation, especially in north-east corner. Mid-height grassland (G) covers 12%; some tracts are dominated by *Imperata* *cylindrica*, others have a mixed composition in which *Themeda australis*, *Ophiuros exaltatus*, *Sorghum nitidum*, *Ischaemum barbatum*, and *Imperata cylindrica* are the most important. Tall forest with an irregular canopy with light-toned crowns (Fid) covers hill ridges in the north. Towards the south is mid-height forest with a small-crowned canopy (Fms) on crests and still farther south it extends also over slopes. Tall forest with a rather closed canopy (F) occurs on valley floors, but mid-height forest with an irregular canopy and sago palms in the understorey (FmM) where valleys are swampy. Areas covered by these are 23%, 18%, 3%, and 2% respectively.

Geology.—Pliocene rocks, predominantly mudstone, some siltstone, and minor intercalated sandy beds, probably subhorizontal to very gently dipping. Slopes locally covered with veneer of colluvium derived from the rocks but in places including remnants of Pleistocene fanglomerate.

Weathering and Soils (22 obs.).—Weathering generally shallow immature, rarely shallow mature, on both slopes and crests. Slopes with slump benches and some crests have only shallow skeletal weathering. Underlying rocks softened by generally strong, locally moderate hydration which possibly extends several tens of feet.

Probable soil composition is UOPB, IODA1, AAU1, UAPB1 common; UOPT, UOPA1, UOTO1, AAOO, AUTQ, AUTA3, MUHO2, IODE4, EUHO6, EUHO7, EUHA7, EAHU1 minor. On crests and on slopes not obviously slumped commonly occur very strongly to strongly developed, acid (rarely strongly acid), moderately thick to thick (rarely moderately thin), very plastic to very firm heavy clay to silty heavy clay soils with prominent red, brown, and light grey mottling, with 0·5–1·5-ft-thick coarser-textured friable to firm sandy clay loam, loam, clay loam, or clay surface horizons, and with thin to moderately thick dark topsoils. Some are moderately gleyed (UOPA1, UAPB1), some slightly gleyed (UOPB), and some not gleyed (UOPT). Also present on convex slopes in approximately equal proportion are moderately developed, weakly acid to acid, moderately thick to moderately thin (rarely thick), very firm to very plastic heavy clay to silty heavy clay (rarely clay) soils, either uniformly textured (IODA1, IODE4, MUHO2) or with 0·5–1-ft-thick coarser-textured, friable to plastic clay loam to clay surface horizons (AAOO, AAU1, AUTQ). Some are moderately gleyed (AAOO, AAU1), others slightly gleyed (IODA1, AUTQ). They commonly have thin to moderately thick or even thick (MUHO2, AAU1) dark topsoils. Although differences are not pronounced, soils on crests appear more often strongly developed and slightly more acid than those on slopes, whilst the latter, probably as a result of slight colluvial accumulation, have thicker coarser-textured surface horizons and more consistently dark topsoils. Soils on the lower-level hill ridges appear less developed than those on normal higher ridges.

Soils on slumped slopes and some foot slopes partly include moderately developed, weakly acid to acid, moderately thick to thick, very plastic to very firm heavy clay to silty heavy clay soils (rarely clay or sandy clay), generally slightly to moderately gleyed (IODA1, AUTA3, AAU1), generally with 0·5–1·5-ft-thick coarser-textured friable to firm sandy loam, clay loam, or clay surface horizons (AAU1, AUTA3, UOTO1) and rarely thick dark topsoils (AAU1). Also common are undeveloped, weakly acid to acid, deep to moderately shallow, firm to very firm or very plastic, slightly stratified silty clay, clay, or silty heavy clay colluvial soils (EUHO6, EUHO7) which are locally slightly gleyed (EUHA7) and commonly have thin dark topsoils. Only soil observed on narrow valley floor is an undeveloped, weakly acid, moderately shallow, moderately gleyed, very plastic heavy clay alluvial soil (EAHU1). In general, soils of alluvial valleys similar to those in Misinki (14) and Pandago (10).

Population and Land Use.—Population of 6340 distributed over 26 villages. Present land use covers 45·7 sq miles (36% of area), 15% in land use intensity class 2, 30% in class 3, 5% in class 4, and 50% in class 5. More intensive land use restricted to eastern occurrences. Exploitation of sago important in subsistence. Some villages also use land in adjoining Screw (18).

Transitions to Other Land Systems.—Pattern of Yindigo is in many places very similar to that of Kworo (30). Boundaries between the two are commonly arbitrary and located on the evidence of field sampling and "intuition" rather than clear differences in photo pattern. As explained, both land systems commonly naturally grade into each other. Generally, however, Yindigo has a coarser ridge pattern, more convex and gentler slopes, and a slightly higher relief. In some cases Yindigo can be transitional to most-dissected parts of Burui (29). Transitional patterns and gradual boundaries also common with Kaugiak (37) and Musendai (32), and to a lesser degree Sandri (35) and Sengi (42), Kaugiak (37) having a higher relief and longer more regular ridges, Musendai (32) a lower relief and gentler slopes, Sandri (35) being much more finely dissected, and Sengi (42) having higher relief and more irregular shorter ridges, commonly with remnants of rock structure.

Forest Resources (7 obs.).—Forest covers 43%; low forest resources. Much forest has a moderate stocking rate (Fid/F, 24 sq miles; Fid, 6 sq miles; Fid/FR, 2 sq miles; Fid/FmM, 1 sq mile). Low stocking rate forests (Fms, 10 sq miles; Fms/FmM, 10 sq miles; Fms/F, 2 sq miles; Fms/Fid/F, 2 sq miles) also occur. Access category Iw.

Agricultural Assessment.—Moderate capability for improved pastures, low capability for arable crops, and very low capability for tree crops. Unsuitable for tree crops mainly because of the poor physical condition and imperfect to poor drainage of the soils, while slump risks on slopes are a contributory factor. These factors are of less importance for arable crops and even less for improved pastures, although there might be some difficulties in pasture establishment. Erosion hazards are main limitation for these land uses. Capability for pastures is well up in the moderate class and this land use offers real possibilities also because stock water can be easily supplied from small dams erected in valleys and slope folds. Minor supporting cultivation of crops may be feasible. Narrow valley floors best used for sago production, pastures, and/or irrigated rice. Soil nitrogen contents mostly moderate, but commonly low. Phosphate contents mostly very low to low, rarely high, but in undeveloped colluvial and alluvial soils commonly moderate, less frequently low to very low. Potash contents range from high to low, with a few very high and very low values; they are mostly high, locally moderate in undeveloped colluvial and alluvial soils. Rather frequent slight, and rather rare severe, soil water stress, mainly on ridge crests and convex slopes.

Engineering Assessment.—Topography a minor limitation in road construction, although many small bridges and large culverts will be needed in E.–W. or SW.–NE. aligned roads. Road cuttings easily made in soils and underlying soft rocks, but may be liable to cave in. Major problems in road construction are: lack of road-surfacing materials, probably restricted to very small and thin surficial quartz gravel and iron concretion beds; low suitability of soils and upper rock strata for subgrade; difficulties in attaining good roadside drainage because of slow permeability; and a tendency to slumping on some slopes. Possible, but not likely, that some brightly mottled subsoils will harden irreversibly upon drying, and may be used as low-grade laterite for road surfacing. Unmade roads should utilize coarser-textured surface soils to reduce slipperiness and bogginess. Soils are CH, and CH with a thin veneer of MH, CL, ML; probable depths are moderately deep, deep, very deep subdominant, shallow minor. Several sites suitable for small airfields without undue earth movement, but surfacing and drainage problems are as for roads.

(32) Musendai Land System (45 sq miles)

Land Forms (Plate 14, Fig. 2).—Gently undulating to rolling interfluve surfaces, level to very gently sloping flat to undulating terrace benches along major rivers, and minor flood-plains and lower alluvial terraces. Altitude ranges from 300 to 1100 ft, 10% below 250 ft and 88% between 250 and 1000 ft. Interfluve surfaces and terrace benches appear to be remnants of a Pleistocene erosional/depositional surface, closely related to and partly contiguous with that of Yambi (28) and Burui (29). Interfluve surfaces (probably 35% of area) between 200 and 400 ft above levels of major rivers have mainly gentle slopes and a relief of 50–75 ft; in places slightly dissected with moderate to moderately steep slopes and a relief of 75–150 ft. Terrace benches are discontinuous and occurrences range in size from a few acres to 0·5 sq mile; largest occur between 60 and 100 ft above stream level and probably cover 40% of area. Locally, small benches (probably 10% of area) are found between 30 and 40 ft, and higher benches at about 150 ft occur in the north. At any one locality no more than two benches (excluding higher interfluve surface) were found. In several cases higher benches appear to merge rather gradually with interfluve surfaces and lower benches with lower alluvial terraces. Benches are mostly level, locally have a very gentle slope and in a few cases a moderate slope. They are partly dissected by steep-sided gullies or stronger dissection has locally resulted in flat-topped, steep-sided ridges. Some very steep to precipitous slopes occur where benches are undercut by streams. Relief nearly always <100 ft. Higher terrace benches and some very gently sloping parts of interfluve surfaces have a microrelief of trenches and some rounded depressions, 0·5–2·5 ft deep, 2–6 ft wide, and 6–50 ft long (rarely longer), and covering 20–50% of where they occur.

Lower alluvial terraces and flood-plains, probably 15% of area, are part of Musendai either as inclusions too small to be mapped as Papul (19) or because they have no clear boundary with the higher older benches. Terraces appear to be generally 10–20 ft above low river level, but one at least 50 ft high observed in the north is also considered younger than the Pleistocene terrace benches discussed. They are discontinuous, mostly level, and probably 50–200 yd wide. Flood-plains are 20–100 yd wide and similar to those of Papul (19).

Streams and Drainage (Fig. 10(*c*)).—Apart from major throughgoing rivers, there are few first- and second-order streams large enough to be recognized on aerial photographs. The drainage net consists mainly of closely to rather widely spaced dendritically arranged streamlets and gullies 1–5 yd wide, most of them probably with intermittent flow. Main streams similar to those described for areas south of mountain ranges in Papul (19).

Surface run-off appears mostly low relative to through drainage but moderate in more dissected areas; land system expected to have little influence on regional flood levels. The flood regime in valleys of major streams is as in Papul (19). Interfluve surfaces imperfectly to well drained and mostly well drained where dissected. Terrace benches imperfectly to poorly drained but younger lower terraces well drained.

Vegetation.—Large parts influenced by shifting cultivation which in some areas is intensive, leading to cane grass regrowth (GtR). Generally, however, rotation cycles are long and about 50% is under secondary forest (FRy-FR). Original cover was presumably tall forest with an irregular canopy mainly with, but also without, light-toned crowns (Fid, Fi). Such forests still cover about 18% and 4%.

On valley floors is tall forest with a rather closed canopy (F) (3%), with tall cane grass vegetation (GtS) along major streams. Mid-height grassland (G) with *Themeda australis*, *Sorghum nitidum*, *Ischaemum barbatum*, and *Imperata cylindrica* common is confined to one occurrence (2%).

Geology.—Subsurface rocks are Pliocene interbedded mudstone, siltstone, and, probably minor, sandstone; surface lithology uncertain. Some terraces along main streams, particularly in south, consist of probably Pleistocene alluvium, but other benches and some foot slopes are probably mainly mudstone and some sandstone, with or without a veneer of alluvium. On interfluve highs surface beds appear to be mudstone and siltstone, but local presence of well-rounded surface gravels could indicate remnants of Pleistocene fanglomerate. Another interpretation is that they accumulated by weathering and denudation from somewhat conglomeratic rocks, known to be locally interbedded in the Pliocene sequence, especially in the north. The information available indicates that the Pliocene rocks are subhorizontal to gently dipping (probably <10°). Recent alluvium, partly calcareous, occurs along major streams.

Weathering and Soils (17 obs.).—Interfluves and terrace benches mostly shallowly immaturely to maturely weathered, but on steeper interfluve slopes and lowest terrace benches weathering is shallow immature to skeletal. Underlying rocks appear strongly softened by hydration for some tens of feet. Flood-plains and lowermost alluvial terraces not weathered, although a very highlying occurrence in the north may have some skeletal weathering.

Probable soil composition is AUTA3, subdominant; UOPA2, IODE4, UOPT common; UAPB2, UOTB1, UOTA2, AAOO, AUTA2, EUHO2,4,5 minor. Soils of flatter interfluve surfaces and higher terrace benches are strongly to very strongly developed, acid (rarely strongly acid), moderately thick to thick (rarely moderately thin or very thick), very firm to very plastic heavy clay, silty heavy clay, and more rarely sandy heavy clay or clay soils, with 1–3-ft-thick coarser-textured (very friable sandy loam to firm clays in places gravelly) surface horizons, but no abrupt texture contrasts, and in some cases thin dark topsoils. Many have brightly red, brown, and light grey mottled subsoils (UOPT; UOPA2; UAPB2). Those on interfluves may (UOPA2) or may not (UOPT) be slightly gleyed; those on terrace benches are always slightly (UOTA2, UOPA2) to moderately (UAPB2) gleyed. On slightly steeper to moderately steep interfluve slopes are moderately developed soils that are weakly acid to acid, moderately thick to thick, very firm to very plastic silty heavy clay to heavy clay soils, slightly gleyed and with 1–1·5-ft-thick coarser-textured (friable loam to firm clay) surface horizons (AUTA2, AUTA3) or uniformly textured (IODE4). On lower terrace benches and moderate slopes of higher benches are moderately developed soils that are weakly acid to neutral (AAOO), moderately thick to thick, slightly to moderately gleyed, very firm to very plastic sandy heavy clay, silty heavy clay, or heavy clay soils with about 1-ft-thick firm to friable clay loam to clay surface horizons (AUTA3), in some cases with a moderately thick dark topsoil (UOTB1).

Soils on lower alluvial terraces include undeveloped weakly acid to weakly alkaline (EUHO2), deep to very deep, more or less stratified, friable to firm alluvial soils with textures from sandy loam to clay, and rarely with a thin dark topsoil (EUHO4, EUHO5). In general, soils on flood-plains and terraces will correspond with those for Papul (19).

Population and Land Use.—Population of 620 distributed over three villages. Present land use covers 28·7 sq miles (64% of area), 17% in land use intensity class 2, 40% in class 3, 22% in class 4, and 21% in class 5. Eastern occurrences mostly used by people in adjacent Yindigo (31), Kaugiak (37), and Seim (46).

Transitions to Other Land Systems.—In the south, boundaries with Yambi (28) and Burui (29) are arbitrary and placed to minimize amount of grassland in Musendai. They are necessary because Yambi (28) and Burui (29) consist solely of Pleistocene sediments, whereas Musendai includes a large percentage of Pliocene sedimentary rocks. Where relief increases slightly, Musendai is transitional to Yindigo (31), more rarely to Kaugiak (37) or Morumu (39). Where flood-plains and low terraces become an important component, Musendai is transitional to Papul (19) and mapping is open to doubt in some cases.

Forest Resources (7 obs.).—Forest covers 38%; low forest resources. Moderately high stocking rate forests (Fid/FR, 7 sq miles; Fid, 4 sq miles) and high stocking rate forest (Fi, 2 sq miles) occupy benches and interfluve surfaces. In the valleys is moderate to high stocking rate forest (F, 1 sq mile). Secondary forest (FR, 3 sq miles) of low stocking rate occurs throughout. Access category Iw.

Agricultural Assessment.—High capability for improved pastures, moderate capability for arable crops, low capability for tree crops, and very low capability for irrigated rice. Erosion hazards, soil acidity, drainage deficiencies, and microrelief are main limitations for arable crops and pastures, whilst poor drainage and physically poor soils in particular depress capability for tree crops. Apart from some narrow flood-plains and very steep slopes there is no land without any capability. Best land occurs on small young terraces above flood level. Marked differences throughout in land quality (waterlogging, soil depth, erosion hazards, etc.) which can only be determined by detailed survey. Dense population and small topographical limitations justify more precise study of land use capability. Irrigated rice-growing feasible only on small flattish terraces not too high above rivers. Rain-water ponding would make more land suitable for this crop. Soil nitrogen contents vary from moderate to low, locally very low, being lowest on flood-plain terraces and parts of upper bench surfaces. Phosphate contents mostly very low, locally low, but moderate to very high values common on low alluvial terraces and flood-plains. Potash contents vary from moderate to very low on flattish upper bench and interfluve surfaces, but are mostly high (locally very high or moderate) elsewhere. Rather frequent slight, and rather rare severe, soil water stress, except on lower alluvial terraces and flood-plains.

Engineering Assessment.—No serious topographical limitations for road construction, but roadside drainage and provision of culverts must be undertaken, because substrata are commonly slowly permeable. To reduce slipperiness of unmade roads full use should be made of coarser-textured surface soils, particularly where they contain gravel and/or iron concretions. Fine sandy surface soils acquire greater bearing strength when mixed with subsoil clay. Cut-and-fill operations easily carried out in weathered soils or soft rocks, which are probably only moderately suitable for subgrade. Road-surfacing materials appear very scarce and mainly restricted to local surface quartz and concretionary gravel, and minor quantities of hard rock gravel and sand in major river beds (including those of adjoining Papul (19)). Possible, but not likely, that brightly mottled subsoils will harden irreversibly upon thorough drying for use as low-grade laterite for road surfacing. Bridging of larger rivers probably main problem in road construction, but generally more easily achieved here than in Papul (19) because of gradual approaches to valley floors, with sedimentary rocks moderately suitable for foundations occurring either as outcrops or at shallow depth. Suitable sites for small airfields, although some levelling and grading will be needed. Soils dominantly CH with a thin veneer of MH, CL, ML, subdominantly CH, and minor CL, ML. Probable depths are very deep, moderately deep subdominant; deep common.

(33) Atitau Land System (7 sq miles)

Land Forms (Plate 15, Fig. 1).—Dissected mountain summit plateaux, with an overall slope of high gradient to gentle slope. They occur at altitudes of 2100–4300 ft, with 68% below 3500 ft. Plateaux have very low to locally low relief (up to 250 ft) and consist of hills and short ridges and spurs with moderately steep, smooth or grooved, and commonly slightly slumped slopes and very broad to very narrow crests. Very locally are valley floors up to 80 yd wide. Plateaux have sharply or poorly defined margins which are ravined.

Streams and Drainage (Fig. 10(*d*)).—Dense to very dense angular to dendritic pattern of very small first-order and some second-order streams, generally flowing in rock-cut narrow valleys of high gradient to very gentle slope, with rapids developing near margins of land system. Surface run-off probably low in relation to through drainage, resulting in streams being largely groundwater-fed and perennial with only minor flood spates. Well drained.

Vegetation.—Relatively high-altitude areas (about 75%) bear mid-height forest with a rather dark-toned even canopy (Fm). On steeper slopes it alternates with *Casuarina papuana* stands (Ca). At lower altitudes is mid-height forest with an irregular canopy (Fmi), locally in mosaic with seral stages (Fmi′), covering 10%. Of areas south of main ranges, surrounded by Flobum (44), one is covered by tall forest with an irregular canopy with light-toned crowns (Fid, 4%), another by older secondary forest (FRm, FR, 10%).

Geology.—Rocks are Upper Miocene interbedded mudstone, siltstone, sandstone, and fine conglomerate; in one case not more than 100 ft thick and overlying igneous basement rock. Possible but unlikely that gabbro or microdiorite is surface rock in some areas. In one occurrence conglomerate appeared to overlie limestone. Steep dips observed in one case.

Weathering and Soils (3 obs.).—Relics of a formerly more extensive weathered surface, largely destroyed following uplift. Weathering mature but mostly shallow.

Probable soil composition is UOTO5, OANT1, subdominant; (IODO1, IODO2) common. Principal soils are strongly developed, strongly acid to acid, thick to very thick, and either plastic to very firm silty heavy clay soils with friable silty clay loam to clay surface horizons (UOTO5) or friable silty clay soils with loam to silty clay loam surface horizons (OANT1). Less-developed soils probably occur on steep slopes of sharp-crested ridges.

Population and Land Use.—Population nil. Present land use restricted to 0·3 sq mile (4% of area) in land use intensity class 3, used by people from adjoining Flobum (44).

Transitions to Other Land Systems.—Air-photo pattern very similar to Yassip (38) and parts of Sandri (35); easily distinguished, however, by location in mountain summit areas. Patterns of Atitau and Dossett (34) are very similar, but they are kept separate because Dossett (34) is generally less hummocky and more spurred; Atitau is mostly associated with clastic sedimentary rocks and Dossett (34) mostly associated with igneous rocks and limestone; and Dosset (34) does not consistently occupy summit level positions but occurs at different levels associated with Kumbusaki (60).

Forest Resources (3 obs.).—Forest covers 71%; low forest resources. Most forest is composed of low stocking rate types, the first being confined to higher altitudes (Fm, 3 sq miles; FRm–FR, 1 sq mile; Fmi and Fmi/Fmi′, 1 sq mile approx.). Access category II, but very difficult to reach through surrounding rugged mountains.

Agricultural Assessment.—Mainly due to erosion hazards and irregular topography but also because of high soil acidity, there is only very low capability for arable crops, low capability for tree crops, and moderate capability for improved pastures. Mostly in altitudinal zone little suited for either normal lowland tree crops or typical highland crops. Excessive cloud and dampness may well restrict choice of crops that can be successfully grown. Agricultural development almost impracticable because of isolated, scattered, and inaccessible position of land system. Soil nitrogen contents probably mostly moderate, phosphate contents very low, and potash contents low to moderate.

Engineering Assessment.—No significance for construction of regional roads. Road could be built within land system without much difficulty, but access roads would have to traverse rugged mountainous and hilly terrain and would be prohibitively costly. No road-building materials available. Soils dominantly MH, subdominantly CH; probable depths are very deep dominant; moderately deep subdominant; deep common.

(34) Dossett Land System (4 sq miles)

Land Forms (Plate 15, Fig. 2).—Very finely spurred branching, very low hill ridges and apparently individual conical hills occurring on level to gently sloping surfaces at various levels associated with foothills, mid slopes, and summit areas of Kumbusaki (60). Altitude ranges from 1100 to 2400 ft, 79% below 2000 ft. Relief 100–200 ft for branching ridges, 50–100 ft for conical hills. These hills resemble cone karst, suggesting presence of limestone. Hill slopes mostly straight and steep, and hill crests very narrow to knife-edged.

Streams and Drainage (Fig. 14(*c*)).—Generally a very dense dendritic to feathery pattern of very small, very short streams, mainly first order but also second and third order. They are in very narrow rock-cut valleys, probably have stony or rocky beds of high gradient to very gentle slope, and are probably mostly perennial. Surface run-off probably moderate in relation to through drainage, giving rise to frequent small flood spates. No stream drainage detected in an area of low rounded hills, indicating it may be limestone with very low run-off. Well drained.

Vegetation.—Mostly covered by mid-height forest with an irregular canopy (Fmi), locally mixed with seral stages (Fmi′). Mid-height forest with a rather dark-toned even canopy (Fm) found in high summit areas (11%). At lower levels older secondary forest (FRm, FR) covers another 11%.

Geology.—No field data. Probably largely igneous basement rocks, possibly also limestone, siltstone, and mudstone of Miocene age.

Weathering and Soils (no obs.).—Aerial photos suggest shallowly immature to mature weathering. Probable soil composition is (IODO2, UOTO5, OANT2) subdominant; (MR–O2) common. Soils possibly similar to those for Kumbusaki (60), but weakly alkaline to alkaline, thin, very dark clay soils probably occur on any limestone hills.

Population and Land Use.—Population is nil. Present land use restricted to 0·3 sq mile (7% of area) in land use intensity class 5, occurring at lower altitude adjoining Morumu (39).

Transitions to Other Land Systems.—Transitional nature to, and differences from, Atitau (33) mentioned in latter. Dossett has generally gradual boundaries with Kumbusaki (60), with which it is intimately associated.

Forest Resources (no obs.).—Complete forest cover; moderate forest resources. Low stocking rate forests (Fmi, Fmi/Fmi′, 3 sq miles; FRM–FR, Fm, 1 sq mile), last type occurring at higher altitudes. Access category III.

Agricultural Assessment.—On the basis of topography alone, there appears to be only low capability for tree crops and improved pastures. Although of low relief, terrain appears too broken for general agricultural development; also severe limitations in accessibility. Portion above 2000 ft a.s.l. has climatic conditions suitable for neither most lowland tree crops nor most highland tree crops. Soil nitrogen contents probably mostly moderate, phosphate contents very low to low, and potash contents low to moderate.

Engineering Assessment.—Largely of no significance for regional road construction. Easternmost occurrence is part of a chain of land systems forming a belt of relatively less rugged terrain that could be significant if a road link was contemplated there between coast and interior. Road construction would still require a large amount of cut-and-fill construction with provision of numerous culverts and small bridges. It may contain sites suitable for quarrying stone. Soils are dominantly MH, subdominantly CH; probable depths are very deep, moderately deep subdominant; very shallow common.

(35) Sandri Land System (49 sq miles)

Land Forms (Plate 16, Fig. 1).—Very low to low, very closely branching, and very densely spurred accordant hill ridges with common steep small slumps, locally developing into small box canyons. Altitude ranges from 240 to 500 ft, 15% below 250 ft. Relief is mostly between 100 and 200 ft, rarely up to 250 ft. Ridge crests very narrow to narrow and together with short moderate to moderately steep upper slopes occupy about 25%. Crests vary from even to rather peaked, ridges are generally short. Land system mostly irregular steep to very steep lower slopes, locally with precipitous sections near streams and above slumps. Locally larger moderate to moderately steep slopes, partly dip slope remnants.

Streams and Drainage (Fig. 10(*e*)).—Dense dendritic pattern of small first- to third-order streams traversing and mostly originating north of land system. Most have very numerous, very short first-order tributaries, producing a very dense overall drainage network. Apart from one larger through-going river, main streams are 3–10 yd wide and have shallow rock-cut beds of low gradient but with a few bars of soft rock. Tributaries have gradients up to gentle slope; many may be intermittent, whilst in drier eastern part larger local first- and second-order streams may also have intermittent flow. Surface run-off probably high in relation to through drainage, but may be moderate in some areas of semi-consolidated sands. Because of low catchment/stream length ratio, flood spates probably frequent but of low intensity. Generally well drained, locally imperfectly drained on crests and gentle upper slopes.

Vegetation.—Tall forest mainly with an irregular canopy with light-toned crowns (Fid, about 43%) but also without these crowns (Fi, about 7%) found on crests and slopes, except near margins with Kworo (30) where mid-height forest with a small-crowned canopy (Fms, about 14%) occurs.

About 28% cover of secondary vegetation (R–FR), with older regrowth stages (FRy–FR) well represented. Small patches of mid-height grassland (G) occur in these parts. Sago (MR) planted in suitable situations.

Geology.—In the west rocks appear to be slightly consolidated compacted sand, commonly with fine gravel of weathered diorite and lenticular mudstone fragments (Lower Pleistocene: Sand River beds). In central and eastern parts rocks probably interbedded Pliocene sandstone, siltstone, and mudstone. Pliocene rocks appear gently dipping, whilst air photos suggest moderate dips in western part near boundary with Nuku (51) or Mambel (48).

Weathering and Soils (6 obs.).—Crests and upper slopes tend to be shallowly immaturely weathered, lower slopes only skeletally weathered. Rocks appear commonly softened by hydration well below main weathering zone, more so on lower slopes than crests. Overall it is a maturely dissected weathered surface.

Probable soil composition is IODE2 subdominant; IODE5, UOTA1, (EUHO8), IODO4, AUTO3, (IODL1) common. Soils on crests and gentle upper slopes moderately to strongly developed, acid, moderately thick to thick, hard to firm sandy clay or clay and firm to very firm silty clay to silty heavy clay soils that are uniformly textured (IODO4) or have coarser-textured friable sandy clay loam to clay loam surface horizons and are slightly gleyed (UOTA1). Steep to very steep hill slopes have moderately developed, weakly acid, moderately thin to thick, firm to friable sandy clay loam, clay loam, silty clay loam, sandy clay, and silty clay soils (usually somewhat sandier at depth) that are either uniform in texture (IODE2, IODE5) or have a coarser-textured, more friable surface horizon (AUTO3). Locally some rock outcrop on steepest lower slopes. No observations of soils of small slump alcoves.

Population and Land Use.—Population nil. Present land use 8·9 sq miles (18% of area), 3% in land use intensity class 3, 97% in class 5. Land used largely by people living in adjoining Kworo (30).

Transitions to Other Land Systems.—With gentler slopes and less dense stream pattern, transitional to Kworo (30) or Yindigo (31). Where relief is greatest, transitional to Emul (36), Kaugiak (37), or Morumu (39). Boundaries, particularly with Emul (36) and Yindigo (31), commonly somewhat arbitrary. In places photo pattern is very similar to Yassip (38), and the two would have been difficult to distinguish if they did not occur in areas widely separated geographically, although Yassip (38) generally has a coarser drainage pattern and less steep slopes.

Forest Resources (4 obs.).—Forest covers 78%; moderate forest resources. Wide variety of forests ranging from high stocking rate (Fi/F, 4 sq miles) through moderate stocking rate (Fid, 11 sq miles; Fid/F, 9 sq miles; Fid/FR, 3 sq miles; Fid/FmM, 1 sq mile) to low stocking rate (Fms, 6 sq miles; Fms/Fid/F, 1 sq mile; Fms/FmM, 1 sq mile; Fms/FR, 1 sq mile; FR, 1 sq mile). Access category III, since difficulties presented by steep slopes are mitigated by very low relief.

Agricultural Assessment.—Low capability for improved pastures and tree crops and very low capability for arable crops. Capability for pastures is clearly higher than that for tree crops. Limitations mainly erosion hazards, but for tree crops also imperfect drainage and insufficient effective soil depth, particularly on crests and upper slopes. Agricultural development will be hindered by rapid alternation of small flatter crests and very steep slopes almost resembling bad-land topography, and is not recommended. Soil nitrogen and phosphate contents range from very low to moderate. Potash contents are probably variable from very low to high. In water balance zone 1 is rather frequent slight, and rather rare severe, soil water stress in IODE4, IODL1, and UOTA1 soils and for shallow-rooting crops.

Engineering Assessment.—In general, road alignment along length of occurrences more difficult than across width, since latter commonly could follow ridge crests, running from SW.–SE. to NW.–NE., whilst former would cut across fine grain of land system. Road cuttings not difficult in the rather soft rocks that seem generally suitable for subgrade. Landslide hazards on steep slopes. Where needed, bridges can be small, or only large culverts are required. Road-surfacing materials scarce or of low quality (weathered sand with some gravel), although they may help to decrease surface slipperiness of unmade roads. Soils are CH, CL, ML, with minor MH and SC; probable depths are moderately deep predominant, shallow, very shallow common.

(36) Emul Land System (91 sq miles)

Land Forms (Plate 16, Fig. 2).—Finely branching or short parallel accordant low hill ridges with generally narrow crests, moderately steep commonly benched upper slopes, and steep to locally very steep lower slopes. Ridges separated by very narrow valleys and can have numerous short stumpy spurs. Altitude ranges from 240 to 1000 ft. Relief mostly 150–200 ft, in some cases up to 300 ft but rarely less than 150 ft. Ridge crests, even to undulating or stepped, range from short to very long, but commonly form intricate patterns. Lower slopes commonly slightly gullied or spurred and in places have small slump benches. Small slump alcoves occur locally. In some instances the land system appears to be bounded in the north-west by minor fault scarps.

Streams and Drainage (Fig. 10(*f*)).—Stream pattern of closely spaced subparallel very short first-order streams perpendicular to dendritically arranged and rather closely spaced second- to fourth-order streams. Streams mostly cut in rock and, except for one or two slightly larger rivers, 3–15 yd wide; beds are shallow but have little or no hard rock gravel. Largest streams have probably low gradients, but first-order tributaries mostly have very gentle to moderate slopes. Surface run-off probably high in relation to through drainage, resulting in frequent flood spates and small residual flow, many short tributaries and some second-order streams probably being intermittent. Generally well drained (in places probably somewhat excessively drained) but imperfect drainage occurs on some gentler upper and foot slopes.

Vegetation.—Secondary vegetation types cover about two-thirds; older regrowth stages (FRy–FR) well represented but in most eastern areas cane-grass regrowth (GtR) also forms an important element. Some small mid-height grasslands (G) occur in western parts. Rest covered with tall forest with an irregular canopy with light-toned crowns (Fid) interspersed with mid-height forest with a small-crowned canopy (Fms) on ridge crests, and tall forest with a rather closed canopy (F) on minor valley floors. Small patches of tall forest (Fid) left in about half of the area under secondary vegetation.

Geology.—Pliocene interbedded sandstone, siltstone, and minor mudstone, at least partly calcareous, and probably very gently to gently dipping (up to 10°). Minor surface beds of colluvium derived from these rocks. Possibly a few thin limestone beds.

Weathering and Soils (9 obs.).—Weathering generally very shallow and skeletal, with underlying rocks mostly softened by hydration to probably up to 10 ft. A few instances of very shallow immature weathering on upper side slopes but not on crests.

Probable soil composition is IODE2, IODE5 subdominant; IODO1 common; IODA2, IODL1, (AUTQ), AUTM, EUHA7, MUHO1 minor. Soils on hill slopes moderately developed, weakly acid, moderately thick, firm clay soils (IODE5) and firm to friable sandy clay to sandy clay loam soils (IODE2). Probably more locally are similar but acid soils (IODO1) which may have a more friable coarser-textured surface horizon and moderately thick dark topsoil (AUTM). On a slumped foot slope is an undeveloped weakly acid, deep, slightly gleyed, stratified colluvial soil with texture ranging from friable sandy loam to very plastic clay (EUHA7). Soils on crests variable and include slightly to moderately developed, weakly acid and locally weakly alkaline, thin to moderately thick, locally slightly gleyed, friable to firm clay loam, silty clay loam, clay, and silty heavy clay soils commonly with a thin to thick dark topsoil (IODA2, IODL1, MUHO1), and in some cases a friable coarser-textured surface horizon (AUTQ).

Population and Land Use.—Population of 4510 distributed over 14 villages. Present land use covers 59·8 sq miles (66% of area), 10% in land use intensity class 2, 33% in class 3, 11% in class 4, and 46% in class 5. More intensive land use restricted to eastern occurrences.

Transitions to Other Land Systems.—Transitional to either Seim (46) or Sengi (46) where slumping is most pronounced. Transitional to Sandri (35) where relief is very low and dissection very close, but where slopes are less steep, crests broader and more undulating with some well-developed slumps, and stream pattern more open, it is transitional to Yindigo (31). Can also have gradual boundaries with Kaugiak (37) which has same relief, but gentler slopes, more widely spaced valleys, and commonly less branching ridges. Where ridges are very short, irregular, not accordant, more slumped, and generally slightly higher, it has been mapped as Morumu (39) and again the two cannot always be easily distinguished. Mapping of Emul restricted to typical occurrences and, generally, transitional cases incorporated with these other land systems.

Forest Resources (2 obs.).—Forest covers 36%; low forest resources. Forests of low stocking rate (Fms/Fid/F, 20 sq miles; Fms/FR, 3 sq miles) cover most of area. Other forests of moderate stocking rate (Fid, 5 sq miles; Fid/FR, 5 sq miles) occur mainly in northern parts. Access category III.

Agricultural Assessment.—Moderate capability for improved pastures, but only low capability for tree crops and very low capability for arable crops. Erosion and topography are main limitations. Unattractive even for small-scale local development for permanent cultivation of annual crops. Insufficient soil depth and locally imperfect drainage are contributory limitations causing low capability for tree crops but are of much less significance for improved pastures. Strong and close dissection will make pasture management more difficult, but facilitate stock watering. Soil nitrogen contents mostly low or even very low, but moderate values are also common, particularly on crests and foot slopes. Phosphate contents generally very low to low, more rarely high. Potash contents mostly moderate, but vary from very high to low. Rather rare slight soil water stress in most parts, except in IODE5 soils, but severe in IODO1, IODL1, AUTO, and AUTM soils on crests and upper slopes.

Engineering Assessment.—No topographic problems if roads aligned to follow ridge crests over long distances (possible in several cases), but across the grain they will be either very winding with many steep gradients or require a large amount of cut-and-fill construction, during which some rather hard sandstone beds may be encountered. Subsurface materials will usually be suitable for subgrade but good road-surfacing materials are virtually absent unless useful limestone deposits are discovered. Unmade roads will become very slippery but not easily boggy after rain. Surfaces may possibly be improved by mixing in pulverized sandstone, particularly if lime stabilization would also be possible. No large, but many very small bridges or culverts are required, unless roads cling to crests. Soils are CH, MH, ML; probable depths are moderately deep dominant, shallow subdominant, very shallow, deep minor. Some long ridge crests may be suitable for small airfield construction without involving a large amount of earth movement.

(37) KAUGIAK LAND SYSTEM (109 SQ MILES)

Land Forms (Plate 17, Fig. 1).—Semi-accordant low hill ridges with irregular slopes, which are benched due to linear slumping or have small slump alcoves. Altitude ranges from 240 to 1200 ft; 10% below 250 ft and 85% between 250 and 1000 ft. Relief mostly 150–200 ft with extremes of 100 and 300 ft. Ridges commonly long and may be subparallel or branching, or have short side spurs. A peculiar pattern of radial main ridges with many tangential secondary ridges (spider-web pattern) occurs just north of Nuku. Crests narrow (locally very narrow or broad), even to undulating, and level to gently sloping. Overall hill slopes predominantly moderate to moderately steep, rarely steep. Short steep to very steep lower hill slopes common near streams, while in other cases there are gentle foot slopes, resulting in relatively wide valleys. Slump benches are 3–15 yd wide, have very gentle to gentle slopes (locally a negative back slope), and are separated by moderately to very steep slope sectors.

Streams and Drainage (Fig. 11(*a*)).—A rather dense, basically dendritic but locally subparallel pattern of first- to third- (rarely fourth) order streams, partly originating within, partly outside the land system. Very short first-order tributaries perpendicular to main streams are relatively widely spaced. Streams have shallow beds without hard rock gravel and with little sand, are cut into rock or colluvium, 2–10 yd wide and of low gradient, probably with high gradient to very gentle slope in short tributaries. Only a few larger rivers, 15–25 yd wide, traverse land system. Surface run-off probably high in relation to through drainage, resulting in frequent flood spates and low residual flow, many smaller streams probably being intermittent. Limited data suggest land system largely well drained.

Vegetation.—Secondary vegetation (R–FR), including cane-grass (*Saccharum*) regrowth (GtR), covers about 75%. Older secondary forest stages (FRm, FR) are a rather important component of this and cover about 30%. Tall forest with an irregular canopy with light-toned crowns (Fid) covers most of rest of land system (20%), with mid-height forest with a small-crowned canopy (Fms) on crests in the south (5%) and tall forest with a rather closed canopy (F) on valley floors (2%).

Geology.—Pliocene sedimentary rocks, probably mainly mudstone, less siltstone, and minor sandstone. Strata probably very gently to gently dipping. Commonly thin surface beds of colluvium of these rocks occur.

Weathering and Soils (5 obs.).—Data available indicate rocks are predominantly shallowly skeletally weathered. Some remnants of shallow immature weathering may be present on crests. Softening of rocks by hydration not pronounced, except locally where system adjoins Musendai (32).

Probable soil composition is EUHO6, IODE1, IODE4 subdominant; (IODA2), (IODL1), (AUTQ) minor. On slump benches are undeveloped, weakly acid, moderately deep, very firm to very plastic silty heavy clay and silty clay colluvial soils (EUHO6). Similar soils may be found in small slump alcoves and on colluvial foot slopes. Slightly to moderately developed, neutral to weakly acid, moderately thin to moderately thick, uniformly textured firm to very firm clay to heavy clay soils (IODE1, IODE4) on moderately steep to very steep slopes. No soils on crests examined but probably similar to those for Seim (46) and Emul (36).

Population and Land Use.—Population of 5590 distributed over 25 villages. Present land use covers 82·7 sq miles (76% of area), 13% in land use intensity class 2, 33% in class 3, 9% in class 4, and 45% in class 5. Most intensive land use restricted to eastern occurrences. Some villages use land in adjacent Musendai (32).

Transitions to Other Land Systems.—Commonly gradual somewhat arbitrary boundaries with, or transitional in pattern to, Morumu (39), Seim (46), Emul (36), Musendai (32), Sandri (35), and Yindigo (31). Because of its rather nondescript pattern, transitional areas commonly included with Kaugiak except in the case of Morumu (39).

Forest Resources (2 obs.).—Forest covers 30%; low forest resources. Forest types range from low stocking rate (Fms/Fid/F, 13 sq miles; FR, 3 sq miles; Fms/FR, 1 sq mile) to moderate stocking rate (Fid, 8 sq miles; Fid/FR, 6 sq miles; Fid/F, 2 sq miles). Access category II.

Agricultural Assessment.—Land use capability appears high for improved pastures but low for arable crops and tree crops, although significantly higher than in Emul (36) which is closely related. Overall conditions similar to but less difficult than in Emul, and overall development probably best based on grazing. However, there appears scope for small tree crop plantations, particularly on less steep benched slopes with deeper colluvial soils and natural terracing to reduce erosion hazards. Permanent cultivation not recommended, because of erosion hazards and because clayey soils commonly appear difficult to till. Soil nitrogen contents probably mainly moderate, although commonly low. Phosphate contents probably mainly very low to moderate; some high values could occur. Potash contents probably mainly high and may range from moderate to very high. Rather rare slight soil water stress in most parts, but severe in IODE4, AUTO, and IODL1 soils and for shallow-rooting crops.

Engineering Assessment.—Road construction problems essentially similar to those for Emul (36). Topographic limitations less serious but less road-surfacing material available. Surficial deposits probably less suitable for subgrade, and unmade roads will tend to be very slippery even after light rain and some may become boggy. Soils are CH with minor CL; probable depths are shallow, deep subdominant; moderately deep common; very shallow minor. Some long straight ridges may be suitable for small airfields.

(38) Yassip Land System (33 sq miles)

Land Forms (Plate 17, Fig. 2).—Very low hill ridges which are very short to rather long, irregular, branching or subparallel and have local small slumps, slump benches, and very steep larger slump alcoves. Altitude ranges from 20 to 1700 ft; 43% below 250 ft, 20% at 250–1000 ft, and 37% above 1000 ft. Relief varies from 50 to 200 ft. Crests are very narrow to narrow and gently sloping. Hill slopes are moderately steep to steep and can be convex or concave. Relatively wide (up to 175 yd), probably colluviated valley floors are common.

Streams and Drainage (Fig. 11(*b*)).—Rather dense dendritic to subparallel pattern of small streams, of which first- and some second-order streams probably have intermittent flow. Gradients are low except for some first-order streams. Most streams flow in rock-cut beds but some larger ones in wider valleys of probably largely colluvial material. Insignificant gravel in stream beds except those of some extraneous through-going larger rivers. Surface run-off likely to be moderate in relation to through drainage, causing only minor flood spates. Well drained.

Vegetation.—Tall forest with a rather open irregular canopy (Foi) was once the most important vegetation type; it now covers only about one-third of land system. Mid-height forest with an irregular or very irregular canopy (Fmi, Fmio) and seral stages (Fmi') occur on unstable slopes (19%). Remaining 42% is or has been gardened with different intensity; older secondary forest (FRm, FR) is common on the one hand, on the other some kunai grasslands (Gl) have developed.

Geology.—Upper Miocene to Upper Pliocene interbedded mudstone, siltstone, and minor sandstone, probably gently dipping to subhorizontal. These rocks are at least partly calcareous.

Weathering and Soils (3 obs.).—Weathering is generally shallow and skeletal, locally on ridge crests deep immature to mature. Rocks tend to be softened by hydration to probably 10 ft or more.

