Ian Baillie

Report No. 62

WOSSAC: 197365
631.473
(595)

Report on a Reconnaissance Soil Survey

of the

MARUDI - LINEI - LONG LAMA AREA

(4 th. Division)

by

J. R. D. Wall
Soil Surveyor

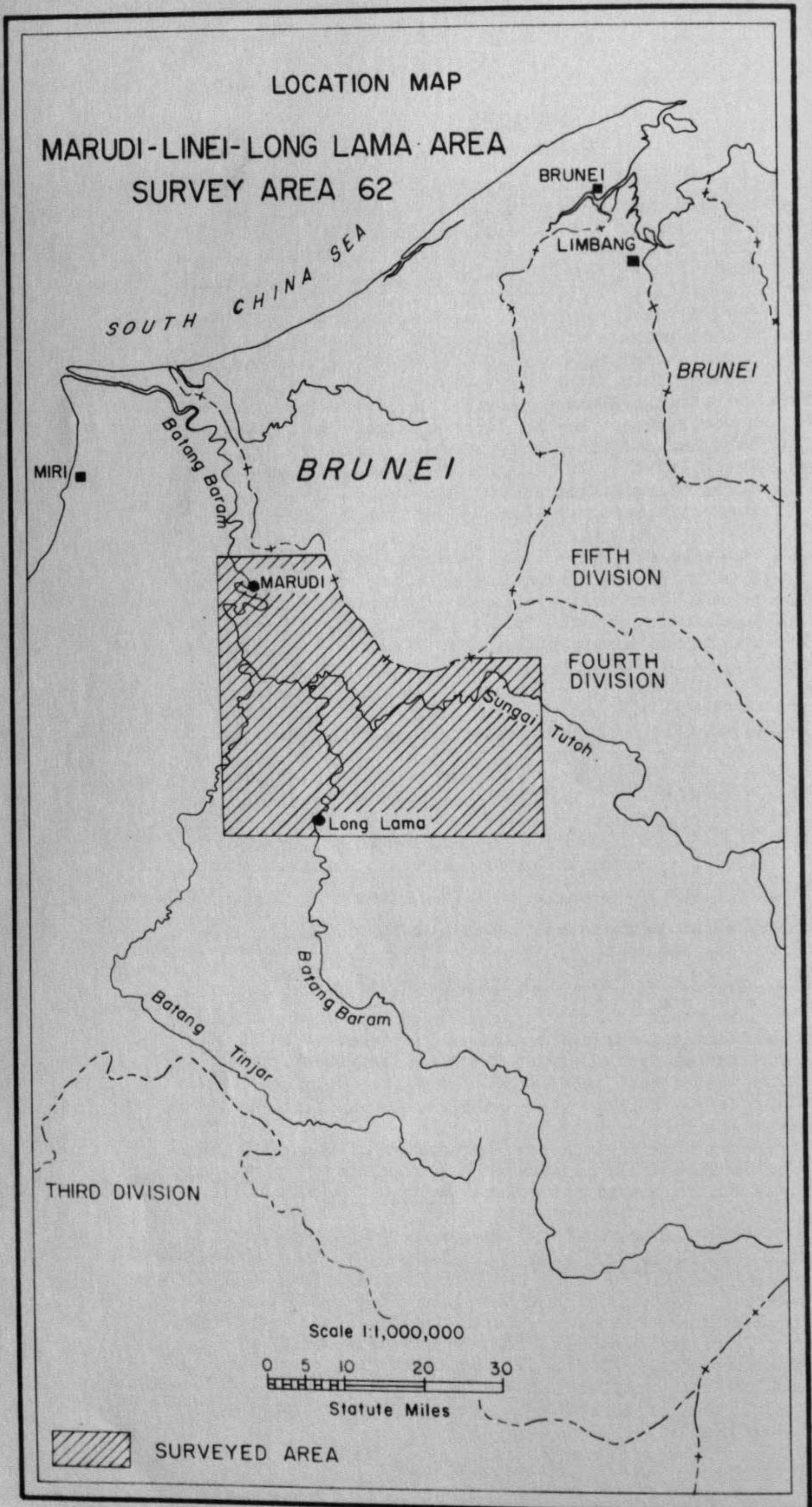
Soil Survey Division
Research Branch

March, 1965.

Dept. of Agriculture
Sarawak

C O N T E N T S

C O N T E N T S


LOCATION MAP
MARUDI-LINEI-LONG LAMA AREA
SURVEY AREA 62
SOUTH CHINA SEA
BRUNEI
LIMBANG
BRUNEI
MIRI
Batang Baram
BRUNEI
MARUDI
FIFTH DIVISION
FOURTH DIVISION
Sungai Tutoh
Long Lama
Batang Baram
Batang Tinjar
THIRD DIVISION
Scale 1:1,000,000
0 5 10 20 30
Statute Miles
SURVEYED AREA

REPORT ON A RECONNAISSANCE SOIL SURVEY OF THE MARUDI-LINEI-LONG LAMA AREA.

by

J.R.D. WALL.

1. INTRODUCTION

This report is the result of requests by 4th Division Development Committee for soil surveys of a) the Marudi-Linei Area; to assess the general agricultural potential of the land and to indicate a possible road route from Marudi to the mouth of the Linei River; and b) the Mid Baram Development Area. The latter is a wide belt of country bounded in part by the Sarawak/Brunei border, the Mulu massif, the high lands of the Apoh-Long Lama-Long Teru region and the Baram swamps: this survey was for both the assessment of general agricultural potential and for the indication of large blocks of land suitable for the Rubber Planting Scheme 'B'.

As the requests were for similar information and the soils of the two areas have much in common it was decided to produce a single report, which for convenience is delimited by the international boundary in the north east, the Mulu massif in the east, and the margins of topographic sheets 3/114/2 and 3 in the south and west and sheet 4/114/14 in the north.

Due to the large size of the area involved it was decided to map the least accessible parts at broad reconnaissance level: with a minimum of groundwork and a maximum of air photograph interpretation. Such areas are indicated on the accompanying soil map by a realiability diagram. The more easily accessible land was surveyed using reconnaissance methods that are now standard for this country; namely a combination of ground checks along significantly located rentis lines and paths, with intensive air photograph interpretation.

Air photographs taken in mid 1964 at scale 1:25,000 were available covering about 80% of the area: their largely good quality facilitated mapping and the compilation of an up-to-date Agricultural Potential and Land Use Map (Map 3). Older, poor quality air photographs of 1951 at scale 1:35,000 were used for mapping the remaining land, mainly in the southeast. The base maps available varied from fully controlled, form-lined, sheets at 1:50,000 scale in the north to a semi-controlled compilation sheet at 1:50,000 scale in the southwest and a semi-controlled sheet at 1:125,000 scale in the southeast. In the last area a base map had to be prepared from the new air photographs at scale 1:50,000, in which considerable scale distortion and displacement between distant points occurs but in which local accuracy is reasonable.

The area totals approximately 980 square miles. Fieldwork in the Marudi area (1:50,000 sheet 4/114/14) started in mid-June and was completed by mid-July by a party of four Agricultural Assistants and the Surveyor. The remaining area required a further six weeks fieldwork in September-October by five Assistants and the Surveyor. Althogether 270 working man-days were put into this survey by the field staff, soils along 228 miles of cut rentis and paths were examined, and 122 soil samples were collected for analysis. The distribution of lines of investigation and sample sites are shown on the Soil Map (Map 1).