Probable soil composition is IODE1,(3),5 subdominant; UOTO5 common. Generally slightly to moderately developed, neutral to weakly acid, moderately thick to thick, uniformly textured, firm to very firm clay soils (IODE1, IODE5). A very strongly developed, strongly acid, thick, firm to very plastic heavy clay soil with friable clay loam to clay topsoil (UOTO5) observed on a spur crest south of main mountain range and similar soils may occur locally on other crests.

Population and Land Use.—Population of 440 in two villages. Present land use covers 8·8 sq miles (27% of area), 6% in land use intensity class 3, 94% in class 5. Very limited land use on occurrences north of ranges is by people in adjoining Paiawa (24).

Transitions to Other Land Systems.—North of mountains, almost indistinguishable from strongly dissected alluvial fans of Panakatan (25); mapping based more on geographical location and field observations than on pattern differences. Transitional to Morumu (39) where relief increases; transitional to Sandri (35), although geographically widely separated, where dissection by steep slump alcoves becomes more pronounced. Mapping distinction between Yassip and very finely dissected Dossett (34), supposed to occur on crystalline basement rock, is rather vague. Yassip differs only gradationally from Kaugiak (37), which tends to have slightly more relief, more regular and longer ridges, and fewer steep slopes.

Forest Resources (3 obs.).—Forest covers 64%; moderate forest resources. Moderate stocking rate forest (Foi) covers 11 sq miles. Remaining types all have low stocking rates (Fmi, 3 sq miles; Fmio, 2 sq miles) including secondary forests (FRm–FR, FR, 4 sq miles). Access category III, but access problems may be reduced by low relief.

Agricultural Assessment.—Very low capability for arable crops mainly because of steep slopes, and low capability for tree crops and improved pastures. Slight alkalinity of some soils could be a contributory disadvantage for tree crops, high soil acidity on some flatter crestal areas a contributory hazard for arable crops and improved pastures. Since terrain is less rugged than in many other hilly land systems, the possibility of some mixed development for tree crops and grazing should not be excluded. Soil nitrogen contents moderate to low; phosphate contents probably mostly very low to moderate, with some high amounts in least-developed soils. Potash contents appear mostly moderate, but may be high to very high in places.

Engineering Assessment.—Road construction problems similar to those in Morumu (39), but somewhat less serious because terrain is less broken. Often possible to align roads in wider valleys along larger streams. Geographically located so that it commonly offers smaller problems in road-building than surrounding land systems. Soils are CH with minor CL; probable depths are moderately deep, shallow subdominant; very deep common.

(39) Moruma Land System (176 sq miles)

Land Forms (Plate 18, Fig. 1).—Mostly disorganized, locally branching short low ridges and hills, locally spurred and in places with dip-slope and outcrop-slope remnants. Altitude ranges from 100 to 2200 ft; 24% below 250 ft, 48% at 250–1000 ft, and 17% at 1000–2000 ft. In a few places relief is as low as 100 ft or as high as 400 ft. Crests are very narrow, locally narrow. Most hill slopes very irregular because of small-scale slumping and benching, but longer steep straight slopes occur in places. Slopes predominantly moderately steep to very steep, locally moderate to gentle (dip slopes, slump benches, crests), locally precipitous (gully heads, slump walls, dissection slopes near larger streams). North of Torricelli Mountains is commonly a chaotic microrelief (amplitude 5–15 ft) probably caused by earthquakes.

Streams and Drainage (Fig. 11(c)).—Dense slightly angular pattern of small streams, commonly with low to high gradients and sinuous courses. Most first- and some second-order streams probably have intermittent flow. Streams flow in narrow valleys with little or no flood-plain development; beds are poor in gravel except for some larger, rather braided streams traversing north of main mountain range.

Generally well drained, with poorly to imperfectly drained pockets in slumps and on gentle slopes due to slow permeability of rocks. Also cause of probably moderate to high ratio between surface run-off and through drainage, leading to rapidly developing flash floods and rather low residual stream flow.

Vegetation.—Secondary vegetation from gardens (R) to old secondary forest (FR), locally with remnants of tall forest with an irregular canopy with light-toned crowns (Fid), covers 48%. Tall and mid-height forests equally share the remainder. Half the tall forest has a rather open irregular canopy (Foi), locally on steeper slopes in a mosaic with seral stages (Fmi′), the rest is tall forest with an irregular canopy (Fi, Fid). Forest with an irregular canopy (Fmi) dominates the mid-height forest group and covers 18% of the land system. In places it is found together with seral stages (Fmi′). Mid-height forest with a very irregular canopy (Fmio) covers 7%. The type with a small-crowned canopy (Fms), covering 2%, is confined to southernmost occurrences, where there is also some mid-height grassland (G).

Geology.—Pliocene interbedded siltstone, mudstone, and mainly fine sandstone, subhorizontal to moderately dipping. North of mountains rocks are commonly calcareous.

Weathering and Soils (14 obs.).—Weathering generally shallow and skeletal, very locally immature north of ranges. Rocks are commonly softened to 10 ft or more by hydration.

Probable soil composition is IODE3 subdominant; IODE2, IODO1, common; AUTO2, AUTO3, IODA1, IODL1, IUHL, EUHL, EUHA6 minor. South of ranges, predominant soils are moderately to slightly developed, weakly acid to neutral, moderately thin to thick, uniformly textured firm to very firm clay loam to sandy clay soils (IODE2, IODE3). Texture appears related to that of stratified sedimentary rock and is locally friable sandy clay loam on sandstone. There are no or very thin dark topsoils. Moderately to strongly developed, acid, moderately thin to thick, rather friable clay loam to clay soils, uniformly textured (IODO1) or with a coarser-textured surface horizon (AUTO3, UOTO1), are more common north of ranges, probably due to higher rainfall. They may overlie calcareous alkaline softened rock. On moderate (mostly upper) slopes commonly occur moderately developed, neutral to weakly acid, moderately thin, very firm silty heavy clay soils, commonly with a firm clay loam to clay surface horizon and thin dark topsoil (AUTO2) and in places slightly gleyed (IODA1). Locally (not always on steepest slopes) occur slightly developed, neutral to weakly acid, shallow to very shallow, firm clay loam to clay soils with thin to moderately thick topsoils (IODL1, IUHL), whilst precipitous slopes have rock outcrop and undeveloped very shallow soils (EUHL). Locally, where slumping has loosened the hydrated rock, are undeveloped, neutral to weakly acid, moderately deep to deep, friable to plastic silty clay colluvial soils that can be slightly gleyed (EUHA6).

Population and Land Use.—Population of 2540 distributed over 17 villages. Present land use covers 60·3 sq miles (34% of area), 2% in land use intensity class 2, 27% in class 3, 10% in class 4, and 61% in class 5. Occurrences in north-west are largely unused.

Transitions to Other Land Systems.—Boundaries are partly distinct, partly gradual with clear transitional forms to other land systems. Differs from Musak (52) in having less dip and strike pattern, from Yassip (38) in having higher relief, and from Numoiken (40) in having lower relief. It has shorter, less regular and less accordant ridges than Kaugiak (37) and a coarser drainage pattern than Emul (36). Slumping is less pronounced and slopes generally steeper than in either Seim (46) or Sengi (42). North of ranges it is not always clearly distinguishable from strongly dissected fans of Panakatan (25) and in places mapping has been carried out more on geographic position than on pattern differences.

Forest Resources (10 obs.).—Forest covers 61%; low to moderate forest resources. Forests with low stocking rate cover much of the area (Fmi, 25 sq miles; Fmio, 12 sq miles; FR, 10 sq miles; FRm–FR, 10 sq miles; Foi/Fmi′, 6 sq miles; Fmi/Fmi′, 3 sq miles; Fms/FmM, 2 sq miles; Fid/G, 2 sq miles; Fms/FR, 1 sq mile). Forests with moderate stocking rate (Foi, 15 sq miles; Fid, 9 sq miles; Fid/FR, 4 sq miles) and with high stocking rate (Fi, 9 sq miles) also occur. Access category III; minor access problems due to wetness possible on poorly drained slumps and gentle slopes.

Agricultural Assessment.—Steep slopes, very irregular topography, and commonly shallow soils give low capability for improved pastures and tree crops, and very low capability for arable crops. Although capability for tree crops seems clearly lower than for pastures, this would not preclude planting of small native coffee blocks as now practised. Any large-scale development, however, appears best orientated towards a grazing industry combined with forestry development on steepest land, and with minor tree or arable crops. Soil nitrogen contents mostly low, less commonly moderate. Phosphate contents mostly very low, less commonly low to moderate, but very high in some very shallow soils on precipitous slopes. Potash contents vary greatly and apparently erratically, mostly very high to moderate but commonly very low. In water balance zone 1 is mostly rather rare to rather frequent slight, and commonly rather rare severe, soil water stress. In this zone frequent severe, and in zones 2 and 3 rare severe, soil water stress occurs in EUHL, IUHL, and IODL1 soils.

Engineering Assessment.—Very broken nature of terrain will result in strongly winding minor roads with many culverts and small bridges. Simpler to achieve good alignment for major roads, because soft hydrated rocks are easy to cut through and appear reasonably suitable for fill. Road surfaces on weathered rock tend to have high bearing strength (as against soils proper which easily tend to become boggy) but are extremely slippery after even minor rain. Road-surfacing materials appear scarce. Moderate landslide risks, and roadside drainage should be well handled. Soils are CH, MH, CL, with minor ML; probable depths are moderately deep dominant; shallow subdominant; very shallow, deep minor.

(40) NUMOIKEN LAND SYSTEM (98 SQ MILES)

Land Forms (Plate 18, Fig. 2).—Generally disorganized patterns of short to very short, commonly spurred or grooved, high hill ridges and hills, rarely of longer peaked ridges. Altitude ranges from 0 to 2600 ft; 8% below 250 ft, 49% at 250–1000 ft, and 39% at 1000–2000 ft. Relief generally between 300 and 500 ft, with extremes of 200 and 750 ft. Crests are knife-edged to narrow, hill slopes predominantly steep to very steep, partly with long straight slope sectors, partly irregular because of common medium-sized to small slumps, producing moderate to moderately steep local slopes. Some precipitous slopes occur as slump walls or near larger streams. Locally remnants of dip and outcrop slopes occur. Chaotic microrelief of 4–15 ft appears common north of ranges and probably is caused by earthquakes.

Streams and Drainage (Fig. 11(*d*)).—Dense to rather open dendritic pattern of mainly small streams, largely with high gradients, but gentle to moderate slopes in first-order streams. Streams flow in narrow valleys in rock-cut beds, mostly poor in gravel. Surface run-off is probably moderate to high in relation to through drainage and frequent flood spates are to be expected, but most streams will also have adequate residual flow due to ground-water seepage. Generally well drained.

Vegetation.—Mid-height forest with an irregular canopy (Fmi), often in conjunction with seral stages (Fmi′) and with *Casuarina papuana* (Ca) on some steepest slopes, covers 45%. Found in higher occurrences and those with chaotic microrelief. Occurrence in latter areas, where tall forest would be expected, could be a result of earthquake damage or correlated with increased humidity or rainfall due to location in frontal zone of Torricelli Mountains, indicated by conspicuous moss cover of trunks. Lower and less steep slopes have tall forest with a rather open irregular canopy (Foi) and, south of ranges, tall forest with an irregular canopy with light-toned crowns (Fid). More than one-third of land system gardened or under secondary vegetation. Where tall cane grass regrowth (GtR) is found rotation cycle will be short, probably <10 years, but still of minor importance here, where older secondary forest stages (FRm, FR) are well represented.

Geology.—Pliocene to Miocene interbedded siltstone, mudstone, and less sandstone and conglomerate, at least locally calcareous. In foothills of main mountain range, pre-mid-Miocene rocks including conglomerate of metagreywacke and metabasalt, and minor limestone. Dips are probably mostly moderate to steep.

Weathering and Soils (6 obs.).—Weathering generally shallow and skeletal, very locally immature. Softening of rocks by hydration appears strongest north of ranges, but tends to vary considerably from place to place.

Probable soil composition is IODE3, EUHO8 subdominant; EUHO7, EUHO9 common; UOTO2 minor. Undeveloped, weakly acid to acid, deep to moderately shallow, friable loam to firm clay colluvial soils containing variable amounts of rock fragments (EUHO7,8,9) appear dominant, with similar but moderately developed, moderately thin residual soils (IODE3) also common. A moderately to strongly developed, acid, thick, firm silty clay soil with friable loam to clay loam surface soil (UOTO2) observed on more strongly weathered rock. It is not clear where and how often such soils occur.

Population and Land Use.—Population of 1250 distributed over eight villages. Present land use covers 25·9 sq miles (26% of area), 29% in land use intensity class 3, 12% in class 4, and 59% in class 5. Most intensive land use occurs only on most easterly occurrences.

Transitions to Other Land Systems.—In many respects very similar to Nopa (57), but less slumped and without the very steep long slopes along margins. Where relief decreases it merges into Morumu (39); where relief increases it merges into Sulen (58). It merges into Musak (52) where dip and strike effect becomes prominent, and into Asier (43) where ridges are longer and more regular with predominantly less steep slopes. Where slopes are strongly grooved and spurred and slumping less noticeable, it merges into Wanabutu (59) or Mup (61).

Forest Resources (6 obs.).—Forest covers 58%; low forest resources. In general, low stocking rate forests (Fmi/Fmi′, 30 sq miles; Fmi, 12 sq miles; Foi/Fmi′, 4 sq miles), including secondary forests (FRm–FR, 3 sq miles; FR, 3 sq miles). Moderate stocking rate types (Fid, 8 sq miles; Foi, 5 sq miles) occur on lower, less steep slopes, two (Fid and Fid/FR) being confined to more southern occurrences. Access category III.

Agricultural Assessment.—Slope steepness alone allows only very low capability for tree crops and improved pastures and agricultural development appears practically unsuitable. Commonly rather shallow soils further restrict the scope for tree crops. Soil nitrogen contents appear to vary from very low to moderate; phosphate contents probably mostly very low, but commonly moderate and locally high. Potash contents variable, probably mostly high, but low to very low also common. In water balance zone 1 there is locally rather rare to rather frequent slight soil water stress, mainly in IODE3 soils.

Engineering Assessment.—To be avoided for road construction, except probably for a road across Torricelli Mountains to link interior with coastal plains. On such a route it constitutes one of the lower relief elements and so may be preferred. Because crests are mostly short and irregular, best to keep roads close to valley bottoms. Many slopes appear unstable, presenting risks of soil creep and landslides. Good roadside drainage essential. Road-building materials scarce. Rocks are commonly sufficiently soft to facilitate easy cut-and-fill operations, but locally, particularly in foothills of ranges, harder rock occurs at shallow depth. Weathered rock would form a strong surface for unimproved roads, but would be slippery when wet. Soils are CH, MH, CL, ML; probable depths are moderately deep dominant; shallow, deep common.

(41) Karaitem Land System (106 sq miles)

Land Forms (Plate 19, Fig. 1).—Long to very long, gentle to moderate, basically concave foot slopes of colluvially disturbed rocks (collapsed ridges and dip slopes), and including some true scree slopes at foot of escarpments. Partly because of mode of formation and partly because of subsequent dissection and landslides, these slopes are very irregular in detail: gullied to ridged, or hummocky to very low hilly with in some places also smooth slope segments. Altitude ranges from 240 to 3700 ft; 30% at 250–1000 ft, 46% at 1000–2000 ft, and 21% at 2000–3500 ft. Internal relief ranges from ultra-low to low, but total relief from upper to lower margins of occurrences is generally moderate, with extremes of 300 and 900 ft. A few long, narrow, moderately sloping, hummocky rock debris slides occur, and there are locally protruding very low to low hills of a more residual nature. Local slopes are thus highly variable, mostly moderate to steep. Some occurrences at high altitude have very steep marginal slopes. A very small area just east of Anguganak contains very low conical hills suggesting the presence of limestone.

Streams and Drainage (Figs. 11(*e*), 13(*f*)).—Large occurrences have an open to moderately dense dendritic to subparallel pattern of streams, with relatively long but small first-order streams joining to form small to moderately large higher-order streams. Narrow but long occurrences crossed by widely spaced larger streams. Streams relatively straight, with only slightly gravelly beds that are generally narrow but can be up to 60 yd wide and are confined in narrow valleys. Stream gradients range from low gradient to gentle slope. Flow is moderately fast and probably perennial throughout due to large amount of ground-water seepage. Two small lakes occur at high altitude. Surface run-off probably low in relation to through drainage, so flood spates tend to be minor except in through-going streams originating in steep hilly or mountainous country outside land system. Mostly well drained, with small imperfectly drained pockets on slump floors.

Vegetation.—Large parts, totalling about 50%, are or have been gardened (R–FR). In western occurrences sago (MR) has been extensively planted in suitable situations. Original vegetation was tall forest which still covers 20%. Types represented are tall forest with a rather open irregular canopy (Foi) and tall forest with an irregular canopy with or without light-toned crowns (Fid, Fi). At higher altitude is mid-height forest with an irregular canopy (Fmi), which is also on steep marginal slopes mixed with seral stages (Fmi′) or *Casuarina papuana* (Ca).

Geology.—Mainly Upper Miocene, less Lower Pliocene interbedded sandstone, siltstone, and mudstone, the sandstone commonly being calcareous. Rocks are mostly deeply colluvially disturbed due to hydration, faulting, and landslides, but locally exhibit moderate dip slopes. Limestone beds are possibly locally intercalated in the sequence.

Weathering and Soils (11 obs.).—Little weathering *in situ*, but indications that deep hydration and widespread shallow immature weathering took place before (and facilitated) collapse of ridges by colluviation, and landslides, which shaped present land forms. Remnants of shallow immature to mature weathering observed on some residual hills.

Probable soil composition is IODO4, EUHO7, EUHO8 subdominant; EUHO9 common; (EAHU3), (EUHA7), EUHL, IODL2, UOTO5 minor. Predominant soils are undeveloped, weakly acid to acid, deep to very deep, commonly slightly stratified colluvial soils, with textures normally ranging from very friable sandy clay loam to firm clay and containing low to moderate amount of variably weathered rock fragments (EUHO7,8,9). Similar but slightly to moderately gleyed soils likely on small slump floors. More rarely and probably mainly near mountains, on both colluvial slopes and protruding low hills, occur strongly developed, acid, moderately thin to thick, very friable sandy clay loam to clay loam soils, with commonly large weathered rock fragments in subsoil (IODO4). Soils on hill crests include a very strongly developed, strongly acid, thick, plastic clay soil with a more friable loam surface soil (UOTO5), and a moderately developed, acid, very thin sandy loam soil on weathered sandstone (IODL2). Such thin soils on crests probably largely associated with former village sites where original soil cover has been removed, whilst very strongly developed soils apparently represent relicts of a weathered surface at about 3000 ft on southern flank of mountains. An undeveloped, neutral, shallow, friable clay loam soil mixed with and resting on coarsely broken-up sedimentary rock (EUHL) observed on one large rock debris slide.

Population and Land Use.—Population of 2500 distributed over 16 villages. Present land use covers 54·8 sq miles (52% of area), 28% in land use intensity class 3, 16% in class 4, and 56% in class 5. Planted sago very important in subsistence in west, where some land is used by people in Minatei (50).

Transitions to Other Land Systems.—When typically developed it has a quite distinct pattern but usually indistinct boundaries. Small areas of protruding hills really inclusions unmappable as Morumu (39) or Yassip (38), and thus Karaitem approaches these two others in pattern in a few places. Distinguished in places with difficulty from Flobum (44) which has steeper overall slopes and greater overall relief, and from Sengi (42) which has better-defined individual ridges. The few cases where dip-slope remnants are noticeable tend to be transitional to Mambel (48).

Forest Resources (5 obs.).—Forest covers 49%; low forest resources. Much forest is of low stocking rate, particularly on steeper parts (Fmi/Fmi′, 14 sq miles; Fmi, 7 sq miles; FR, 8 sq miles; FRm–FR, 2 sq miles; FRm, 1 sq mile). Remainder consists of moderate stocking rate forests (Fid, 9 sq miles; Fid/FR, 5 sq miles; Foi, 4 sq miles) and one high stocking rate forest (Fi, 5 sq miles). Access category II; minor access problems due to wetness occur on slump floors.

Agricultural Assessment.—Topographic irregularities mean very low capability for arable crops but moderate capability for tree crops and improved pastures. Soil depth and acidity generally favourable for tree crops, but above 2000 ft a.s.l. it may be difficult to find suitable tree crops. Difficult to assess present stability of slopes, but some landslides could occur after very heavy rain or earthquakes, causing greater damage to tree crop plantations than to improved pastures. Irregular terrain better for small holdings than for larger farm units. Optimum land use is probably a combination of small tree crop plantations and improved pasture lands with timber exploitation and forest plantations in most dissected areas. Soil nitrogen contents mostly moderate, but commonly very low to low. Phosphate contents often very low, but low to moderate values also common. Potash contents tend high to moderate, but low values not uncommon. Very high phosphate and potash contents occur in shallow stony soils associated with rock debris slides. Rare to rather rare severe soil water stress only on very few steep slopes with IODL2 and EUHL soils in water balance zones 1 and 2.

Engineering Assessment.—Provided many small cut-and-fill operations are acceptable as standard procedure, road construction would be relatively simple, since little consolidated rock will be encountered and drainage conditions are generally adequate. If roads must follow closely the existing shape of terrain, it means very winding roads or very steep gradients. Close attention should always be given to roadside drainage and culverting to minimize danger of landslide damage. Construction of larger bridges only infrequently necessary. One of several cases where Karaitem offers the best possibilities for road construction in a given area is in traversing the mountain ranges from north to south; it forms the lowest pass (about 1500 ft), SSE. of Aitape, and also affords good penetration north of Lumi and in the eastern part of the area. Soils are CH, MH, ML, with minor CL; probable depths are moderately deep, deep subdominant; shallow common; very shallow, very deep minor.

(42) SENGI LAND SYSTEM (106 SQ MILES)

Land Forms (Plate 19, Fig. 2).—Most nondescript topography of all the hilly land systems. Low, locally very low, rather broad, and usually long hill ridges, generally with narrow, locally with broad crests and with mostly moderate to moderately steep side slopes that are very irregular due to small-scale slumping producing a hummocky surface, small alcoves, and minor spurs. Altitude ranges from 240 to 2000 ft; 69% below 1000 ft. Relief is mostly 100–300 ft, in some cases up to 400 ft. Branching of ridges pronounced only in very limited areas; many ridges somewhat asymmetrical with steeper (moderately steep to steep) slopes on one side, probably as a result of dipping rock strata. Crests generally accordant, mostly even to undulating, but locally peaked. Short upper hill slopes rarely, and short lower slopes commonly, steep to very steep, but in other places gentle foot slopes result in relatively wide valleys.

Streams and Drainage (Fig. 11(*f*)).—Stream pattern essentially dendritic, generally rather open, but locally dense, and consists of rather long first- to third-order main streams, probably only 5–20 yd wide, and of very short first-order tributaries mostly perpendicular to main stream. Shallow main streams have mostly low, locally high gradients, tributaries have gradients of very gentle to gentle slope. Stream beds are cut into colluvium or rock, largely devoid of hard rock gravel and sand, and locally bordered by very narrow (10–50 yd wide) flood-plains. Larger throughgoing rivers (30–50 yd wide) are rare and likely to have very limited amounts of hard rock gravel. Surface run-off is probably low to moderate in relation to through drainage, thus flood spates tend to be rather infrequent and a relatively large residual flow is maintained throughout the year; virtually all streams are perennial.

Insufficient data to assess drainage status. Probably largely well drained, with small poorly drained pockets in slump floors and seepage areas.

Vegetation.—Original vegetative cover was tall forest with an irregular canopy with light-toned crowns (Fid) of which 30% is left, not counting scattered patches in areas of secondary forest (Fid/FRy–FR). Secondary vegetation now widespread but rotation cycles seem long because secondary forest is well represented. Sago planted (MR) on slump floors and in seepage areas.

Geology.—Pliocene sedimentary rocks, probably mainly mudstone and siltstone, at least locally calcareous, and probably mostly with gentle to moderate dips. Surficial beds are probably commonly colluvium of these rocks.

Weathering and Soils (1 obs.).—Irregular topography suggests (although not supported by single observation of very shallow immature weathering on a steep upper slope) that softening of rocks by hydration may be pronounced and widespread. Skeletal weathering probably widespread, and remnants of immature and even mature weathering were noticed and may not be uncommon on crestal areas.

Probable soil composition is IODO1, (EUHO7) subdominant; (IODO4, IODE4, EUHO8) common; (IODA2, EUHA7) minor. Only soil observed is a moderately developed, acid, moderately thick, uniformly textured, firm silty clay soil with weathered rock fragments in the subsoil (IODO1). Similar soils, but including slightly developed and undeveloped, weakly acid soils, are likely to predominate, mostly of clay texture and moderately thin to thick. Pockets of gleyed soils probably present in slump alcoves and on benches. Some apparently strongly developed reddish soils seen on crests but not examined. Shallow soils occur probably on steepest slopes. Generally soil pattern probably rather similar to that of Asier (43).

Population and Land Use.—Population of 1660 distributed over 10 villages. Present land use covers 58·7 sq miles (55% of area), 17% in land use intensity class 3, 6% in class 4, and 77% in class 5. Planted sago important in subsistence.

Transitions to Other Land Systems.—Having no really characteristic pattern, Sengi is in places transitional to Asier (43) (higher relief), Mambel (48) (more pronounced dip and strike pattern), Karaitem (41) (more typically colluvial land forms), Emul (36) (steeper, closer, and more branching ridges), Kaugiak (37) (more regular slopes, closer spaced ridges), Sandri (35) (lower, much closer, steeper, and spurred ridges), Yindigo (31) (lower relief, generally more convex slopes), and Morumu (39) (shorter, steeper, less accordant ridges).

Forest Resources (no obs.).—Forest covers 46%; low forest resources. Forest of moderate stocking rate (Fid, 32 sq miles; Fid/FR, 11 sq miles) and of low stocking rate (FR, 6 sq miles) occurs. Access category II.

Agricultural Assessment.—Insufficient information prevents precise assessment, but apparently there is moderate capability for tree crops and improved pastures but only low capability for arable crops, because of erosion hazards and irregular topography. This assumes that soil depth and pH are generally not a serious limitation for tree crops and the extent of poorly drained soils is small. Superficial landslides could be a hazard for tree crops. Limited development possible for both grazing and tree crops, particularly as the area is commonly surrounded by land systems with lower capability. Soil nitrogen contents probably mostly moderate, but low to very low values may not be uncommon. Phosphate contents probably mostly very low, but moderate to low values may also be common. Potash contents probably high to very high, but low values are also common. In water balance zone 1 is locally rather rare, on steeper slopes rather frequent, slight soil water stress, which would occur more generally for shallow-rooting crops.

Engineering Assessment.—Moderate topographical problems for road-building, commonly smaller than those in adjoining land systems. Roads can often follow ridge crests for long distances and then relief and slopes can be negotiated without too much difficulty, whilst only small bridges are required. Road cuts simple to make in soft rocks and colluvium, but will require stabilization. Landslide risks and absence of suitable subgrade and road metal are main problems. Roadside drainage will need particular attention and many culverts will be required. Unmade roads will tend to be very slippery and easily become untrafficable after rain. Soils are CH, MH, ML, with minor CL; probable depths are moderately deep dominant, deep subdominant, shallow common.

(43) Asier Land System (106 sq miles)

Land Forms (Plate 20, Fig. 1).—Broad, long to short, high hill ridges with straight or concave, locally smooth but generally closely gullied slopes, locally merging into spurs. Altitude ranges from 500 to 3600 ft; 11% below 1000 ft, 59% at 1000–2000 ft, and 29% at 2000–3500 ft. Relief varies from 300 to 700 ft. Hill slopes are moderately steep, in places steep, more rarely moderate. Slumping nearly always evident, locally as large slumps but generally as few to many small slump alcoves and toes, which can give the slopes a hummocky appearance. Rarely the photo pattern shows dip and outcrop slopes in the form of poorly developed chevron ridges. Crests are generally rounded and narrow, in places very narrow, rarely broad. They are generally even to undulating, with gentle crest slopes, and locally form low emergent crestal ridges with steep slopes.

Streams and Drainage (Fig. 12(*a*)).—Rather coarse-textured subangular to dendritic pattern of long main streams (mainly second- to fourth-order), with short subparallel first-order tributaries in narrow rock-cut channels with gradients mostly of moderate slope. Higher-order streams in either rock-cut beds or very narrow (up to 100 yd wide) flood-plains and have gradients mostly from high gradient to very gentle slope. Streams are shallow and moderately fast. Beds of locally originating streams are probably only little to moderately gravelly, but those of larger through-going streams originating in areas of igneous rocks are rich in gravel, cobbles, and boulders, and up to 70 yd wide. Surface run-off probably low to moderate in relation to through drainage, and all streams are perennial due to ground-water seepage and probably experience only minor flood spates. Well drained except for small slump floors.

Vegetation.—Over half is gardens and secondary vegetation, up to old secondary forest (R–FR). Sago (MR) is planted and exploited in small wet sites caused by slumping. Tall and mid-height forests each occupy 22%. Tall forests with an irregular canopy with or without light-toned crowns (Fid, Fi) are equally represented. The mid-height forest mainly found is the type with an irregular canopy (Fmi), but the type with a very irregular canopy (Fmio) also occurs. Because of unstable slopes seral stages (Fmi′) occur amidst tall as well as mid-height forest.

Geology.—Pre-mid-Miocene to Upper Miocene siltstone, mudstone, less sandstone, and minor fine conglomerate. Surface materials commonly colluvium of these rocks.

Weathering and Soils (2 obs.).—Subject to appreciable weathering in the past, but subsequent dissection has left only remnants of shallow immature weathering, mainly on ridge and spur crests. Underlying rocks softened by hydration to considerable depth, which has facilitated mass movement and colluviation on hill slopes.

Probable soil composition is EUHO7, (IODO1) subdominant; (EUHO8), (IODE3), IODO4, EUHA7 common. Sparse field data suggest mostly undeveloped, acid to weakly acid, deep to very deep, friable to firm clay loam to clay colluvial soils, with varying amounts of rock fragments (EUHO7 observed). Similar, but moderately gleyed soils probably on small slump floors. Moderately developed, acid to weakly acid, moderately thin to moderately thick residual clay loam to clay soils probably on more stable slopes. A strongly developed, acid, moderately thick, plastic clay soil with few weathered rock fragments (IODO4) exemplifies soils found locally on crests with remnant weathering.

Population and Land Use.—Population of 2560 distributed over 19 villages. Present land use covers 44 sq miles (42% of area), 27% in land use intensity class 3, 73% in class 5. More intensively used areas occur in the west. Planted sago is important in subsistence.

Transitions to Other Land Systems.—In many respects, a scaled-down version of Flobum (44), and in places transitional to it. In marginal cases it has features transitional to Sulen (58) (high relief, steep spurred slopes), Numoiken (40) (very short irregular ridges), Imbia (54) (steep slopes, chevron ridges), or Sengi (42) which has lower relief.

Forest Resources (1 obs.).—Forest covers 55%; low forest resources. Much forest is of low stocking rate (Fmi, 14 sq miles; *Fi/Fmi', 5 sq miles; Fmi/Fmi', 3 sq miles;* Fmio, 2 sq miles), including secondary forests (FR, 9 sq miles; FRm–FR, 7 sq miles). Remainder is either moderate stocking rate (Fid, 13 sq miles) or high stocking rate (Fi, 7 sq miles) forest occurring at lower altitudes. Access category III; minor access problems due to wetness occur on small slump floors.

Agricultural Assessment.—Moderate capability for tree crops, slope steepness being the major limitation, terrain irregularity and locally rather shallow soils minor restrictions. Since gullies and hummocks are probably a greater limitation for improved pastures than for tree crops and also because of soil acidity, capability for this type of land use is assessed as low; capability *for permanent cultivation of arable crops* judged very low. On the other hand, climatic limitations affecting land above 2000 ft would be more serious for tree crops than for improved pastures in a rather large proportion of the land system. Thus, there appears to be scope for expanding existing land use, partly in small tree crop plantations, partly by cattle-grazing on improved pastures; no potential for large-scale planned development. Soil nitrogen contents probably moderate to low; phosphate contents probably vary from very low to moderate; potash *contents probably high to moderate, but low in more developed* soils on crests.

Engineering Assessment.—Road construction unlikely to be required in the near future. Of the high hilly land systems, it offers smallest topographical difficulties since road alignment could often follow crests or river courses for rather long distances and there are few very steep slopes to be negotiated. Many gullies and hummocks require much small-scale cut-and-fill work, which would be easy to carry out in the soft materials. Good roadside drainage needed to minimize landslide hazards. Road-surfacing materials probably very scarce. Colluvial slope mantle material seems reasonably suitable for subgrade and fill. Soils are CH, MH, ML, with minor CL; probable depths are moderately deep dominant, deep subdominant, shallow common.

(44) Flobum Land System (112 sq miles)

Land Forms (Plate 20, Fig. 2).—Very broad low mountain ridges and mountain slopes with predominantly moderately steep (locally steep or moderate) overall slopes. Altitude ranges from 400 to 3700 ft; 6% below 1000 ft, 42% at 1000–2000 ft, and 50% at 2000–3500 ft. Overall relief is mostly 700–1000 ft with extremes at 400 and 1200 ft. Strong mass movement has produced a highly irregular local relief of 50–150 ft on these slopes, with an array of hummocks, slump alcoves, gullies, and ridges, with local slopes varying from gentle to very steep. A few long rock debris slides occur. In places mountain ridges are clearly essentially strike or chevron ridges. Single mountain slopes locally dissected into broad but irregular spurs with moderately steep to steep slopes. Crests mostly narrow to broad and commonly form emergent crestal ridges and crestal hummocks with short very steep side slopes. Lower slopes near incising streams locally very steep.

Streams and Drainage (Fig. 12(*b*,*c*)).—Coarse- to very coarse-textured pattern of mainly subparallel main streams (second to fourth order), with relatively few subparallel to dendritic first- and second-order tributaries. Latter are very small and have very narrow stream beds with gradients of gentle to moderate slope. Main streams, found only in largest occurrences, have 20–80-yd-wide beds of high gradient located in very narrow flood-plains or cut into rock. All streams are perennial and have fast flow and shallow depth. Gravel and boulders plentiful *in beds of rivers* originating in mountains north of Flobum, but rather scarce or very scarce in locally originating streams. Surface run-off probably low to moderate in relation to through drainage, leading to *much ground-water seepage to streams* and a low incidence of flood spates.

Well drained except for numerous small slump floors that are imperfectly to very poorly drained.

Vegetation.—About half is under secondary vegetation (R–FR). Sago (MR) extensively planted in many suitable situations formed by irregular secondary relief. Original vegetation probably mainly mid-height forest with an irregular canopy (Fmi) which is still left in places. It also covers steeper slopes, where it is mixed with seral stages (Fmi') which reflect the unstable nature of the slopes. Highest crests, about 1% of area, carry mid-height forest with a rather dark-toned even canopy (Fm). On rock debris slides is *Casuarina papuana* (Ca). Tall forests with an irregular canopy (Fi, Fid) cover 12% of area, occurring at lower altitudes; on steeper slopes they are mixed with seral forest (Fmi').

Geology.—Miocene siltstone, less sandstone and fine conglomerate; on northern flank of main mountain range occur *pre-mid-Miocene siltstone and conglomerate* with metabasalt and metagreywacke pebbles. Locally intercalated beds of massive limestone occur. Surficial beds commonly consist of colluvium of these rocks.

Weathering and Soils (9 obs.).—Field evidence suggests considerable weathering in the past, together with deep hydration of rocks, probably an important contributing factor in producing the mass movement described above. Stream dissection together with this mass movement has in turn destroyed much of the weathering profiles, now mainly in higher crestal areas as shallow immature to deep mature weathering. Remainder of Flobum only skeletally weathered or merely hydrated.

Probable soil composition is *EUHO8, EUHO9, IODO1* subdominant; UOTO2, UOTO5, EUHA6, (EAHU3), (EUHL), MR–E minor. Most common soils are undeveloped, weakly acid to acid, deep to very deep colluvial soils with slightly stratified *profiles of friable loam to clay loam and varying amounts* of rock fragments (EUHO8, EUHO9). Similar, but neutral gleyed and normally more clayey and plastic soils (EUHA6 observed) found on slump floors, probably occupying 8%. Undeveloped, shallow to very shallow or stony soils probably occur on the steepest slopes near crests and streams, on back walls of slumps, and on rock debris slides. On relatively large areas (probably 30%) where weathering is evident, occur moderately to more rarely strongly developed, acid to strongly acid, moderately thin to thick, friable to firm clay soils (IODO1), commonly with very friable loam to clay loam surface horizons (UOTO2) and containing variable amounts of weathered rock fragments. A very strongly developed, strongly acid, thick, plastic heavy clay soil with friable clay loam to clay surface horizons *(UOTO5) observed* on slumped upper hill slope, but such soils seem restricted to small remnant weathered summit areas. Observed on limestone was a moderately developed, alkaline and calcareous, thin, rather stony, very dark over dark firm clay soil (MR–E); such soils appear rare.

Population and Land Use.—Population of 4230 distributed over 29 villages. Present land use covers 52·7 sq miles (47% of area), 28% in land use intensity class 3, 28% in class 4, and 44% in class 5. Planted sago is important in subsistence. Eastern occurrences largely unused.

Transitions to Other Land Systems.—Gradual transitions occur to Karaitem (41) which has fewer steep overall slopes and no massive mountain ridges; to Om (45) which is steeper and more vigorously dissected; to Asier (43) which has lower relief and a closer pattern of ridges; and to Minatei (50) which has more clearly defined dip and outcrop slopes.

Forest Resources (6 obs.).—Forest covers 46%; low forest resources. Much forest comprises low stocking rate types (Fmi/Fmi', 20 sq miles; Fmi, 15 sq miles; Fi/Fmi, 3 sq miles; Fm, 2 sq miles), including secondary types (FR, 4 sq miles; FRm–FR, 3 sq miles). Remainder is high stocking rate forest (Fi, 6 sq miles) and moderate stocking rate forest (Fid, 5 sq miles) which occur at lower altitudes. Last three were observed to have higher stocking rates than average for each type. Access category III; minor access problems due to wetness occur on slump floors.

Agricultural Assessment.—Broken nature of terrain with common steep local slopes means very low capability for arable crops but moderate for improved pastures. Capability for tree crops is low because it is also depressed by local poor drainage, local shallow soils, and the fact that part of Flobum occurs above 2000 ft where climatic conditions are rather unfavourable for both normal lowland crops and typical highland crops. However, common acidity of soils is probably more favourable for tree crops than improved pastures. Unsuitable for large-scale development, but scope for some extension of permanent agricultural land use near present population centres in small tree crop plantations and particularly by introduction of cattle grazed on improved pastures. Soil nitrogen contents probably mostly moderate to low. Phosphate contents generally range from very low to moderate. Potash contents variable, mostly high to low.

Engineering Assessment.—Smallest difficulties in road construction of the mountainous land systems. South of the Raihu River it provides a relatively easy passage through the main mountain range. It may even be preferred to adjoining land systems of less relief but with very severe dissection and steeper slopes, because of its more massive character with fairly gentle long overall slopes and relatively minor dissection. Problems of road construction include slope instability which may cause landslide damage; irregular terrain which requires many small cut-and-fill operations or leads to very winding roads; scarcity of good road-building materials (gravel and stone obtainable only from some larger stream beds and very local limestone occurrences, or may have to be quarried in neighbouring land systems); and need for long fairly steep gradients when roads are built across the (mostly N.–S.) grain of mountain ridges. Roads along the grain can be more conveniently located along major streams or crests. Large bridges rarely required, but many culverts needed for proper roadside drainage. Soils are dominantly MH, subdominantly CH, ML; probable depths are moderately deep dominant, deep subdominant, shallow common, very shallow, very deep minor.

(45) Om Land System (24 sq miles)

Land Forms (Plate 21, Fig. 1).—Steep to very steep, locally moderately steep low mountain ridges and slopes severely slumped and dissected into very irregular, rugged topography of spurs, slumps, rock debris slides, ravines, steep-sided hills, and low scarps. Altitude ranges from 400 to 4500 ft; 11% below 1000 ft, 41% at 1000–2000 ft, 41% at 2000–3500 ft, and 7% above 3500 ft. Local relief is 100–300 ft, with a total relief of 800–1500 ft. Crests tend to be knife-edged to narrow and local slopes are mostly very steep to precipitous. Where particularly hilly, land forms are suggestive of karst topography and probably related to occurrence of limestone.

Streams and Drainage (Fig. 10(*d*), 12(*c*)).—Fine-textured angular to subparallel pattern of small first- and second-order streams in deeply incised narrow rock-cut beds with gradients of moderately steep to steep slope. Stream beds are rocky and stream flow perennial. Surface run-off probably high in relation to through drainage, except on limestone, and would cause frequent minor flood spates. Well drained.

Vegetation.—Almost complete cover of mid-height forest. Forest with a rather dark-toned even canopy (Fm) common on crests and less steep upper slopes and occupies about 15%. Owing to rugged unstable nature of slopes seral vegetation types (Fmi' and *Casuarina papuana*) are common, and occur in intricate mosaic with mature mid-height forest with an irregular canopy (Fmi). Some lower slopes (6%) adjacent to Karaitem (45) have been gardened.

Geology.—No field data. Probably pre-mid-Miocene rocks, largely relatively small thicknesses of conglomerate, siltstone, and limestone, steeply uptilted against igneous basement rock, and probably with much surficial colluvium.

Weathering and Soils (No obs.).—Weathering probably slight, but rocks (except limestone) probably deeply hydrated. Probable soil composition is (EUHO8, EUHO9) subdominant; (IODO1, IODO2, IODL2, MR–O2) common; (EUHL) minor. Soils probably mainly undeveloped, weakly acid to acid, shallow to deep, loamy colluvial soils with many rock fragments and could be similar to those for Flobum (44) and Sulen (58). Weakly alkaline to alkaline, thin, very dark clay soils associated with rock outcrop probably occur on limestone.

Population and Land Use.—Population nil; present land use negligible.

Transitions to Other Land Systems.—Transitional between Flobum (44) and Sulen (58), combining irregular topography of former with ruggedness and slope steepness of latter.

Forest Resources (1 aerial obs.).—Forest covers 67%; low forest resources. Forest of low stocking rate types (Fmi/Fmi', 11 sq miles; Fmi/Fm, 4 sq miles; Fmi, 3 sq miles). Access category IV.

Agricultural Assessment.—Very rugged topography denotes no capability for agricultural development. Soil nitrogen contents probably vary from moderate to very low; phosphate contents probably nearly always very low to low; and potash contents likely to be quite variable.

Engineering Assessment.—To be avoided for road construction. In places it could be a potential source of road-building material (limestone, some conglomerate), although commonly too inaccessible. Soils are dominantly MH, subdominantly CL, ML, and minor CH; probable depths are moderately deep dominant, very shallow subdominant, shallow, deep common.

(46) Seim Land System (221 sq miles)

Land Forms (Plate 21, Fig. 2).—Low hill ridges with a pattern of more or less polygonally branching, commonly rather peaked crests and short spurs partly enclosing irregular small to large slump alcoves with mostly gentle to moderately steep slopes. Altitude ranges from 400 to 1700 ft; 86% below 1000 ft. Relief extremes are 100 and 400 ft. Overall hill slopes predominantly concave. Crests range from very narrow to broad and commonly have a sharp break to short steep to very steep upper side slopes, thus producing emergent crestal ridges that may be benched. Very few gentle straight slopes resemble dip-slope remnants. Some steep hill slopes are grooved or spurred, rather than slumped. Short very steep slopes occur locally above slump alcoves and as lower slopes near incised streams. Elsewhere are hummocky gentle lower slopes which may locally merge into flattish valley floors up to 150 yd wide. Gentle lower slopes near a major river appear to be a slip terrace. Slump alcoves range from 40 to 600 yd in diameter and generally have irregular hummocky surfaces with gentle to moderate slopes dominant where ridges are far apart, and moderately steep to steep slopes dominant, commonly with small slump benches, where ridges are more closely spaced.