Figure 1. Mean monthly temperatures at Miri and Bintulu, 1951-1963

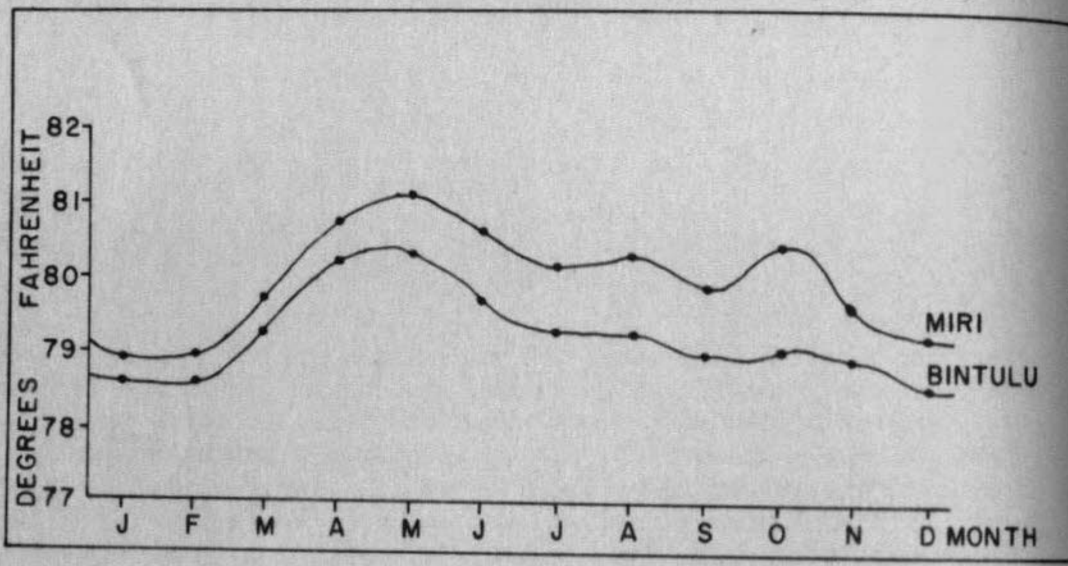


Figure 2 Mean diurnal range of temperature at Miri and Bintulu 1951-1963

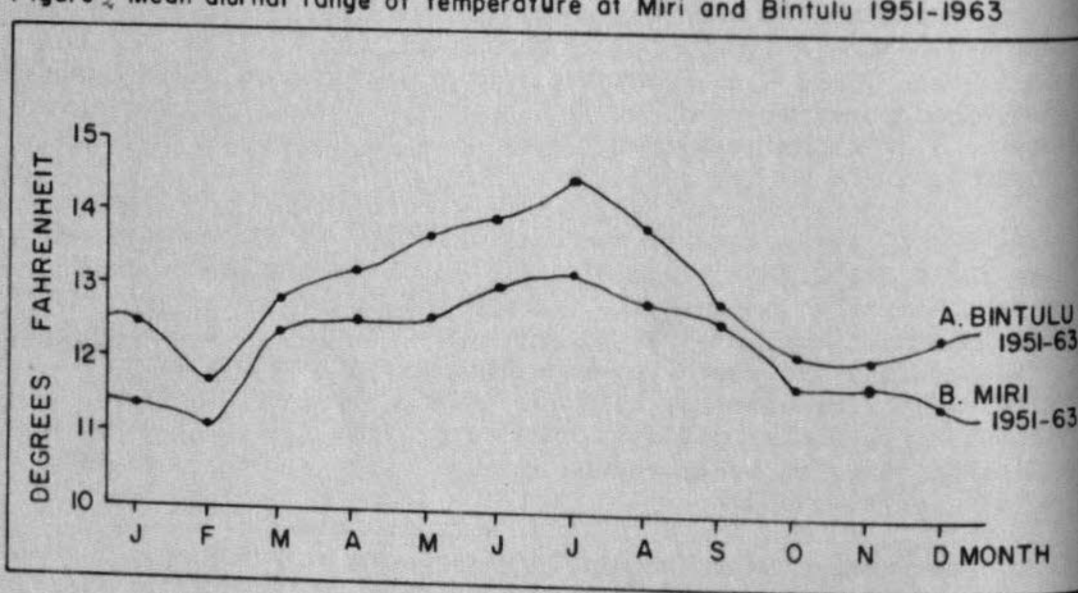
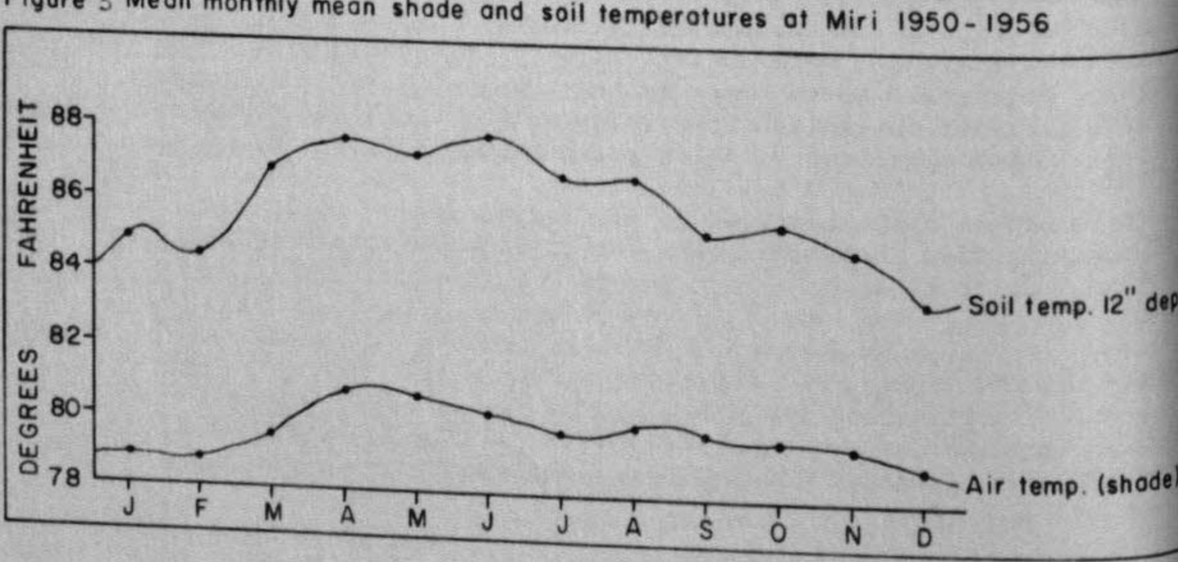


Figure 3 Mean monthly mean shade and soil temperatures at Miri 1950-1956



2. GENERAL CHARACTER OF THE AREA.

.1 1. CLIMATE.

This section is included because the Marudi-Linei-Long Lama area has good potential for agricultural development, and persons interested in introducing unfamiliar crops will require some knowledge of the climate to set against known climatic requirements of crops. Full meteorological data (see References) is available from 1951 from Miri, a coastal station 26 miles distant from Marudi and 50 miles from Long Lama. Rain gauges have been established in Marudi since 1912, at Long Lama since 1957 and Long Panai since 1962. Gauges outside the area have been maintained at Long Akah (Long San) from 1955, Tiris (Bekenu) from 1958, and Long Pilah, Long Sinei and Long Naha'a in the highland to the southeast since 1963. Only in the case of Marudi's and Long Lama's rainfall data are the figures likely to give a reliable picture of any part of this area: the other extrapolated data can only provide a broad indication of what may occur and is likely to be most inapplicable to the highland areas in the east. Lowland coastal climate in this part of Sarawak is described more fully in Survey Report No.35/2 of Luak Experiment Station, 28 miles away from Marudi (Wall, 1964, a).

Mean monthly shade temperatures in the Marudi-Linei-Long area are unlikely to differ widely from 79° to 81°F., as shown in fig. 1, except in the highest hilly land where night temperature may be slightly cooler. The mean diurnal range may exceed those of Miri shown in fig. 2 since the presence of the sea has a moderating effect on temperature: the extremes of 93°F. maximum and 68°F. minimum at Miri also may be exceeded for the same reason. Soil temperatures shown in fig. 3 should be closely similar to those of sandy soils in this area.

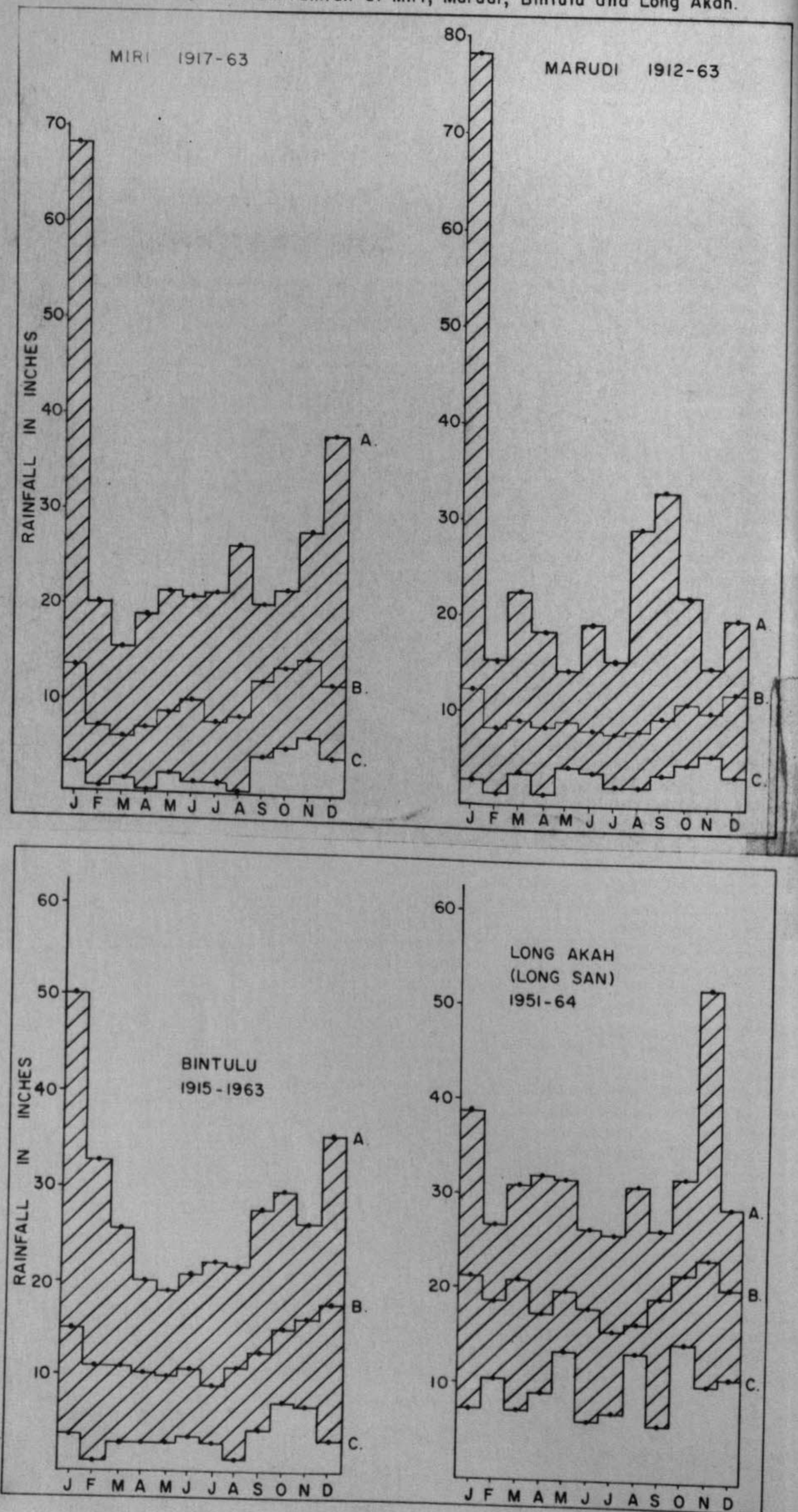
Rainfall data for Marudi and Miri is shown in fig. 4. Marudi has a uniformly distributed rainfall with a slightly wetter season between September and January. At Long Akah, the station with the highest recorded rainfall in Sarawak with an annual (10 years) mean of 230 inches, the monthly mean distribution is fairly constant and high as shown in fig. 4: this station should be more representative of the highland areas than Marudi.

Rainless periods at all the stations of between 8 and 15 days are common. At the end of such periods it is likely that drought-susceptible plants will suffer, particularly those growing on the more sandy soils. (see Bako, Matang, Nyalau, Miri and Sabangang soil families in section 3), taking into account estimated rain-water losses by evapo- transpiration and surface water run off (Wall, 1964, a). The highest eastern part of this area is least likely to be affected by this feature of the rainfall. Daily rainfalls exceeding five inches are rare, as are months with rainfall less than four inches.

2 2. GEOLOGY

This section is based on work by Wilford (Wilford, 1961) Haile (Haile, 1962) and Liechti (Liechti, 1960).

Figure 4 A. Absolute monthly maximum rainfall. B. Mean monthly mean rainfall. C. Absolute monthly minimum rainfall at Miri, Marudi, Bintulu and Long Akah.



The entire area is underlain by sedimentary rocks of late Mesozoic and Tertiary age, on which have been laid down recent Quaternary sediments and peat. The general distribution of the rocks is such that the oldest outcrop in the southeast with an overall northeast-southwest strike. Younger rocks successively outcrop northwards. To the north and east of the Tutoh and Baram rivers is the curving outer rim of a gently dipping syncline (followed by the international boundary between Sarawak and Brunei). The most recent alluvial deposits fill extensive basins in central and western areas and these are in turn covered by deep peat accumulations.

The Mulu Formation is of Palaeocene age and outcrops in the extreme east of this area. It consists of thick successions of submetamorphic shales and slates, dark in colour, hard and slightly phyllitic. Subordinate grey, thick-bedded quartzites occur in places.

Classed as part of the Palaeocene Kelalan Formation is the Temala Member which occurs as a large, wedge-shaped outcrop crossed by the lower Temala River. It consists of clay-shales interbedded with massive and thick-bedded, slightly calcareous sandstones and limestones.

The Melinau Formation is formed of light grey, massive or thick-bedded pure limestone of Miocene-Eocene age found mainly in the Melinau Valley in the east. Small lenses also occur flanking the Temala Member such as at Batu Gading.

Younger rocks of Miocene age comprise the Setap Shale Formation, which occurs extensively in the southwest and east, and as a long, narrow north-trending outcrop in the Marudi area. The rocks are dominantly shale and clay-shale, although fine-grained, thin-bedded quartzitic sandstones occur in the southeast. Calcareous beds are rare in the Baram-Tutoh area, but more common in the Tinjar area.

The Batu Blah Member of the Setap Shale Formation forms a long, narrow, north-trending outcrop between the lower Tutoh and Baram rivers. It consists of sandstones separated by clay-shales. The sandstones are mainly hard, fine-grained, grey to grey-blue and carbonaceous.

In the Marudi-Linei River area and forming the arc of the international boundary are the similar, synclinal, Miocene to early Pliocene Belait and Lambir formations. Both are dominated by moderately to gently dipping sands, sandstones and clay-shales. The sandstones are uniformly pure, hard, grey to white, thin- to thick-bedded and massive. Softer sandstone occurs in the upper Teboweng River and Peninjau Hill areas. The shales are bluish gray and silty to sandy. Lambir Formation rocks tend to be more calcareous than those in the Belait Formation.

Late Pliocene rocks are to be found in a small hilly area forming the apex between the lower Tutoh and the Baram rivers. The rocks are weakly consolidated sands, clays and lignite.

Quaternary deposits are common in the Peking, Tutoh, Linei and Selijau valleys and in the vicinity of Marudi. The older material occurs in terraces generally less than 30 feet thick and consists of boulders, gravel and sand in the Tutoh Valley, sand in the Linei Valley and mixed sand, clay and gravel in the Marudi area.