Streams and Drainage (Fig. 12(*d*)).—Stream pattern of rather widely to rather closely spaced, long, winding, subparallel to subradial first- to fourth-order local streams with rather regularly and rather closely spaced, very short first-order tributaries, generally at right angles to larger streams. Overall pattern is rather angular. Streams range in width from 5 to 20 yd. In addition, land system is traversed by a few larger meandering through-going streams 30–50 yd wide. Stream beds are cut into bed-rock or colluvium, are shallow, have little or no hard rock gravel or sand, and have mostly low gradients, but gradients up to very gentle slope in short first-order tributaries. Through-going streams have sandy to rather fine gravelly beds. Surface run-off probably moderate to high in relation to through drainage, so flood spates will occur frequently and river flow decrease rapidly in rainless periods. Many first-order tributaries probably have intermittent flow, particularly in eastern part.

Mostly well drained, some crests and very steep upper slopes excessively drained, some slump floors, benches, foot slopes, and broad crest surfaces imperfectly to poorly drained.

Vegetation.—Almost entirely under secondary vegetation (R–FR). In the east, tall cane-grass regrowth (GtR) (26%) forms a conspicuous element. Areas where sago is exploited (MR) are of minor importance (7%) and found only in the west. Mid-height grassland dominated by *Imperata* (GI) covers about 1%. In about 32% small patches of tall forest with an irregular canopy with light-toned crowns (Fid) are found amongst the secondary vegetation, but larger tracts are rare (2%). Tall forest with a rather open canopy (Fo) occurs on some valley floors (3%).

Geology.—Pliocene mudstone, in places interbedded with siltstone and minor sandstone. These rocks are at least partly calcareous and appear to be horizontally bedded or very gently to gently dipping. Superficial beds are commonly colluvium of mudstone. In extreme west near Lumi (26) are remnants of Pleistocene alluvium on some broader crests and as thin colluvial mantles on slumped dissection slopes.

Weathering and Soils (24 obs.).—Colluvial mantle commonly found at surface is generally not weathered, rarely shallowly skeletally weathered. Hill slopes and crests are generally shallowly skeletally weathered, but rock may be softened by hydration to a depth of some tens of feet, apparently least on emergent crestal ridges. Shallow immature weathering seen once on remnant of Pleistocene alluvium on a crest and once on what appeared to be a gentle dip-slope remnant. Carbonates probably have been leached out of upper rock strata in many places.

Probable soil composition is EUHO7 subdominant; EUHO6, EUHA5, IODE1 common; (EUHO9), EUHA6, EAHS3, (EAHU3), EAHY2, EUHL, IODE3, IODE4, IODL1, AUTO2, AUTA2, UOTA1 minor. Colluvial mantle characterized by undeveloped soils which are mostly weakly acid (rarely neutral), deep to very deep, slightly stratified firm to plastic clay loam, silty clay and clay soils (EUHO7), but also moderately shallow, very plastic silty heavy clay soils (EUHO6) with very low to high amounts of rock fragments in subsoil. In the far west, where colluvium is partly derived from Pleistocene alluvium, similar but more acid soils probably will be found. Particularly on gentle lower slopes, slump floors, and slump benches occur neutral, moderately shallow to very deep, slightly to moderately gleyed (rarely strongly gleyed), firm clay soils (EUHA6) and very plastic (silty) heavy clay soils (EUHA5, EAHS3), which may have loam to clay surface horizons that are soft underfoot (EAHY2). These gleyed soils have thin dark topsoils.

On steep to very steep erosional slopes soils are neutral, rarely weakly acid in reaction, and include some undeveloped, shallow, friable clay loam soils with many rock fragments (EUHL); slightly developed, moderately thin, uniformly textured firm clay or silty clay soils with thin or without dark topsoils (IODE1), as well as similar but moderately developed, moderately thick soils (IODE3); and (probably rarely) similar clay soils with a friable clay loam surface horizon (AUTO2). In places these soils have thin dark topsoils. A similar, weakly acid, moderately thin, very firm silty heavy clay soil (IODE4) observed on a gently sloping mudstone slip terrace. Ridge crests and benches near crests can have soils similar to those of erosional slopes (IODE1, IODE4), but surprisingly often have slightly developed, neutral, very thin to thin, friable to firm clay loam, clay, or silty clay soils (IODL1). Moderately developed, weakly acid to acid, moderately thick to thick, slightly gleyed, very firm to very plastic silty heavy clay soils with friable clay loam to clay surface horizons observed on a crestal dip-slope remnant (AUTA2), and in a remnant of old alluvium on a broad hill crest (UOTA1).

Population and Land Use.—Population of 16,630 distributed over 77 villages. Present land use covers 200·5 sq miles (91% of area), 1% in land use intensity class 2, 64% in class 3, 15% in class 4, and 20% in class 5. Planted sago is important for subsistance only in a few western occurrences.

Transitions to Other Land Systems.—Difference between Seim and Dreikikir (46) largely one of relief and boundaries with the higher Dreikikir are commonly arbitrary. Where characteristic polygonal pattern is poorly expressed, Seim is transitional to Sengi (42). Where individual slump alcoves are less conspicuous and stream pattern is denser, it has gradual boundaries with Morumu (39), Kaugiak (37), and Emul (36); where dip slopes acquire some significance, it has gradual boundaries with Mambel (48). Relation with Ningil (49) discussed under the latter.

Forest Resources (9 obs.).—Forest covers 13%; very low forest resources. Forests of moderate stocking rate (Fid, 10 sq miles; Fid/FR, 9 sq miles) and low stocking rate (FR, 3 sq miles) found on hills. Minor areas of moderate to high stocking rate forest (Fo, 7 sq miles) occur on valley floors. Access category II; minor access problems due to wetness expected on foot slopes, benches, and slump floors.

Agricultural Assessment.—High capability for improved pastures but low capability for arable crops and tree crops. Erosion hazards main limitation to cropping, and overall capability is reduced by presence of scattered but significant areas of very steep slopes unsuitable for any form of agricultural use. Lower rating for tree crops than for improved pastures due to local or common limiting effects of poor drainage, effectively shallow soils, and rather high pH. Development mainly for pastoral industries is recommended, because of great irregularity in detail of the terrain and because a very large area has been cleared of forest. Such development could be associated with local cropping and small tree crop plantations on most suitable land and with timber plantations on steeper slopes. Soil nitrogen contents mostly moderate, but commonly low. Phosphate contents generally low to very low, rarely moderate to very high. Potash contents very high to high. In water balance zone 1 is rather frequent slight, and rather rare severe, soil water stress (frequent severe in EUHL and IODL1 soils) on crests and steeper upper slopes, and generally for shallow-rooting crops.

Engineering Assessment.—Major problems in road construction are scarcity of suitable subgrade and road-surfacing materials and danger of slump damage to roads. Materials may have to be brought in from far away, and road maintenance may be costly. Topographically, it presents only moderate problems. Minor roads will be very winding if following indented and peaked ridges, and very slippery if not grassed or surfaced. Generally small amounts of cut-and-fill are often necessary, but cutting is easy in the soft rocks. Only rarely are larger bridges required, but much attention should be paid to roadside drainage and many culverts provided. Soils are dominantly CH, subdominantly MH, and minor CL; probable depths are deep dominant, moderately deep subdominant, shallow, very shallow common.

(47) Dreikikir Land System (143 sq miles)

Land Forms (Plate 22, Fig. 1).—Massive, but strongly slumped, mostly long, high hill ridges, and few low mountain ridges, commonly with a semi-polygonal crest pattern of zigzagging main ridges and branching side spurs. Altitude ranges from 400 to 2000 ft; 79% below 1000 ft. Relief is mainly between 300 and 700 ft, but can be as low as 200 ft and as high as 1000 ft. Crests normally very narrow to narrow, with few broad to very broad sectors which in a few cases appear to be dip-slope remnants. They are even or somewhat peaked with normally very gentle to moderate slopes. Crests commonly bounded by short steep to locally precipitous upper hill slopes, resulting in emergent crestal ridges on top of main ridges. Hill slopes locally consist of medium-sized to very large hummocky concave slump alcoves with moderate to steep slopes, partly surrounded by upper ridge slopes and side spurs and commonly backed by very steep to cliffed slump walls up to 100 ft high. In other localities are long strongly hummocky moderately steep to steep hill slopes with many small slumps. In other cases again, slopes have large benches with very gently sloping surfaces parallel to main crest and separated by steep to precipitous rather short slopes. Lower hill slopes near streams mostly very steep, but moderate to moderately steep colluvial or residual foot slopes locally occur. Thus steepest slopes occur mostly just below hill crests and just above streams, but are also common on mid slopes as either slump walls or side slopes of benches. Normal straight hill slopes, mostly steep and in places grooved, also occur throughout. Flood-plains along major streams are either very narrow (10–50 yd) or altogether absent.

Streams and Drainage (Fig. 12(*e*)).—Drainage pattern of rather closely to rather widely spaced main streams, ranging from first to fourth order, and with subparallel to subangular alignment that may have been influenced by faults and joints. More closely spaced short first-order tributaries commonly aligned at right angles to main streams, enhancing angularity of overall pattern. Streams flow very largely in shallow rock-cut beds, 10–30 yd wide for main streams and probably mostly having high gradients. First-order tributaries may have gradients up to moderate slope. Probably very little hard rock gravel and sand in river beds, except in a few through-going larger rivers 30–60 yd wide. Surface run-off probably high relative to through drainage so frequent flood spates are likely to occur, but through drainage appears sufficient for all but the smallest streams to be perennial. Generally well drained, but many small areas of slump floors and benches are imperfectly to poorly drained due to seepage.

Vegetation.—About 75% is covered with secondary vegetation, ranging from gardens and coffee plantations to old secondary forest (R–FR), with patches of cane-grass regrowth (GtR) in eastern areas and much planted sago (MR) in the west. Scattered patches of original tall forest cover are type with an irregular canopy with light-toned crowns (Fid). Together with several larger tracts this forest covers about 25%. In extreme north, 2% is covered with mid-height forest with an irregular canopy (Fmi).

Geology.—Pliocene interbedded siltstone, sandstone, and mudstone which are probably mostly very gently to gently dipping; at least locally calcareous. Surficial beds commonly colluvium derived from these rocks.

Weathering and Soils (15 obs.).—Colluvial material and rocks on precipitous straight slopes generally not weathered. Very shallow skeletal weathering on other straight slopes and most crests. Remnants of very shallow immature or mature weathering found on some wider crests, including dip-slope remnants. Rocks, particularly sandstone, commonly softened by hydration probably to a considerable depth particularly on crests and upper hill slopes, less on steepest slopes and lower erosional slopes.

Probable soil composition is EUHO7, IODE3 subdominant; AUTO1 common; EAHU3, EAHS3, (EUHA5, EUHA6), EUHL, IUHL, IUHO1, IODL1, AUTA1, UOPT minor. Soils on crests are acid to weakly acid, commonly with moderately thick to thick dark topsoils. They are mostly slightly to moderately developed, thin to moderately thin, firm to friable clay to clay loam soils (IUHL, IUHO1) and slightly gleyed, very firm to very plastic clay soils with a more friable clay loam surface horizon (AUTA1). On a crestal gentle dip-slope remnant was a very strongly developed, acid, thick, very plastic to very firm silty heavy clay soil with a thick firm clay surface horizon and prominent light grey, red, and brown mottling in subsoil (UOPT). Principal soils of slump alcoves, benches, and slumped slopes are undeveloped, weakly acid (rarely acid), deep to very deep, slightly stratified firm clay to sandy clay colluvial soils with varying amounts of rock fragments in varying parts of the profile (EUHO7). In poorly drained areas of slumps and benches are undeveloped, weakly acid, deep to very deep, slightly to strongly gleyed, rather stratified colluvial soils in which texture may vary from slightly plastic to friable loam, to firm to plastic sandy heavy clay (EAHU3, EAHS3).

Residual soils on moderately steep to very steep slopes are slightly to moderately developed, weakly acid to alkaline, moderately thick, uniformly textured firm clay to sandy clay soils (IODE3) and very firm silty clay to silty heavy clay soils with a more friable clay loam surface horizon (AUTO1). On precipitous slopes were slightly developed or undeveloped, weakly acid to neutral, shallow to very shallow, friable clay loam to clay soils

(IODL1, EUHL). These are associated with rock outcrop and rocky cliffs.

Population and Land Use.—Population of 6730 distributed over 32 villages. Present land use covers 121·5 sq miles (85% of area), 32% in land use intensity class 3, 46% in class 4, and 22% in class 5. Planted sago is important in subsistence in west. Very few occurrences are unused.

Transitions to Other Land Systems.—Although ridge pattern is commonly more linear, areas are included that are distinguished from Seim (46) almost solely by their greater relief. Where there is evidence of more steeply dipping rocks, it is transitional to Mambel (48).

Forest Resources (3 obs.).—Forest covers 26%; very low to low forest resources. Forest mainly of moderate stocking rate (Fid, 24 sq miles; Fid/FR, 10 sq miles), with smaller areas of low stocking rate (Fmi, 2 sq miles; FR, 1 sq mile). Access category III; minor access problems due to wetness may arise on slump floors and benches.

Agricultural Assessment.—Moderate capability for improved pastures, but only low capability for tree crops and very low capability for arable crops. Land use capability varies strongly from place to place, small areas with high to moderate capability, locally even for arable crops, being separated by areas of very low to nil capability. Thus possibilities of local agricultural development cannot be ignored. Erosion and topographic hazards are main limitations, plus, particularly for tree crops, local insufficient effective soil depth, poor drainage, and more rarely rather high pH. Pastoral development seems the most appropriate, with local opportunities for tree crop plantations and cultivated crops, whilst steepest slopes should be kept under forest. Phosphate contents vary irregularly from moderate to very low; potash contents appear generally high, locally very high or moderate. In water balance zone 1, rather frequent slight to frequent severe soil water stress occurs on steeper slopes and crests, particularly in AUTO1, EUHL, and IODL1 soils.

Engineering Assessment.—Because of great topographic limitations, common landslide hazards, and scarcity of road-building materials, regional road construction should be avoided. Local access roads best located on ridge crests and access to them is usually simpler from the south than the north where ridges commonly descend abruptly to lower terrain. Rocks commonly appear to include interbedded sandstone which could be of some use for road surfacing, particularly in combination with lime stabilization. Soils are dominantly CH, subdominantly MH, CL; probable depths are deep, moderately deep, shallow subdominant; very shallow common.

(48) MAMBEL LAND SYSTEM (280 SQ MILES)

Land Forms (Plate 22, Fig. 2).—Rough terrain of strongly slumped, mostly high hilly chevron and strike ridges. Altitude ranges from 300 to 2100 ft; 70% below 1000 ft. Relief ranges from 200 to 900 ft. Although varying much in size, slumps tend to be large. Oval to heart-shaped, relatively shallow, but large slumps (up to 700 yd wide) occur only on dip-slope faces. Their hummocky and gullied floors have moderately steep overall slopes aligned to the dip of the rocks; they are backed by short very steep to precipitous slump walls. Other dip-slope slumps are deeper, have smaller floors, and concave steep to moderately steep back slopes. Slumps on outcrop faces are smaller, have concave floors with moderate to steep slopes, and very steep to precipitous back walls. Intact upper dip-slope remnants are rare, but superficially slumped and hummocky or closely gullied dip slopes with moderate to moderately steep overall slopes are more common. Very steep to precipitous intact outcrop slope remnants are scattered throughout. Outcrop slopes particularly, but also other hill slopes, are strongly spurred where there are closely spaced narrow but deep small slumps. Locally, slumping has virtually obliterated original chevron forms, leaving only short asymmetrical hummocky ridges with moderately steep to very steep slopes. Severe slumping has commonly led to development of even-crested or peaked emergent crestal ridges with narrow to very narrow crests and short very steep side slopes. Although moderate colluvial foot slopes are locally present, lower hill slopes near streams are generally very steep to precipitous, particularly along larger through-going streams.

Streams and Drainage (Fig. 12(*f*)).—Dense to moderately dense pattern of first- to fourth-order streams which is partially parallel, partially angular, and partially dendritic. Preference for higher-order streams to follow the strike, with many first-order tributaries at right angles. Gradients probably low to high in higher-order streams, very gentle to moderate slope in first-order streams. Some larger through-going streams have discontinuous narrow (50–150 yd) flood-plains; local streams flow in shallow 5–30-yd-wide beds with little or no hard rock gravel, and cut into rock or colluvium. Except for smallest first-order streams, they are expected to be perennial. Surface run-off is probably moderate to high relative to through drainage, thus flood spates would be relatively infrequent and residual flow substantial.

Drainage status of slump floors varies from good to very poor, that of dip slopes from imperfect to poor. Steeper slopes are well drained but tend to become excessively drained when precipitous.

Vegetation.—Vegetation essentially the same as for Nuku (51), but area under secondary vegetation is even larger (60%) at the expense of area under tall forest.

Geology.—Upper Miocene and Pliocene interbedded siltstone, sandstone, and mudstone, generally with moderate dips. Surficial rocks in slumps consist of colluvium.

Weathering and Soils (6 obs.).—Rocks seem deeply softened by hydration and leached of carbonates but true weathering appears restricted to a few dip-slope remnants where it is skeletal or very shallow immature.

Probable soil composition is IODE2, (IODE3, IODE4), IAUO3, AUTO2, (EUHO7) common; (EUHA5, EUHA6, EAHU3, EAHS3, EAHY2), UOTO1, UOTH, AAU1, (IODE1, IOBL, EUHL) minor. Most soil observations made on dip-slope remnants. Here occur mostly moderately developed, acid, moderately thick to thin, not gleyed to moderately gleyed, friable to very plastic clay loam to silty heavy clay soils, with friable loam to clay loam surface layers and in some cases moderately thick dark topsoils (UOTO1, UOTH, AAU1). On moderately slumped dip slopes and on the floor of a large dip-slope slump moderately to slightly developed, weakly acid to acid, thin to moderately thick, firm sandy clay loam to very firm clay soils were observed, which may be uniformly textured (IODE2), have a coarser-textured more friable surface horizon (AUTO2), or be gleyed and have a thick dark topsoil (IAUO3). Other soils on similar and/or smaller or more concave slumps are probably undeveloped, weakly acid to neutral, deep, slightly to moderately gleyed, but locally not gleyed or strongly gleyed, slightly stratified, but predominantly clayey colluvial soils.

No data for emergent crestal ridges which probably have slightly to moderately developed, weakly acid to neutral (locally acid), thin to moderately thick, uniform clay soils; for steep spurred hill slopes, probably with moderately developed, weakly acid, moderately thin to moderately thick uniform clay loam to clay soils; or for scattered very steep to precipitous slopes which are likely to have weakly acid to weakly alkaline, thin, sandy clay loam to clay soils with some outcrop of soft rock. All these are probably similar to soils for similar situations in Nuku (51), Seim (46), and Dreikikir (47).

Population and Land Use.—Population of 8960 distributed over 50 villages. Present land use covers 153 sq miles (55% of area), 25% in land use intensity class 3, 31% in class 4, and 44% in class 5. Planted sago is important in subsistence. South-western occurrences are largely unused.

Transitions to Other Land Systems.—Transitions to Nuku (51) discussed in the latter. Similarly, there is no sharp boundary between Mambel and Minatei (50) and Flobum (44), the distinction lying largely in the coarser pattern and/or greater relief and altitude of the last two and the prevalence of clearly recognizable large slumps in Mambel. As dip and strike effects in Mambel become less distinct, there is a gradual transition to Dreikikir (47) if relief is similar or greater and to Seim (46) and Sengi (42) if relief also decreases. In typical development, however, they, particularly Seim (46), are quite distinct.

Forest Resources (3 obs.).—Forest covers 46%; low forest resources. Most forest is of moderate stocking rate (Fid, 101 sq miles; Fid/FR, 22 sq miles). Remainder is of low stocking rate (FR, 2 sq miles; Fid/G, 4 sq miles; FRm–FR, 1 sq mile) and, apart from secondary forest, is generally confined to steeper parts.

Access category IIIw, because of access problems due to wetness on slump floors and dip slopes.

Agricultural Assessment.—With topographic problems, erosion hazards, and poor drainage as main limitations, land use capability appears moderate for improved pastures but low for tree crops and particularly for arable crops. Since land characteristics vary strongly no large-scale agricultural operations are possible except for grazing. Much is too steep for cultivation, but some arable land occurs in pockets of more gentle slopes on relatively well-drained slump floors and dip slopes. Tree crops best planted on well-drained land in slumps, slumped dip slopes, and less steep hill slopes. Insufficient soil depth is a contributory limitation for tree crops on steep slopes. There may be substantial landslide danger which would have more serious consequences for tree crops than for arable crops or pastures. Small plots of paddy rice could be grown successfully in some rather level very poorly drained slump alcoves. Steepest slopes are unsuitable for agriculture. Soil nitrogen contents are low to moderate. Phosphate contents tend to be very low on dip slopes, slumped dip slopes, and residual steep slopes, but range from low to high on slump floors and very steep slopes. Potash contents are mostly high and even very high, but are commonly low to moderate on dip slopes and slumped dip slopes. In water balance zone 1 there is locally rather rare to rather frequent soil water stress, mainly on dip-slope remnants, crests, and steep upper slopes.

Engineering Assessment.—Road-building problems are broadly comparable with those for Nuku (51), but seem somewhat greater because the apparently lower degree of slope stability will increase chances of landslide damage. The very irregular topography would require more cut-and-fill operations (not a great problem in these soft rocks) and road foundations would be less solid because of the softness of rocks and colluvial mantles. Soils are dominantly CH, subdominantly CL, and minor MH; probable depths are moderately deep, deep, shallow subdominant, very shallow minor.

(49) Ningil Land System (8 sq miles)

Land Forms (Plate 23, Fig. 1).—Very gently to gently sloping, flattish to broadly but slightly undulating surfaces (dip slopes), bounded by scarps and back-cutting ravines (box canyons) with precipitous to cliffed slopes 200–400 ft high. Altitude ranges from 600 to 1500 ft; 56% below 1000 ft. Surfaces (about 70%) vary in width from 350 to 1700 yd and are 700–3500 yd long. Eastern (downslope) fringes have no scarps and are dissected into strongly slumped irregular ridges with narrow rounded crests, mainly moderate to steep slopes, and some gentle foot slopes, and a relief of 50–250 ft. Such land probably occupies 20–25%, the remainder consisting of scarp slopes.

Streams and Drainage (Fig. 13(*a*)).—Rather dense to rather open pattern of subparallel mainly second- and third-order streams, largely originating outside the land system, and with short first- and second-order tributaries. Total pattern thus created is subangular. Most streams are in deep narrow valleys with colluvial fill, backed by scarps. River beds probably 5–20 yd wide, shallow, with little or no hard rock gravel, and probably have high gradients merging into very gentle or gentle slope gradients in headwaters. Surface run-off probably moderate in relation to through drainage; flood spates therefore relatively infrequent and rarely of great magnitude.

Flattish surfaces are probably largely imperfectly drained, dissection ridges well drained with small poorly drained pockets in slump floors, scarps excessively drained.

Vegetation.—Tall forest with an irregular canopy with light-toned crowns (Fid) covers 63%. Remainder is garden, or under various stages of regrowth up to old secondary forest, locally with planted sago (R–FR/MR).

Geology.—Pliocene interbedded calcareous siltstone and mudstone dipping gently to SSE.

Weathering and Soils (2 obs.).—Dip-slope surfaces appear to have very shallow immature weathering, dissection slopes very shallow skeletal weathering. Underlying sedimentary rocks appear to be very little hydrated and leached, and remain largely consolidated.

Probable soil composition is AUTA3 dominant; (UOTA1) subdominant; IODE1 common; (IODE4, EUHO6, EUHA3) minor. A moderately developed, weakly acid, moderately thick, slightly gleyed, very firm to very plastic silty heavy clay soil with a firm clay loam to clay surface horizon (AUTA3) observed on dip-slope surface, where similar soils of other families, including more acid soils, may also occur. A slightly developed, neutral, moderately thin, uniformly textured very firm to very plastic silty clay soil (IODE1) observed on a hill spur of dissected eastern margin and is probably fairly typical of soils of slumped dissection slopes, although variations in soil depth and gleying are likely to occur, associated with irregular land forms. Deeper and probably slightly gleyed undeveloped clay soils may occur on some colluvial foot slopes. Scarps have rock outcrop and very shallow, probably alkaline clay loam soils.

Population and Land Use.—Population is nil. Present land use covers 2·7 sq miles (33% of area), 48% in class 3, 52% in class 5. Land used by villagers in adjoining Seim (46) and Mambel (48).

Transitions to Other Land Systems.—Most of land system has a unique photo pattern, in essence a gentle-dip variant of Nuku (51). Where dissection and slumping are prominent, Ningil is similar to and has gradual boundaries with Sengi (42); in the west larger slumps and emergent remnant ridges begin to appear in a gradual transition to Seim (46). Thus, Ningil may be a remnant of the kind of landscape from which Seim (46) developed by dissection and slumping.

Forest Resources (2 obs.).—Moderate stocking rate forest (Fid) covers 63% (5 sq miles); moderate forest resources. Access category IIw; difficulties presented by bounding scarps and above-normal wetness of soils on flatter areas.

Agricultural Assessment.—Moderate capability for arable crops, high capability for improved pastures, but only low capability for tree crops, mainly as a result of imperfect drainage, effectively rather shallow soils, and in places rather high pH. Best arable land on "plateau" surfaces, but even here measures to control erosion may generally be required; this is also the most suitable land for improved pastures, but much land on steeper, slumped dissection slopes is also suitable for them. Soil nitrogen contents generally moderate, locally low; phosphate contents probably highly variable, but mostly low; potash contents mostly high, in places probably moderate on "plateau" surfaces, and very high on some dissection slopes.

Engineering Assessment.—Advantages for road construction of "plateau" surfaces partly offset by problems of surrounding scarps. Only a few points where these scarps are hardly developed, and present road from Anguganak to Nuku utilizes such a point to traverse the land system. Access roads for local development best made from the east, where there are no scarps but some risk of slump damage to roads. Proper attention to roadside drainage needed on "plateau" surfaces. Unmade roads would tend to become very slippery after even little rain and impassable after heavy rain. No useful sources of road metal. Soils are CH with minor CL; probable depths are moderately deep dominant, shallow common, very shallow, deep, very deep minor. Some surfaces appear sufficiently smooth and in the right direction for airfield construction without much earth-moving works; a SE. downslope of between 3° and 8° cannot be avoided.

(50) Minatei Land System (7 sq miles)

Land Forms (Plate 23, Fig. 2).—High hilly complex of very long gently sloping dip slopes (approx. 60% of area) bounded by very steep to precipitous outcrop slopes 200–300 ft high (approx. 10%) and hummocky, slumped, moderate to steep lower slopes (approx. 30%). Altitude ranges from 1400 to 3300 ft; 57% above 2000 ft. Relief is 400–700 ft. Dip slopes, sloping S.–SE., generally have superficial slumping and gullies with a relief of 10–30 ft; they occur at different levels, separated by outcrop slopes.

Streams and Drainage (Fig. 13(*b*)).—Coarse but locally fine-textured, rather radial dendritic to subparallel pattern of small, mostly first- and second-order streams which are perennial and flow in 10–30-yd-wide beds cut in rock or colluvial materials, and with little or no hard rock gravel. Stream gradients probably range from high gradient to gentle slope in some first-order streams. Surface run-off probably low to moderate relative to through drainage so that streams have a high rate of sustained flow and relatively few flood spates. Mostly well drained, but some dip-slope sections and slump floors appear to be imperfectly to poorly drained.

Vegetation.—Vegetation very much like that of Flobum (44) at its mid- and higher-altitude levels. Gardening, including sago exploitation (MR), is even more intensive; also some mid-height grassland (G) is found. Over 80% is under secondary vegetation (R–FR). Remains of original forest of mid-height type (Fmi, Fm).

Geology.—Upper Miocene interbedded siltstone, mudstone, and sandstone, gently to moderately dipping S.–SE.

Weathering and Soils (3 obs.).—Weathering rather pronounced, resulting in deep skeletal weathering and shallow immature weathering on dip slopes and at least part of hummocky lower slopes, and shallow mature weathering remnants on upper dip slopes.

Probable soil composition is UOTO2 subdominant; (UOTA1, IODO3, IODO4, EUHO9) common; IODL2 (EAHU3, EUHA6, UOTO5) minor. Moderately to strongly developed, acid, moderately thick, plastic clay to clay loam soils with very friable loamy surface soils (UOTO2) on a dip slope and hummocky lower slope, and a moderately developed, acid, very thin, very friable loamy soil on weathered rock (IODL2) on an outcrop slope. Probably also moderately to strongly developed, acid, gleyed soils on dip slopes and less-developed or undeveloped, acid to weakly acid soils on lower slopes, probably gleyed on slump floors. Very strongly developed, strongly acid, thick soils locally on upper margins of dip slopes.

Population and Land Use.—Population of 510 distributed over five villages. Present land use covers 4·2 sq miles (60% of area), all in land use intensity class 5. People also use land in adjacent Karaitem (41). Planted sago is very important in subsistence.

Transitions to Other Land Systems.—Typically transitional between Flobum (44) and Nuku (51), resembling the former in weathering, drainage pattern, slumping, and altitude, the latter in its marked display of dip slopes and outcrop slopes. Relief is also intermediate between these two.

Forest Resources (1 obs.).—Forest covers 57%; low forest resources. Forest comprises low stocking rate types (FR, 3 sq miles; Fmi, 1 sq mile, the latter confined to higher altitudes). Access category II; also possible minor access problems due to wetness on dip-slope sections and slump floors.

Agricultural Assessment.—Low capability for arable crops, but moderate capability for tree crops and particularly for improved pastures. Erosion hazards main limitation for arable crops, with soil acidity and local poor drainage as contributing factors. Capability for tree crops not rated higher owing to slight soil-depth limitations and local drainage deficiencies, but also because this land is largely above 2000 ft, climatically not very suitable for the common tree crops grown in New Guinea. Capability for a climatically adapted tree crop would be greater than indicated. In this altitudinal range, prospects for a cattle industry based on improved pastures appear best possibility for development if access can be improved. Soil nitrogen contents generally moderate, but low to very low on very steep slopes. Phosphate contents probably largely very low, locally low, and moderate on some slump floors. Potash contents probably low to high, with lower values mostly on dip slopes.

Engineering Assessment.—Can be avoided in regional road communications in favour of more suitable Karaitem (41). Local access roads could be provided from the south with only moderate topographic problems. Landslide hazards in the deeply softened rocks may be a problem, so that good roadside drainage in this wet area is required. Relatively few bridges and stream culverts needed. Road-metal materials appear very scarce, but can be brought in from nearby larger rivers and possibly quarries in nearby Sulen (58) and Barida (56). Soils are dominantly Ch, subdominantly MH, CL; probable depths are moderately deep, deep subdominant; shallow, very deep common; very shallow minor.

(51) Nuku Land System (193 sq miles)

Land Forms (Plate 24, Fig. 1).—Complex of rather triangular low to high hilly chevron ridges with long, moderate to moderately steep (rarely gentle) dip slopes, sharply bounded by steep to very steep, and locally precipitous outcrop slopes. Included are a few strike ridges with similar slopes and very narrow even crests up to 2 miles long. Altitude ranges from 400 to 2600 ft; 68% below 1000 ft and 29% at 1000–2000 ft. Relief is essentially variable, mostly 200–500 ft with extremes of 100 and 600 ft, the latter mainly along marginal scarps and major rivers. Dip slopes, occupying 60–70%, generally face SW.–S., rarely SE.–E., and are commonly "layered" with short very steep to precipitous slopes separating two or three dip-slope levels. They may be smooth but are more often gullied or superficially slumped, with low transversal benches (up to 30 ft) or small slump alcoves. A few large slump alcoves occur, but are not typical. Outcrop slopes mostly face NW., N., or NE., rarely E. or W.; they range from strongly slumped irregular steep slopes (about 20%) to straight precipitous scarps (<5%). Scarps most conspicuous along northern margins between Nuku and Lumi. Downslope, they locally merge into moderately steep to steep scree slopes and foot slopes.

Streams and Drainage (Fig. 13(*c*)).—Rather open to rather dense pattern of streams characterized by a relatively small number of first-order and a large number of higher-order streams. Although there is noticeable alignment of higher-order streams along the direction of the strike and some angularity caused by streams breaking through it, pattern is more dendritic than expected from the high degree of directional organization in land forms. Apart from a few medium-sized to large through-going rivers, streams are 5–20 yd wide, shallow, and rapidly flowing in predominantly rock-cut beds with little or no hard gravel, and with gradients ranging from low gradient in higher-order streams to very gentle to gentle slope in most first-order streams. Surface run-off may be high in relation to through drainage and contribution of groundwater seepage to stream flow relatively low. Thus streams are probably subject to frequent flood spates and have low residual flow, some first- and second-order streams in drier eastern parts probably intermittent.

Drainage of dip slopes commonly imperfect due to slow soil permeability, and ranges from good to poor. Slump floors and benches are mostly poorly to very poorly drained due to seepage; remainder of hill slopes well drained but precipitous outcrop slopes excessively drained.

Vegetation.—Tall forest with an irregular canopy with light-toned crowns (Fid) probably once covered most of land system, with mid-height forest (Fmi/Fmi′) on crests and steeper slopes at higher altitudes; now 46% and 2% are left under these types. Secondary vegetation types, from gardens to old secondary forest (R–FR), particularly common in northern occurrences. In west sago (MR) is commonly planted on slumped slopes; in east tall cane-grass regrowth (GtR) follows gardening before woody regrowth species move in. Locally mid-height grasslands (G), some dominated by *Imperata* (GI), have developed.

Geology.—Pliocene interbedded siltstone, sandstone, and mudstone, probably commonly calcareous, and locally including marl with shell fragments, and very local thin intercalated limestone. Rocks have gentle to moderate dips, predominantly SW.–S., very locally SE.–E.

Weathering and Soils (17 obs.).—Weathering has led to removal of carbonates and softening of rocks by hydration to depths varying from a few to some tens of feet. Very shallow immature weathering common on dip slopes, but locally weathering is only skeletal, very locally shallow mature. Outcrop slopes and slumped dip-slope sectors shallowly skeletally weathered.

Probable soil composition is AUTA3 subdominant; UAOU, EUHO7 common; IODE3, IODE4, OANT1, IODA1, IOEL, AUTA1, AUTQ, AAU3, EAHU3, EUHA6 minor. On dip slopes are mostly moderately developed, acid to weakly acid, slightly and more rarely moderately gleyed, very firm to plastic clay to heavy clay soils, mostly (UAOU, AAU3, AUTQ, AUTA1, AUTA3) but not always (IODA1) with coarser-textured friable loam to clay surface soils. These soils commonly have a moderately thick to thick solum, locally it is moderately thin to thin. Dark topsoils are mostly thin or absent but locally moderately thick (UAOU, AAU3, AUTQ). In one locality, a strongly developed, strongly acid, thick, firm to friable clay soil with silty clay loam surface soil (OANT1) was observed. Where superficial slumping has destroyed the weathered mantle undeveloped soils occur, such as a weakly acid, very deep, slightly stratified, firm clay loam to silty heavy clay soil (EUHO7). Soils of same family, but with more rock fragments and locally cobbles and stones were observed on a scree and foot slope below a very steep outcrop slope.

Outcrop slopes have mostly moderately developed, weakly acid, moderately thin to moderately thick, uniformly textured, firm to plastic clay to heavy clay soils with thin dark topsoils (IODE3, IODE4) but slightly developed, thin clay loam soils (alkaline (IOEL) in profile observed) occur on precipitous slopes, usually in association with rock outcrop. On slump floors and benches in dip slopes and outcrop slopes are undeveloped, neutral to weakly acid, deep, moderately gleyed, stratified colluvial soils with textures ranging from friable or slightly plastic sandy clay loam to plastic or firm clay (EAHU3, EUHA6).

Population and Land Use.—Population of 5550 distributed over 27 villages. Present land use covers 75 sq miles (39% of area), 27% in land use intensity class 3, 36% in class 4, and 37% in class 5. Planted sago important in subsistence in the west. More intensive land use restricted to eastern occurrences; south-western occurrences not used at all.

Transitions to Other Land Systems.—Typical photo pattern is very distinct. It differs from Musak (52) in having less steep dip slopes and a coarser pattern, and from Wuro (53) also in having a lower relief. It is distinguished from Mambel (48) by being much less slumped, but because of great local variations in slumping several boundaries between them are necessarily arbitrary. It differs from Minatei (50) in being less massive, having slightly less relief but steeper dip slopes, and in occurring at lower altitude. Where dip slopes become gentle, it can be transitional to Ningil (49) which is clearly more plateau-like.

Forest Resources (8 obs.).—Forest covers 58%; moderate forest resources. Main forest of moderate stocking rate (Fid, 87 sq miles; Fid/FR, 14 sq miles), with low stocking rate forest (FR, 4 sq miles; Fmi/Fmi', 3 sq miles; FRm–FR, 2 sq miles; Fid/G, 2 sq miles) mainly at higher altitudes. Access category IIw; access problems due to wetness on dip slopes and slump floors.

Agricultural Assessment.—Moderate capability for improved pastures, but only low capability for tree crops and very low capability for arable crops. Potential largely concentrated on dip slopes, but even there erosion hazards are such that terracing may be required for permanent cultivation. However, improved pastures could be alternated with one or two years cropping on favourable sites. Shallowness and drainage deficiencies of soils are main reasons for down-grading capability for tree crops relative to that for improved pastures. Topographically, larger dip-slope areas are rather favourable for plantations or improved pastures. Land use capability of irregular and mostly very steep side slopes and outcrop slopes is negligible; this land is mostly best left in forest. Small wet slump floors may be utilized for very small scale rice-growing. Soil nitrogen contents moderate to low. On dip slopes phosphate contents mostly low to very low, rarely moderate; and potash contents vary from high to very low. On slumped dip slopes, outcrop slopes, foot slopes, and slump alcoves, phosphate contents vary from moderate to very low and potash contents are generally high. In water balance zone I is rather frequent slight soil water stress, except on colluvial slopes with EUHO7, EUHA6, and EAHU3 soils.

Engineering Assessment.—Topographical problems in road construction are less serious than they appear at first. Outcrop slopes would be difficult to negotiate but dip slopes present no major topographical problems. Since landscape is strongly peaked, it is generally necessary to keep roads close to valley bottoms, although this would result in longer, more winding alignments. Road cuts in dip slopes could promote landslides of soil and rock down dip planes above the cut. Any roads through in a roughly N.–S. direction would probably best follow valleys of major streams, although these are generally so narrow that cuttings would commonly be required. A rather large number of small bridges and culverts required in road-building. Subsurface materials would generally have enough bearing strength, but would be slippery after even slight rain, when forming surface of unmade roads. Lack of suitable pavement materials, although harder sandstone beds cropping out in valleys could be at least moderately suitable. Soils are dominantly CH, subdominantly MH, and minor CL; probable depths are moderately deep dominant, deep subdominant, shallow, very shallow common.

(52) MUSAK LAND SYSTEM (19 SQ MILES)

Land Forms (Plate 24, Fig. 2).—Low to high hogback hills with straight steep dip slopes and short very steep to precipitous outcrop slopes. Altitude ranges from 400 to 3000 ft; 58% below 1000 ft, 27% at 1000–2000 ft, and 15% above 2000 ft. Relief varies from 200 to 700 ft and is quite irregular. Crests are knife-edged to very narrow, locally narrow, and have gentle to steep slopes. Some dip slopes are clearly gullied or dissected but slumping is always minor. Distinct orientation of ridges along the strike.

Streams and Drainage (Fig. 12(*c*), 13(*d*)).—Dense but rather disorganized pattern of small streams, partly parallel across the strike with perpendicular feeder streams along it, partly more dendritic. Few through-going streams present in larger occurrences. Gradients mostly high, up to steep slope in first-order streams. Stream beds largely rock-cut and probably mostly gravelly. Most streams are expected to be perennial. Surface run-off probably high in relation to through drainage, causing frequent short flood spates in small streams. Well to excessively drained.

Vegetation.—Predominance of steep and very steep slopes expressed in the vegetation by common occurrences of seral stages of mid-height forest with an irregular canopy (Fmi', some Ca), which are found together with mature forest (Fmi) or tall forests with irregular canopies (Fid, Foi); together they cover 60%. The rest is gardened or under regrowth. Old secondary forest (FR) is common and mapping of the boundary between it and the forest types with irregular canopies is rather arbitrary in places. Some sago is planted in valleys.

Geology.—Miocene to Pliocene interbedded siltstone, sandstone, and conglomerate, with moderate to steep dips. The strike is usually (W.)NW.–(E.)SE., but locally almost N.–S. Similarly, dips are in many different directions. Sandstone and siltstone can be calcareous.

Weathering and Soils (3 obs.).—Weathering is very shallow and skeletal, except on some dip-slope surfaces which are shallowly immaturely weathered. Rocks appear less hydrated than in land systems with more horizontal rock bedding.

Probable soil composition is (IODO1, IODE2), UOTO2 subdominant; EUHL, (IODL1) common; (IUHL), MUHO1 minor. Data on soils too scarce for a comprehensive picture. Observation of a moderately developed, acid, moderately thick, firm clay soil with friable clay loam surface horizon (UOTO2) in line with general predominance of moderately to strongly developed soils on dip slopes in the area. Outcrop slopes and probably also dissected dip slopes appear to have weakly acid to weakly alkaline soils, ranging from undeveloped very shallow loamy soils (EUHL) associated with rock outcrop to slightly developed moderately thin friable clay loam (and possibly sand clay loam) soils which possessed a thick dark topsoil (MUHO1). All soils more or less gravelly where developed on conglomerate.

Population and Land Use.—Population of 620 distributed over three villages. Present land use covers 9·4 sq miles (49% of area), 36% in land use intensity class 3, 20% in class 4, and 44% in class 5. Occurrences north of ranges are largely unused.

Transitions to Other Land Systems.—As dip-and-strike effect becomes less pronounced there is a gradual transition to Morumu (39) or Numoiken (40). As dip slopes become longer and less steep there is a transition to Nuku (51) and as relief increases, a transition to Wuro (53).

Forest Resources (1 obs.).—Forest covers 47%; low forest resources. Much forest has a low stocking rate (Fmi/Fmi', 7 sq miles). Forests with moderate stocking rate (Fid, 2 sq miles; Foi, 1 sq mile) occur on dip slopes, the former type in southern occurrences. Access category IV.

Agricultural Assessment.—At best, very low capability for improved pastures but any development appears unwarranted. Soil nitrogen contents are probably low to moderate. Phosphate contents appear very low on dip slopes, moderate to low but in some cases very high on outcrop slopes. Potash contents probably vary mostly from very high to moderate in a rather irregular manner. In water balance zones 1 and 2 rare severe soil water stress occurs in EUHL, IODL, and IUHL soils on very steep slopes and crests.

Engineering Assessment.—Should be avoided in road construction. May be a poor source of gravel where no other road-building materials can be found within reasonable distance. Soils are CH, MH, CL, with minor ML, SC; probable depths are moderately deep, very shallow, shallow subdominant, deep common.

(53) Wuro Land System (7 sq miles)

Land Forms (Plate 25, Fig. 1).—Hogback mountains with long, straight, steep dip slopes and short, very steep to precipitous outcrop slopes. Land forms essentially similar to those of Musak (52) but more massive. Altitude ranges from 400 to 3500 ft; 27% below 1000 ft, 50% at 1000–2000 ft, and 23% above 2000 ft. Relief is 600–1200 ft.