Recent alluvium, exposed mainly alongside major rivers and in the numerous small upper valleys among the hills, is largely clay with subordinate silt and sand. Gravel and boulder beds were noted below recent alluvium in the Tutoh valley upstream from Long Terawan. The alluvium is covered in lower valleys and in the extensive Tinjar-Baram-Apoh swamps by peat at least 40 feet in depth and is probably accumulating at an overall rate of about one foot per 100 years (Wilford, 1961, p.117).

2.3 3. TOPOGRAPHY AND DRAINAGE

There is a close relationship between landforms, lithology and structure. Several major units can be disceарned; principally the high, steep hilly land of the Mulu area, the rugged karstic Melinau limestone, the high steep ridges near the Temala River, the low dissected hills of the Setap Shale Formation, the ridge and cuesta country of the Lambir and Belait formations, the terraces, the alluvial valleys and the peat swamps. The main features of each are described below.

Map 2 shows the relief as classified in terrain classes by slope and amplitude of relief. Each terrain class of necessity includes slope facets of other classes due to the scale of mapping used and the classes are therefore best considered as representing the dominant relief present. Juding by relief alone, Terrain Class 8 is considered unsuitable for agriculture; Terrain Class 7 is considered marginal for some tree crops with careful terracing. Classes 4 and 6 are suitable for some tree and annual crops with terracing. Classes 1, 2, 3 and 5 are topographically suitable for agriculture, with terracing in places only. It should be remembered that suitable terrain may bear unsuitable soils.

2.3.1 1. High Hill Land

In the east, between the middle Apoh Valley and the Melinau area and associated with the Mulu Formation of rocks, are groups of steep, high ridges estimated to rise to well over 1,000 feet above local base level. Rather lower land occurs on the western margin of this hilly area close to the Terawan River. The hills are mapped as Terrain Class 7 but include many slope facets of Terrain Class 8, steeper than 35°. The ridges are long, sharp and generally aligned with the strike in a northeast - southwest direction. Landslides are not visible through the primary forest but may exist due to the steepness and length of slopes. The drainage pattern is angular. Due to there being a main watershed close to the true left bank of the middle Tutoh River streams flow southwest away from this part of the Tutoh to meet either the Apoh River or the Tutoh River in its lower reaches.

2.3.2 2. Karst Land.

With the drainage system of the Melinau River are separate groups of high, rugged, cliffed karstic limestone hills. The largest hills are elongate along the strike. Many small remnants (lapiés) occur in the floodplain protruding by 5-100 feet from the surrounding alluvium. All such land is mapped as Terrain Class 8. There is no apparent surface drainage in the hills.

2.3.3 3. High Ridges of the Temala River Area.

The land in this unit is similar to but lower than that described under 1 above and has affinities with the ridge and cuesta country described under 5 below. Based principally on rocks of the Temala Member and the Setap Shale Formation, these hills form series of distinctive, longitudinal, steep-sided ridges aligned with the strike. Most ridges are estimated to rise at least 200 feet above local base level and have slopes between 20° and 35°; they therefore form part of Terrain Class 7. Many slope facets, particularly south-facing scarp slopes, exceed 35° and so are within Terrain Class 8. The drainage system is parallel; the streams flow mostly to the Temala or Apoh rivers along the strike.

2.3.4 4. Low Dissected Hills

The Setap Shale Formation underlies practically all this land, which extends from the Tinjar to the Apoh and Tutoh valleys and which occurs also in the Selijau valley, a tributary of the lower Tutoh River. The hills are mostly less than 150-200 feet high and are commonly less than 50 feet above local base level. Slopes range between 15° and 30° largely. Dissection has continued to such an extent that long ridges are the exception and the most typical physiography is groups of slightly elongate low hills, penetrated by and interfingering with numerous small valleys. Most land is of terrain classes 4 and 6 with subordinate areas of terrain classes 5 and 7.

The drainage systems vary between a recognisable angular to parallel pattern, such as in the area between Long Lama and the Teru River, to a completely amorphous dendritic pattern in the most thoroughly dissected land. It is peculiar feature of these areas that the true right bank tributaries of the Tinjar, Baram and Apoh rivers are almost without exception much longer than those on the left banks: this indicates an overall southeast to northwest gradient of the region which is followed by the main tributaries but which is crossed roughly at right angles by the main rivers.

2.3.5 5. Ridge and Cuesta Country

The distribution of these landforms is confined largely to outcrops of the Belait and Lambir rock formations in the Marudi and Linei River areas. The hills rise to between 100 and an estimated 1,000 feet above local base level: typically they consist of long, narrow, sharp ridges and cuestas. The ridges, with slopes largely between 20° and 45°, occur throughout this landscape and generally have a steeper scarp face than dip slope: they are mapped in terrain classes 7 and 8 with subordinate patches of terrain class 6. Landslides are common under primary forest.

Cuestas with steep scarp slopes and comparatively gentle dip slopes are most common on the western and southern flanks of the Belait Formation syncline, to the west of the Linei Puteh River and southwest of the Linei Merah River. Similar topography characterizes the upper Ridan Valley hills and the area from Dabai south to Nyambong which is underlain by the Lambir Formation. Geological dips in these places are gentle and surface dipslopes of 10° to 20° are common, contrasting with adjoining cliffed escarpments facing west and south, on which there are many landslides. These land forms are shown as terrain classes 3 and 5 mainly but also as terrain class 7 where they are too small in area to differentiate from steep ridges.

The drainage pattern is angular, commonly in the form of a parallel curved system.

.3.6 6. Terraces.

Terraces are widespread in the valleys of the Peking, Tutoh, Linei Merah and lower Selijau rivers, also in the vicinity of Marudi. Most have been mapped as Terrain Class 2. Small patches of lowlying ground in the Peking area also have been interpreted as terraces from air photographs.

In the Tutoh Valley there appear to be at least three levels, at 20-30 feet, about 80 feet and 200-250 feet above the adjacent main river banks, of which the higher two are most common. The largest terraces, some covering more than a half square mile, are flat-topped to undulating and are in the process of dissection by gullies flanking the terrace. The smallest remnants are commonly long, narrow, flat-topped ridges, parallel to the main river.

Terraces in the Linei Merah area have not been examined in the field, but from the form-lined map and from air photograph interpretation there appears to be a higher level at 200-250 feet and a lower level at about 50-100 feet above local base level: both are extensive. It is possible that some parts are structural benches since the geological dip in this area is low: Wilford however (Wilford, 1961) shows these areas as terraces on the geological map. River dissection in this area of almost horizontally bedded strata has left a wide mature valley system at about 150-300 feet above the general base level of erosion that causes the absolute height of the terraces to be in the region of 300-700 feet.

In the lower Selijau Valley are terrace remnants at about 60 feet above the local floodplain, the same height as the highest level along the Puyut Road and small ridge-top relics in the nearby Brit area. Elsewhere in the vicinity of Marudi there are extensive terraces at 30-40 feet (airport, Ridan area) and between 10-30 feet and 60-80 feet (Puyut Road) above local base level.

There is no apparent surface drainage on the terraces, all rainwater passing rapidly through the soil cover.

.3.7 7. Alluvial Valleys

All recent alluvial land is mapped as Terrain Class 1 although levee slopes, for example, are commonly such that they properly form part of Terrain Class 2. The upper river valleys are narrow with moderately steep gradients and their courses vary from being completely unaffected by underlying geological structure, such as in lowlying country, to being strongly influenced by the strike, particularly in the higher country. Waterfalls and rapids are rare except in the extreme headwaters.

The middle courses of main rivers run through wide valleys and the rivers maintain a slightly meandering course, confined by adjacent hills, with a low gradient. Only in the Tutoh and Melinau Valleys are boulder and gravel rapids common, almost as far downstream as Long Terawan on the Tutoh River. The Apoh River is badly choked with mudbanks and logs.

Alluvial land in the lower main river courses, including the main Baram valley in this area, is a little wider than that in the middle course valleys. The meander belt varies from a half to three miles in width and there are few confining hills, the main restrictions to lateral development being adjacent peat swamps. At the confluences of the Tinjar and Tutoh rivers with the Baram River the floodplains are enlarged and contain tortuous meanders. No rivers in the Marudi-Linei-Long Lama area are tidal but most are subject to flooding, particularly during the 'landas' season. Certain areas, notably in a wide belt fringing hill land near the Loagan Bunut, Bain and Peking areas, and also in the Tasong area of the Baram are particularly susceptiable to flooding. The Bunut-Peking belt contains many, small, permanently flooded areas caused possibly by regional land subsidence combined with encroaching peat swamps which tend to block up small river channels.

2.3.8 8. Peat Swamps

These areas occupy the lowlying alluvial basins of lower and middle main river courses and are mapped in Terrain Class 1. The swamps in this area are known to be highly developed (Anderson, 1964, p.14) and biconvex in section with an almost flat centre and comparatively steep gradients at the margins. Within 350 feet of the Baram River at Lubok Pasir the swamp rises to 20 feet above river bank level. Swamps in most places border on riverine alluvium but in the Bain area of the Tinjar and in the Maloi-Long Bemang - Long Panai belt the swamps abut onto low hills, and fill small valleys among the hills.

The larger swamps have a markedly stilted, water table and are drained by surface seepage except at the margins where small streams form a weak radial pattern.

2.4 4. VEGETATION AND LAND USE.

Comparing Map 3 of the Agricultural Potential and Land Use in the area and maps 1 and 2 of Soil and Terrain it is clear that most primary forest coincides with the presence of peat swamps, high hills, hills with strongly podsolic soils, terraces and limestone hills: in addition the factor distance from navigable rivers is important and this appears to be the main reason that even good agricultural land is left unused in remote areas. Forest Reserves and Protected Forests include largely poor to marginal agricultural land; fairly large parts of the Telang-Usan Protected Forest however consist of land suitable for agriculture.

The appearance of Lowland Dipterocarp forest is affected strongly by the presence of different soils. In the Tutoh to Apoh River area, mainly east of the Terawan River on the high steep hills, the forest as seen on air photographs contains many large, light-toned, emergent crowns similar to those on calcareous, shale-derived soil in the coastal Sibuti area. On sandstone-derived hills the crown size is smaller and the tones darker; on the gentle dip slopes of cuestas the forest resembles kerangas vegetation.

'Kerangas' (Tropical Heath) forest occurs on the most gentle dip slopes of cuestas and on podsolized sandy soil of terraces: large areas in the Linei Merah basin consist of this vegetation. Limestone hills contain thin, stunted specialized forest existing on pockets of organic soil among bare rock.

Forest on recent clayey alluvial soils varies between that consisting of common tall large-crowned trees with thick tangled undergrowth known locally as 'Lutan Karap', to a type dominated entirely by 40 foot tall trees locally known as 'Kayu beliti' (Mallotus muticus) and to low, stunted vegetation in the belt subject to frequent flooding between the Bunut and Beking districts. Soil in the last area is largely shallow clay overlying deep peat.

Peat swamp vegetation can be classed broadly into three groups. Central raised parts of highly developed swamps contain 'padang' forest of a few, low, stunted trees with much moss and sedges. Surrounding this forest on the sloping periphery of the swamps is a belt of distinctive, tall trees dominated by 'sengawan' (Shorea albida) which in places gives way to Mixed Swamp Forest on the outer peripheries. Commonly the 'sengawan' forest joins alluvial areas or hills without an intervening mixed swamp forest zone.

Secondary forest alongside rivers is due principally to wet rice cultivation, commonly using the 'sawah' system, although there are large seedling rubber gardens on this type of land close to Marudi. Secondary forest on hills is almost entirely the result of hill rice cultivation. Small seedling rubber gardens occur close to longhouses and Rubber Planting Scheme 'A' rubber has been successfully introduced in a few places such as at Long Bemang. Mixed, vegetable-fruit gardens can be found particularly on river levees: bananas are a well-known product of the Baram valley.

SOILS OF THE AREA

The soils are described under main headings of soil associations. These are mapping units easily recognised in air photograph interpretation. In detailed surveys it is generally possible to use as mapping units soil series or related series grouped together as soil families. At reconnaissance level, however, although soil series and soil families commonly can be recognised in the field, they seldom can be mapped as such due to their complexity of distribution, the lack of complete information or to the scale of mapping. Recourse is made therefore to soil associations which consist of several (rarely one) series grouped into one or more families, the name(s) of the dominant family or families being given to the association.

The scope and definition of the term soil association has taken on a different emphasis from that described originally (Andriesse, 1962). The same names and the same modal concepts of the original associations are retained however.

.1 1. RESIDUAL SOILS

The rocks in the area are all of sedimentary origin, ranging from massive sandstones (Belait, Lambir formations), sandstone - shale successions (Temala Member, Batu Blah Member), shales and sandy shales (Setap Shale Formation), and sub metamorphic shales and sandstones (Mulu Formation) to limestones (Melinau Formation). Landforms developed over the various rocks range from gently dipping cuestas, pronounced ridges, low dissected hills and high mountains to the rugged karst country of Melinau. Under the prevailing continuously hot and wet climate the dominant soil-forming process is vertical leaching of soluble bases, humus and sesquioxides, and all residual soils in the Marudi-Linei-Long Lama area are consequently podsolized to varying degrees depending principally on the type of parent rock and landform.

The most strongly podsolized residual soils are derived from the massive sandstones of the Belait and Lambir formations and occur where the landforms consist of gently dipping cuestas, such as in the Linei Merah and Teboweng valleys. Soils in such places are mainly members of the Bako and Matang families which belong to the Podsol and Red-Yellow Podsolic Great Soil Group respectively (Thorpe, Smith, 1949). The Bako Family soils are shallow humus podsols with a light grey A2 horizon overlying a humus-enriched B horizon which generally rests directly on hard sandstone. The Matang Family soils contain a sesquioxide-depleted light grey A2 horizon which changes to deep yellow or reddish yellow sandy loam with depth. Both families occur in the Bako-Nyalau Association.

Less strongly podsolized residual soils belonging to the Nyalau Family, a member of the Red-Yellow Podsolic Great Soil Group (op.cit), also occur in large areas over the Belait and Lambir formations and over the Temala and Batu Blah Members where the topography is more dissected and the slopes steeper. The soils are well drained, deep, yellowish brown to reddish yellow in colour with sandy A and B horizons, the texture and generally the colour becoming distinctly heavier and denser with increasing depth. The Nyalau Family forms an important part of the Nyalau, Bako-Nyalau, Nyalau-Merit and Nyalau-Kapit associations.

The least podsolized residual soils overlie shale-dominated rocks of the Setap Shale and Mulu formations with low to high hills and steep to gentle slopes. The soils are members of the Merit Family, which belongs to the Red-Yellow Podsolic Great Soil Group (op.cit), and are characterized by clay loam to clay textures, yellowish brown to reddish yellow colours and good to imperfect internal drainage. In this area shallow phases (less than 24 inches deep) are common and subsoils are generally stony, particularly where developed from the Mulu Formation.

The Merit Family of soils is dominant in the Merit, Merit-Nyalau, Merit-Kapit and Sabangang-Merit-Nyalau associations.

Lithosols less than 12 inches deep are classed in the Kapit Family regardless of whether the parent rock is sandstone or shale. Such soils are generally found on the most steeply sloping land in Terrain class 8 and are particularly common over the Mulu Formation. Since their profiles are rarely developed they are strictly Regosolic Lithosols by definition (op.cit). Where bare rock is found, such as among the limestone karst country, the material is classed as Rock which includes all outcrops of bare rock regardless of type.

.1.1 1. <u>Merit Association</u>

The Merit Association is widespread but restricted in distribution largely to outcrops of the argillaceous Setap Shale Formation in the central areas. The topography consists mainly of low, dissected, moderately steep hills and short ridges in terrain classes 4, 5 and 6.