Streams and Drainage (Fig. 13(*c*)).—Widely spaced parallel streams of second and third order, perpendicular to the strike and partly consisting of through-going streams up to 30 yd wide. These have high gradient and shallow moderately gravelly or stony beds cut into rock. Small first-order tributaries commonly subparallel, and inclined at sharp angles to the strike, with gradients of gentle to moderately steep slope. Small occurrences have only few very small streams. All streams likely to be perennial. Surface run-off probably high in relation to through drainage, causing frequent short flood spates. Well drained, with excessively drained rocky scarps.

Vegetation.—Largely covered with mid-height forest with an irregular canopy, together with its seral stages (Fmi/Fmi'). Secondary vegetation (R–FR/MR) covers 8% of area.

Geology.—Miocene interbedded siltstone, sandstone, and conglomerate, with moderate to steep dips and (W.)NW.–(E.)SE. strike.

Weathering and Soils (No obs.).—Weathering and soils expected to be similar to those of Musak (52), although rock outcrop is probably more common and weathering even less pronounced, with a corresponding decrease in moderately developed and an increase in slightly developed or undeveloped soils. Probable soil composition is (IODE2, IODO1) subdominant; (EUHL, IODL1, UOTO2) common; (IUHL) minor.

Population and Land Use.—Population of 210 in two villages. Present land use covers 0·6 sq mile (8% of area), all in land use intensity class 3. Some people use land in adjoining Asier (43).

Transitions to Other Land Systems.—Photo pattern generally quite distinct. Where relief becomes lower, Wuro is transitional to Musak (52); where dip slopes become gentler it merges into Nuku (51); and where dips are very steep it has similarities with Imbia (54).

Forest Resources (No obs.).—Low stocking rate forest (Fmi/Fmi') cover 6 sq miles; low to moderate forest resources. Access category IV.

Agricultural Assessment.—No significant land use capability. Chemical soil fertility aspects similar to those of Musak (52).

Engineering Assessment.—To be avoided for road construction, but a possible source of subgrade and poor-quality road-surfacing material. Unified soil classes similar to those of Musak (52). Probable soil depths are moderately deep, very shallow, shallow subdominant; deep minor.

(54) Imbia Land System (39 sq miles)

Land Forms (Plate 25, Fig. 2).—Subparallel high hill ridges with chevron spurs and steep frontal dip-slope facets. Altitude ranges from 800 to 3000 ft; 16% below 1000 ft, 70% at 1000–2000 ft, and 14% above 2000 ft. Relief is commonly 400–700 ft, with extremes of 300 and 900 ft. Ridges are aligned perpendicular to and chevron spurs roughly parallel to the strike, which is generally NW.–WNW. but NNE. in one occurrence in centre of survey area. In some cases subparallel ridges are linked on north side by a backing ridge parallel to the strike; it can have a very steep to precipitous back slope. Ridge and spur crests are mostly very narrow. Ridge crests are even or somewhat peaked or stepped and have gentle to moderate slopes; spur crests have mostly steep slopes. Hill slopes are mainly straight and steep to very steep, with few moderately steep slopes. Frontal dip-slope facets have steep to moderately steep, rarely very steep slopes, and are smooth or slightly grooved or slumped. Small, but commonly long slumps and rock debris slides are scattered throughout.

Streams and Drainage (Figs. 11(*b*), 13(*f*)).—Pattern of rather closely spaced subparallel streams that are mainly through-going second- to fourth-order rivers with headwaters outside land system. Apart from many gullies between chevron spurs, there are only a few short first-order tributaries. All streams appear perennial and flow in very narrow rock-cut valleys. Beds of larger streams are shallow, 10–30 yd wide, probably with rapids and deeper pools, and probably have high gradients. Gradients of tributaries may vary from gentle to moderately steep slope. Bed loads probably generally contain little hard rock gravel and sand. Surface run-off probably high in relation to through drainage, resulting in frequent minor flood spates. Generally well drained, but some crests and upper slopes may be excessively drained.

Vegetation.—About 75% has been affected by cultivation. Locally, however, patches are left of tall forest with an irregular canopy with light-toned crowns (Fid). Remainder, consisting of steepest and more inaccessible parts, still under primary forest, mainly tall and some mid-height with an irregular canopy (Fi, Fmi, Fmio), alternating with tracts of seral forest (Fmi′).

Geology.—Steeply dipping Miocene sedimentary rocks, probably interbedded siltstone and mudstone with less sandstone and minor fine conglomerate.

Weathering and Soils (1 obs.).—Weathering nowhere more than shallow skeletal; rocks softened by hydration to probably not more than 5–10 ft.

Probable soil composition is (IODE2, IODE3, EUHO8) subdominant; EUHL, (IODL1) common. Only soil observed, on a very steep upper slope, is an undeveloped, weakly acid, shallow, firm clay soil with low to very high rock fragments (EUHL). Somewhat deeper, undeveloped colluvial soils, and slightly developed, weakly acid, moderately thin, residual soils of sandy clay loam to clay texture are also likely, with some rock outcrop on crests and steepest slopes.

Population and Land Use.—Population of 1400 distributed over seven villages. Present land use covers 29·3 sq miles (75% of area), 26% in land use intensity class 3, 5% in class 4, and 69% in class 5. Parts apparently used by villages in adjacent Karaitem (41).

Transitions to Other Land Systems.—Where crests become strongly peaked, and dip slopes rather than chevron spurs are prominent, it is transitional to Nuku (51). Where chevron spurs are weakly expressed and overall slopes less steep, transitions occur to Asier (43). In a few cases the pattern has some affinity with that of Musak (52) or Wuro (53).

Forest Resources (No obs.).—Forest covers 51%; low forest resources. Much forest is of low stocking rate types (FR, 7 sq miles; Fi/Fmi′, 6 sq miles; Fmi, 2 sq miles; Fmi/Fmi′, 1 sq mile) and the rest is moderate stocking rate forest (Fid, 3 sq miles; Fid/FR, 2 sq miles). Access category IV.

Agricultural Assessment.—Judging from topographic conditions alone there is probably only very low capability for pastures. Land probably best left in forest, or reafforested for watershed protection. Soil nitrogen contents probably mostly moderate, although low contents may also be common. Phosphate contents probably vary mostly from moderate to very high, but may locally be low to very low. Potash contents probably vary from low to very high. In water balance zone 1 is rather rare to rather frequent slight soil water stress in IODE2, IODE3, and EUHO8 soils and rather frequent severe soil water stress in EUHL and IODL1 soils.

Engineering Assessment.—Topographic limitations make road construction from east to west (parallel to strike) virtually impossible, but north–south roads (at right angles to strike) could be aligned more simply by being cut into valley sides just above through-going rivers. Such roads would either be very winding around numerous small salients and re-entrants or require a large amount of cut-and-fill. There would be a definite landslide risk. Some road-surfacing gravel may be available in stream beds. Generally to be avoided for road construction where possible. Soils are CH, MH, CL, with minor ML; probable depths are moderately deep dominant, very shallow subdominant, shallow common.

(55) Aitape Land System (7 sq miles)

Land Forms (Plate 26, Fig. 1).—Very low to high isolated short to long hill ridges and branching ridge complexes, rising abruptly from coastal plain to altitudes of 100–500 ft, 70% of area being below 250 ft. Crests are narrow and slightly rounded. Hill slopes are straight or convex and locally spurred. Slopes are steep, locally very steep or moderately steep.

Streams and Drainage.—Only very small gullies occur. Surface run-off probably only low to moderate in relation to through drainage due to rapid permeability of rocks and most soils. Generally well drained, locally excessively drained.

Vegetation.—Original vegetation, still covering 43%, is tall forest with a rather open and small-crowned canopy (Fos); the rest is cleared for villages, coconut plantations, and gardens, or is under regrowth (R–FRm). Old secondary forest (FR) is rare.

Geology.—Miocene to Pliocene massive limestone and mostly andesitic boulder and cobble conglomerate with a calcareous matrix.

Weathering and Soils (2 obs.).—Weathering generally very shallow skeletal, locally shallow immature. Probable soil composition is MR–O2 predominant; (IODO4) common. Soils observed are slightly to moderately developed, neutral, thin, blocky, very dark, stony, firm clay loam to clay soils (MR–O2), tonguing into hard bed-rock. Local patches of unclassified moderately deep reddish clay soils were observed in passing.

Population and Land Use.—Population unknown but small. Present land use covers 4·0 sq miles (57% of area), 28% in land use intensity class 2, 48% in class 3, and 7% in class 5. Remaining 17% under non-indigenous plantation. Indigenous land use by people from Nubia (2) and Aitape Station.

Transitions to Other Land Systems.—Boundaries are clear and sharp. Mapped on geographical location rather than pattern, because pattern would be difficult to distinguish from Yassip (38), Morumu (39), or Numoiken (40). On the whole these have a more slumped, less convex appearance than Aitape but this is not always easy to see.

Forest Resources (1 obs.).—Forest resources moderate; 43% covered with a high stocking rate forest (Fos). Stocking rate considerably higher than the average for this forest type. Access category III, although access problems reduced by its occurrence as isolated hills in plains.

Agricultural Assessment.—Erosion hazards and unfavourable soil characteristics mean low capability for improved pastures and very low capability for tree crops. Soil nitrogen and phosphate contents appear to be generally moderate, potash contents high. Rare severe soil water stress in MR–O2 soils.

Engineering Assessment.—Easily avoided for road construction; a very useful source of materials for road building and making cement bricks in the coastal plain. Soils are MH; probable depths are very shallow predominant, shallow, moderately deep common.

(56) Barida Land System (31 sq miles)

Land Forms (Plate 26, Fig. 2).—High hill ridges and low mountain ridges with narrow to very broad (but very low hilly) crests, and with predominantly smooth, commonly convex side slopes. Altitude ranges from 220 to 2800 ft; 55% below 1000 ft, 39% at 1000–2000 ft, and 6% above 2000 ft. Relief is mostly 300–900 ft, but up to 1300 ft. Hill slopes mostly steep to moderately steep. Some occurrences have very steep to locally precipitous upper slopes, commonly with adjoining moderate foot slopes of a colluvial nature. Some steep slopes dissected into disordered very steep very short ridges and hills, slightly reminiscent of cone karst. Only very few small dolines seen on broad crests.

Streams and Drainage (Figs. 11(*d*), 13(*f*)).—Generally widely spaced, moderately to steeply sloping small streams flow in ravines, and probably have mostly intermittent flow. Stream pattern slightly radial to angular; stream density greater on some dissected very steep slopes and hilly summit areas. Lowest occurrence in west has largely perennial streams with headwaters in surrounding land systems; courses appear largely fault or joint-controlled. Stream beds normally filled with large and small limestone boulders. Largest streams only have narrow alluvial terraces. Surface run-off may vary from very low to moderate in relation to through drainage, depending on soil and rock permeability. Well drained, locally probably excessively drained.

Vegetation.—Mid-height forests cover 64%. Type with rather dark-toned even canopy (Fm, 20%) occurs on several crests, probably indicating frequent envelopment by clouds. Remainder of crests covered with mid-height forest with an irregular canopy (Fmi) which extends also over the slopes, on steep slopes in conjunction with seral stages (Fmi′), with *Casuarina papuana* (Ca), or with forest with a very irregular canopy (Fmio). In lower parts forest is higher and tall forest (14%) with a rather open irregular canopy (Foi), or with an irregular canopy (Fi) occurs. Gardens and secondary forest (R–FR, 22%) mainly confined to lower areas.

Geology.—Miocene porous massive limestone, tuffaceous limestone, marl, and argillaceous limestone. One occurrence north of Lumi probably underlain by crystalline basement rocks. Doubt as to whether some occurrences in extreme east are indeed limestone.

Weathering and Soils (3 obs.).—Weathering extremely shallow (1–3 ft), but strong in that original rock has very largely disappeared in overlying soils.

Probable soil composition is MR–O2, MR–E subdominant; AUTO1 common. Soils are slightly to moderately developed and weakly alkaline. They range from thin, very dark brown friable clay loam with limestone pebbles and cobbles (MR–O2) on pure limestone, to moderately thin, very dark (grey) brown rather friable clays overlying dark grey-brown, very firm to plastic heavy clay (MR–E) on tuffaceous limestone, to similar, moderately thick, and more plastic soils with thin dark clay topsoils (AUTO1) on marl and argillaceous limestone. Such soils observed on moderate to steep slopes. It is not known what soil conditions prevail on moderate colluvial slopes, or on very steep slopes, which are expected to be stony and rocky.

Population and Land Use.—Population of 130 in one village. Present land use covers 5·7 sq miles (18% of area), 16% in land use intensity class 3, 84% in class 5. Gardening confined to lower slopes and shared by people living outside.

Transitions to Other Land Systems.—On the whole, pattern is unique and boundaries fairly distinct. Locally it appears transitional to Mup (61) and to Om (45) which is more rugged but appears to contain some limestone layers producing similar land forms to those of dissected steep parts of Barida.

Forest Resources (3 obs.).—Forest covers 74%; moderate forest resources. Much forest has a low stocking rate and generally occurs on higher parts (Fmi, 10 sq miles; Fm, 5 sq miles; FR, Fmio, Fmi/Fmi′, 3 sq miles). Moderate stocking rate (Foi, 3 sq miles) and high stocking rate (Fi, 2 sq miles) forests found in lower more accessible parts. Latter forest shows a much higher stocking rate than average for this type. Access category IV for steepest parts, III for less steep occurrences.

Agricultural Assessment.—Steep slopes, rugged terrain, and stoniness mean land use capability for improved pastures is only low. Additional limitations of shallow alkaline soils and locally rather poor physical soil conditions mean only very low capability for tree crops. Generally not attractive for development, also because of difficult access to many occurrences. Soil nitrogen contents moderate to high; phosphate contents vary from moderate to very low; potash contents appear to be high in soils on impure limestone but low in soils on pure limestone. In water balance zone 3 there is rare severe soil water stress, except where soils are unusually deep.

Engineering Assessment.—To be avoided for road construction. Apart from Aitape (55) it is only major source of limestone in the area, and its more accessible north-western occurrences may become a valuable source of this material. Soils are dominantly MH, subdominantly CH, with minor OH surface layers at high altitude; probable depths are very shallow dominant, shallow subdominant, moderately deep minor.

(57) Nopa Land System (11 sq miles)

Land Forms (Plate 27, Fig. 1).—Blocks of irregular, low to high, slumped short hill ridges with longer, less slumped but more grooved or spurred marginal slopes. Altitude ranges from 0 to 3200 ft; 32% at 250–1000 ft, 32% at 1000–2000 ft, and 29% above 2000 ft. Relief within blocks is 200–400 ft, along their margins 600–900 ft. Ridge crests range from knife-edged to narrow and tend to be peaked. Hill slopes vary from moderate to very steep, and are normally irregular, spurred to hummocky. Smooth steep slopes occur locally. Medium-sized to large slump alcoves are often common, and gentle to moderate short colluvial foot slopes occur locally. Marginal slopes are less irregular, longer, and normally steep to very steep.

Streams and Drainage (Fig. 14(*a*)).—Small dendritic systems of mainly first- and second-order streams tend to be orientated in radial pattern around centre of blocks. Streams, flowing in narrow rock-cut beds, are short, small to very small, and have gradients from high gradient to very gentle slope, but near the margins gentle to moderate slope, with rapids and small falls. Gravel probably scarce except near margins. Surface run-off probably high to moderate in relation to through drainage, resulting in rather frequent flood spates but also sustained residual river flow, except probably in some first-order streams. Well drained.

Vegetation.—Tall and mid-height forests occupy 49 and 50%; area under secondary vegetation is only 8%. Mid-height forest is type with an irregular canopy (Fmi) mixed with seral stages (Fmi′, Ca) and is indicative of unstable slopes. At lower altitudes tall forest with a rather open irregular canopy (Foi) predominates.

Geology.—No field data. Photo interpretation suggests basic igneous basement rocks (gabbro, ?diorite) and possible Tertiary volcanic rocks, overlain by 300–500-ft-thick pre-mid-Miocene mudstone, siltstone, and possibly minor intercalated sandstone.

Weathering and Soils (No obs.).—Probably very similar to those of Numoiken (40), but hydration of sedimentary rocks probably more widespread and thorough. Soils along margins could be similar to those of Wanabutu (59), Mup (61), or Sulen (58). Probable soil composition is (EUHO8, EUHO9, IODE3) subdominant; (IODO2, IODL1) common; (UOTO2, UOTO4) minor.

Population and Land Use.—Population nil. Present land use, covering 0·5 sq mile (4% of area), is all in land use intensity class 3 and comprises a small area near the coast used by a village in adjacent Kabenau (21).

Transitions to Other Land Systems.—Quite distinct from its surroundings, appears to combine characteristics of Numoiken (40) and Wanabutu (59). Separate from Numoiken (40) because of its apparently more complex lithology and significantly higher relief along margins.

Forest Resources (No obs.).—Forest covers 82%; moderate forest resources. Moderate stocking rate forest (Foi, 5 sq miles) occupies areas at lower altitude. Forests with low stocking rates (Fmi/Fmi′, 4 sq miles; Fmi, 1 sq mile) occur elsewhere. Access category III.

Agricultural Assessment.—Only very low capability for tree crops and improved pastures. Development, except possibly forest exploitation, is not recommended. Soil nitrogen contents probably mostly moderate to low; phosphate contents mostly very low to low; and potash contents variable, partly very low to low, partly moderate to high. In water balance zone 3 there is rather severe soil water stress only in very shallow IODL1 soils on very steep slopes.

Engineering Assessment.—Road-construction problems are generally similar to those indicated for Numoiken (40). It should and can be avoided in road location. It may be a potential source of road material, quarried from basic igneous rock along margins. Soils are CH, MH, ML, with minor CL; probable depths are moderately deep dominant, deep, shallow, very shallow common.

(58) Sulen Land System (80 sq miles)

Land Forms (Plate 27, Fig. 2).—Essentially low mountainous country with a pattern of widely spaced major ridges, commonly W.–E. to NW.–SE.-aligned, with more closely spaced secondary spurs and ridges branching off irregularly. Altitude ranges from 250 to 6100 ft; 22% below 1000 ft, 35% at 1000–2000 ft, 36% at 2000–3500 ft, and 6% at 3500–4500 ft. Relief normally 700–1000 ft, locally as low as 400 ft near margins, as high as 1200 ft in central Torricelli Mountains. Crests mostly very narrow, locally (mainly on lowest ridges near margins and some of highest ridges) narrow to broad and rounded. Crest slopes range from moderate to steep. Hill slopes are steep to very steep and very irregular due to slumping or grooving. Precipitous slopes occur locally near incising rivers and at back of slumps.

Streams and Drainage (Fig. 14(*b*)).—Considerable fault and joint control resulting in distinct (N.)W.–(S.)E. and less N.(E.)–S.(W.) alignment of second- and higher-order streams. All streams flow in bouldery rock-cut channels, with very narrow gravel and boulder terraces along larger streams only. Gradients range from high gradient in larger streams to moderate to steep slope in first- and second-order streams. Average drainage pattern is dense and even smallest first-order streams are likely to be perennial. Surface run-off is probably high to very high in relation to through drainage, leading to frequent and sometimes severe flood spates in streams. Well drained.

Vegetation.—Very similar to that of Om (45). Also, relative areas of each type are much the same but secondary vegetation is even less common, covering only 2%. Some tall forest, mainly with a rather open irregular canopy (Foi, 5%), is found at lower altitude on coastal occurrences.

Geology.—Air photos indicate pre-mid-Miocene sedimentary rocks, flanking or capping crystalline basement outcrops. Field observations near margins were on slightly metamorphosed fault-zone rocks (metabasalt, metagreywacke, mixtures of diorite-brecciated hard mudstone and massive crystalline limestone), close to contact with the basement. Limestone is probably rare. Presence of basement outcrop confirmed by one observation on micro-gabbro close to boundary with Somoro (63).

Weathering and Soils (4 obs.).—Limited data suggest generally very shallow skeletal weathering with local shallow to deep immature weathering on rounded crests, upper slopes, and some lower slopes.

Probable soil composition is IODL2, (IODO1, IODO2) subdominant; AUTO2, AUTM, common; UOTO4 minor. Soils are weakly acid to acid and appear to be slightly to moderately developed, thin to moderately thin, friable loam and clay loam soils, locally stony, on predominant steep to very steep slopes (IODL2 observed). Moderately thick, firm to plastic clay soils with friable loam to clay loam surface horizons and thin to moderately thick dark topsoils found on rounded crests and upper slopes (AUTM, AUTO2), while neutral to acid, very shallow soils are likely on precipitous slopes. A strongly developed, acid, thick, plastic heavy clay soil with more friable clay loam to clay surface horizon (UOTO4) observed on a very steep lower slope, and similar soils may occur on small pockets of more weathered rock elsewhere.

Population and Land Use.—Population of 50 in one village. Present land use covers 1·9 sq miles (2% of area) associated with the village and all in land use intensity class 5.

Transitions to Other Land Systems.—Most boundaries are tentative because of gradual or minor differences with surrounding land systems. Its pattern is less massive, less angular, more slumped and hummocky than that of Somoro (63), but more massive and less slumped and hummocky than that of Om (45). It has essentially higher relief than Numoiken (40), Wanabutu (59), and Asier (43), although there is overlap; it is less disorganized than Numoiken (40), less spurred or grooved than Wanabutu (59), and steeper than Asier (43).

Forest Resources (4 obs.).—Forest covers 51%; low forest resources. Forest is mainly of low stocking rate (Fmi/Fmi′, 37 sq miles; Fmi, 11 sq miles). At lower altitudes moderate stocking rate forest occurs (Foi, 3 sq miles). Access category IV.

Agricultural Assessment.—No agricultural capability for development because of topographic problems and erosion hazards, to which must be added common limitations of stoniness and rarely rockiness, commonly shallow soils, and in large parts over 2000 ft a.s.l. a very wet cool cloudy climate to which most tree crops are poorly adapted. Soil nitrogen contents appear mostly moderate, commonly low. Phosphate contents are mostly very low to low, in places moderate. Potash contents appear variable, being mostly low to very low, but probably moderate to high in several cases.

Engineering Assessment.—Topography presents formidable obstructions to road construction, necessitating either very winding roads or large cut-and-fill construction works. If construction is unavoidable, roads should follow river courses as much as possible because of the irregularity of ridge and crest patterns and the availability of road-surfacing materials in stream beds and in outcrops of fresh rock which are likely to include more crystalline and less sedimentary rock near valley bottoms than near ridge crests. Many culverts and small bridges will be required, and roadside drainage to intercept ground-water seepage and run-off is essential since there is a real but apparently not excessive risk of landslide damage to road works. Roads must be cut into hill slopes, since any existing strips of river terrace are subject to flash flooding. Soils are CH, MH, CL; probable depths are moderately deep dominant, shallow subdominant, very shallow common, deep minor. Potential for hydro-electric development possible but unlikely.

(59) Wanabutu Land System (15 sq miles)

Land Forms (Plate 28, Fig. 1).—High hill ridges form narrow blocks strongly elongated in an approximately east–west direction. Altitude ranges from 30 to 2200 ft; 51% at 250–1000 ft, 43% at 1000–2000 ft, and 4% above 2000 ft. Relief varies between 400 and 800 ft. Ridges have short to rather long and commonly peaked, narrow to very narrow crests and steep to very steep, generally markedly grooved or spurred slopes. Slumping is inconspicuous.

Streams and Drainage (Fig. 14(*d*)).—Drainage pattern nearly exclusively of very small rock-cut first-order streams (virtually gullies) with gradients of moderately steep to steep slope. Few transverse through-going larger rivers flow in gorge-like valleys. Streams are very shallow, in probably rocky and bouldery stream beds. Surface run-off is probably high in relation to through drainage. Probably well to excessively drained.

Vegetation.—Mid-height forest with an irregular canopy and its seral stages (Fmi, Fmi′) cover 60%. *Casuarina papuana* (Ca) grows on steepest slopes. Tall forest, mainly with a rather open irregular canopy (Foi), is found on lower parts, totalling 28% together with secondary vegetation (R–FRm) which covers one-eighth.

Geology.—No field data. Igneous rock, either gabbro and diorite basement rock, or pre-mid-Miocene metabasalt, basalt, and other extrusive rocks.

Weathering and Soils (No obs.).—Weathering is probably shallow skeletal. Probable soil composition is (IODO2, IODL2, AUTO3) subdominant; (UOTO4) common; (OANT2) minor. Probably moderately developed, acid to weakly acid, very thin to moderately thin clay loam soils with weathered rock fragments, locally stony and with some rock outcrop on steeper slopes. They are probably similar to those of Sulen (58) and Kumbusaki (60). Strongly developed soils may occur locally, mainly on broader crests.

Population and Land Use.—Population nil. Present land use restricted to 0·5 sq mile (3% of area) of land use intensity class 5 near the coast, probably used by people from Nubia (2).

Transitions to Other Land Systems.—In many respects very similar to Kumbusaki (60). It differs in having generally steeper slopes, slightly higher relief, coarser and less dendritic stream pattern, and more elongated shape to individual occurrences. It has lower relief, more symmetrical and more grooved slopes than Daum (62), is less slumped than either Numoiken (40) or Sulen (58), and intermediate in relief between these two. It is less steep and dissected and has slightly higher relief than Mup (61).

Forest Resources (No obs.).—Forest covers 87%; moderate forest resources. Much forest of low stocking rate types (Fmi/Fmi′, 9 sq miles; FRm, 2 sq miles), but in lower parts moderate stocking rate forest (Foi, 4 sq miles) is found. Access category IV.

Agricultural Assessment.—Very low capability for tree crops and improved pastures, and for all practical purposes unsuitable for agricultural development. Soil nitrogen contents probably moderate to low; phosphate contents mostly very low, although moderate to low values may also be common. Potash contents probably low to very low but with several moderate to high values. In water balance zone 3 there is rare severe soil water stress in IODL2 soils on very steep slopes and crests.

Engineering Assessment.—To be avoided for road construction. Since access is generally not very difficult, it could offer possibilities for quarrying road metal and aggregate for construction projects in coastal plain. Soils are CH, MH, CL; probable depths are moderately deep dominant; shallow, very shallow, deep common; very deep minor.

(60) Kumbusaki Land System (15 sq miles)

Land Forms (Plate 15, Fig. 2).—Sharply and densely spurred branching high hill ridges with very narrow gently sloping to steep crests and steep to very steep, mostly straight slopes. Altitude ranges from 1100 to 2500 ft; 81% below 2000 ft. Relief extremes are 200 and 800 ft. Longest, grooved slopes occur along northern margin, with some south-facing precipitous box canyons. In the south are small areas of short steep smoother ridges with rounded narrow crests and occasional small steep slumps, and very local hummocky moderate lower slopes.

Streams and Drainage (*Fig.* 14(*c*)).—Very dense, locally dense dendritic pattern of small streams up to fourth order. Streams flow in narrow rock-cut valleys and have pebbly to bouldery and rocky beds with gradients of very gentle to gentle slope, and moderate slope along northern margins. Surface run-off probably high in relation to through drainage and all streams have a perennial flow of sustained yield, but with frequent flood spates. Well drained.

Vegetation.—Mid-height forest with an irregular canopy (Fmi) covers about two-thirds and mid-height forest with a rather dark-toned even canopy (Fm) another 14% at higher altitudes. *Casuarina papuana* (Ca) as well as seral mid-height forest (Fmi′) is uncommon, in line with greater slope stability compared with land systems such as Mup (61) and Daum (62). At lower altitude tall forest with an irregular canopy with light-toned crowns (Fid) and some secondary vegetation (R–FR, R–FRm/MR) are found, covering 18% and 5% respectively.

Geology.—Igneous basement rock; gabbro and metabasalt observed.

Weathering and Soils (3 obs.).—Weathering mostly shallow immature to skeletal, with local shallow mature weathering on ridge crests.

Probable soil composition is IODO2 dominant; OANT2 subdominant; (IODL2) common. On side slopes are moderately developed, acid, moderately thin, friable clay loam to clay soils, commonly with weathered rock fragments, and overlying hard but broken, or soft but compact weathered rock (IODO2). Thinner soils may occur on steepest slopes. A very strongly developed, strongly acid, moderately thick, firm to friable clay soil with clay loam surface horizon (OANT2) observed on a steeply sloping crest.

Population and Land Use.—Population nil. Present land use restricted to 0·8 sq mile (5% of area) of land use intensity class 5 adjacent to Karaitem (41).

Transitions to Other Land Systems.—A typically transitional type. Relationship to Wanabutu (59) and Daum (62) discussed under these land systems. It is commonly similar to Mup (61), differing in greater apparent slope stability, a lower proportion of very steep to precipitous slopes, and in being a distinct landscape, surrounded by, rather than intimately associated with, typically sedimentary rock land systems.

Forest Resources (3 obs.).—Forest covers 93%; moderate forest resources. Forest mainly low stocking rate forest types (Fmi, 9 sq miles; Fm, 2 sq miles). At lower altitudes, a moderate stocking rate forest (Fid) covers 3 sq miles, particularly in southern parts. Access category IV.

Agricultural Assessment.—Largely because of steep and dissected topography Kumbusaki has only very low capability for tree crops or improved pastures. Rather small soil depth is a local contributory limitation for tree crops, soil acidity for improved pastures. No real scope or need for agricultural development. Soil nitrogen contents mostly moderate and vary from high to low; phosphate contents very low to low; potash contents mostly low, but possibly higher in very shallow soils.

Engineering Assessment.—No need for road construction. Severe dissection would require much cut-and-fill, culverting, and small bridges, or lead to very winding roads. However, slopes appear generally stable and soil and rock materials suitable for fill and subgrade. Suitable quarry sites probably can be found on lower slopes near streams; these might be of some significance if road construction was required in adjoining sedimentary rock land systems to the south and west. Soils are dominantly MH, subdominantly CH, CL; probable depths are moderately deep dominant, very deep subdominant, shallow, very shallow minor.

(61) MUP LAND SYSTEM (11 SQ MILES)

Land Forms (Plate 28, Fig. 2).—Characterized by high hilly relief and predominantly very steep little-slumped slopes, Mup varies in pattern. Included are isolated hills and short ridges, partly dissected into narrow spurs and protruding 300–800 ft above surrounding slopes in a manner similar to volcanic necks. It consists also of dense patterns of branching or parallel ridges carved out by dissection from the general slope of the terrain and protruding only little above this general slope along the upslope margin. In this latter case internal relief varies from 100 to 400 ft, but total relief between upslope and downslope margins is 400–700 ft. Transitional forms between these two types also occur. Altitude ranges from 400 to 3700 ft; 9% below 1000 ft, 49% at 1000–2000 ft, and 40% between 2000 and 3500 ft. Ridge crests knife-edged to very narrow and with gentle to steep slopes; hill slopes commonly grooved or finely spurred and in places precipitous.

Streams and Drainage (Fig. 13(*f*)).—Apart from gullies no streams occur on isolated hills. Areas with ridge patterns have a dense to very dense, subparallel to subangular pattern of very small, mostly first-order streams. Gradients vary from very gentle to moderate slope, stream beds are in very narrow rock-cut valleys, probably bouldery. All streams probably perennial. Frequent but minor flood spates would result from the probable high surface run-off in relation to through drainage. Generally well drained.

Vegetation.—About 82% covered by mid-height forests; type with a rather dark-toned even canopy (Fm) occurs on crests and upper slopes (20%). Elsewhere occurs type with an irregular canopy (Fmi), commonly in mosaic with seral forests (Fmi′, Ca). On lower southern slopes of Torricelli Range is tall forest with an irregular canopy with light-toned crowns (Fid), but in this area secondary forest stages (FRy, FRm, FR) prevail (18%).

Geology.—Igneous basement rock, commonly forming windows in areas of sedimentary rock. Rock types similar to those of *Somoro* (63). A very thin veneer of colluvium derived from sedimentary rocks occurs locally.

Weathering and Soils (1 obs.).—Probably very shallow skeletal weathering, with common rock outcrop near valley bottoms and on some crests, and slightly more weathering on smooth somewhat less steep hill slopes.

Probable soil composition is (IODE2) dominant; EUHO9, (EUHL) common; (IODO2) minor. Virtually no information on soils, only observation being an undeveloped, acid, moderately deep, friable to firm clay loam and clay soil (EUHO9) developed in superficial colluvium of Pliocene sedimentary rock and overlying hard basement rock. Such soils can be expected in other places, where Mup forms lenses or windows in slopes on predominantly sedimentary rocks. On the whole, it is expected that slightly to moderately developed, weakly acid to acid, thin to very thin soils predominate, similar to those of Somoro (63). Locally on more stable slopes, more developed, acid, thicker soils may occur similar to those for Kumbusaki (60).

Population and Land Use.—Population nil; present land use negligible.

Transitions to Other Land Systems.—Typical transitional aspects to Somoro (63) on the one hand and to Kumbusaki (60) on the other, discussed under these land systems.

Forest Resources (No obs.).—Forest covers 55%; low forest resources. Forest is a mixture of low stocking rate types (Fmi/Fmi′, 3 sq miles; Fmi/Fm, 1 sq mile; Fm, 1 sq mile; Fmi, 1 sq mile). Access category IV.

Agricultural Assessment.—Because of very steep slopes, strong dissection, and common instability of slope mantle, it has no capability for agricultural development. Soil nitrogen contents probably low to moderate; phosphate and potash contents strongly variable but mostly high.

Engineering Assessment.—To be avoided for road construction. Its occurrence as isolated areas within sedimentary rock zones without suitable road-building materials could make Mup a useful source of these where roads are planned nearby, which will be probably only rarely. Soils are dominantly CL, subdominantly MH; probable depths are moderately deep dominant, shallow subdominant, very shallow common.

(62) Daum Land System (17 sq miles)

Land Forms (Plate 29, Fig. 1).—Low mountains, generally characterized by very long, moderately steep to steep, northern to north-eastern slopes and shorter, very steep to locally precipitous, southern to south-western slopes. Relief is mostly 800–1000 ft with extremes at 600 and 1500 ft. Altitude ranges from 400 to 4100 ft; 3% below 1000 ft, 34% at 1000–2000 ft, and 61% at 2000–3500 ft. Major ridge crests are very narrow to narrow, commonly even, but in places peaked. Northern slopes are mostly densely gullied to ravined, with some precipitous straight slopes along lower margins and major ravines. Southern slopes are ravined or strongly spurred, with common rock debris slides. Very short, very steep to precipitous transverse ridges locally present on southern slopes.

Streams and Drainage (Fig. 14(*d*)).—Rather dense patterns of small streams that are relatively long and dendritic on northern slopes, very short and angular to subparallel on southern slopes. Mostly first- and second-order, rarely third-order, streams which flow in narrow rock-cut valleys, probably with rocky and bouldery beds with gradients of gentle to moderately steep slope. Surface run-off may vary from low to very high in relation to through drainage, depending on soil and slope conditions. All streams have a perennial flow of sustained yield, but with frequent minor flood spates. Well drained.

Vegetation.—Mid-height forest covers the whole area. About two-thirds is the type with a rather dark-toned even canopy (Fm), the rest has a rather irregular canopy (Fmi). On unstable slopes is *Casuarina papuana* (Ca); on lower slopes are seral stages to mid-height forest (Fmi′).

Geology.—No field data. Sharp angularity of photo pattern and scarcity of slumping suggest basic igneous basement rocks. Pattern also suggests the presence of N.–NE.-dipping dip slopes and steeper outcrop slopes in south and south-west; such structures are common in sedimentary rocks but were not observed in igneous rocks elsewhere in the area. Possibly Daum represents a tilted block of igneous rocks, fault-bounded in the south.

Weathering and Soils (No obs.).—Land forms and vegetation patterns suggest immature to mature weathering on many upper slopes but virtually no weathering on very steep lower slopes. Probable soil composition is (IODO2, IODL2, BUHL) subdominant; (UOTO5, OANT2) common. Soils may be partly similar to those for Aititau (33) and Kumbusaki (60) and partly to those for Somoro (63), and range from strongly developed, strongly acid, very thick, firm clay soils to undeveloped, weakly acid to neutral, very shallow loam soils with rock fragments.

Population and Land Use.—Nil.

Transitions to Other Land Systems.—Whilst basically unique in pattern, Daum generally has an indistinct boundary with adjoining Sulen (58) and with Wanabutu (59) in the east. Distinguished from Somoro (63) by its lower relief and much higher incidence of apparently stable slopes, and from Kumbusaki (60) by higher relief and less intricate dissection.

Forest Resources (1 aerial obs.).—Forest covers 18%; very low forest resources. Forest is a low stocking rate type (Fmi/Fmi′, 4 sq miles) occurring on lower-altitude parts. Access category IV.

Agricultural Assessment.—In the absence of field data no proper assessment can be given. On the basis of land forms alone, probably very low capability for tree crops and improved pastures. Owing to poor accessibility and the position of a large area at altitudes above 2000 ft, which is generally unfavourable for tree crops, there appear to be no practical possibilities for agricultural development. Soil nitrogen contents probably moderate on crestal areas, low on steep slopes. Phosphate contents generally very low to low, but may be high in very shallow soils on very steep slopes. Potash contents probably partly low, partly very high to moderate.

Engineering Assessment.—To be avoided for road construction. Possibly a potential source of quarried stone for various types of construction, suitable quarry sites probably occurring mainly near streams on lower slopes. Because of its isolated position this may be of value only if roads are constructed to open up areas of Karaitem (41) and Asier (43) immediately south. Soils are dominantly CL, subdominantly CH, MH; probable depths are moderately deep, very shallow, deep, shallow subdominant.

(63) Somoro Land System (111 sq miles)

Land Forms (Plate 29, Fig. 2).—Extremely rugged, low, locally high mountains with an angular, locally subparallel pattern of massive ridges, locally branching into spurs. Altitude ranges from 240 to 5400 ft; 7% below 1000 ft, 24% at 1000–2000 ft, 54% at 2000–3500 ft, and 14% at 3500–4500 ft. Relief extremes are 600 and 2000 ft. Crests are mostly peaked, locally long and straight. They are knife-edged to very narrow but locally, particularly on summits, narrow and rounded. Hill slopes are straight and commonly grooved or slightly spurred, and have many narrow long superficial landslip scars that are commonly unstabilized.

Slopes are very steep, locally steep; they tend to become steepest and locally precipitous near valley bottoms.

Streams and Drainage (Fig. 14(*e*)).—Coarse-textured angular pattern of mainly first- and second-order streams, flowing as torrents with rapids in shallow, rocky or bouldery channels in very narrow, rock-cut valleys. Pattern appears to be strongly fault- and joint-controlled. First-order streams commonly have gradients of moderately steep to steep slope, second-order streams of gentle to moderate slope. Few higher-order streams with gradients of very gentle slope have discontinuous narrow boulder and gravel terraces. All streams likely to be perennial, but due to probably high surface run-off in relation to through drainage, flood spates arise frequently and advance very rapidly. Well drained.

Vegetation.—Covered entirely by mid-height forests. Type with a rather dark-toned even canopy (Fm) occurs on crests and upper slopes (20%). It merges into type with an irregular canopy (Fmi) on remainder of the slopes, a small part of which are covered with seral forest (Fmi'). *Casuarina papuana* (Ca) occurs on very unstable slopes, and *Casuarina* sp. (Cs) is found on narrow terraces affected by flood spates.

Geology.—Mainly basic igneous basement rocks, probably mainly gabbro, granodiorite, and diorite, with some metabasalt and epidosite along outer margins.

Weathering and Soils (2 obs.).—Weathering appears to be shallow skeletal with virtually none on steepest slopes. Rounded crests are probably shallowly immaturely weathered.

Probable soil composition is IODE2 dominant; EUHL subdominant; (IODO4) common. Very limited information suggests undeveloped, neutral, very shallow to shallow, gravelly loam soils (EUHL), with moderately developed, weakly acid, moderately thin to moderately thick, friable clay loam soils with varying amounts of rock fragments (IODE2) on somewhat more stable slopes. Such soils may overlie hard, rather fresh, or soft coarse sandy weathered rock. Rock outcrop is common near valley bottoms. More strongly developed, acid, thicker soils may be present on small rounded crests.

Population and Land Use.—Nil.

Transitions to Other Land Systems.—Pattern is generally distinct. In places, however, where spurring and slumping are more pronounced it is difficult to distinguish from Sulen (58). Most of these transitional cases are mapped with Sulen (58), since this appears to be lithologically more heterogeneous. Somoro is distinguished from Mup (61) in having higher relief and coarser dissection. They share no common boundary, Mup consisting of small outcrops of basement rock windows in a sedimentary rock landscape. Thus some foothill areas of Somoro would probably have been mapped as Mup (61) had they formed isolated occurrences.

Forest Resources (No obs.).—Forest on only 5%; forest resources *nil. Forests* (Fmi/Fmi', 4 sq miles; Fmi, 1 sq mile; Fm, 1 sq mile) all have low stocking rates, Fm occurring on higher areas. Access category IV.

Agricultural Assessment.—No capability for agricultural development owing to steepness of slopes as well as instability of shallow soil cover. Soil nitrogen contents appear to be low but may be moderate or high at higher altitudes. Phosphate contents probably largely high but would be very low in more developed soils on crests. Potash contents could vary from low in most developed soils to very high in undeveloped, very shallow soils.

Engineering Assessment.—To be avoided for road construction. An enormous potential source of stone for road metal and other construction purposes, but generally too inaccessible to be of practical use except in construction of roads across the ranges, which would follow low passes in other systems but always very close to Somoro. Also less inaccessible occurrences east of Nigia River and could be of some value as a source of stone for works in eastern coastal plain. Soils are dominantly CL, subdominantly MH; probable depths are moderately deep, very shallow, shallow subdominant. Although prospects appear poor due to high stream gradients and seismic instability, there is more opportunity for construction of hydro-electric works here than in any other land system.

(64) Maio Land System (45 sq miles)

Land Forms (Plate 30, Fig. 1).—Mostly low to very low, but locally high hill ridges of variable land form. Part consists of individual hill ridges, but particularly in south-east Maio resembles a dissected plateau surface with a maze of finely branching very low to low short ridges and hills, including a few small upland areas with moderate slopes and very low relief. Altitude ranges from about 200 to 850 ft; about 90% above 250 ft. Relief is mostly between 100 and 300 ft, but locally as low as 50 ft or as high as 700 ft. Some individual ridges branch into major spurs with moderate to steep spur crest slopes. Large complex in south-east is enclosed in the east and north by a continuous peaked encircling ridge and in the west by a precipitous slope along the Sepik River. Ridge is 300–700 ft high with steep to very steep, locally grooved outward slopes to surrounding swamps. Crests are knife-edged to very narrow, locally narrow, and range from rather even to moderately peaked or stepped. Hill slopes are steep to very steep, locally moderately steep, and commonly strongly grooved, but in places strongly spurred and even rather smooth. Terracettes, 2–4 ft wide, 3–12 ft long, and with moderate to moderately steep slopes, are found on steepest slopes and small gullies occur in places. Locally slump alcoves 30–150 yd wide occur, with moderately steep to steep irregular floors and very steep back walls. Very small moderately steep colluvial foot slopes are locally present, as well as very small alluvial fans at base of ridges. In large occurrences are a few high-gradient to very gently sloping valley floors 40–80 yd wide.

Streams and Drainage (Fig. 14(*f*)).—Individual ridges have no proper streams, whilst large ridge complexes have a dense to very dense dendritic pattern of very small, up to fourth-order streams. Except for some third- and fourth-order streams cut into colluvium or alluvium, streams flow in shallow rock-cut beds 2–8 yd wide and generally have low to high gradient, but up to gentle slope in some first-order tributaries. Stream beds are probably stony and in places also sandy. Stream flow is mostly moderately rapid, shallow, and probably nearly always perennial. Surface run-off probably moderate in relation to through drainage, and small flood spates would occur frequently. Well drained.