The association is dominated by soils of the Merit Family with subordinate Kapit (section 3.1.3) and Nyalau family (section 3.1.2) soils found mainly on steep ridges protruding from the general level of surrounding country, such as the Berei Selamat Hill in the Apoh Valley. Small valleys contain Malang (section 3.2.12) and Bijat family (section 3.2.15) soils mainly.

Merit Family soils in this area have the following profile features. Surface litter and humus are characteristically rare and beneath a thin (in places absent) dark yellowish brown to greyish brown sandy loam to clay loam topsoil lies a weakly expressed (in places absent) A2 horizon. This is normally coloured yellowish brown with a sandy loam to clay loam texture and friable consistence with a weak crumbly to blocky structure. There is a gradual change to underlying B horizons which are coloured yellowish brown, less commonly reddish yellow. B horizons are clay loams or clays, firm to very firm and blocky to weakly columnar when dry. Clay skins are generally clear on structural faces of the B horizon and iron-coated and iron-impregnated shale remnants form stony layers in places. Quartzitic sandstone and sandstone fragments form hard stony layers in the subsoil where the shale is interbedded with these rocks, as in the Sualai area of 5th Division (Wall, 1964, b) but this is rare. In the lower B horizons there is a gradual to rapid change to weathering rock: and there are commonly reddish and light grey mottles, the latter caused by gley (impeded drainage) and/or weathered light grey shale particules. In places the gleying and mottling may dominate the yellowish matrix colour.

Shallow phases less than 24 inches deep are found on both steep and moderately steep slopes. Soils less than 12 inches deep to the weathering rock are classed under the Kapit Family. Internal drainage of these soils is generally free to imperfect.

Analyses of four Merit profiles (S4097/04, S4125/30, S4073/79, S4090/96 - locations shown on Map 1, Soil), three resembling Luak Series (Wall, 1964, a) the dominant soil series of the family seen in this area, indicate normal levels of 'reserve' nutrients for this part of Sarawak. Calcium levels, at between 100-300 parts per million in the topsoil decreasing to 100-150 parts per million in the subsoil (generally lowest in the B horizons) are at the lower end of the wide range found in 4th and 5th Divisions. Magnesium and potassium levels are normal, ranging from 1,000-5000 parts per million in the topsoil to 900-3,100 and 5,800-8,900 parts per million in the lower subsoil. Phosphorus appears to be the limiting factor for some crops on similar, shale-derived soils (Bailey, 1965) and the 'reserve' levels of 100-300 parts per million in the rooting zone of four profiles analysed here are probably 'low' on this basis. Downward leaching of the most soluble bases is thought to occur as shown by the increasing values of potassium and magnesium down the profile.

Crops grown successfully on Merit soils include rubber, hill rice, hill sago (Apoh Valley), tubers and oil palm (Long Lama). Secondary growth from annual crops commonly includes sheet bamboo.

The main physical factor limiting cultivation is erosion on unprotected steepslopes. The surface water runoff over these soils tends to be rapid and judging by the shallow profiles and the thin A2 horizons sheet wash is effective; deep gullies landslides and other large scale soil movements appear to be rare. Clayey soils exposed to direct sun are prone to surface baking, which adversely affects soil structure and hinders microbiological activity; at the same time humus is destroyed. The soils are suitable, with appropriate manuring, for both perennial and annual crops. Slopes exceeding approximately 15° should be terraced.

3.1.2 2. Nyalau Association

The Nyalau Association has a widespread distribution coincident predominantly with arenaceous rock formations, particularly the Lambir and Belait formations. It is mapped largely north of the Tutoh River and east of the lower Baram on moderately high hills, ridges and cuestas of terrain classes 4, 5, 6 and 7.

As the name implies the dominant soils are members of the Nyalau Family: subordinate soils belong chiefly to Kapit (section 3.1.3) Merit (section 3.1.1) Matang and Bako families (section 3.1.7); the Kapit soils are found on steep scarp slopes and the Bako and Matang soils on gentle dip slopes. Members of the Merit Family are in places dominant. Small valleys contain Semilajau (section 3.2.9), Plan (section 3.2.10) and Malang (section 3.2.12) soils.

Nyalau Family soils have the following characteristics in this area: a surface layer of litter and humus under primary forest of as much as four inches, overlying a distinct dark yellowish brown to dark greyish brown A1 horizon. This changes abruptly downwards to a sandy loam or sandy clay loam horizon coloured yellow to yellowish brown, and friable, massive to weakly blocky or crumbly with common roots. Old root channels may contain pale yellow soil surrounded by reddish yellow halos. The B horizon is generally a deep yellowish brown to reddish yellow sandy clay loam to sandy clay, that is friable to firm, with massive to weak blocky structure and clear clay skins on structural faces; faint pale yellow or red mottles may be present. The C horizon is found usually at depths of at least three feet and contains much weathering sandstone in a sandy clay loam to sandy clay matrix. Reddish and light grey mottles are typical in places; iron-coated sandstone fragments are common deep subsoil features.

Shallow phases less than 24 inches deep are rare. Internal drainage is free to moderate except at footslope sites. Sand grades are characteristically medium to fine.

One profile has been analysed of an extremely sandy Nyalau soil (Peninjau Series - S.3465/71). Comparing this profile with other Nyalau soils from nearby areas (Wall, 1964, a. and c.) it can be inferred that the degree of podsolization is greater and the initial endowment of weatherable minerals from the parent material is lower in Nyalau than in Merit soils.

The only crops grown on Nyalau soils in the area in addition to hill rice are rubber and pepper.

Erosion is the main physical limitation to cultivation. Unlike the Merit soils, however, gullying and landslips are common features and sheet wash is thought to be comparatively rare - probably since the surface water run off is lower and soil infiltration correspondingly greater. Many large-scale landslips have taken place on both scarp and dip slopes of cultivated land where Nyalau soils occur, such as at Peninjau Hill; even under primary forest large-scale earth movements are visible as in the Lingi Puteh Valley, mainly on hillsides exceeding an estimated 25°.

The soils with appropriate manuring are suitable for both perennial and annual crops; rooting is much freer in these soils than in the Merit Family although the general fertility is lower. Slopes exceeding approximately 10-15° should be terraced with care.

.1.3 3. <u>Kapit Association</u>

The Kapit Association occurs in many small areas of which only the largest have been indicated. The association is mapped where large steep-sided hills and cliffed escarpments of terrain classes 7 or 8 can be seen on air photographs, such as parts of Peninjau Hill. The main occurrences are on scarp-producing rocks of the Temala Member in the south and the Lambir, Belait and Mulu rock formations in the north and east.

The soils belong to the Kapit, Nyalau (section 3.1.2) and Merit (section 3.1.1) families, each being dominant in small areas within the association. Kapit soils are defined as Lithosols, less than 12 inches deep over weathering sedimentary rocks. The profile is invariably stony and the main distinguishable horizon on the most stable slopes is a thin dark-coloured A1. The soils are generally well-drained; surface water run off is rapid. Due to their patent unsuitability for cultivation on steep slopes no analyses of Kapit soils have been made. Associated Merit and Nyalau soils are predominantly stony, shallow phases with restricted rooting depth. This, combined with the steepness of slope, with favours erosion, makes them almost entirely unsuitable for cultivation.

.1.4 4. Merit-Nyalau Association

The areas mapped as the Merit-Nyalau Association are largely where mixed argillaceous-arenaceous beds of the Temala and Batu Blah members and the Setap Shale Formation outcrop in the Marudi area, the lower Tutoh-Baram river area and in the Melinau locality. The topography consists of hills with low to high, gentle to steep slopes, mainly of terrain classes 4, 6 and 7.

The dominant soils are members of the Merit Family (section 3.1.1); rather more clayey than usual Nyalau Family soils (section 3.1.2) tend to occur on ridge-top sites and Kapit Family soils (section 3.1.3) are also found, mainly on the steepest scarp slopes. Alluvial land in the many small valleys contains principally Malang (section 3.2.12) and Bijat (section 3.2.18) soils.

There tends to be two distinct textural types of the Merit Family. One is a yellowish brown clay loam on clay resembling Luak Series (Wall, 1964, a), the other is a yellowish brown fine sandy loam to fine sandy clay loam on clay resembling Labang Series (op.cit). Each appears to be dominant in small, fairly distinct areas, probably related directly to the incidence of mixed sandstone-shale lithologies. The soils are well to moderately well drained, commonly shallower than 24 inches and are suitable for the cultivation of annual and perennial crops. Hill rice and rubber are the two main crops grown now.

The main limitation to cultivation, excepting nutrient deficencies, is the risk of erosion on steep slopes. Both gullying and sheetwash probably occur as described in sections 3.1.1 and 3.1.2 above.

1.5 5. Merit-Kapit Association

The mixed arenaceous-argillaceous Temala Member and the Mulu Formation form high, steeply sloping hills of terrain classes 6, 7 and 8 with predominantly shale-derived soils of the Merit and Kapit Families. Minor patches of Nyalau soils are found, mainly on ridge tops, and mixed Malang-Semilajau family soils occur in the valleys (section 3.2.11). From air photographs it appears possible that some scarp slopes southwest of the Tutoh River many consist of limestone.

The Merit Family soils coincide with the gentler slopes and are as described in section 3.1.1, but commonly have a fine sandy upper subsoil texture resembling Labang Series (Wall, 1964, a) and are shallow. The parent material is rarely deeper than 36 inches and generally at depths of between 18-24 inches. Stony subsoils are common in which fragments of moderately hard shale and hard sandstone predominate.

Kapit Family soils, although subordinate in this association, occur in many small patches on all slope facets. They are dominant however on the cliffed upper scarp slopes of long ridges. The solum is shallower than 12 inches to weathering rock and is usually stony with a fine sandy clay loam matrix. Rocks commonly outcrop at the surface.

It is inferred from the generally shallow soils in this association that the steep slopes are subject to severe surface erosion. No crops are cultivated on these soils and only the deeper Merit soils are at all suitable for cultivation; the areas are small and scattered however.

3.1.6 6.

Nyalau-Kapit Association

The Nyalau-Kapit Association has been mapped in the high, hilly, ridge and cuesta country with terrain classes 6, 7 and 8 where the arenaceous Belait formation outcrops, largely in the Linei Puteh and Linei Merah river systems, and where the Temala Member outcrops near the Temala River.

The dominant soils are members of the Nyalau Family, similar to those described in section 3.1.2. Kapit soils (less than 12 inches deep) are common however, particularly on the upper slopes of long, cliffed and steep ridges but they also occur on gentle slopes indicating that in such places the underlying rocks are resistant to weathering. Minor areas of Merit Family soils have been noted in places and the narrow valleys contain mainly weakly developed Semilajau Family soils.

3.1.7 7.

Bako-Nyalau Association

The Bako-Nyalau Association occurs only on the long, gentle dip slopes of cuestas of terrain classes 3 and 5, underlain by Lambir and Belait formation massive sandstone. Soils of the Bako and Nyalau families are dominant with subordinate Kapit (section 3.1.3) Matang and Merit (section 3.1.1) family soils in places. The few narrow valleys contain Semilajau (section 3.2.9) and Plan (section 3.2.10) family soils.

Bako family soils in this area are most common in slight hollows and almost flat locations. They are characterized by thick surface litter and humus, resembling mor, beneath which is a thick, well-rooted, dark greyish brown A1 horizon of sandy loam to loam texture, very friable to loose consistence and weak crumb to single grain structure. The leached A2 horizon is generally less than 30 inches deep, and consists of a light grey sandy loam to loamy sand, streaked with humus from above, loose, single grain to very friable and with few roots. The B horizon is variable: in the most extreme case it is a very dark brown sandy loam, firm and slightly peaty overlying hard sandstone. There may be a slightly humus-enriched yellowish brown soil or layer of crumbling rock beneath the dark-coloured B2, of it may rest directly on hard sandstone. The parent rock is in all cases massive siliceous sandstone.

Shallow phases occur and where the depth to weathering rock is less than 12 inches the soil is classed as a member of the Kapit Family. Internal drainage is excessive as far as the B horizon where soil water movement is impeded. Analyses of Bako soils from this area have not been made but analyses of a Bako Series soil in the Limbang Valley (Wall, 1965, c) show extremely low 'reserve' nutrient levels below the topsoil. In addition to the low fertility the soil has shallow rooting depth, is subject to erosion and is therefore considered unsuitable for cultivation. No crops have been seen on this soil.

Nyalau Family soils found mainly on low ridges, convex slopes and upper slopes are described in section 3.1.2 above. Intergrades between the Bako and Nyalau families are classed under the Matang Family, which has the following characteristics. The surface litter and humus layer tends to be thick and overlies a well-developed, well-rooted A1 horizon of dark greyish brown colour and sandy loam texture. The leached A2 horizon is generally less than 12 inches thick and has a light grey to pale yellow colour, generally a sandy loam texture and a weakly developed structure. This horizon changes rapidly with increasing depth to yellow, yellowish brown or reddish yellow sandy loam, in places a sandy clay, that is friable to firm with a weak blocky structure.

The Matang profile is generally well drained and stoneless within the upper 20-40 inches: shallow phases have not been noted but almost certainly occur. Although analyses of Matang soils are not available it can be expected that the A2 horizon is depleted of nutrients similar to Bako soils, and that the lower subsoil has levels similar to those of the Nyalau soils. Due to the suspected low fertility of the A2 and the susceptibility to erosion the soils are considered unsuitable for cultivation: they are in places used for hill padi with poor results.

2. ALLUVIAL SOILS

The surface Quaternary alluvium in the area is all derived from sedimentary rocks described in section 2.2 and varies in size from clays to sands, gravel and boulders. The material is thought to be characterised by a predominantly siliceous sand fraction and kaolinitic clay fraction. Landforms developed over the material range from flat-topped terraces, fragmentary ridge-top terraces, river levees and river basins. The dominant soil-forming processes in the terraces are governed by climate, resulting in podsolization, and in the lowlying land, by topographic control over the water table which results in varying degrees of hydromorphism.

The most extreme podsolization has taken place in loose, siliceous sands of low terraces in the Marudi area and has resulted in the formation of humus podsols in the Podsol Great Soil Group (Thorp, Smith, 1949), in places the 'giant' variety: such soils are members of the Mari Family, which is characterized by deep light grey A2 horizons abruptly overlying a humus B horizon which in turn rests directly on comparatively impermeable strata. The Sabangang Family, a member of the Red-Yellow Podsolic Great Soil Group (op.cit) is a less strongly podsolized terrace soil and in many respects resembles the Nyalau Family (section 3.1.2). It consists in this area of a thin to thick dark yellowish brown topsoil above a pale yellow to yellowish brown, friable sandy loam to sandy clay loam.

Beneath this horizon the texture becomes heavier and the colours stronger and there is commonly a high proportion by volume of quartzitic gravel. The remaining terrace soils are members of the Gaya Family in the Regosol Great Soil Group (op.cit): these soils are loose light grey sands directly overlying gravelly sand with a minimum of soil development.

Lowlying, recent alluvial soils are subject to periodic inundations and fluctuating ground water table. The most recently deposited sediments on the river levees range from loose sands to clays: in places the resultant soils can be classed in the Recent Alluvial Great Soil Group (op.cit), in which soil development has scarely begun, but soil formation in most is thought to be sufficient to warrant classifying them tentatively with the Low Humic Gley soils or as an intergrade to the Red-Yellow Podsolic soils (op.cit). The main families are the Malang and Semilajau families which are largely yellowish brown, moderately well drained and deep.

Soils in the river basins behind levees are poorly drained and predominantly clayey. Bijat Family soils in the Low Humic Gley Great Soil Group (op.cit) are dominant: these consist mainly of light grey, reddish brown-mottled plastic clays. Closer to swamp margins are Half Bog soils (op.cit) of the Mukah Family which are light grey plastic clays with as much as three feet of peat as topsoil.