Vegetation.—Mid-height forest with a small-crowned rather even canopy (Fmsv) covers 82%. Gardens, coffee plantations, and regrowth up to medium-aged secondary forest (R–FRm) are found on the rest. Sago (MR) has been planted on some fans. Mid-height grassland (G) covers some spurs north and north-east of Ambunti.

Geology.—Palaeozoic or Mesozoic, steeply to very steeply dipping mica schist (commonly with quartz veins) and quartzose mica schist, in places interbedded with quartzose sandstone. Gold has been mined in south-east, but no indication can be given of yield or of possible existence of further ore bodies.

Weathering and Soils (5 obs.).—Rocks appear mostly disintegrated and leached to probably 10–50 ft with very shallow mature to immature weathering profiles at the surface. No suggestion that weathering decreases with increasing slope steepness; instead there is some evidence that crests are less weathered.

Probable soil composition is IODO5 dominant; IODX subdominant; (IODL2) common. Moderately (IODO5) or strongly (IODX) developed, strongly acid, moderately thick to moderately thin (rarely thin), uniformly textured friable to firm silty or sandy clay to friable or very friable clay loam or silty clay loam soils merging into compact but unconsolidated coarser-textured weathered rock. They are usually covered by a 1- or 2-in. organic root mat and commonly contain very low to high amounts of weathered rock fragments, increasing with depth. Similar, but moderately developed, thin soils probably occur locally on precipitous slopes and narrow crests.

Population and Land Use.—Population of 1960 distributed over nine villages. Present land use covers 9 sq miles (18% of area), 31% in land use intensity class 3, 3% in class 4, and 66% in class 5. Sago, planted on small fans and valleys or exploited from natural stands in adjacent Kabuk (9), Pandago (10), and Ambunti (20), is very important in subsistence.

Transitions to Other Land Systems.—Photo pattern is very similar to Aitape (55) for individual ridges and rather similar to Dossett (34) and parts of Kumbusaki (60) for larger ridge complexes in south-east. In fact, had Maio occurred in close association with these land systems instead of being geographically widely separated, it probably could not have been distinguished as a separate mapping unit. Pattern differs from Waskuk (65) largely by having lower relief, but the intricate variations in relief have led to a small amount of overlap between them.

Forest Resources (5 obs.).—Forest covers 82%; moderate forest resources. Only one forest type with a low stocking rate (Fmsv, 36 sq miles) occurs. Access category III.

Agricultural Assessment.—Low capability for tree crops and very low capability for improved pastures. Steepness of slope and close dissection are major limitations, whilst strongly acid reaction of soils would be less of a disadvantage for tree crops than for pastures. For two reasons, it still might be desirable to investigate experimentally the possibility of growing tree crops. Firstly, in the Sepik plain area Maio appears more suitable for plantation agriculture than any other land system except the small Ambunti (20). Secondly, there is good access via the Sepik River which means relatively low transport costs for removal of produce as well as for the supply of farm requirements such as fertilizers. Soil nitrogen contents are low; phosphate contents are very low; and potash contents mostly low, commonly very low, but probably high in very shallow soils. Rare severe water stress in IODL2 soils on very steep slopes, particularly of isolated hill ridges.

Engineering Assessment.—Obvious topographic problems in road construction. Crests are commonly too short, too narrow, or too peaked to be suitable for road alignment. Roads are therefore best located on lower slopes, which requires cut-and-fill operations over almost their full length. This would generally be easy in unconsolidated weathered materials although some hard rock cutting might be required on salient spurs. Many small bridges and culverts would be needed in large south-east area. On the credit side, landslide hazards appear relatively small, soils and weathered rock are probably suitable as subgrade, and hard rock should be available for road surfacing. However, this last may often be buried beneath thick layers of weathered rock, and schists and sandstone appear to be of only low to moderate quality for road-surfacing purposes. Together with small parts of Waskuk (65), Maio forms a "bridge" of high ground through the Sepik swamps from Ambunti to the north-west; this is of obvious value if plains north of Sepik flood-plain are to be opened up by a road link with the Sepik River. Rather long stretches of swamp land would still have to be traversed by such a road north of main hill ridges, but this may be facilitated by incorporating small outlier hills in a road alignment to link up with Yilui (13) and using them as quarries of earth fill, subgrade, and road-surfacing materials. Even though these materials may not be particularly suitable, the hills are virtually the only large source of rock for at least 30 miles north of Sepik River. Soils are dominantly MH, subdominantly CL; probable depths are deep dominant, moderately deep subdominant, shallow, very shallow minor.

(65) Waskuk Land System (22 sq miles)

Land Forms (Plate 30, Fig. 2).—Low mountain and some high hill ridges, generally with mostly strongly grooved or finely spurred slopes. In places major spurs branch off the main ridges, either with steep spur crests or as foothill spurs with gentle crest slopes. Altitude ranges from 180 to just over 1500 ft a.s.l.; about 75% at 250–1000 ft and 20% above 1000 ft. Relief is mostly between 700 and 1300 ft but locally as low as 150 ft on foothill spurs. Hill slopes are predominantly very steep, but commonly steep or precipitous. Common for lower slopes to be the steepest, while moderately steep slumped slopes occur locally near crests. Very steep slopes commonly have a microrelief of 2–5-ft-wide terracettes, sloping 5–10° and occupying 20–30% of the slope, and of longitudinal corrugations with an amplitude of 6–8 ft but up to 15 ft where gullies have developed in depressions. Crests are knife-edged to very narrow and stepped or somewhat peaked. Broad (500–1000 yd wide) concave or moderately to moderately steeply sloping hilly summit areas (8%) occur locally on highest ridges. They consist of closely spaced short ridges with steep slopes and a relief of 50–100 ft.

Streams and Drainage (Fig. 11(*a*)).—Stream net consists of a number of rather closely spaced, very small, individual stream systems ranging from a single first-order stream to dendritic nets with up to third-order streams. At margins of Waskuk these streams disappear in swamp land or form ill-defined channels in alluvial fans of Ambunti (20). Streams have rock-cut bouldery beds 2–5 yd wide and with gradients ranging from gentle to moderately steep slope, probably even steep slope in some first-order tributaries. Flow is very rapid, very shallow, and probably intermittent in smallest streams. Surface run-off is probably high relative to through drainage and short flood spates are likely to be frequent. Well drained, with a tendency to excessive drainage on very steep upper slopes and crests below 1000 ft a.s.l.

Vegetation.—Mid-height forest with a small-crowned rather even canopy (Fmsv) covers 74%. Gardens and regrowth up to medium-aged secondary forest (R–FRm) are found on remainder.

Geology.—Palaeozoic or Mesozoic mica-schist and micaceous gneiss with quartz veins appear to be the major rock types, very steeply dipping.

Weathering and Soils (4 obs.).—Rocks appear mostly shallowly skeletally weathered, resulting in their partial to almost complete disintegration and strong leaching. Immaturely weathered surface materials are only 1–3 ft thick and locally absent. Deeper immature to mature weathering may occur on broad summit areas.

Probable soil composition is IODL2 predominant; IODO5 common; (IODX) minor. Predominant are moderately developed, strongly acid to locally acid, very thin, very friable sandy clay loam to silty clay soils merging into sandy and gritty, or gravelly weathered rock (IODL2). Very thin soils are somewhat stony or associated with minor rock outcrop, particularly near crests. More locally occur similar, but moderately thin, very friable to friable clay loam to silty clay loam soils (IODO5); these together with similar, but strongly developed, soils are probably most common on the hilly summit areas. At and near summits of highest ridges soils are covered by about 9 in. of organic root mat.

Population and Land Use.—Population of 600 distributed over three villages. Present land use covers 5·8 sq miles (26% of area), 28% in land use intensity class 3, 72% in class 5. Sago is very important in subsistence and is collected in neighbouring Kabuk (9), Pandago (10), and Ambunti (20).

Transitions to Other Land Systems.—Relationship with Maio (64) discussed in the latter. Photo pattern rather similar to that of Wanabutu (59) and Daum (62), and separation might have been difficult if they had occurred in close association.

Forest Resources (2 obs.).—Forest covers 74%; moderate forest resources. A forest of low stocking rate (Fmsv, 17 sq miles) occurs. Access category IV.

Agricultural Assessment.—No capability for agricultural land use because of its ruggedness, very shallow, strongly acid soils, and local rockiness and stoniness. Soil nitrogen contents moderate to low; phosphate contents very low; potash contents probably vary from very low to moderate. Rare severe soil water stress in IODL2 soils, particularly on lower crests and hill slopes.

Engineering Assessment.—As discussed in Maio (64), Waskuk forms part of a "bridge" of higher ground, partially linking the Sepik River at Ambunti with plains to the north. Any road construction along this "bridge" cannot completely avoid this very rugged land system. Such a road would be best aligned by cutting into lowermost slopes wherever possible. To avoid an excessively winding road, deep cuttings through some lower spurs and passes built across some higher ridges would be needed. Road-cutting will be more difficult than in Maio (64) because hard fresh rock may be present closer to land surface. This raises value of Waskuk as a source of road metal and construction stone. Also the gneissic rock occurring in some parts is likely to be more suitable for construction work than the schist and sandstone. Soils are dominantly CL, subdominantly MH, SC; probable depths are shallow, very shallow subdominant, deep, moderately deep common.

APPENDIX IV

Relations between Population, Land Use Intensity, and Land Use Capability of Land Systems

By R. H. Fagan,* J. R. McAlpine,† and H. A. Haantjens†

I. Population and Land Use of Land Systems

Details of the distribution of the population and of the five land use intensity classes over the land systems are given in Table 22. In this table the land systems have been arranged in order of decreasing land use intensity index, and grouped into six classes of land use intensity index (Appendix I).

II. Land Use Intensity and Land Use Capability

Table 23 has been compiled for a number of different purposes. First, it presents a comparison between the present land use intensity index and the land use capability indexes of the land systems (Part VII, Section II(*c*)). Secondly, it lists the land systems belonging to each land use capability group shown on the map of agricultural land use capability. Thirdly, the table shows the manner in which land systems within one group differ in their suitability for irrigated rice. Thus, Table 23 is a supplement for those land use capability groups in which the suitability for irrigated rice varies irregularly, because this suitability has not been used as a criterion in defining the groups (Part IX, Section I(*e*)). The derivation of the indexes, which are also given in the synoptic land system descriptions in Part III, is explained in Appendix I.

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TABLE 22

DISTRIBUTION OF POPULATION AND LAND USE OVER LAND SYSTEMS

Land System	Area (sq miles)	Population	Land Use Intensity Index	Land Use Intensity Class (sq miles) Very High	High	Medium	Low	Very Low
Intensively used								
Madang (1)	1	1060	60	—	0·8	0·2	—	—
Nubia (2)	28	7540	55	—	8·0	10·9	1·1	0·5
Romei (22)	3	440	37	—	1·1	0·5	—	0·8
Moderately used								
Seim (46)	221	16,630	29	—	1·9	128·2	30·3	40·1
Aitape (55)	7	—	27	—	1·3	2·2	—	0·3
Dreikikir (47)	143	6730	23	—	—	39·0	56·0	26·1
Kaugiak (37)	109	5590	23	—	10·9	27·6	7·2	37·0
Musendai (32)	45	620	23	—	4·8	11·4	6·4	6·1
Lightly to moderately used								
Emul (36)	91	4510	19	—	6·1	19·7	6·7	27·3
Kabenau (21)	5	560	18	—	—	2·2	—	0·3
Lumi (26)	22	510	15	—	—	1·6	9·1	2·7
Imbia (54)	39	1400	14	—	—	7·6	1·6	13·3
Mambel (48)	280	8960	12	—	—	38·8	47·3	66·9
Musak (52)	19	620	12	—	—	3·4	1·9	4·1
Yindigo (31)	128	6340	11	0·2	6·7	13·9	2·0	22·9
Flobum (44)	112	4230	11	—	—	14·8	14·5	23·4
Karaitem (41)	106	2500	11	—	—	15·6	8·6	30·6
Lightly used								
Nuku (51)	193	5550	9	—	—	20·6	26·8	27·6
Sengi (42)	106	1660	9	—	—	10·0	3·3	45·4
Morumu (39)	176	2540	8	—	1·4	16·2	5·9	36·8
Screw (18)	60	100	8	1·4	2·8	2·7	0·3	2·7
Asier (43)	106	2560	7	—	—	11·7	—	32·3
Po (15)	49	200	7	—	0·5	6·2	0·5	3·7
Ningil (49)	8	—	7	—	—	1·3	—	1·4
Pes (17)	143	1160	6	—	3·9	13·4	—	2·5
Minatei (50)	7	510	6	—	—	—	—	4·2
Yilui (13)	48	1380	5	—	—	1·4	4·5	5·9
Numoiken (40)	98	1250	5	—	—	7·6	3·0	15·3
Burui (29)	108	1510	4	—	0·8	3·6	8·6	4·1
Maio (64)	45	1960	4	—	—	2·8	0·3	5·9
Waskuk (65)	22	600	4	—	—	1·6	—	4·2
Papul (19)	62	320	4	—	—	3·9	0·8	3·9

Table 22 (*Continued*)

Land System	Area (sq miles)	Population	Land Use Intensity Index	Land Use Intensity Class (sq miles) Very High	High	Medium	Low	Very Low
Ambunti (20)	5	—	4	—	—	0·5	—	0·2
Yassip (38)	33	440	3	—	—	0·5	—	8·3
Barida (56)	31	130	3	—	—	0·9	—	4·8
Panakatan (25)	26	—	3	—	—	1·9	—	0·3
Very lightly used								
Wuro (53)	7	210	2	—	—	0·6	—	—
Sandri (35)	49	—	2	—	—	0·3	—	8·6
Murik (3)	9	—	2	—	—	—	—	—
Palimbai (11)	102	1390	1	1·1	—	—	—	—
Nopa (57)	11	—	1	—	—	0·5	—	—
Atitau (33)	7	—	1	—	—	0·3	—	—
Pandamp (6)	96	210	<1	—	0·2	—	0·6	—
Kabuk (9)	30	—	<1	—	—	—	0·5	—
Pandago (10)	215	80	<1	—	0·8	1·1	—	1·4
Nigia (12)	107	—	<1	—	—	0·2	—	—
Misinki (14)	238	—	<1	—	—	—	—	3·0
Nagam (16)	233	360	<1	—	—	1·6	—	5·8
Aiome (23)	25	60	<1	—	—	0·3	—	—
Paiawa (24)	72	390	<1	—	—	1·6	—	—
Yambi (28)	110	560	<1	—	—	0·3	0·8	—
Kworo (30)	113	730	<1	—	—	—	—	4·7
Om (45)	24	—	<1	—	—	—	—	1·7
Sulen (58)	80	50	<1	—	—	—	—	1·9
Dossett (34)	4	—	<1	—	—	—	—	0·3
Kumbusaki (60)	15	—	<1	—	—	—	—	0·8
Mup (61)	11	—	<1	—	—	—	—	0·3
Wanabutu (59)	15	—	<1	—	—	—	—	0·9
Unused								
Nigre (27)	132	190	—	—	—	—	—	—
Chambri (4)	21	—	—	—	—	—	—	—
Sanai (5)	55	—	—	—	—	—	—	—
Pora (8)	49	—	—	—	—	—	—	—
Kobar (7)	17	—	—	—	—	—	—	—
Daum (62)	17	—	—	—	—	—	—	—
Somoro (63)	111	—	—	—	—	—	—	—
Total	4660	94,340		<3	52	451	249	541

TABLE 23

PRESENT LAND USE INTENSITY INDEX AND LAND USE CAPABILITY INDEXES OF LAND SYSTEMS ARRANGED BY LAND USE CAPABILITY GROUP

Land Use Capability Group	Land System	Present Land Use Intensity Index	Land Use Capability Index				
			Overall*	Arable Crops	Tree Crops	Improved Pastures	Irrigated Rice
A1	Aiome (23)	<1	79	70	94	72	11
A2	Nubia (2)	55	78	80	69	86	25
	Pes (17)	6	73	77	60	83	65
A3	Nagam (16)	<1	68	74	32	98	37
	Romei (22)	37	66	62	42	85	31
A4	Papul (19)	4	62	60	59	66	32
	Ambunti (20)	4	62	58	57	72	41
A5	Kabenau (21)	18	55	55	40	70	20
	Screw (18)	8	51	49	30	74	48
B1	Paiawa (24)	<1	45	37	53	45	2
	Lumi (26)	15	42	34	43	50	3
B2	Musendai (32)	23	42	40	26	60	12
	Ningil (49)	7	39	34	21	62	0
	Po (15)	7	38	41	14	58	30
	Yilui (13)	5	33	35	13	51	60
	Yambi (28)	<1	32	29	16	52	18
B3	Seim (46)	29	32	18	24	52	2
	Kaugiak (37)	23	31	17	25	51	0
B4	Karaitem (41)	11	31	17	33	43	0
	Minatei (50)	6	31	20	27	47	2
	Sengi (42)	9	30	15	40	35	0
C1	Burui (29)	4	27	21	13	47	15
	Mambel (48)	12	26	15	21	42	4
C2	Asier (43)	7	24	10	35	26	0
C3	Dreikikir (47)	23	26	12	25	42	2
	Kworo (30)	<1	22	11	17	39	2
	Emul (36)	19	21	12	15	36	0
	Nuku (51)	9	21	11	14	39	2
	Atitau (33)	1	21	12	22	30	0
	Flobum (44)	11	19	10	16	31	0
C4	Yindigo (31)	11	22	15	8	42	3
	Misinki (14)	<1	21	17	4	42	60
	Nigre (27)	0	18	14	4	35	39

TABLE 23 (*Continued*)

Land Use Capability Group	Land System	Present Land Use Intensity Index	Land Use Capability Index				
			Overall*	Arable Crops	Tree Crops	Improved Pastures	Irrigated Rice
C5	Yassip (38)	3	19	9	22	25	0
	Morumu (39)	8	15	6	15	25	0
	Sandri (35)	2	15	7	14	24	0
C6	Dossett (34)	<1	14	5	18	20	0
	Panakatan (25)	3	13	5	19	16	0
	Barida (56)	3	13	5	6	27	0
D	Aitape (55)	27	11	4	6	24	0
	Madang (1)	60	9	6	5	15	0
	Maio (64)	10	9	3	14	10	1
	Kumbusaki (60)	<1	8	5	10	10	0
E1	Numoiken (40)	5	5	0	6	10	0
	Wanabutu (59)	<1	5	0	8	6	0
	Nopa (57)	1	5	0	8	7	0
	Daum (62)	0	5	0	7	9	0
	Imbia (54)	14	5	0	5	9	0
	Musak (52)	12	4	0	3	8	0
	Pandago† (10)	<1	5	4	0	10	46
E2	Palimbai (11)	<1	3	3	0	5	12
	Om (45)	<1	3	0	3	5	0
	Wuro (53)	2	2	0	3	4	0
	Mup (61)	<1	2	0	3	4	0
	Sulen (58)	<1	2	0	2	3	0
	Nigia (12)	<1	2	1	0	5	16
	Waskuk (65)	4	1	0	1	1	0
	Murik (3)	2	1	0	0	3	5
	Sanai (5)	0	1	0	0	4	23
	Pandamp (6)	<1	0	0	0	0	5
	Kabuk (9)	0	0	0	0	0	5
	Kobar (7)	0	0	0	0	0	4
	Pora (8)	0	0	0	0	0	4
	Chambri (4)	0	0	0	0	0	0
	Somoro (63)	0	0	0	0	0	0

* Mean of indexes for arable crops, tree crops, and improved pastures.

† The small areas of Pandago land system occurring in the Sepik flood-plain have been mapped as land use capability group E2.

ISBN 0 643 00007 0

Printed by CSIRO, Melbourne

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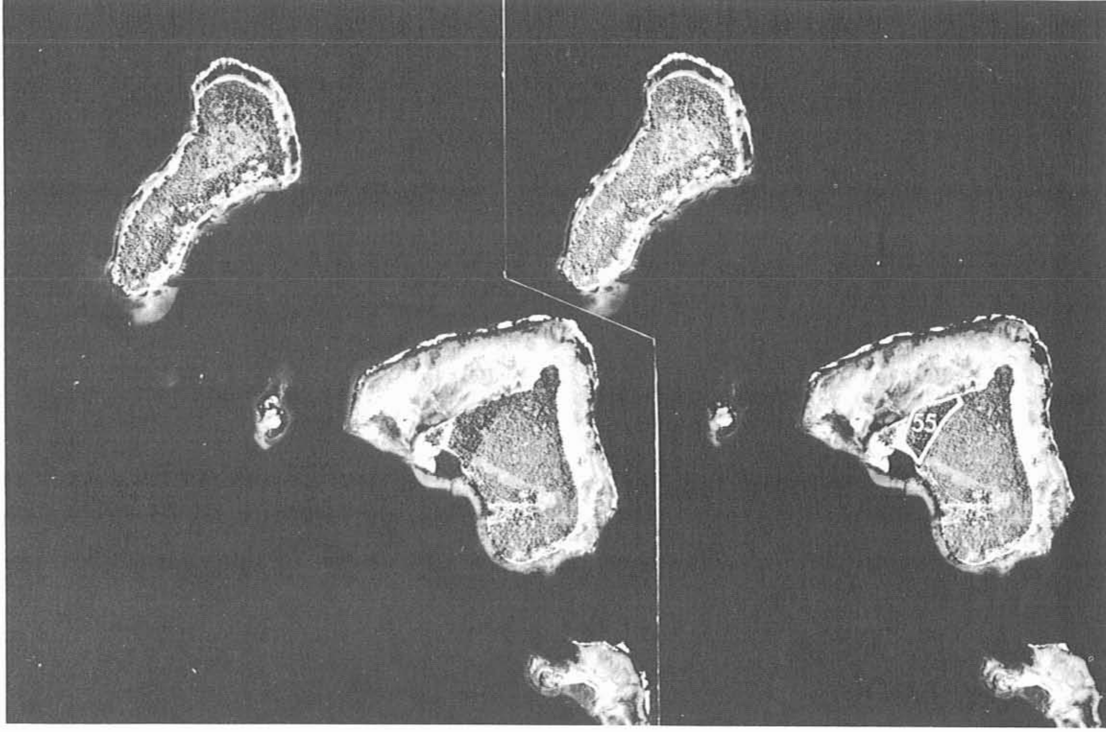
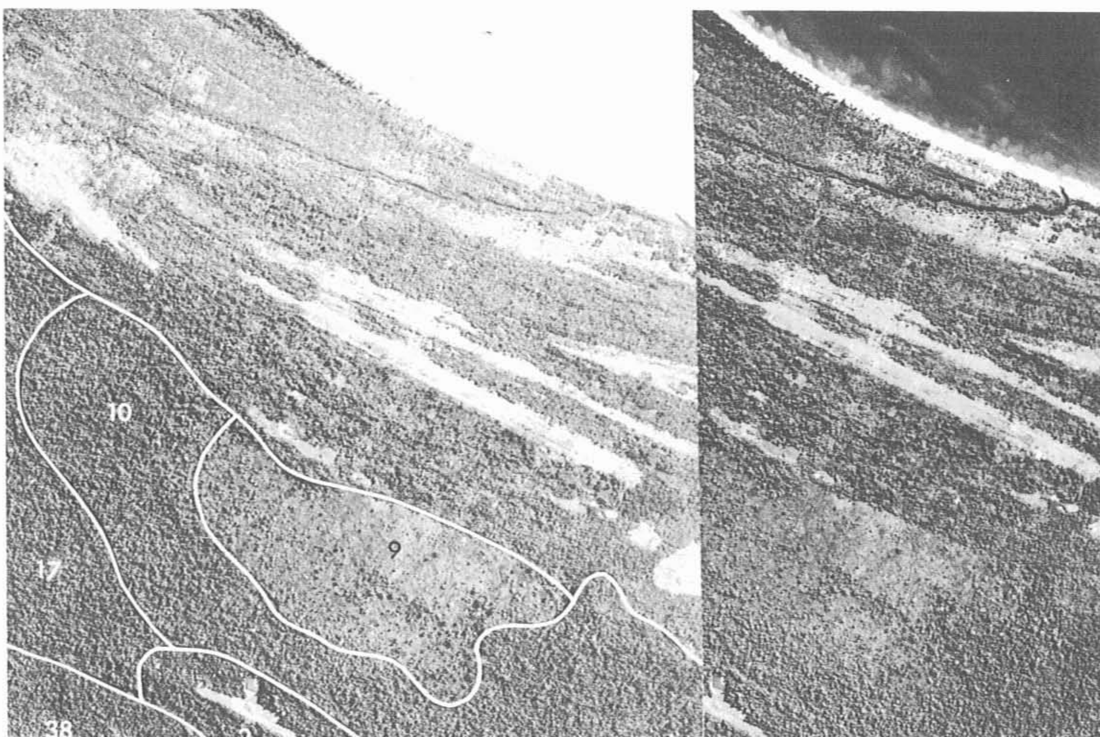


PLATE 1

Fig. 1.—Madang (1) land system; raised coral platforms; gardens, coconut plantations, and secondary vegetation.

Fig. 2.—Nubia (2) land system; sandy beach ridges; gardens, coconut plantations, secondary vegetation, and kunai grassland; swales with sago palm vegetation.



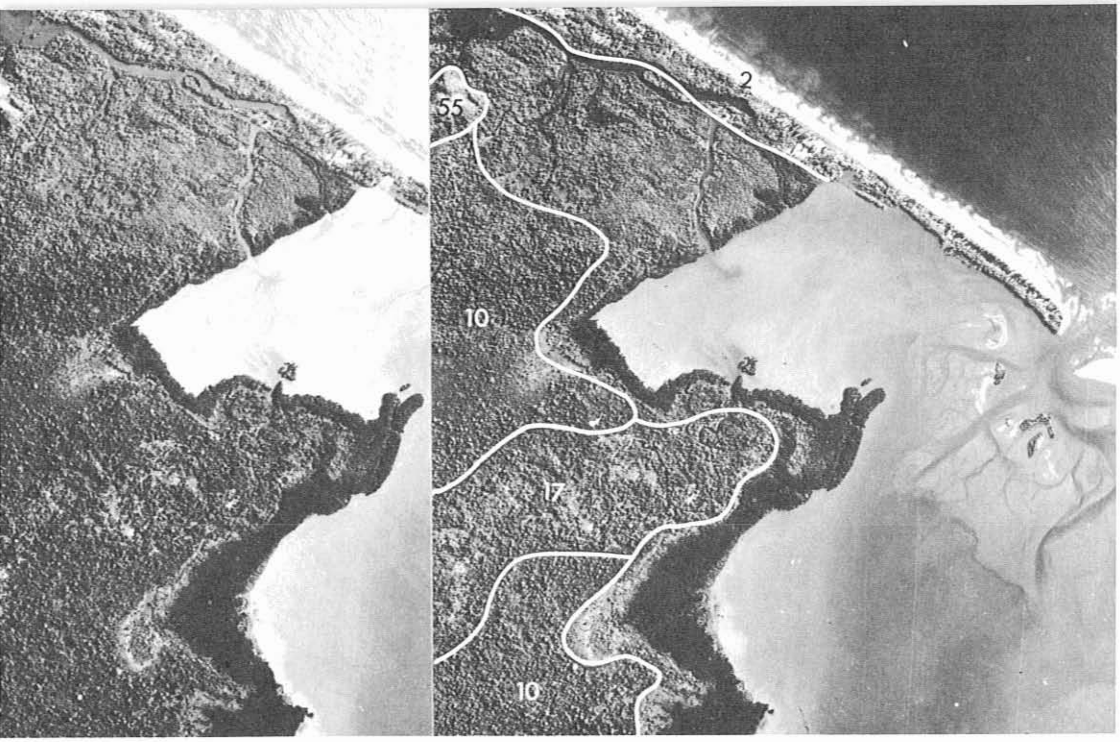
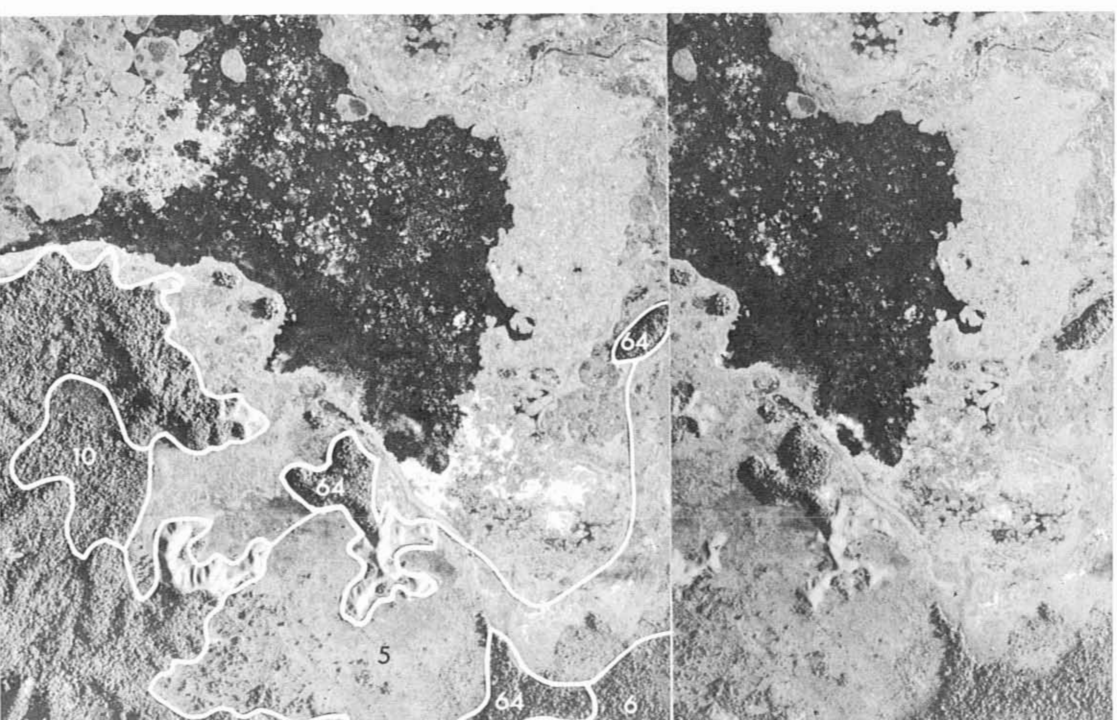


PLATE 2

Fig. 1.—Murik (3) land system; tidal flats; mangrove vegetation, mixed with *Nypa* palms in north-west.

Fig. 2.—Chambri (4) land system; back-swamp plains; aquatic vegetation, floating grasses, sedge lands, and fern lands.



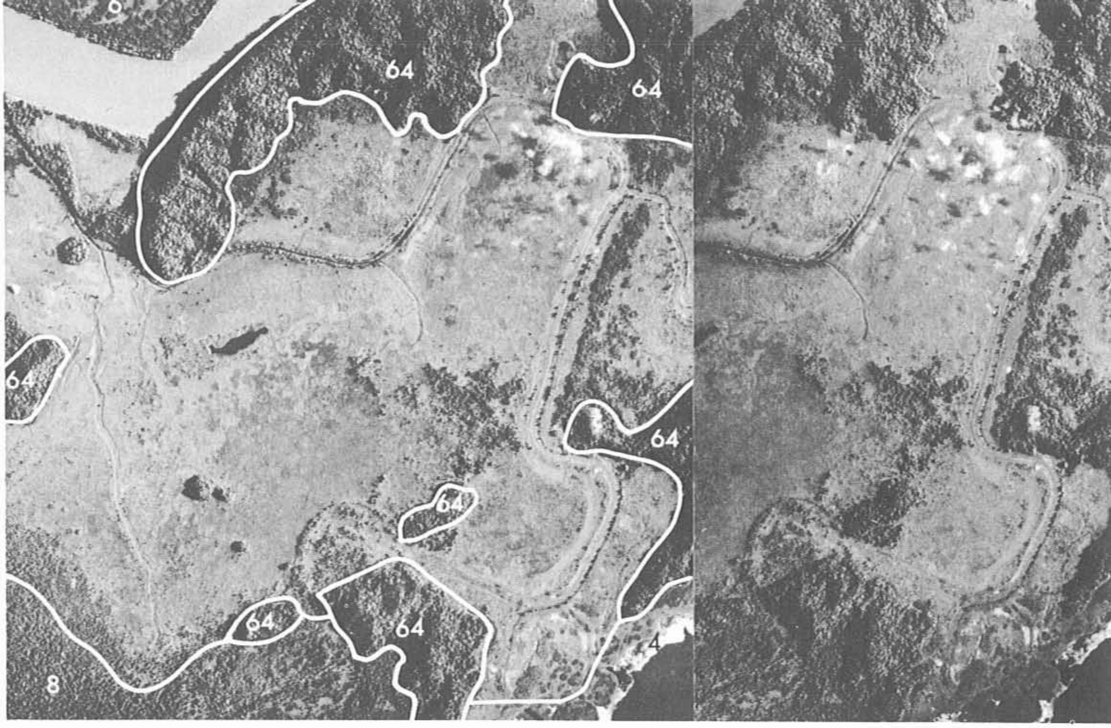


PLATE 3

Fig. 1.—Sanai (5) land system; back-swamp plains; tall grassland of reed and associated grasses; a patch of tall sedge vegetation in north-west.

Fig. 2.—Pandamp (6) land system; back-swamp plains; pandan vegetation interspersed with reed and tall sedge vegetation.

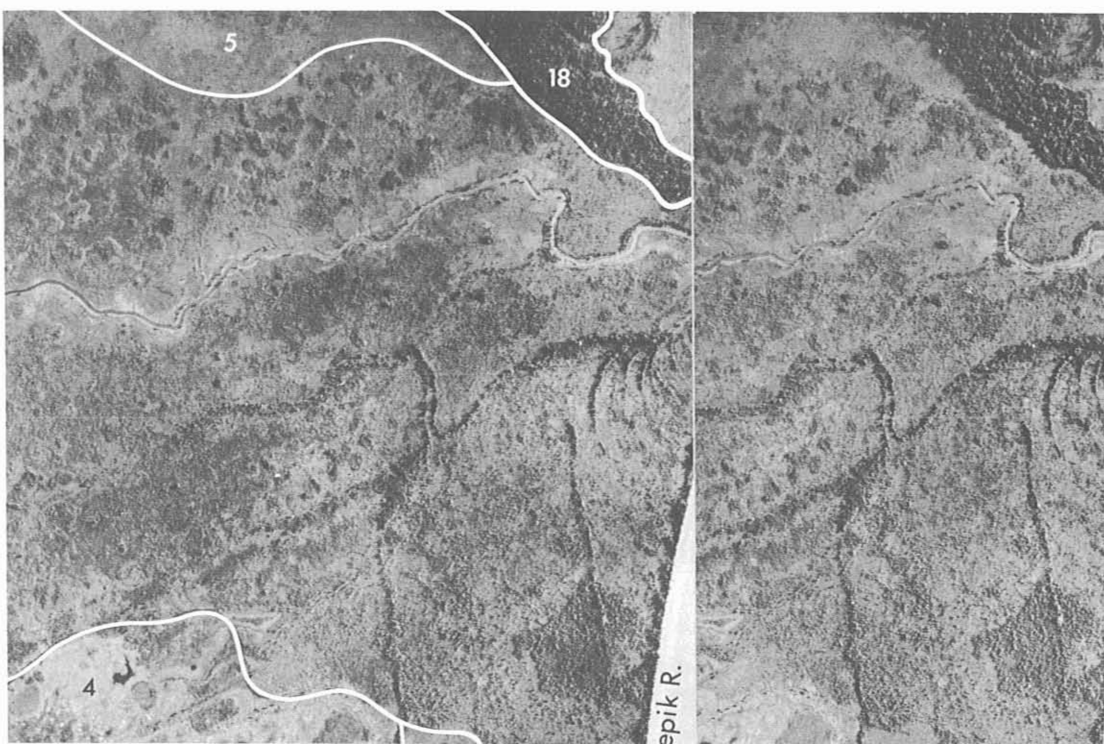
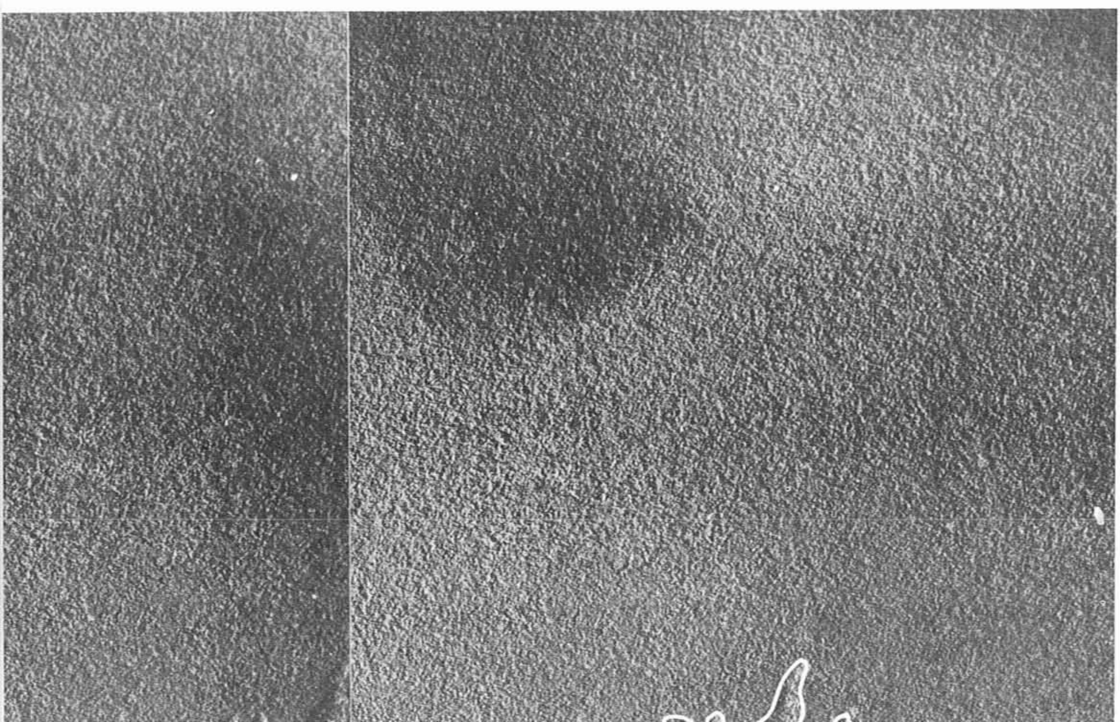


PLATE 4

Fig. 1.—Kobar (7) land system; peaty back-swamp plains; woodland with tall sedge undergrowth.

Fig. 2.—Pora (8) land system; peaty back-swamp plains; mid-height forest with an open canopy with *Campnosperma*, and with sago palms in the understorey.



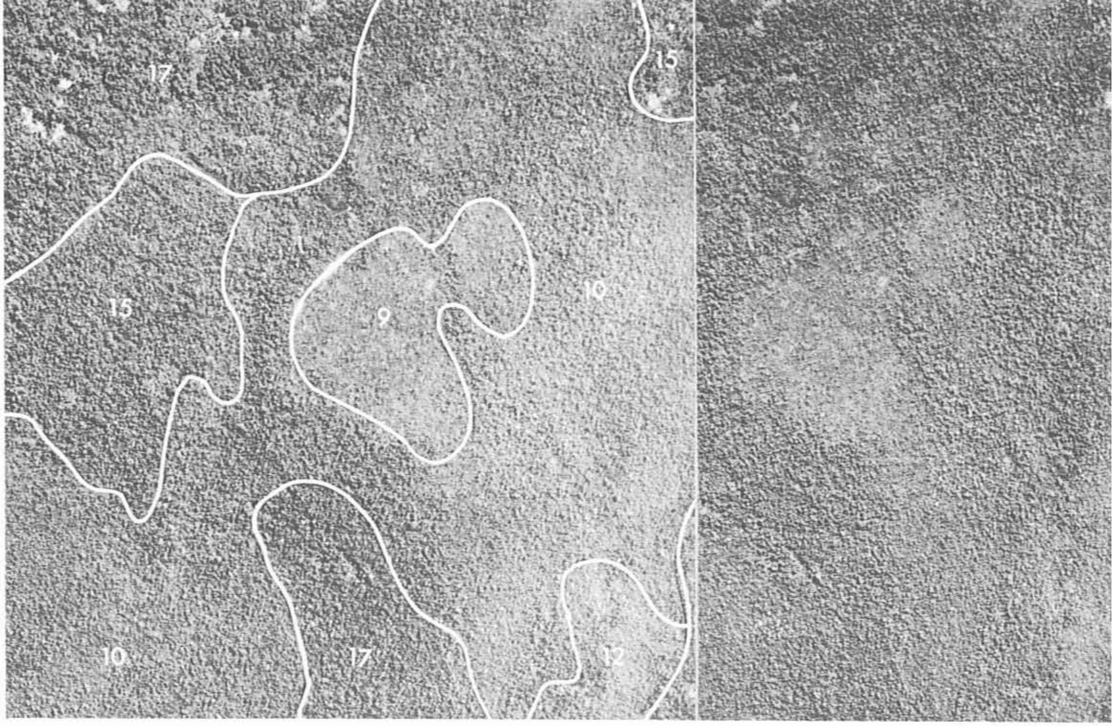
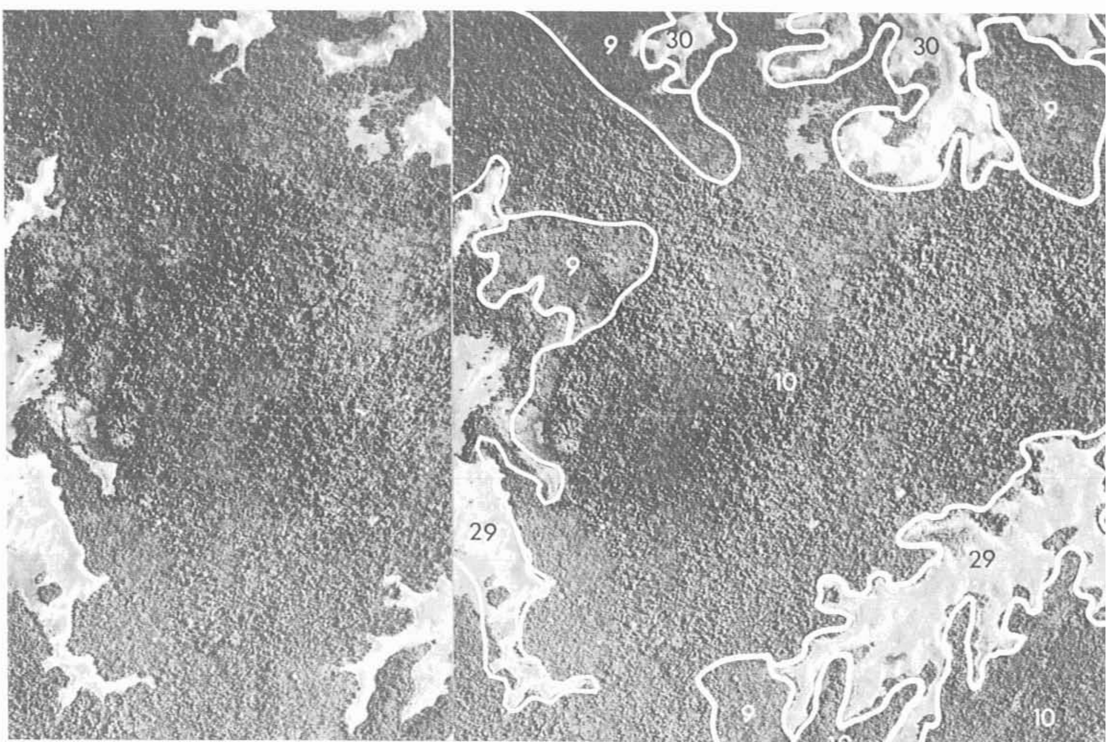


PLATE 5

Fig. 1.—Fan-toe swamps of Kabuk (9) land system with stunted sago palm vegetation, and of Pandago (10) land system with sago palm vegetation with emergent trees and mid-height forest with an open canopy and sago palms in the understorey.

Fig. 2.—Blocked valley swamps of Kabuk (9) land system with sago palm vegetation, and of Pandago (10) land system with vegetation as described above.



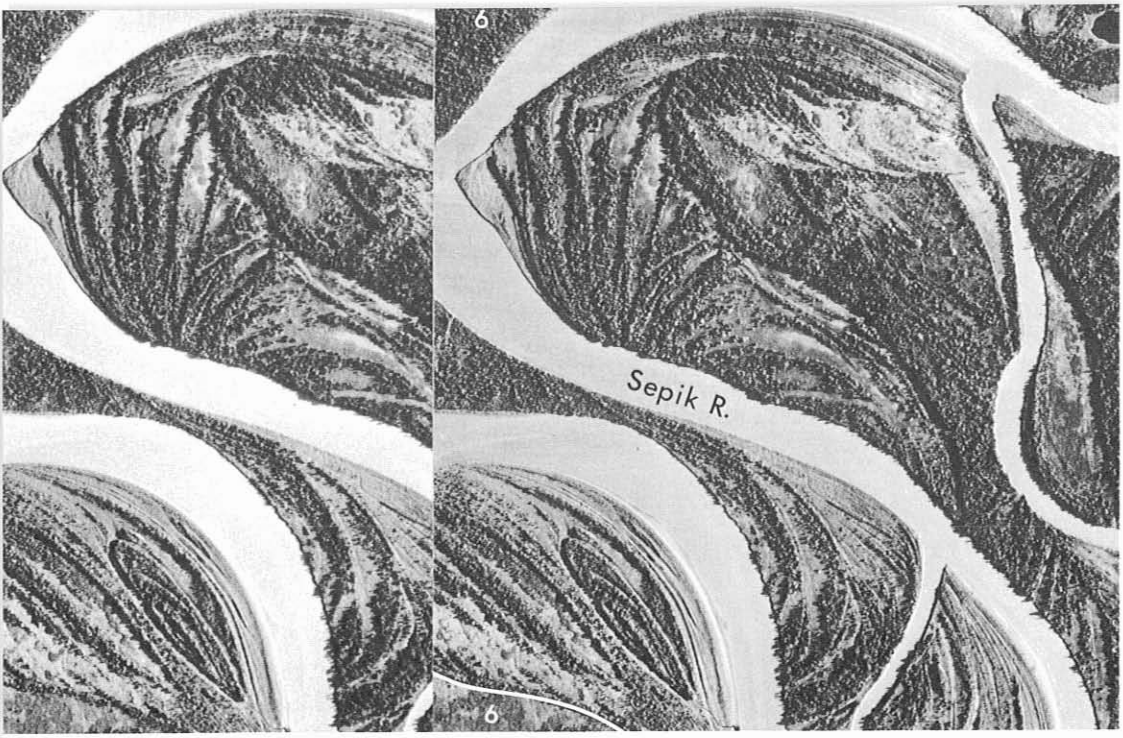
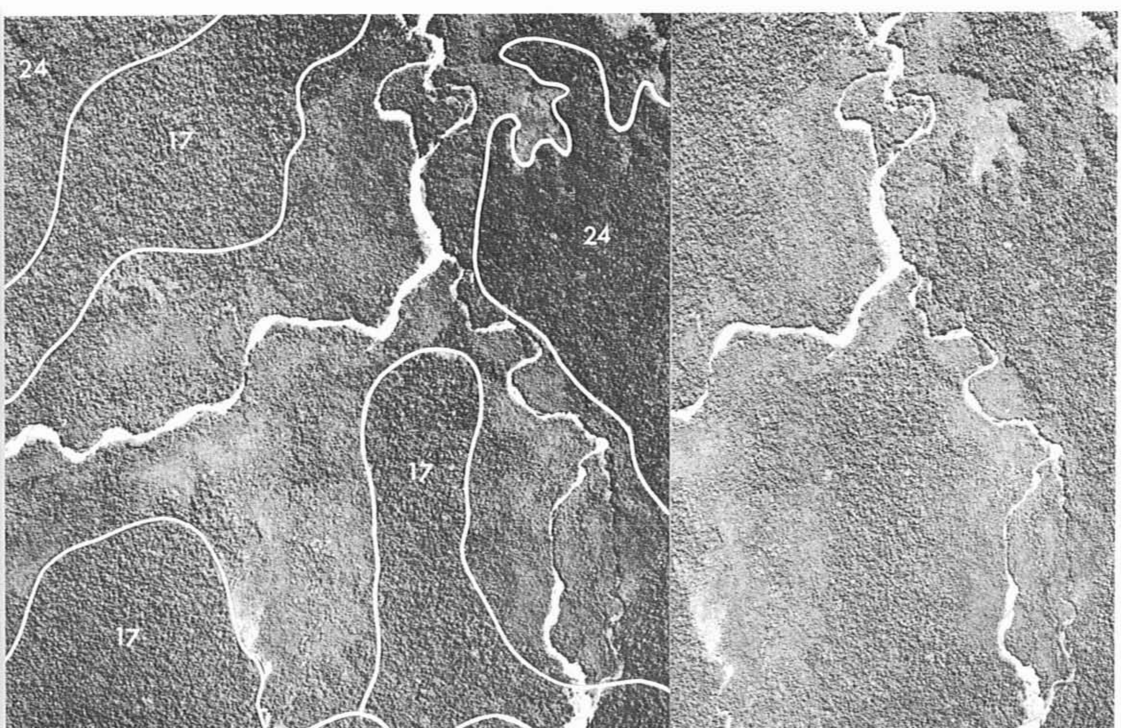


PLATE 6

Fig. 1.—Palimbai (11) land system; scroll plains of the Sepik River; tall forest with an open canopy with light-toned crowns on older, cane grass on younger scrolls; cane grass with reed and pandan vegetation in swales.

Fig. 2.—Nigia (12) land system; distributary flood-plains and scroll plains; mid-height forests with open canopies with pandans common in the canopy or understorey.



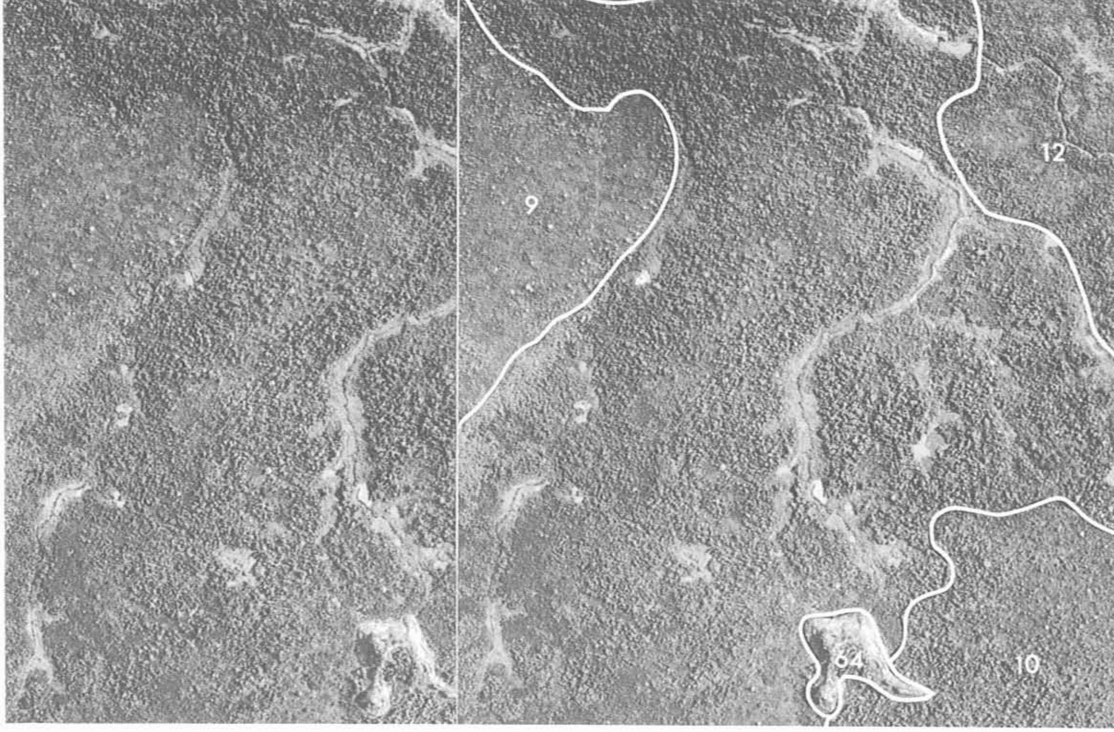
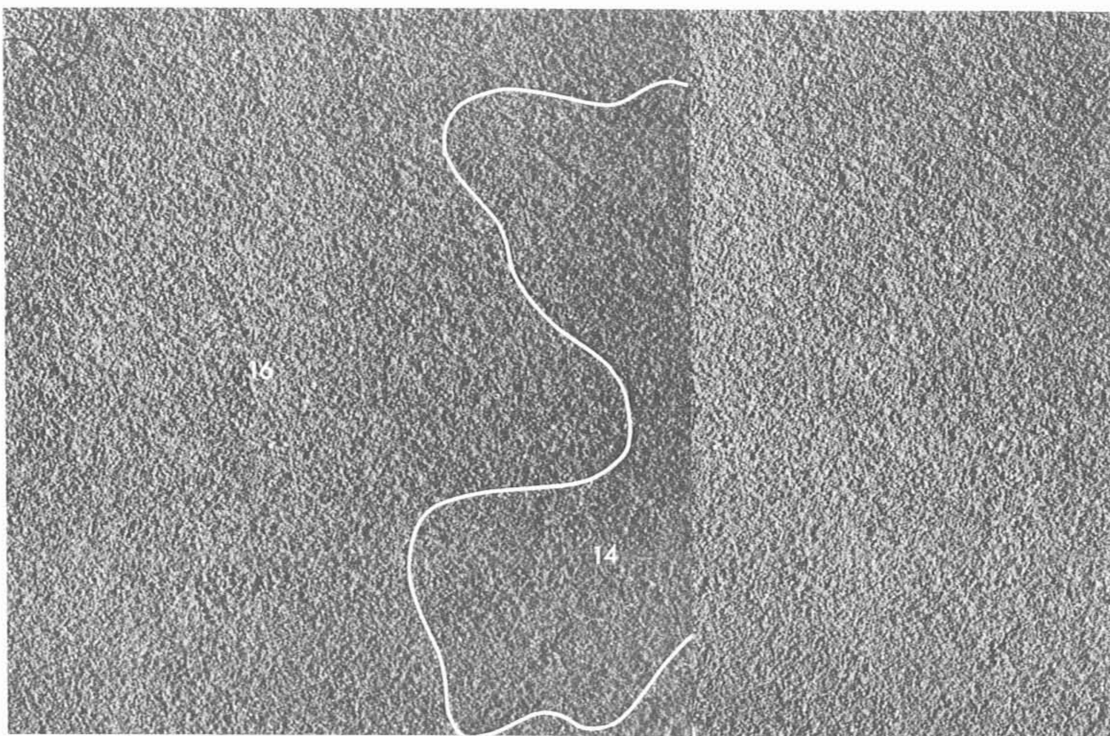


PLATE 7

Fig. 1.—Yilui (13) land system; distributary levee/back-plain complex; village sites, gardens, and coffee plots on levees; back plains with mid-height forest with an irregular canopy with pandans and sago palms.

Fig. 2.—Misinki (14) land system; poorly drained alluvial clay plains; tall forest with an open canopy and sago palms in the understorey. Nagam (16) land system; alluvial clay plains; tall forest with a rather open canopy.



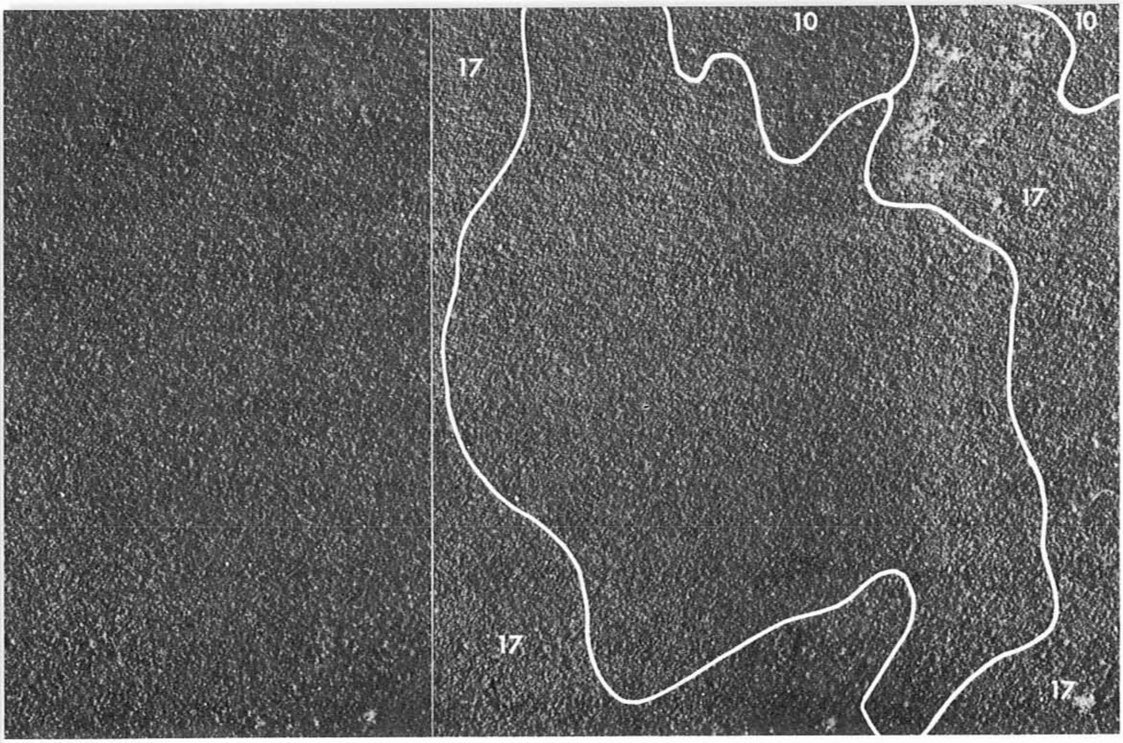
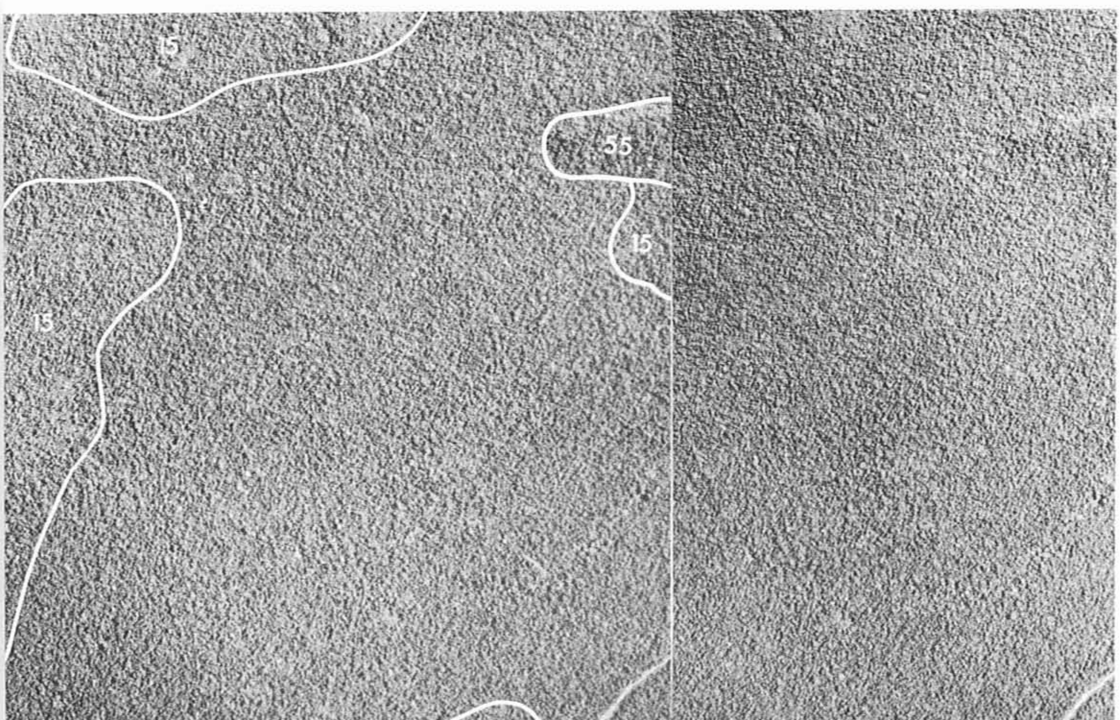
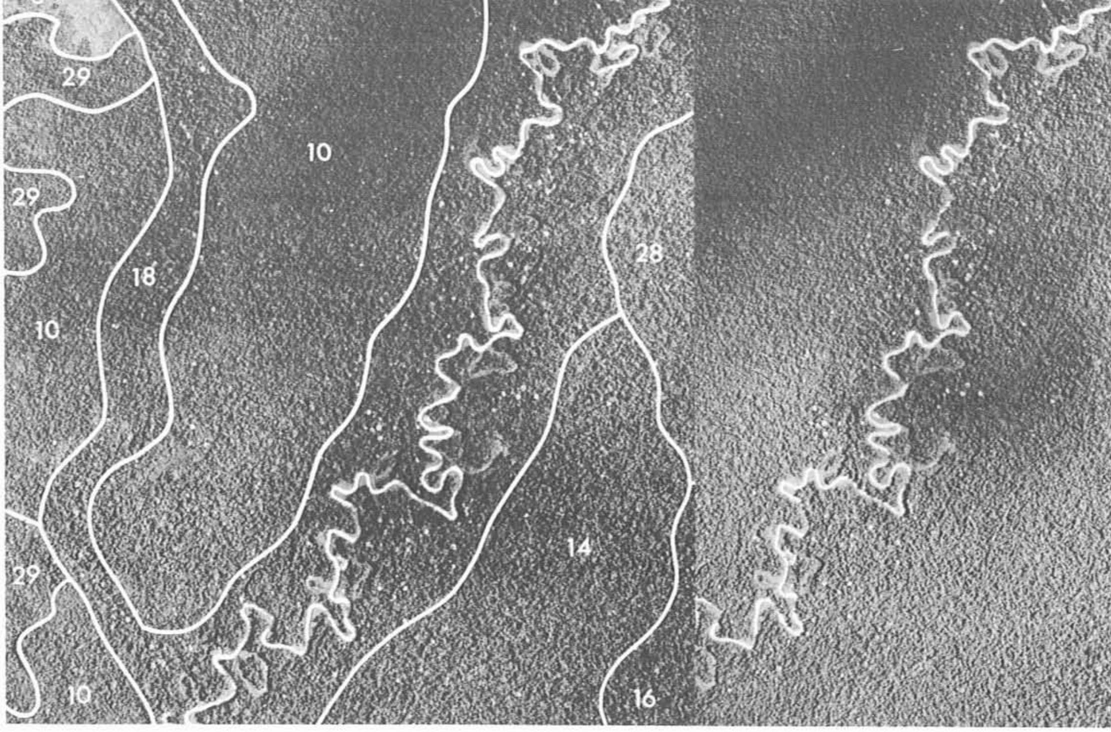


PLATE 8

Fig. 1.—Po (15) land system; flood-plains of lowermost fan sectors; tall forest with an open canopy and sago palms in the understorey.

Fig. 2.—Pes (17) land system; fan plains; tall forest with a rather open canopy.





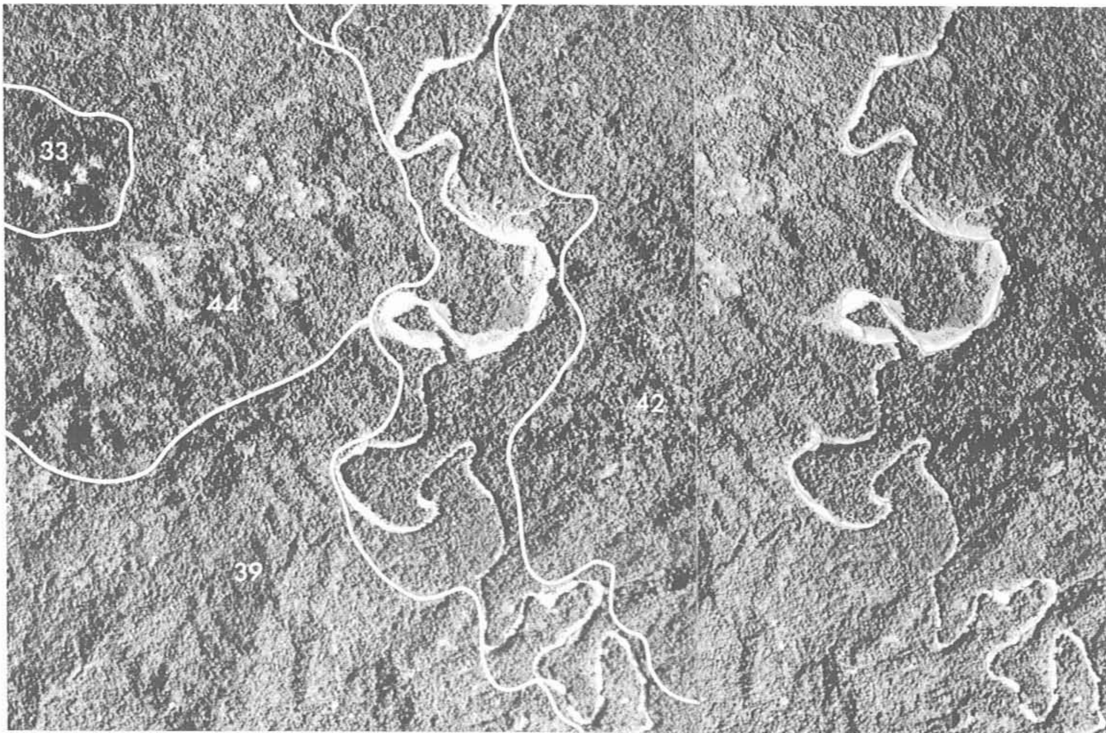


PLATE 9

Fig. 1.—Screw (18) land system; levees and narrow scroll flood-plains; tall forest with an open canopy with light-toned crowns; cane grass on scrolls.

Fig. 2.—Papul (19) land system; river terraces and flood-plains in confined valleys; tall forest with a rather closed canopy; cane grass on scrolls and lowest terraces; secondary forest in south.

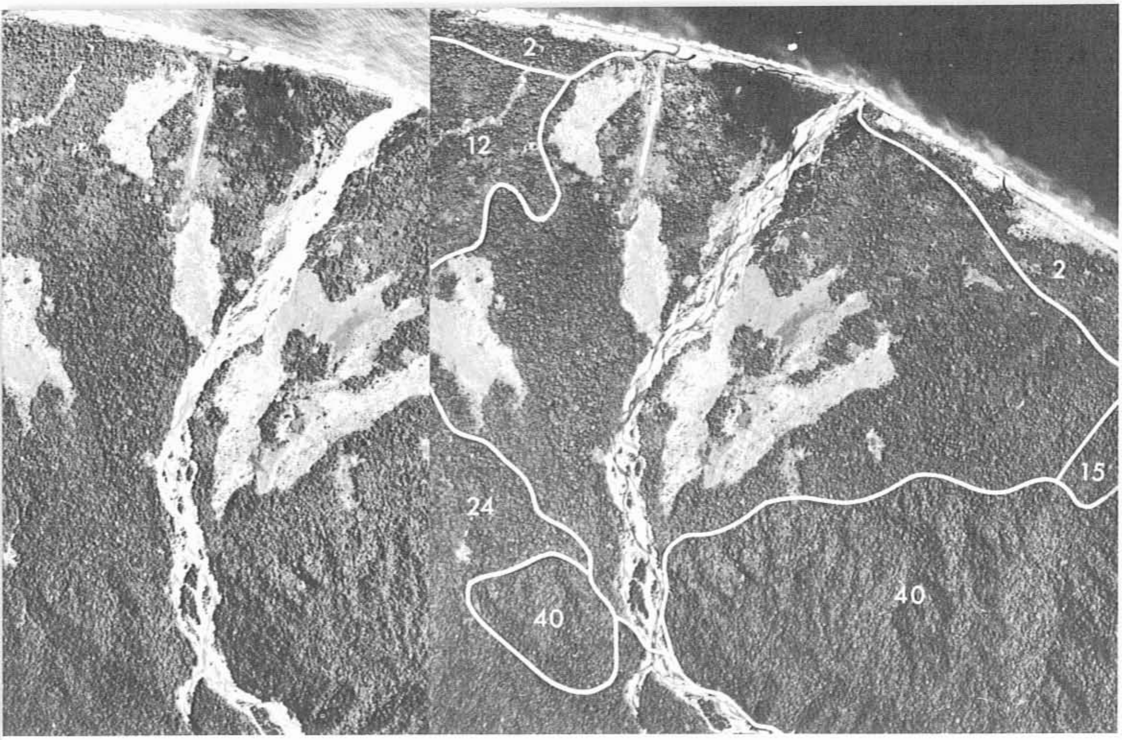
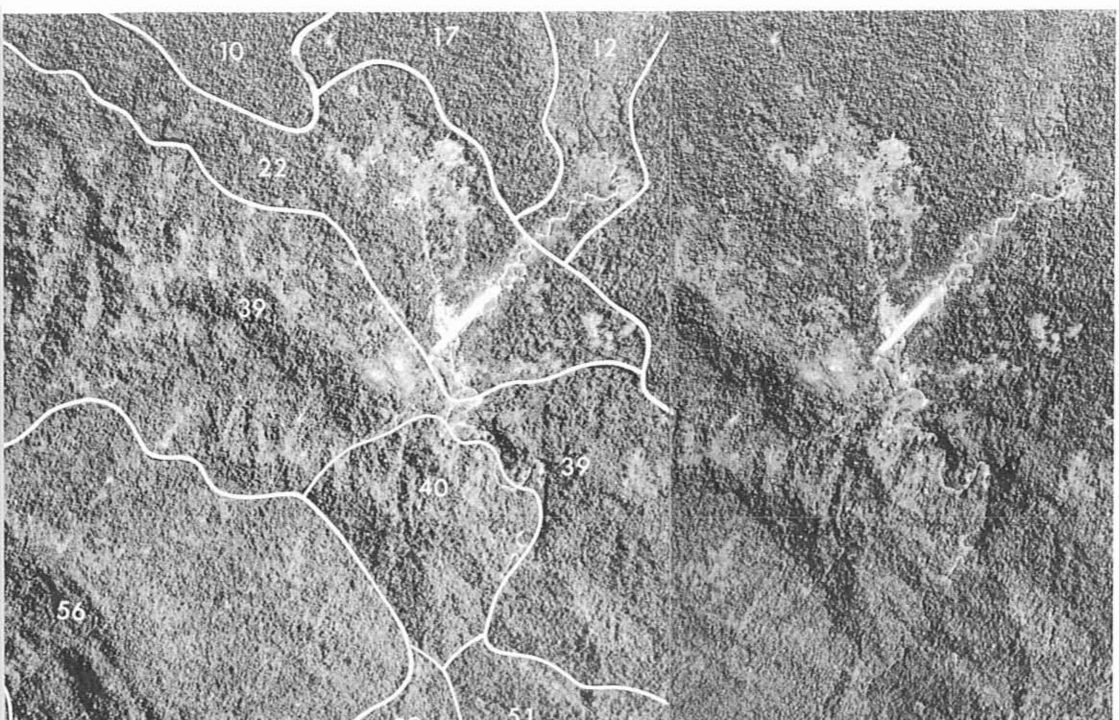


PLATE 10

Fig. 1.—Kabenau (21) land system; coastal fan plains and terraces; secondary vegetation, including grassland, and exploited sago palm vegetation; tall forest with a rather open canopy.

Fig. 2.—Romei (22) land system; colluvio–alluvial fans and aprons derived from limestone; gardens and regrowth up to medium-aged secondary forest (also on adjacent hills).



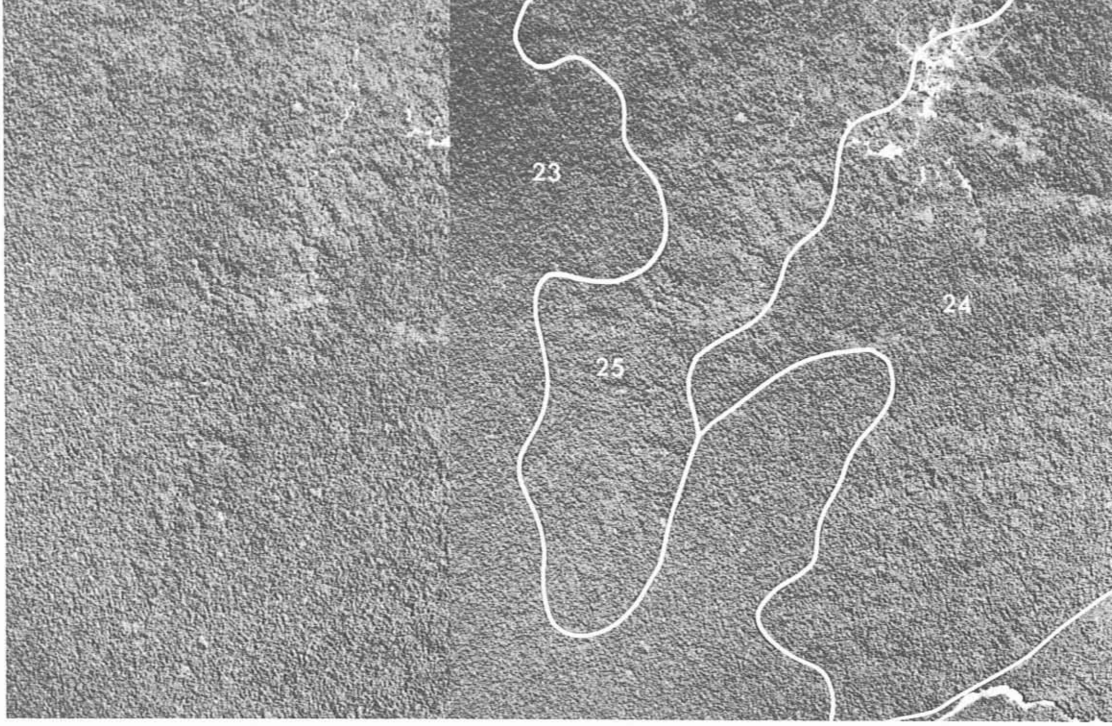
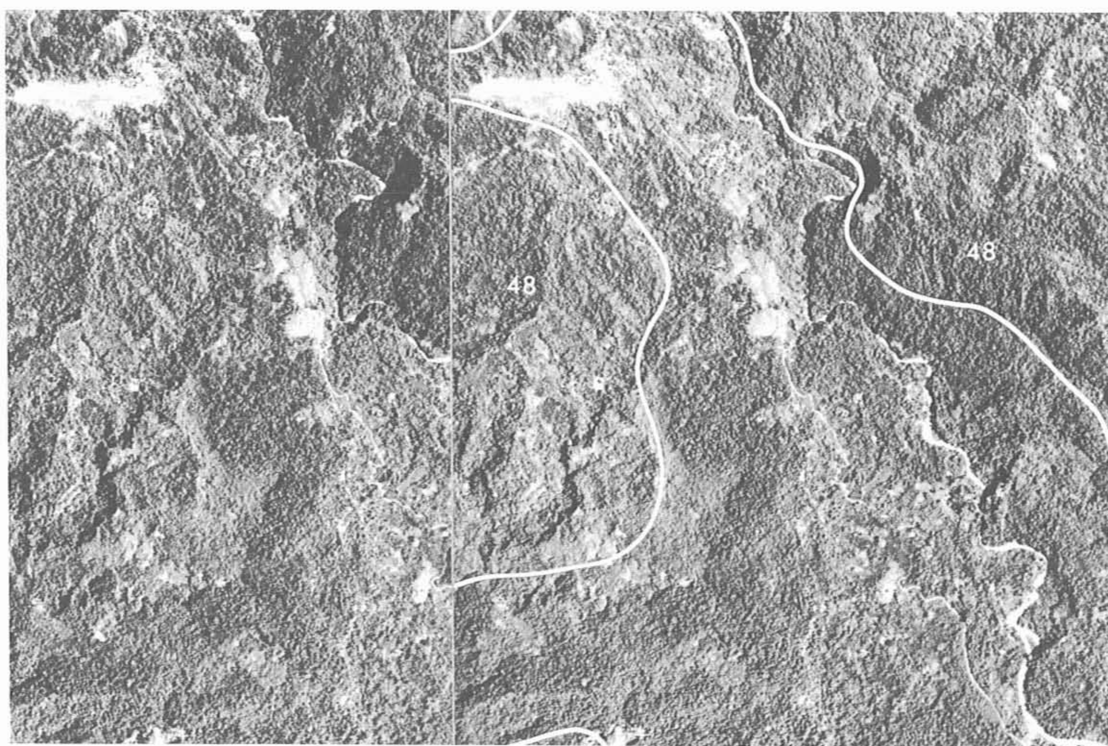


PLATE 11

Fig. 1.—Aiome (23), Paiawa (24), and Panakatan (25) land systems; marginally, partially, and wholly dissected weathered fan surfaces; tall forest with a rather open and small-crowned or irregular canopy.

Fig. 2.—Lumi (26) land system; little to strongly dissected fan surfaces and terraces overlying mudstone; gardens to old secondary forest; some tall forest with an irregular canopy with light-toned crowns.



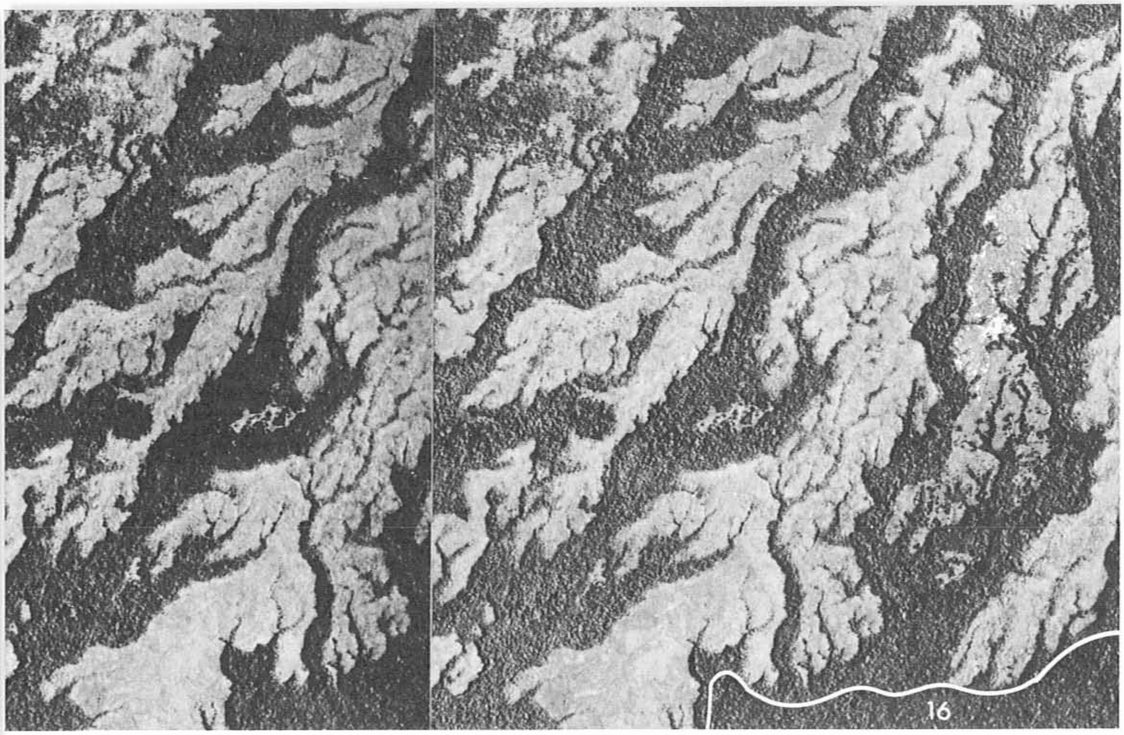
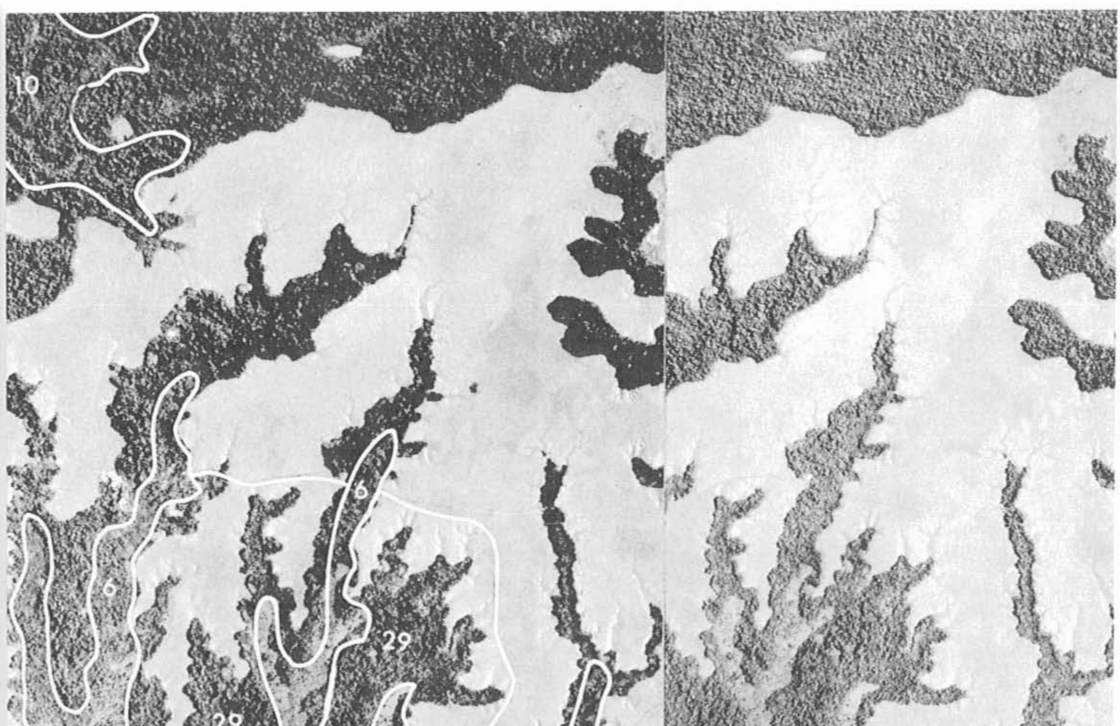


Plate 12

Fig. 1.—Nigre (27) land system; weathered plains; fern vegetation, often with sedges common; mid-height forest with an irregular canopy with sago palms in the understorey.

Fig. 2.—Yambi (28) land system; slightly dissected weathered plains; mid-height grassland; mid-height forest with an irregular canopy in north, and with sago palms in the understorey in valleys.



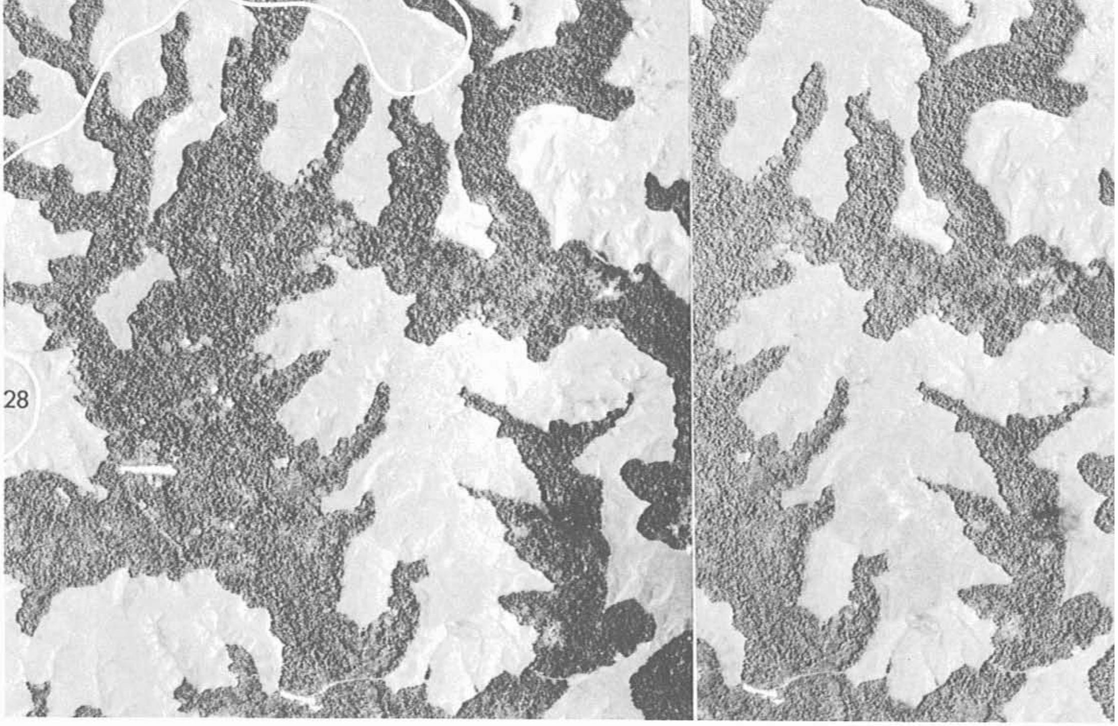
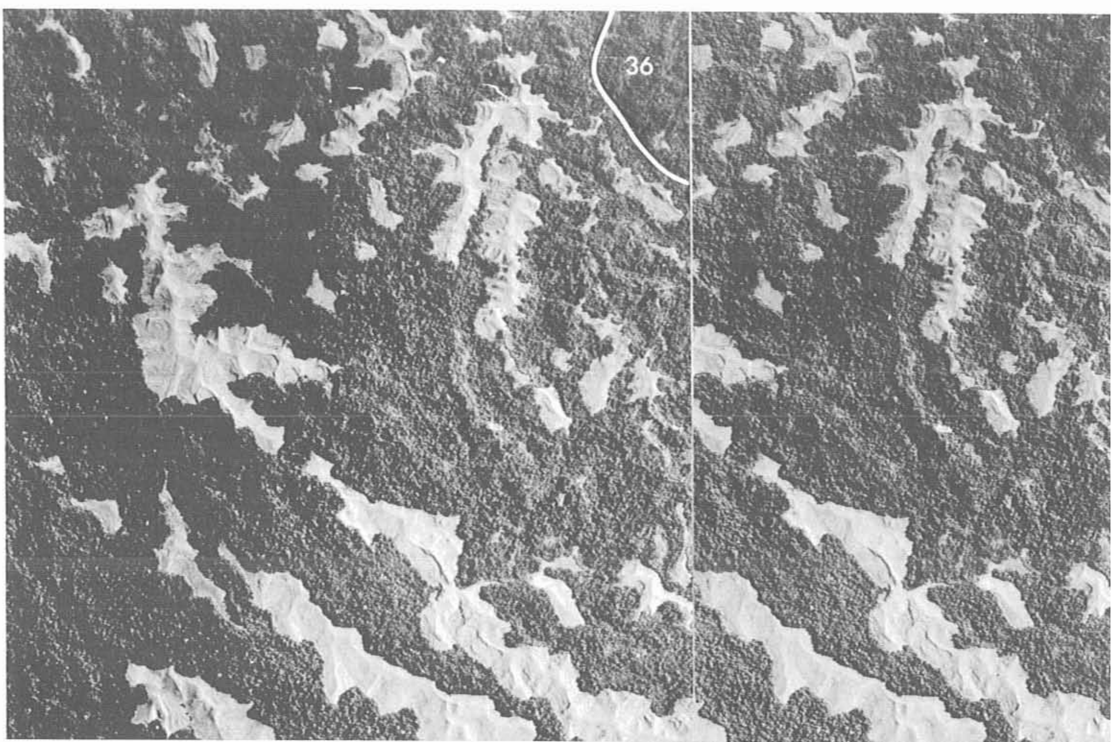


PLATE 13

Fig. 1.—Burui (29) land system; dissected weathered plains; mid-height grassland; secondary vegetation and exploited sago palm vegetation in most valleys.

Fig. 2.—Kworo (30) land system; slumped very low hill ridges of strongly dissected weathered plains; mid-height grassland and forest with a small-crowned canopy on ridges; mid-height forest with an irregular canopy and sago palms in the understorey in valleys.



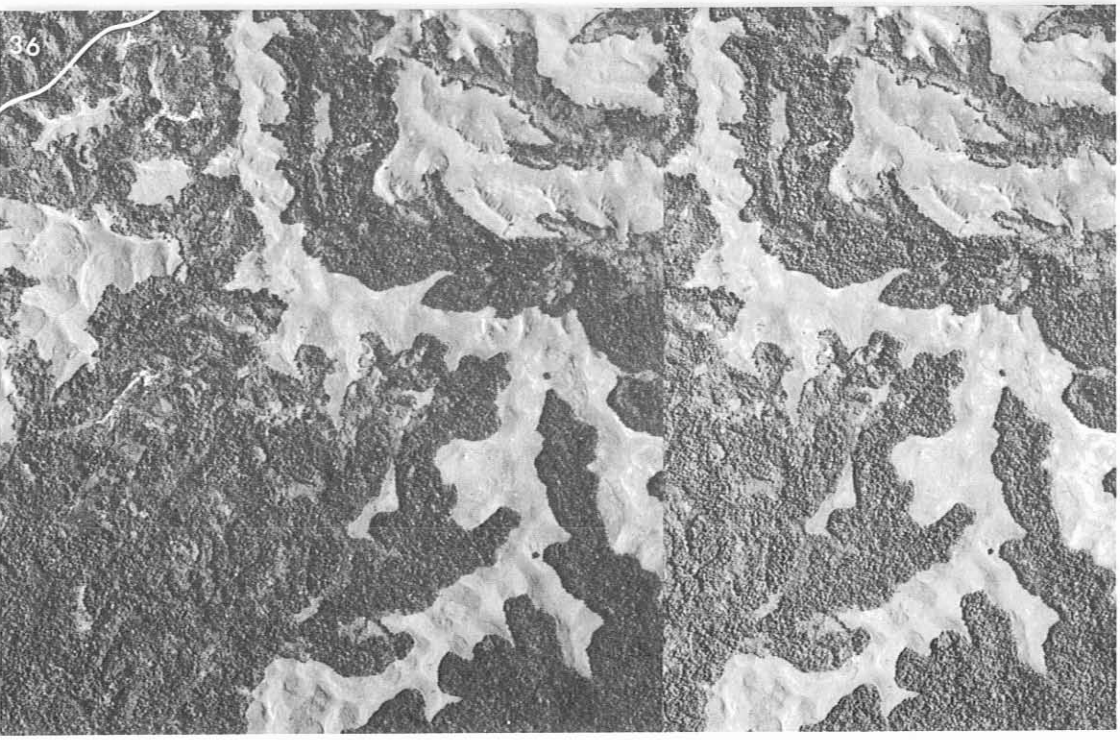
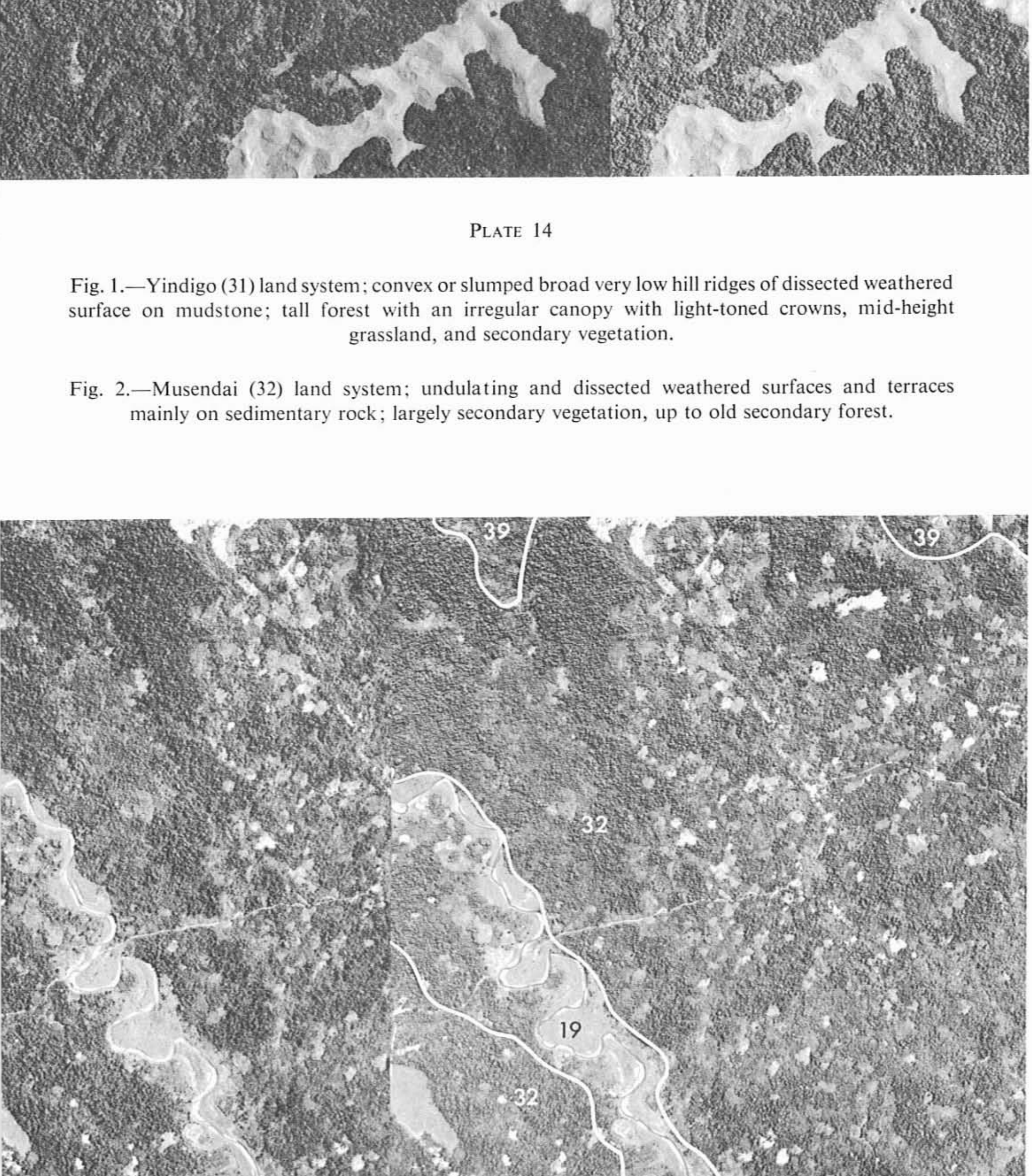


PLATE 14

Fig. 1.—Yindigo (31) land system; convex or slumped broad very low hill ridges of dissected weathered surface on mudstone; tall forest with an irregular canopy with light-toned crowns, mid-height grassland, and secondary vegetation.

Fig. 2.—Musendai (32) land system; undulating and dissected weathered surfaces and terraces mainly on sedimentary rock; largely secondary vegetation, up to old secondary forest.



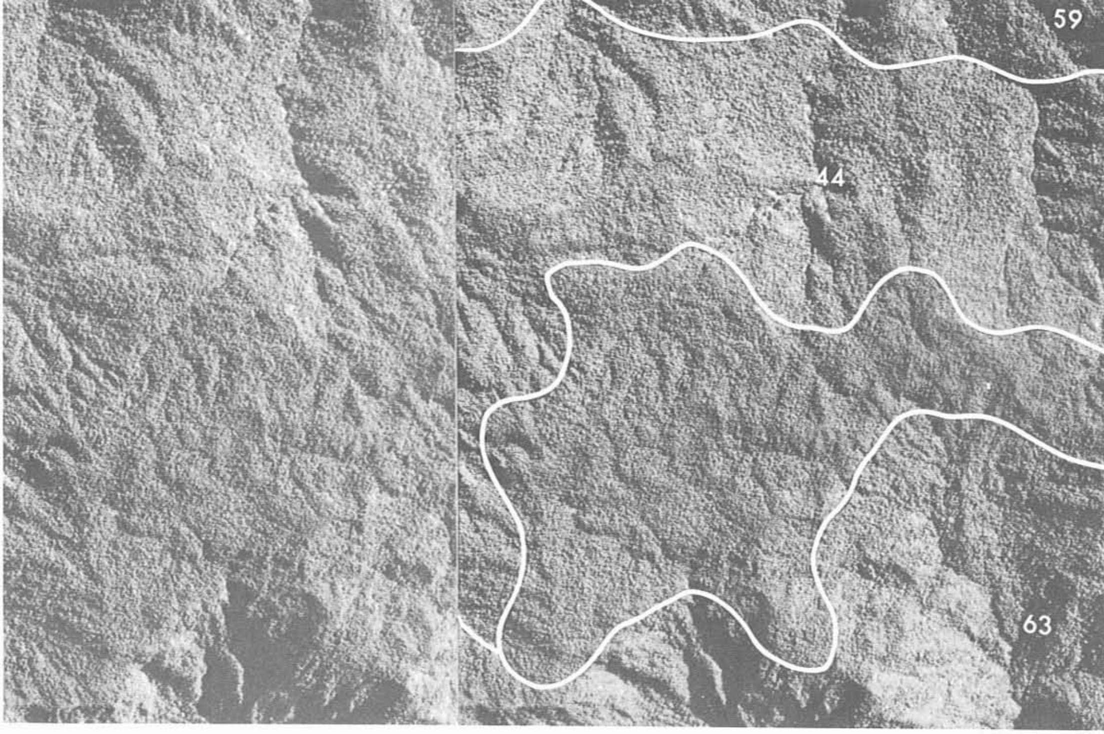
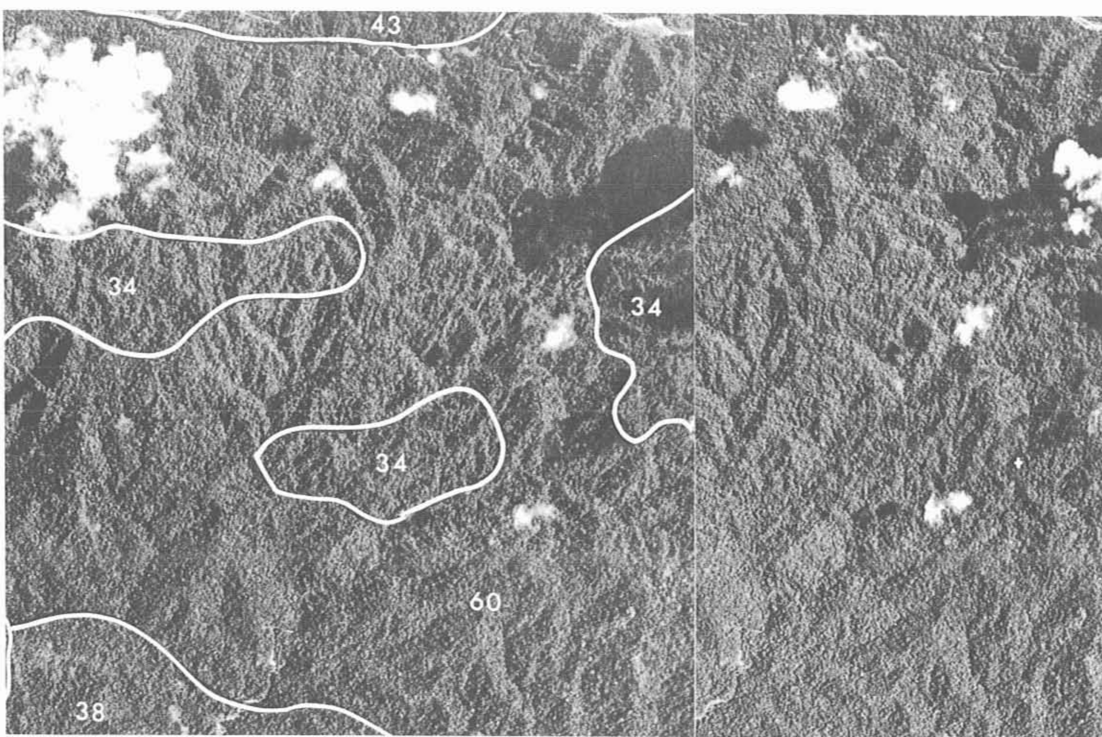


PLATE 15

Fig. 1.—Atitau (33) land system; very low hilly weathered mountain summit areas; mid-height forest with a rather dark-toned even canopy.

Fig. 2.—Dossett (34) and Kumbusaki (60) land systems; finely spurred branching steep very low (34) and very steep high (60) hill ridges on basic igneous rocks; forests with irregular canopies, mid-height in north, tall and with light-toned crowns in south.



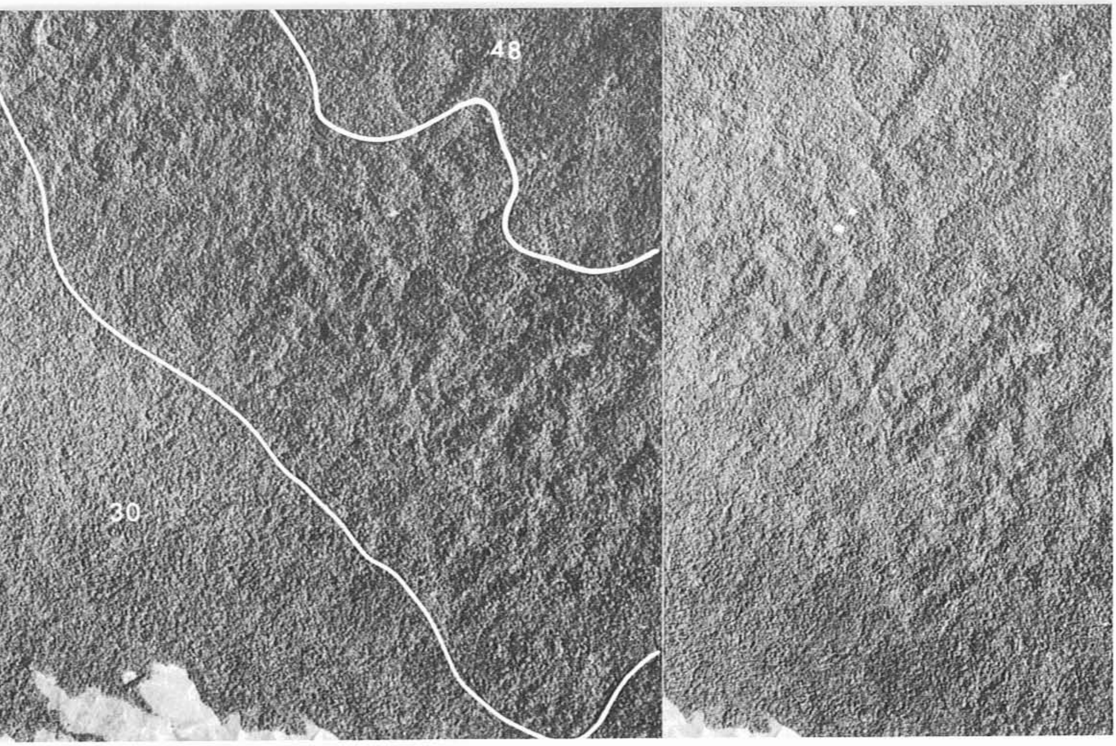
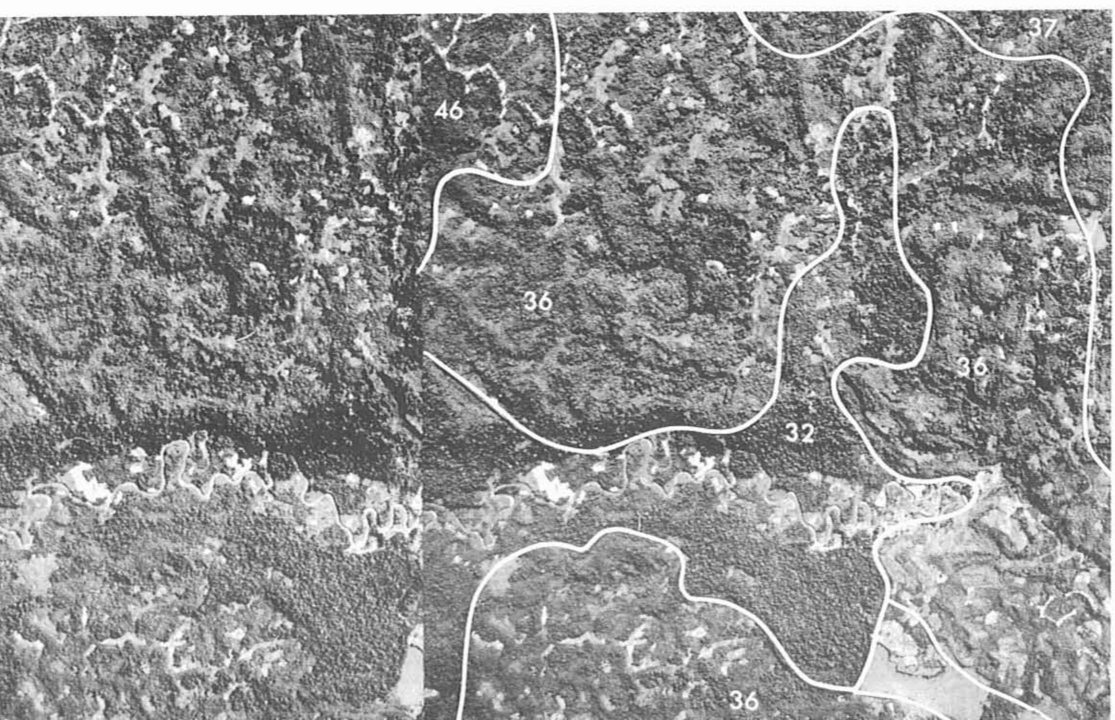


PLATE 16

Fig. 1.—Sandri (35) land system; very intricately dissected steep accordant hill ridges on (semi-)consolidated sedimentary rocks; tall forest with an irregular canopy with light-toned crowns.

Fig. 2.—Emul (36) land system; finely branching steep convex accordant hill ridges on interbedded sedimentary rocks; gardens and secondary vegetation, including cane grass regrowth.



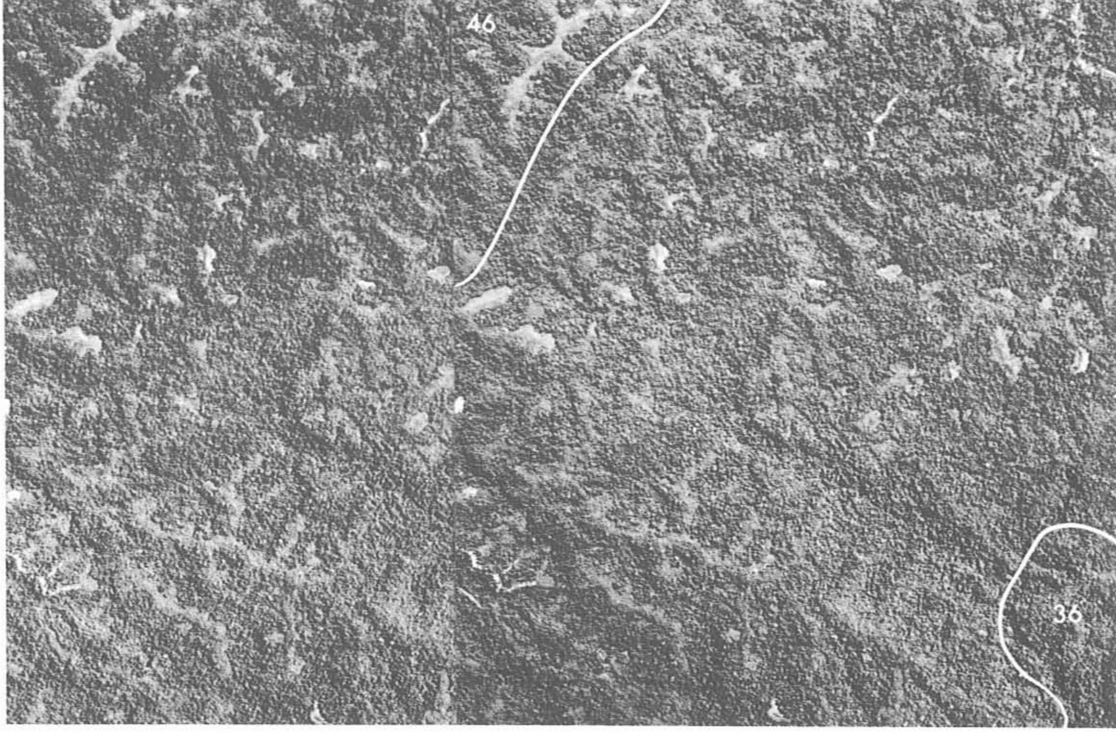
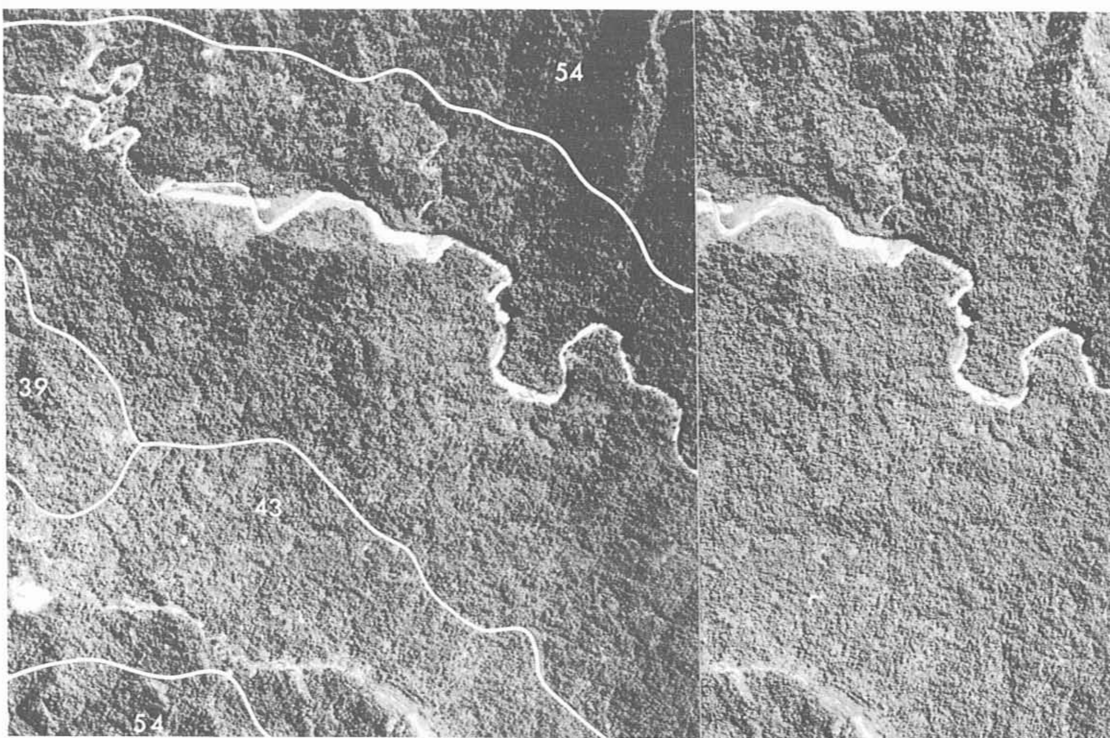


PLATE 17

Fig. 1.—Kaugiak (37) land system; benched to slumped semi-accordant low hill ridges mainly on mudstone; gardens and regrowth, including old secondary forest; remnants of tall forest with an irregular canopy with light-toned crowns.

Fig. 2.—Yassip (38) land system; short slumped steep very low hill ridges on sedimentary rocks; mainly medium-aged and old secondary forest.



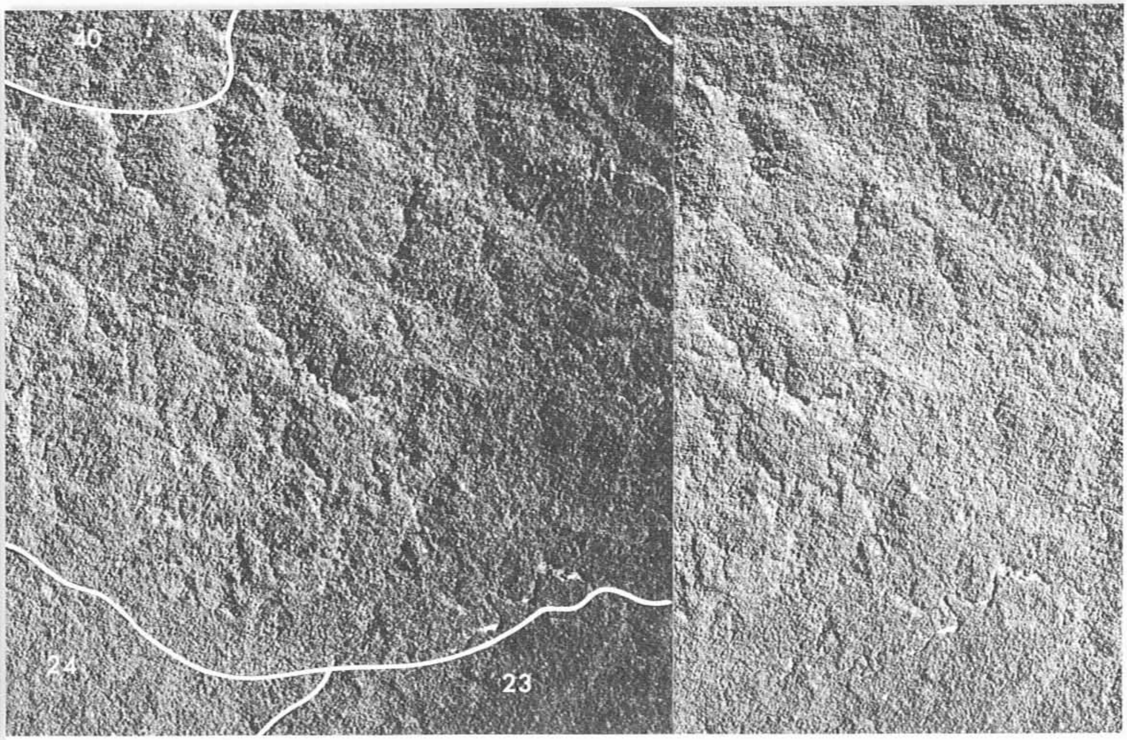
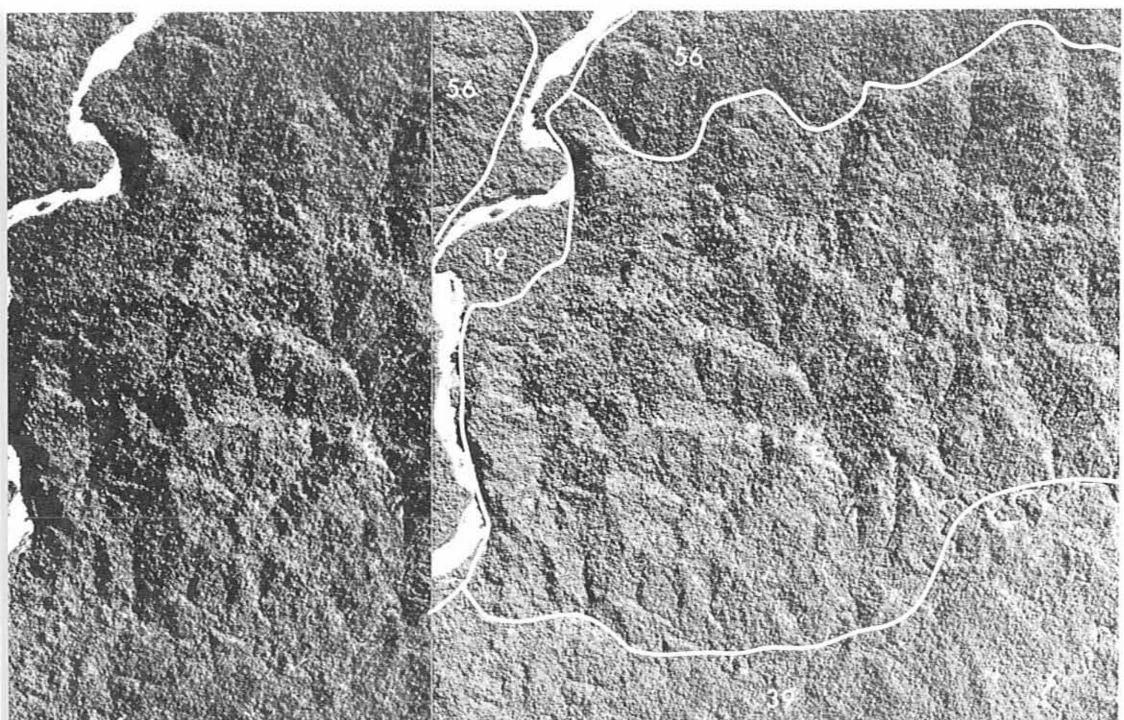


PLATE 18

Fig. 1.—Morumu (39) land system; short slumped and spurred steep low hill ridges on sedimentary rocks; tall forest with a rather open irregular canopy; medium-aged and old secondary forest mainly in north.

Fig. 2.—Numoiken (40) land system; short slumped and spurred steep high hill ridges on sedimentary rocks; tall forest with a rather open irregular canopy, seral stages on steeper slopes.



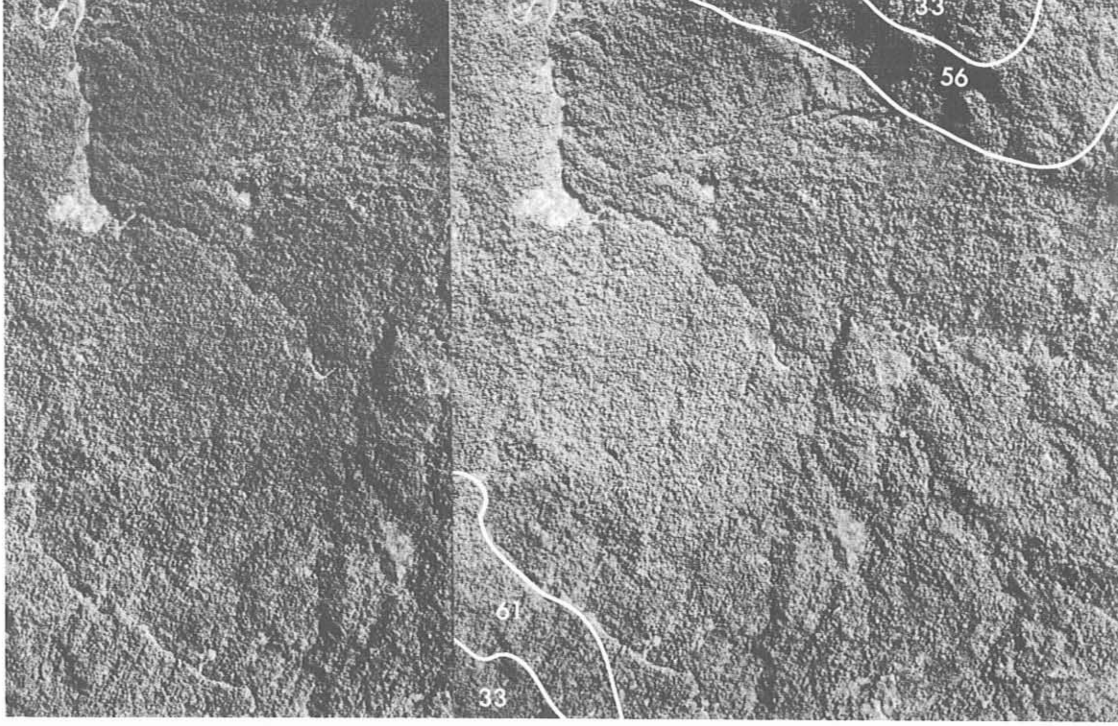


PLATE 19

Fig. 1.—Karaitem (41) land system; dissected long slopes with hummocky to low hilly surfaces on softened sedimentary rocks and rock debris; gardens, planted sago, and secondary forest.

Fig. 2.—Sengi (42) land system; broad even to undulating low hill ridges with hummocky slopes on softened sedimentary rocks; tall forest with an irregular canopy with light-toned crowns; secondary vegetation in west and south-west.

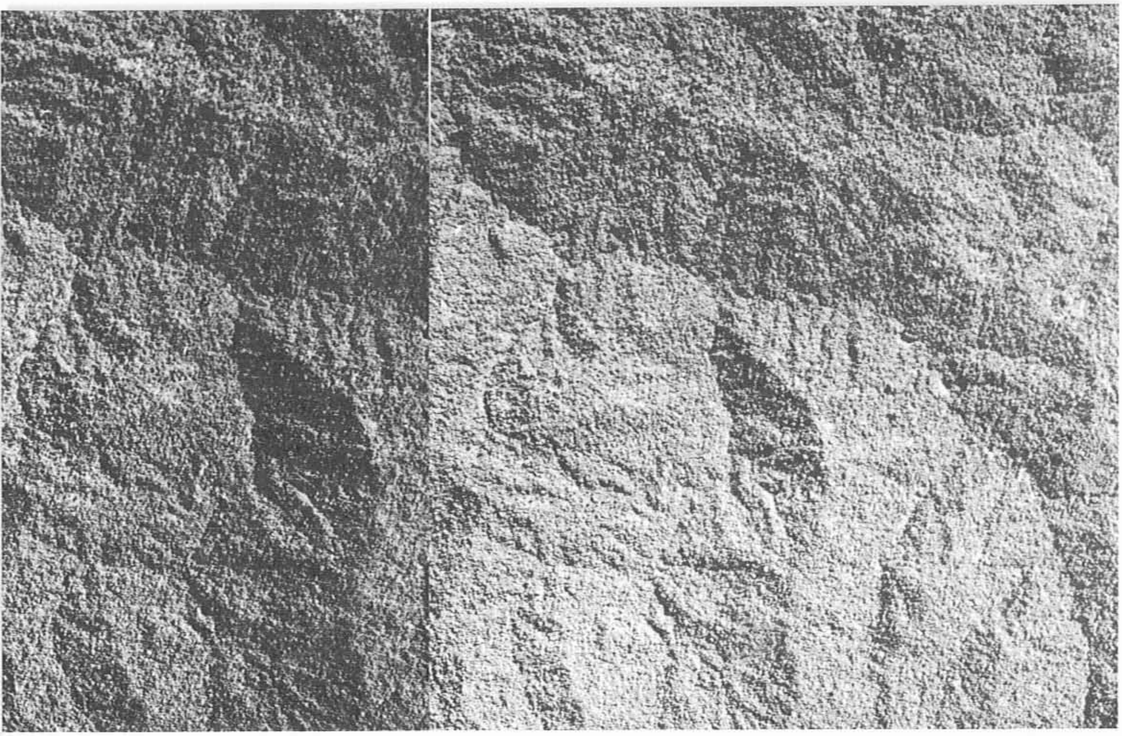
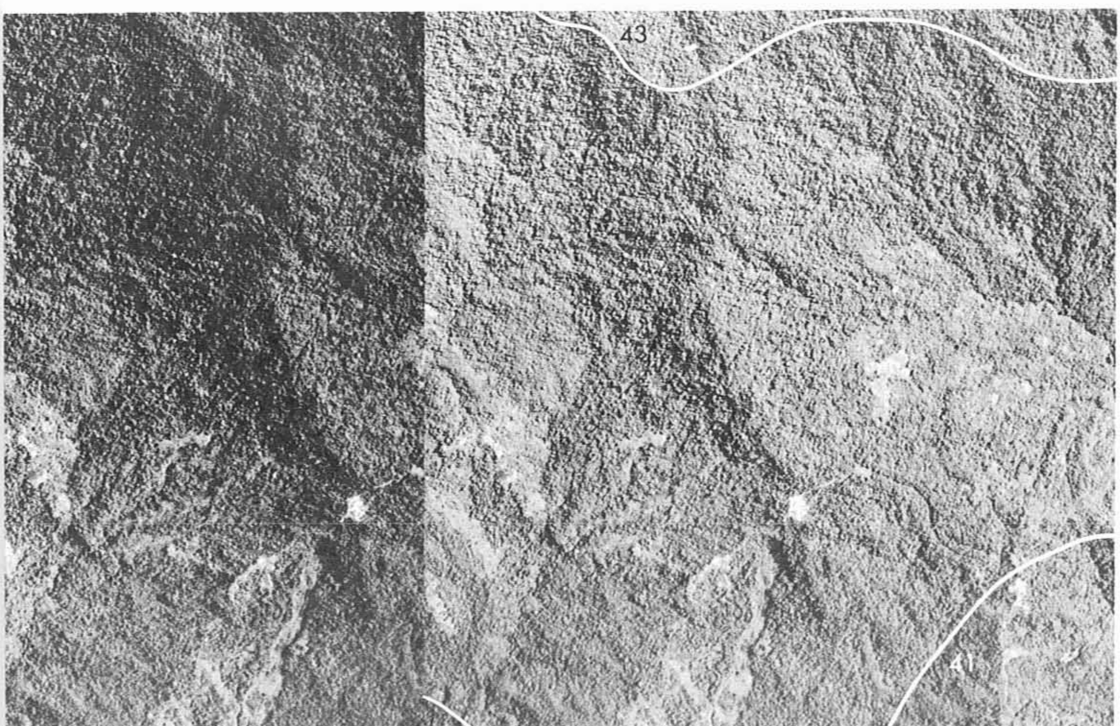


PLATE 20

Fig. 1.—Asier (43) land system; broad even to undulating steep high hill ridges with hummocky slopes on softened sedimentary rocks; tall forest with an irregular canopy; some mid-height forest with a dark-toned even canopy on crests.

Fig. 2.—Flobum (44) land system; broad low mountain ridges with irregular slumped slopes on softened sedimentary rocks; gardens and secondary vegetation; mid-height forest with a dark-toned even canopy on highest crests.



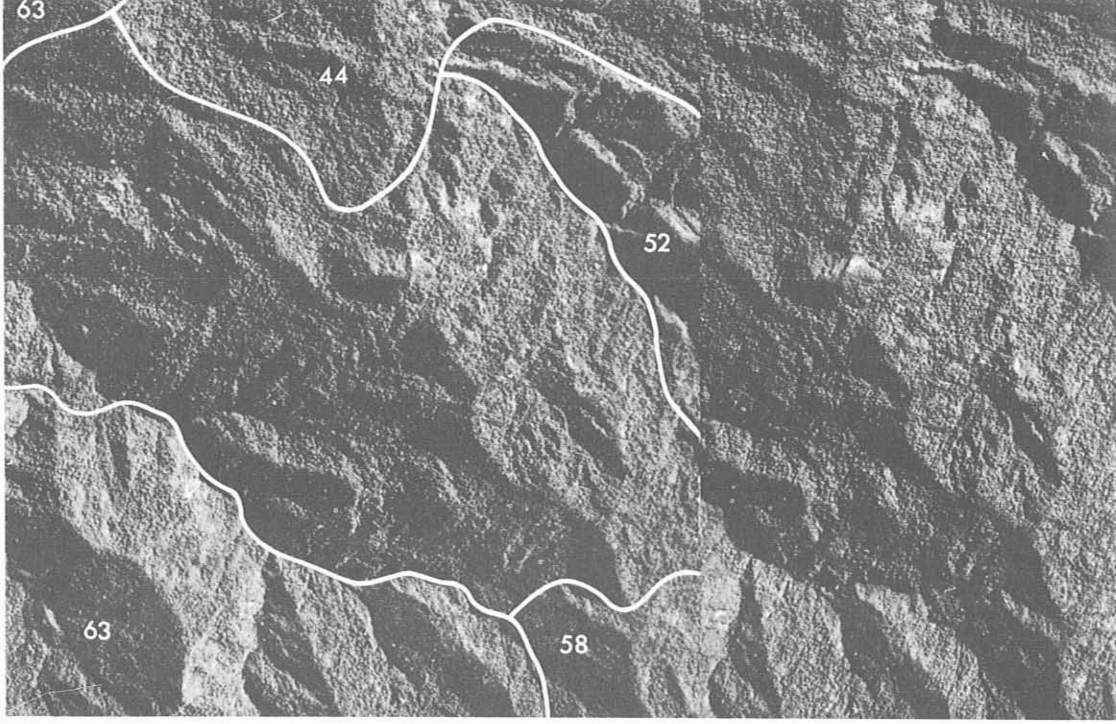


PLATE 21

Fig. 1.—Om (45) land system; very irregular slumped and dissected steep low mountain ridges and slopes on softened sedimentary rocks; mid-height forests mainly with an irregular canopy, including seral stages.

Fig. 2.—Seim (46) land system; polygonal pattern of concave slumped peaked low hill ridges on partially softened mudstone; gardens and secondary vegetation, including cane grass regrowth.

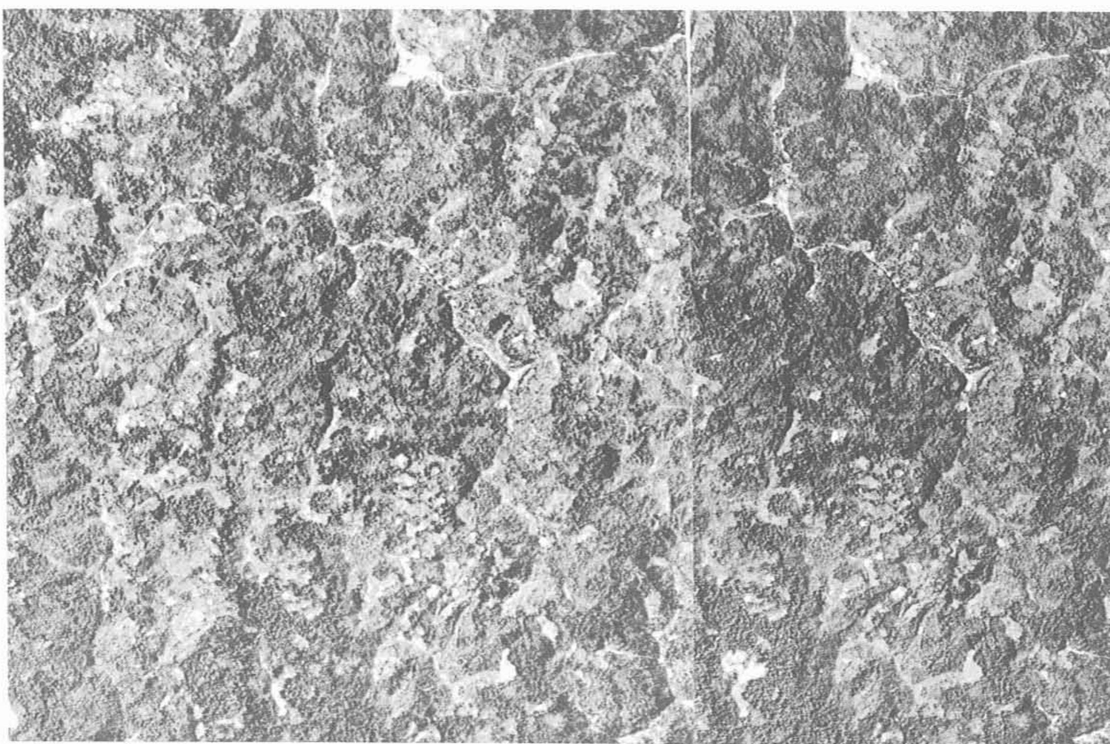


PLATE 22

Fig. 1.—Dreikikir (47) land system; semi-polygonal pattern of steep slumped peaked high hill ridges on interbedded sedimentary rocks; gardens, sago planted on slump floors, and secondary vegetation.

Fig. 2.—Mambel (48) land system; irregular peaked high hill ridges with slumps and dip-slope remnants; tall forest with an irregular canopy with light-toned crowns.

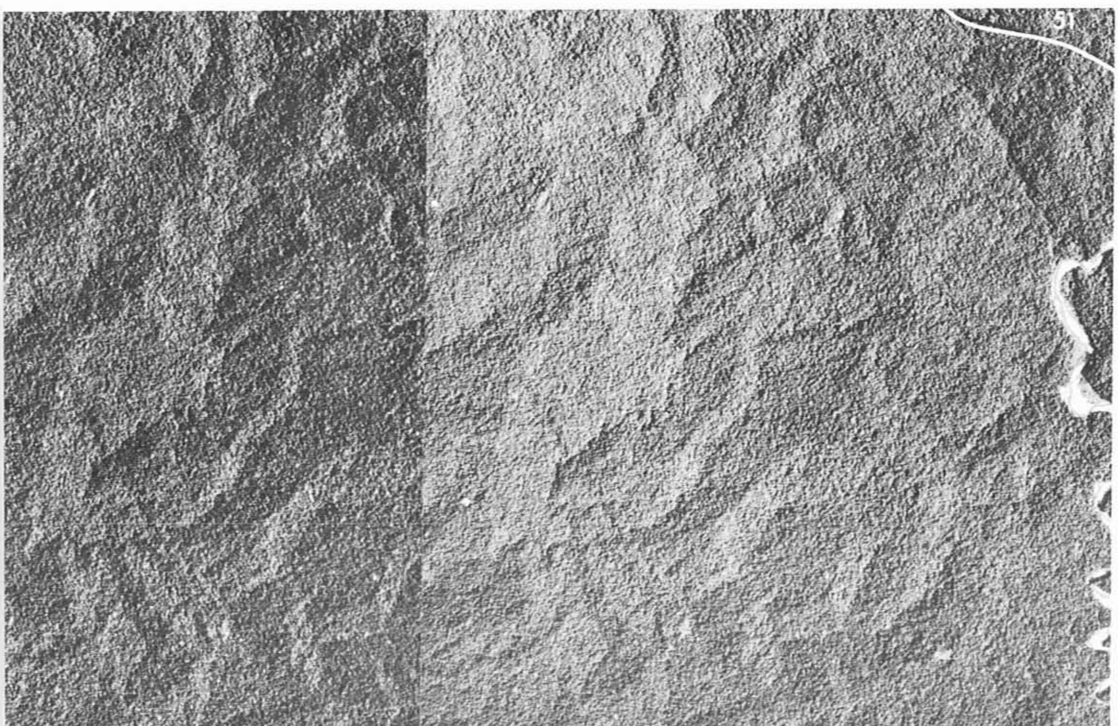
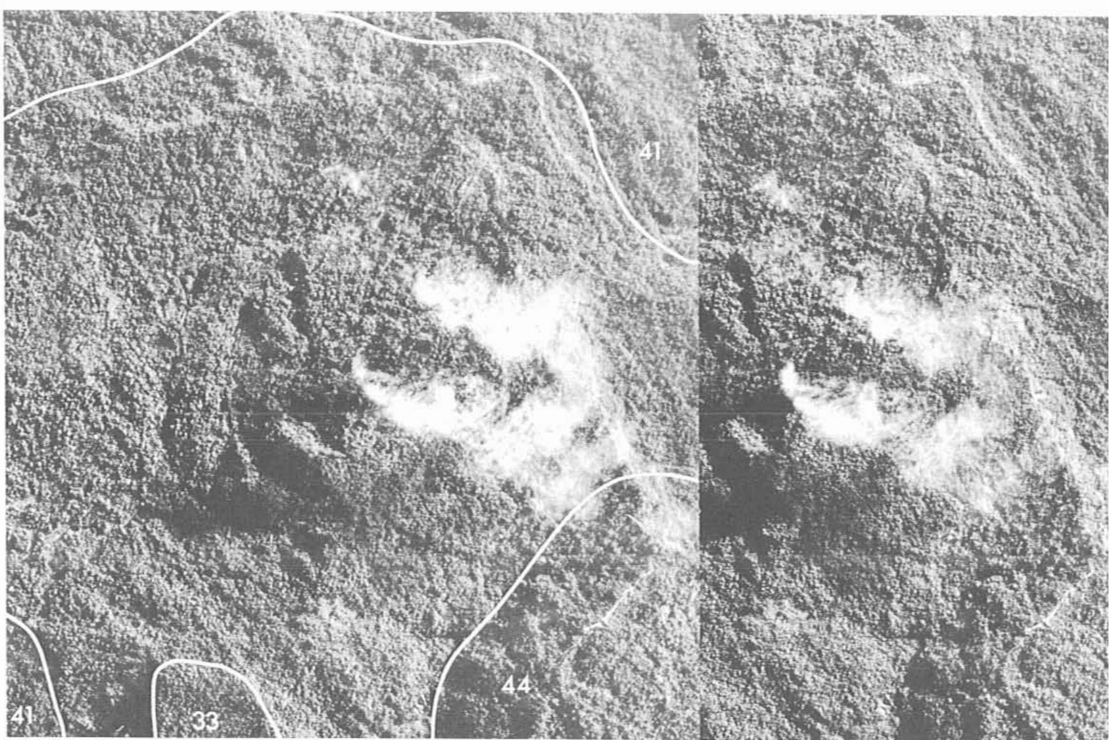


PLATE 23

Fig. 1.—Ningil (49) land system; gently sloping undulating dip-slope surfaces bounded by scarps and ravines; mainly secondary vegetation; tall forest with an irregular canopy with light-toned crowns in south.

Fig. 2.—Minatei (50) land system; high hill ridges of partially dissected long dip slopes, short outcrop slopes, and scarps; mid-height forest with an irregular canopy; secondary vegetation, including large areas of planted sago.



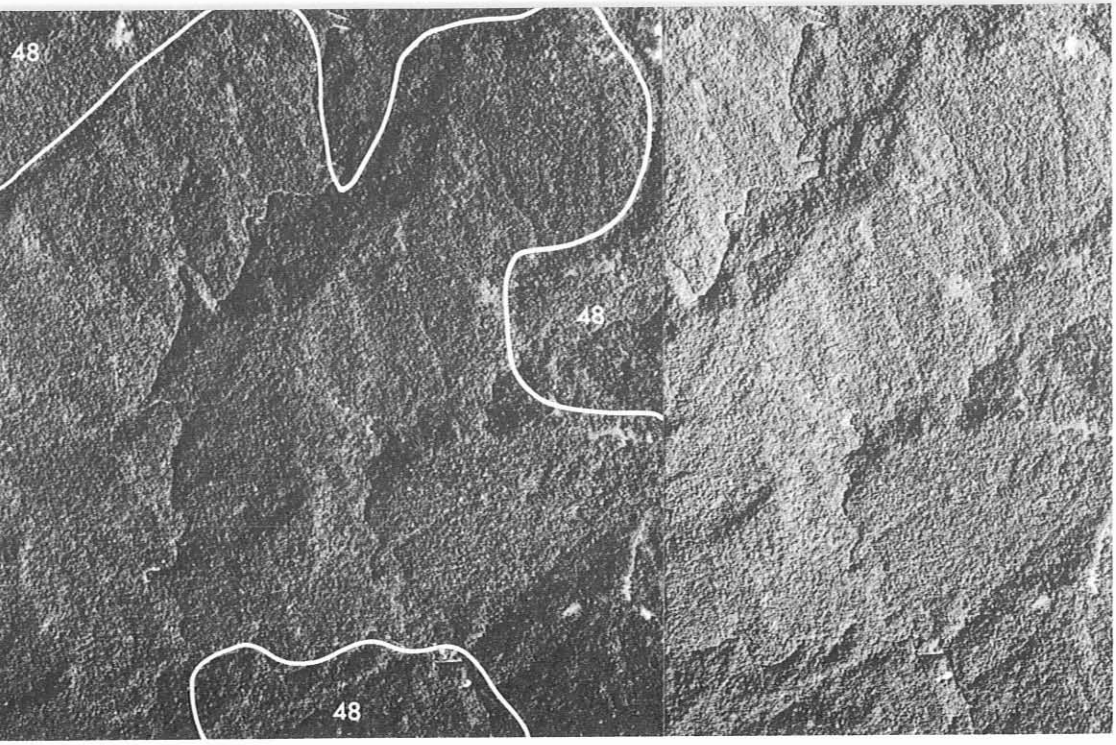


PLATE 24

Fig. 1.—Nuku (51) land system; somewheat peaked low to high hill ridges of rather triangular dip slopes, outcrop slopes, and scarps; mainly tall forest with an irregular canopy with light-toned crowns.

Fig. 2.—Musak (52) land system; very steep sharp asymmetrical hill ridges on tilted sedimentary rocks; mid-height forest with an irregular canopy and its seral stages.

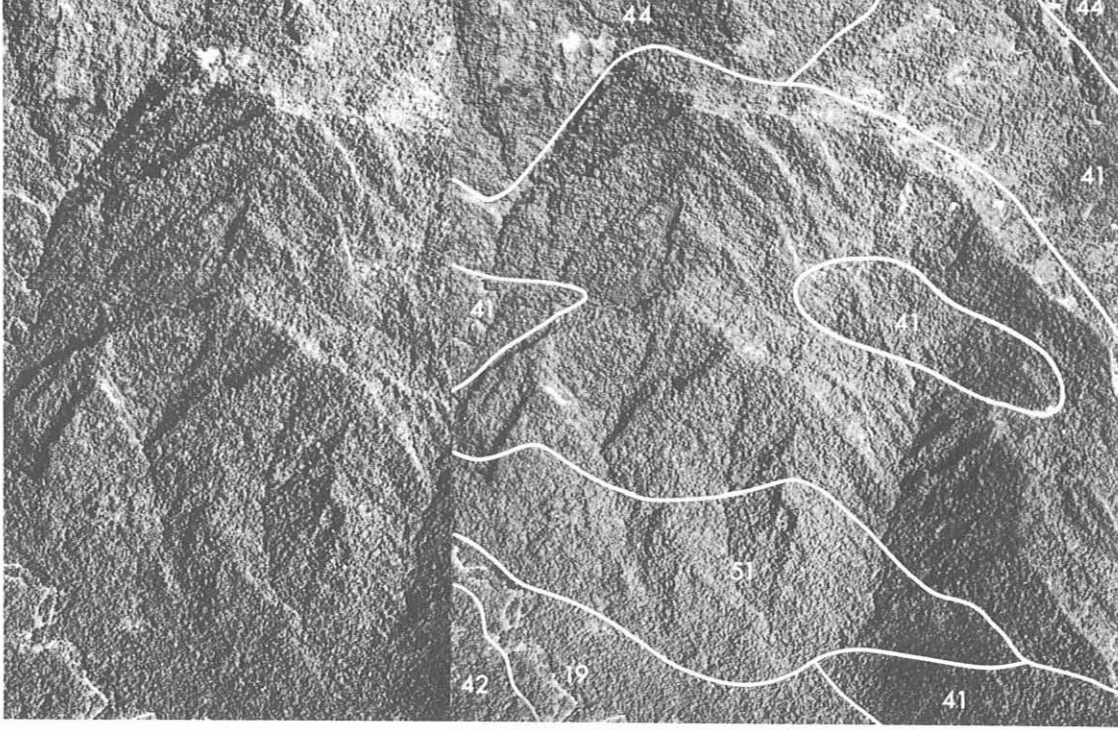
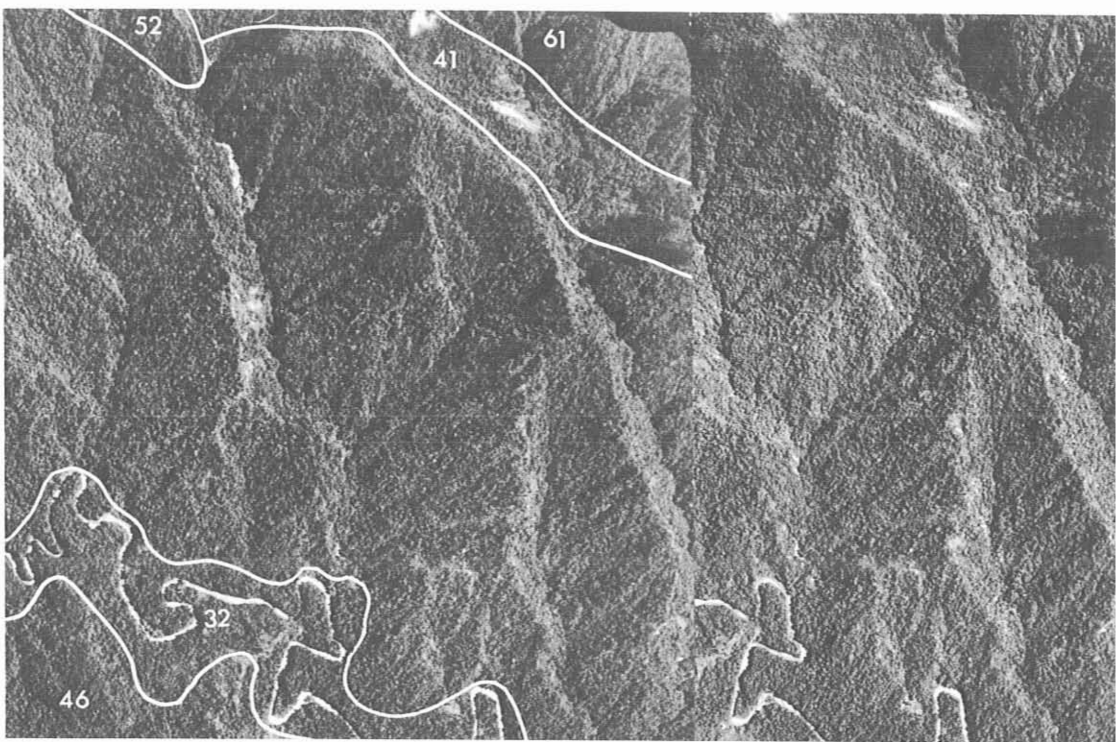


Plate 25

Fig. 1.—Wuro (53) land system; very steep sharp asymmetrical low mountain ridges on tilted sedimentary rocks; mid-height forest with an irregular canopy and its seral stages.

Fig. 2.—Imbia (54) land system; subparallel very steep sharp spurred high hill ridges with dip-slope fronts, on tilted sedimentary rocks; secondary vegetation, mainly old secondary forest.



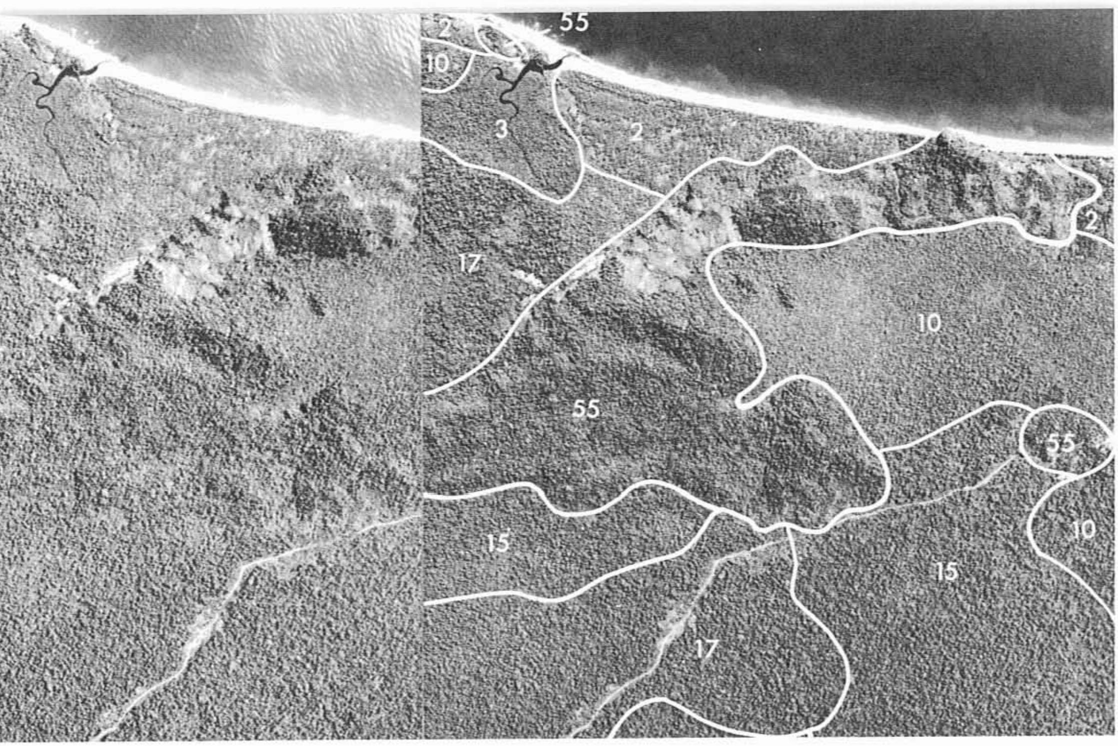
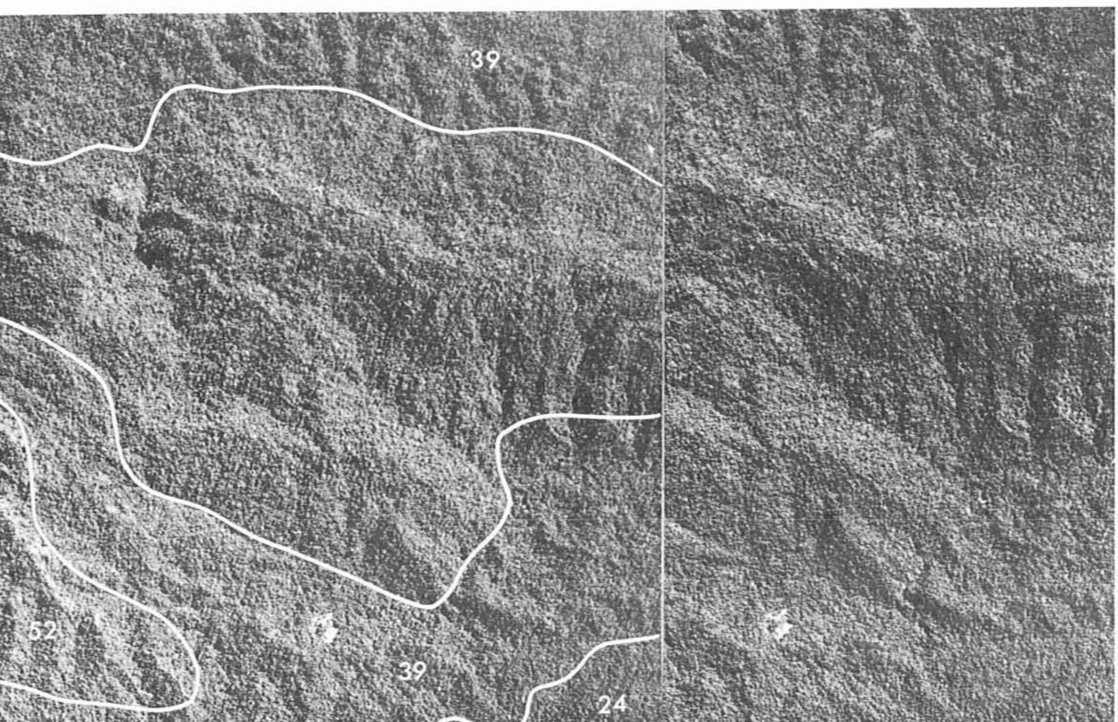


PLATE 26

Fig. 1.—Aitape (55) land system; isolated low to high hill ridges on limestone and calcareous conglomerate in the coastal plain; tall forest with a rather open small-crowned canopy, secondary vegetation in north.

Fig. 2.—Barida (56) land system; steep convex high hill and low mountain ridges on limestone with scarps and foot slopes; mid-height forest with an irregular canopy.



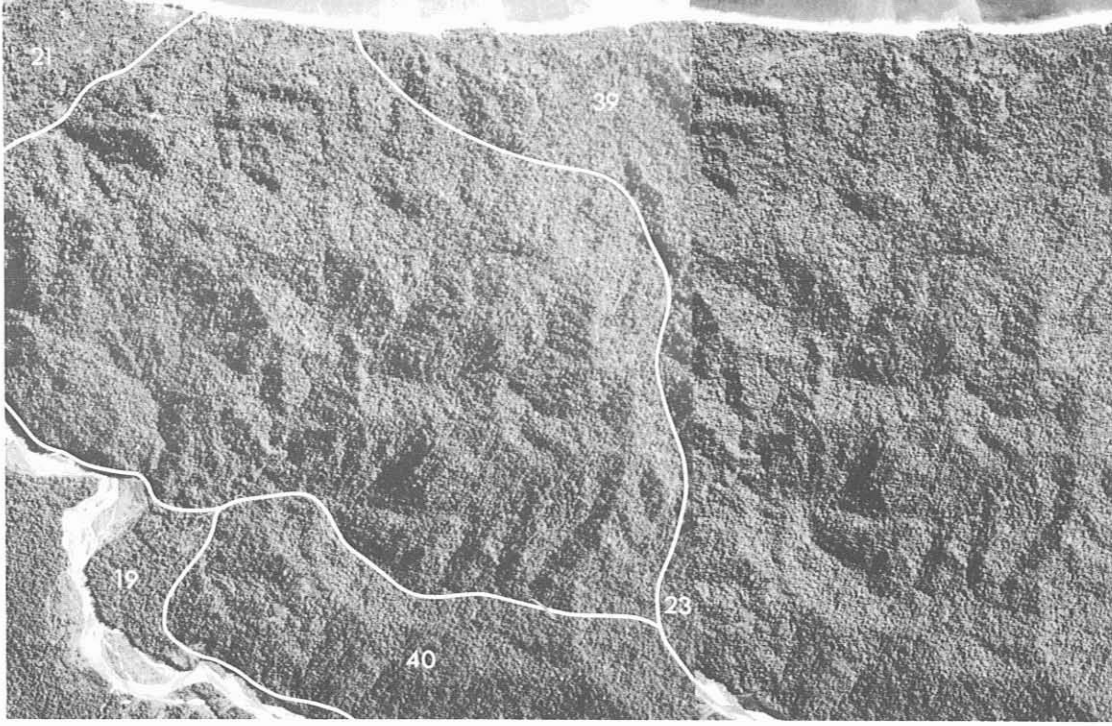


PLATE 27

Fig. 1.—Nopa (57) land system; blocks of steep irregular short hill ridges of igneous rocks capped by sedimentary rocks; tall forest with a rather open irregular canopy.

Fig. 2.—Sulen (58) land system; very steep slumped and gullied spurred low mountain ridges of igneous, sedimentary, and metamorphic rocks; mid-height forests, generally with an irregular canopy and seral stages, but with a dark-toned even canopy on crests.

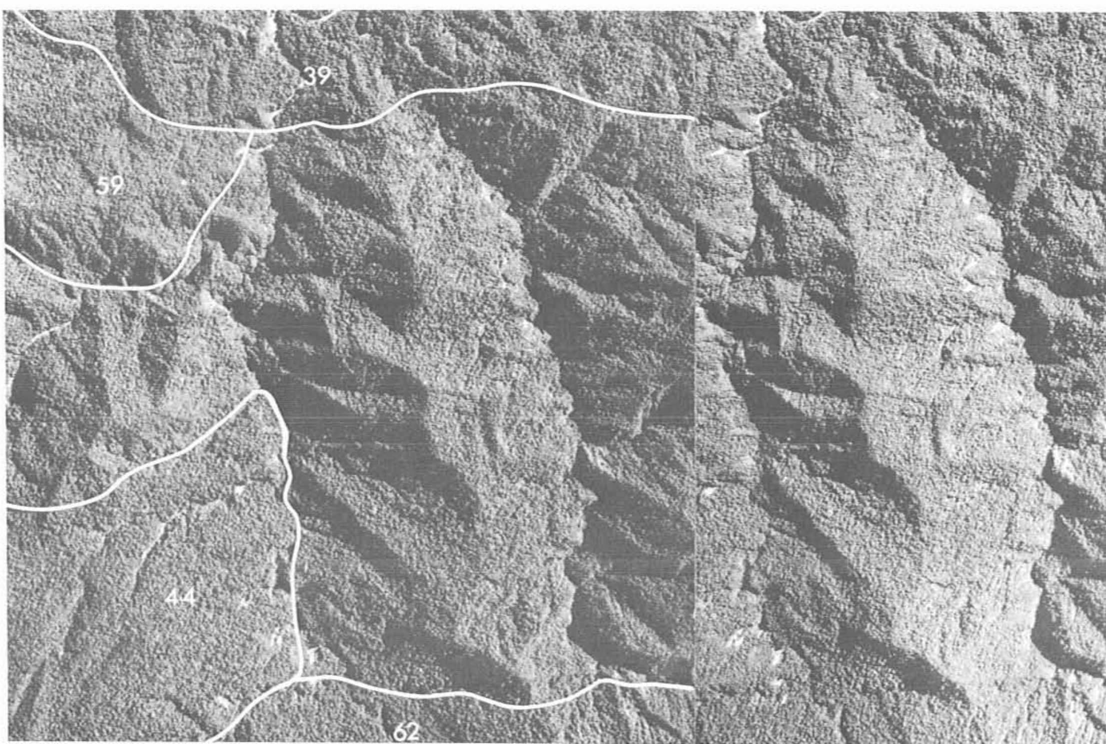


PLATE 28

Fig. 1.—Wanabutu (59) land system; narrow blocks of very steep spurred high hill ridges on basic igneous (?volcanic) rock; tall forest with a rather open irregular canopy.

Fig. 2.—Mup (61) land system; very steep protruding high ridges and hills of basic igneous rock; mainly mid-height forest with an irregular canopy and with *Casuarina* on steepest slopes.

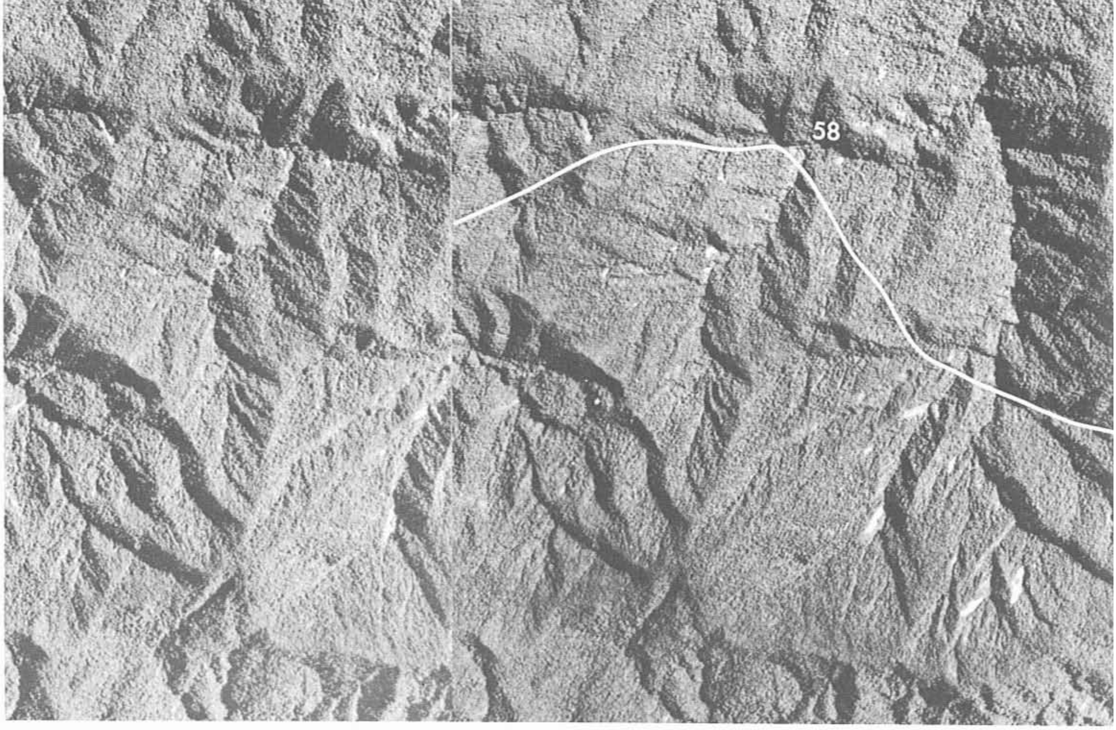
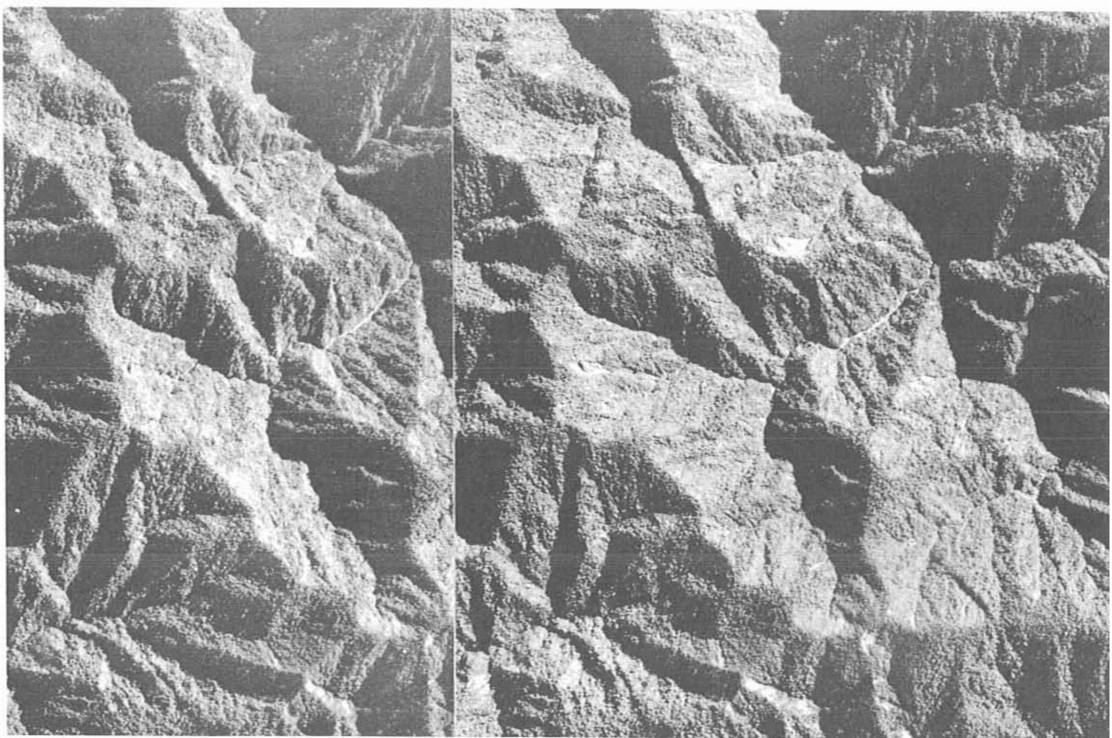


PLATE 29

Fig. 1.—Daum (62) land system; very steep asymmetrical low mountain ridges of basic igneous rock, with gullied long slopes and broken scarps; mid-height forest, mainly with a rather dark-toned even canopy.

Fig. 2.—Somoro (63) land system; very steep massive to angularly spurred sharp mountain ridges on granodiorite and gabbro; mid-height forests, mainly with an irregular canopy and with seral stages with *Casuarina* on frequent landslides.



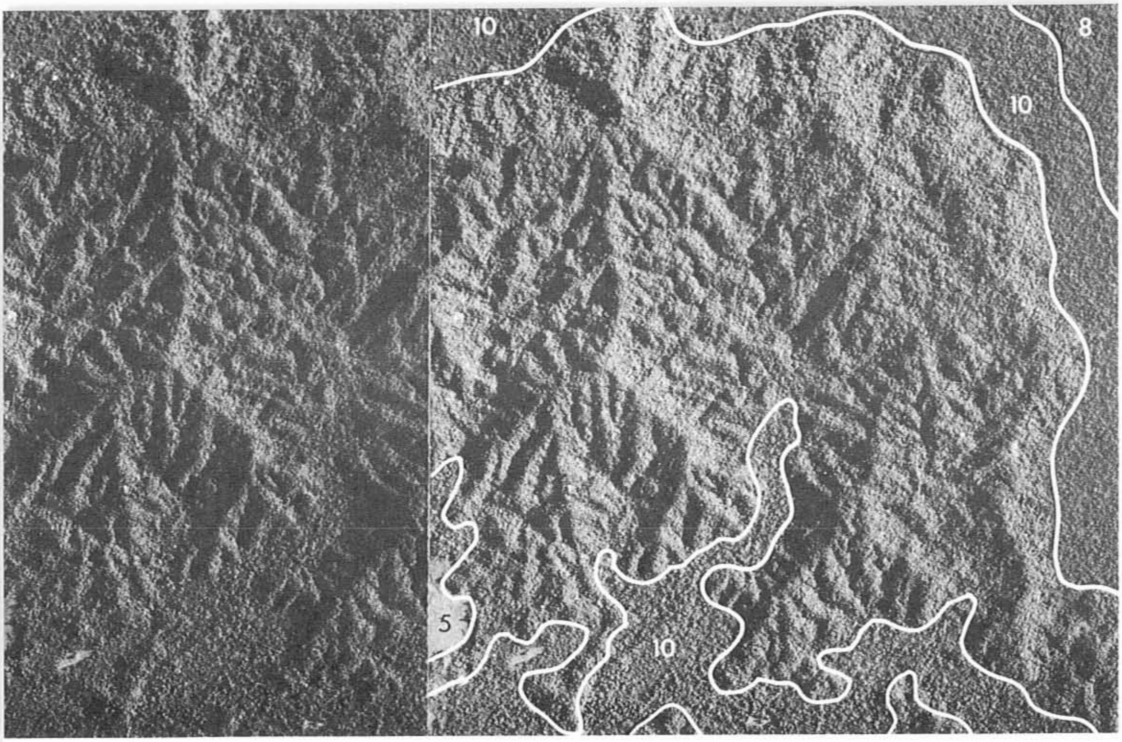


PLATE 30

Fig. 1.—Maio (64) land system; very steep finely branching hill ridges on schist and quartzite; mid-height forest with a small-crowned rather even canopy.

Fig. 2.—Waskuk (65) land system; very steep spurred low mountain ridges on schist and gneiss; mid-height forest with a small-crowned rather even canopy; Ambunti (20) land system; colluvio–alluvial fans; tall forest with a rather open canopy.

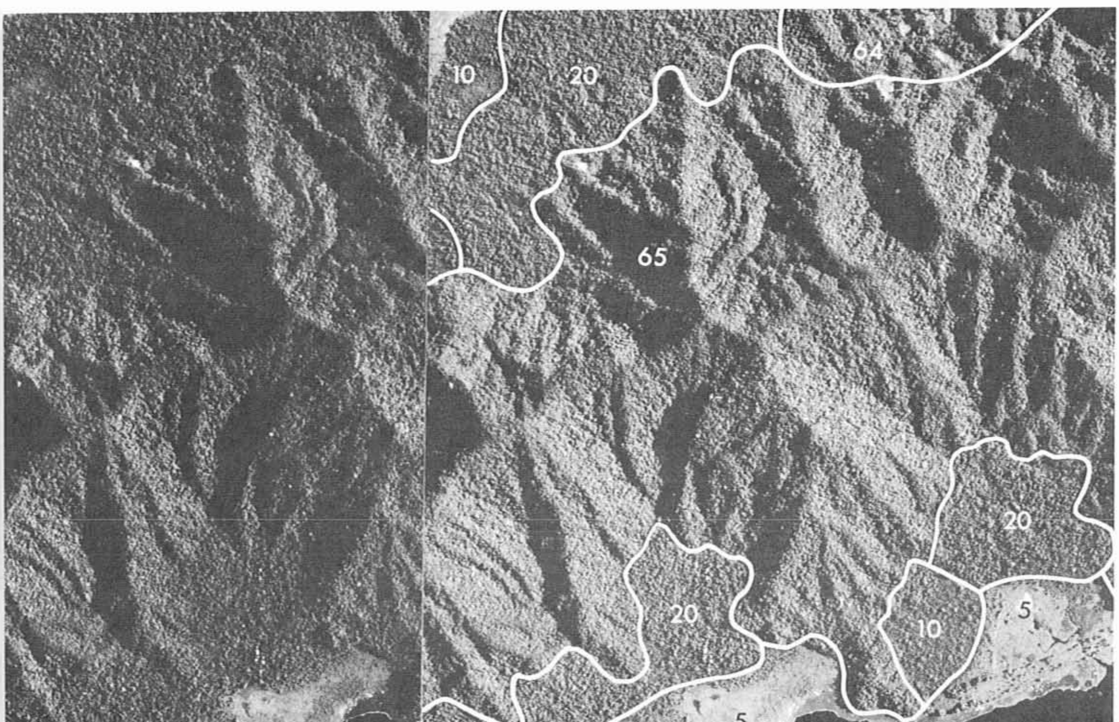
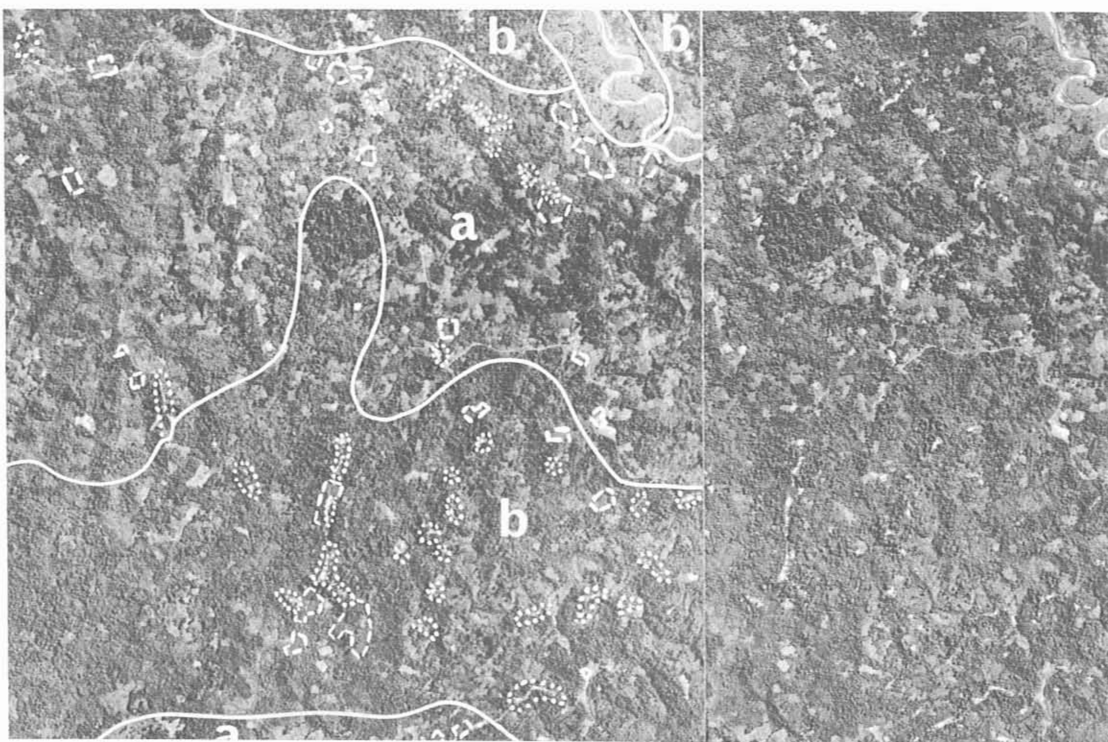


PLATE 31

Fig. 1.—Very high land use intensity for subsistence cultivation with near-permanent field boundaries on terraces of Screw (14) land system. Settlements (broken lines) are on adjoining land systems. Coffee blocks are indicated by dotted lines.

Fig. 2.—High (*a*) and medium (*b*) land use intensity for subsistence cultivation. Dense settlement in villages (broken lines); many coffee blocks (dotted lines) in the high intensity class.



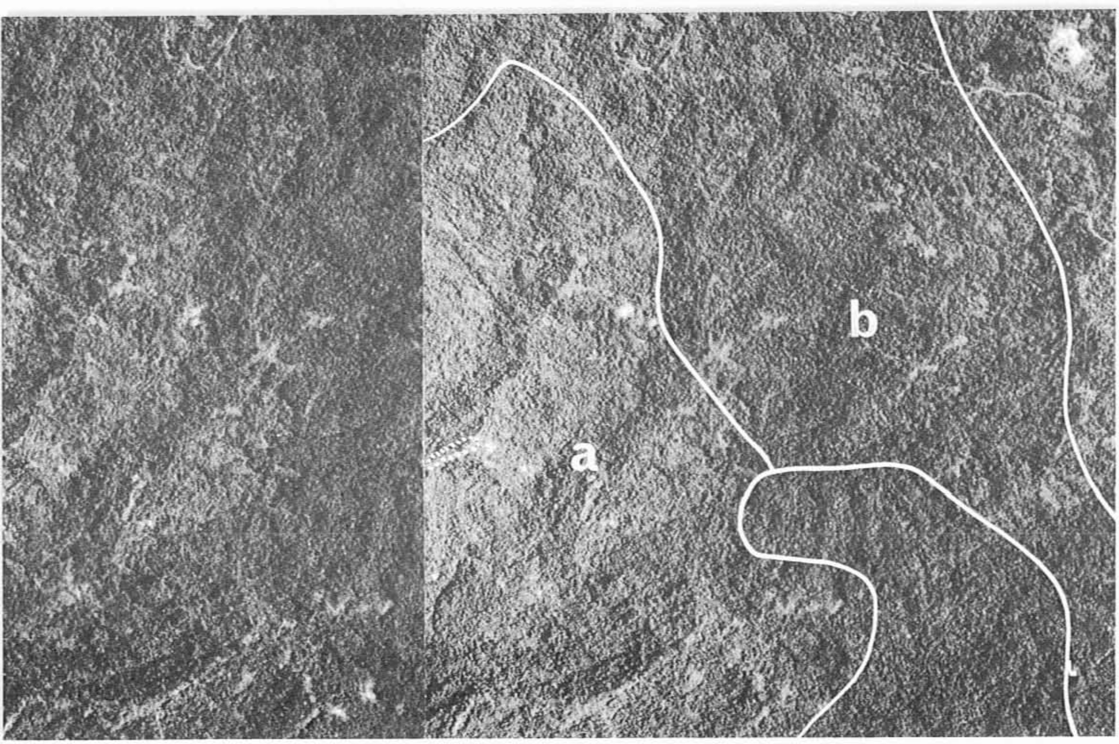


PLATE 32

Fig. 1.—Low (*a*) and very low (*b*) land use intensity for subsistence cultivation. Moderate to sparse settlement in villages. Much old secondary forest in very low intensity class.

Fig. 2.—Five non-stereoscopic examples in Nigre (26) land system of light-toned "meanders" of slight rises of coarser sediments with friable reddish soils, amidst clay plains with plastic mottled soils. All sediments are strongly weathered.