2.1 1. <u>Miri Association</u>

The Miri Association is restricted in distribution to the Marudi area on low Quaternary terraces of Terrain Class 2. The association is dominated by soils of the Miri Family with subordinate colluvial-alluvial soils in gullies and valleys.

Miri Family soils in this area are characterized by the following profile features. The surface litter and humus is invariably thick and well-rooted; the A1 horizon is a well-defined, dark greyish brown sandy loam, very friable with single grain to weak crumb structure; it overlies a deep, light grey, loamy sand to sand A2 horizon which is loose, structureless and stained in places by humus from above. The B2 horizon is generally divided from the A2 abruptly; it is dark brown to dark greyish brown, friable to firm and is generally moist to wet. Pale brown, streaky mottles commonly occur within this horizon which in places is at least three feet thick: the mottling in one profile examined formed a distinct reticulate pattern.

Shallow phases with the humus B horizon less than 24 inches from the surface were noted mainly in the Ridan River vicinity; elsewhere the profiles were normal to deep (where the B horizon was not encountered within auger depth - 48 inches). Internal drainage is excessive to the B horizon where it is generally impeded and where normally ground water movement is laterally above the surface of the perched water table formed by that horizon.

Miri Family soils are, unsuitable for cultivation due to extremely low chemical fertility and poor drainage properties. Attempts have been made at planting pineapples and rubber but the results are poor.

.2 2. Sabangang Association

The Sabangang Association occupies medium height Quaternary terraces of Terrain Class 2, mainly in the Tutoh Valley and in the Marudi area. The soils are predominantly members of the Sabangang Family: subordinate soils belong to Merit (section 3.1.1), Nyalau (section 3.1.2), Gaya and Miri (section 3.2.1) families.

The Sabangang Family is here characterized by soils with the following properties. The surface litter and humus is of variable thickness and rests on dark yellowish brown, well-rooted, friable to loose sandy loam topsoil. Beneath is yellowish brown (rarely pale yellow) sandy loam to sandy clay loam, friable and weakly structured, which forms the A2 horizon. The B horizons are generally deep, coloured reddish yellow and in most places contain abundant quartzitic gravel and boulders: poorly drained profiles have been noted but these are rare in comparison with the dominant well-drained soils.

Analyses of one profile (S4105/11) from the Apoh Valley near Long Atip with poor subsoil drainage indicates a uniform 'reserve' phosphorus level of less than 100 parts per million. 'Reserve' calcium increases from 100 parts per million in the topsoil to 240 parts per million at four to six feet depth, magnesium from 290 to 1,090 parts per million, and potassium from 1,600 to 5,750 parts per million. A better drained soil from 5th Division (S2965/70 - Wall,1964, d) has slightly lower values than these. Exchangeable cations are low, in magnesium particularly.

Sabangang soils, although used extensively for rubber in the Puyut area, and in places for hill rice, are considered marginal for cultivation due to the gravelly subsoil which gives insufficient rooting depth. They are subject to gullying on terrace flanks.

Small patches of Gaya Family soils have been noted in the Puyut area and in the lower Tutoh (Ikang) and upper Tutoh Valley. Gaya soils resemble those of the Miri Family (section 3.2.1) in that there is a thick, matted surface 'mor' layer above a loose, white sand A2 horizon. No humus accumulation is evident in the Gaya Family however and there is generally a rapid change at a depth of 6-18 inches to quartzitic boulders in a loose sand matrix. The soil is completely unsuited to cultivation.

.3 3. Miri-Sabangang Association

The Miri-Sabangang Association has been mapped in areas where the two dominant families appear to occur in roughly equal proportions such as in the Tutoh Valley. The families are described in sections 3.2.1 and 3.2.2 above; in these areas also they are largely unsuitable for cultivation because of low fertility, shallow rooting depth and possible erosion.

.4 4. Miri-Nyalau Association

The Miri-Nyalau Association occurs largely in the Marudi area, and as a small patch near the Melinau River, as low to medium height terraces of Terrain Class 2, mainly, and subordinate patches of classes 4, 6 and 7 where peripheral gullying has occurred.

In the Lubok Nibong area the low terraces have a thin veneer of alluvial material in which shallow Miri Family (section 3.2.1) profiles have developed and through which Nyalau Family (section 3.1.2) soils protrude on terrace flanks and in gullies. It is thought that the same features occur in the terraces close to the Ridan River.

Near the junction of the Melinau and Tutoh rivers is a moderately high terrace beneath primary forest containing mixed Miri and Nyalau family soils. The Nyalau soils outcrop largely on the flanks of deep gullies. Members of the Merit (section 3.1.1) and Sabangang (section 3.2.2) families occur in places, where the soils are considered to be unsuitable, or in places marginal, for cultivation due to low fertility and the risk of erosion.

2.5 5. Sabangang-Merit Association

Where medium height terraces in the Marudi and Tutoh River areas are being dissected the soils are largely a mixture of Sabangang and Merit families. The topography consists of steep-sided ridges, hills and gullies of terrain classes 6 and 7 mainly with small flat terrace remnants of some summits. Flanks of many hills contain what are thought to be essentially Merit profiles with gravel and boulders of colluvial origin (from the terrace material upslope) embedded in them. Apart from the stones the soils of the Merit and Sabangang families are commonly similar; in these areas the soils are marginal or suitable for cultivation except on the steepest slopes and where the presence of gravel close to the surface impedes rooting. Part of the land has been used for hill rice.

From air photographs and local information there appear to be patches of uncultivated low terrace land among deep peat swamp north of the Peking River. These are not shown on the maps prepared by Sir Bruce White (White, 1956) and since the area was not examined in the field druing this survey it is possible that the patches are mistaken for peat swamp vegetation. The areas are tentatively mapped in the Sabangang-Merit Association although it is probable that Gaya (section 3.2.2) and Miri (section 3.2.1) soils are also present.

.6 6. Sabangang-Merit-Nyalau Association

Where the parent rocks are successions of sandstone and shale, as in the Tutoh Valley near the Melinau River, the derived soils are largely a mixture of the Nyalau (section 3.1.2) and Merit (section 3.1.1) families. In this locality an added complication is the presence in places of gravel and boulders on upper ridge slopes indicating a former terrace with Sabangang or Gaya family soils (sections 3.2.2 and 3.2.1). The topography consists largely of moderately high hills and ridges of terrain classes 6 and 7. The land is probably suitable for cultivation on slopes less than 25-30° but terracing would be essential. Small areas have been used for hill rice.

.7 7. Sabangang-Malang Association

During soil investigations in the upper Apoh Valley areas were noted close to the main river in which soils of the Sabangang Family (section 3.2.2) on low terraces are mixed with recent Malang family (section 3.2.12) alluvium. Subordinate Bijat (section 3.2.15) and Merit Family (section 3.1.1) soils are intermixed in small patches.

The Sabangang soils occur on dissected terraces lower than 15 feet above adjacent recent alluvium, which consists principally of light dissected, moderately well-drained yellowish brown to reddish yellow clays of the Malang Family.

Hill rice and vegetables have been planted on the Sabangang soils with poor results and they are considered to be marginal to unsuitable for cultivation here mainly due to the presence of abundant gravel within a few inches of the surface. Malang soils planted with rice yield good crops and are suitable for cultivation but are liable to flooding.

8 8. Sabangang-Mukah Association

Low terraces occur in the Melinau Valley which are reported by Wilford (verbally) to support peat, in places deep. These areas were not investigated in the field and have been tentatively classed as containing mixed Sabangang-Mukah Family soils. The Sabangang family (section 3.2.2) is the most common terrace soil in the Tutoh Valley and has been checked in the Melinau Paku Valley just to the northeast of the survey area. The overlying peat probably contains deep patches of Anderson Family soils (section 3.3.1) in addition to the Mukah soils (section 3.2.16).

This association has not been cultivated and is considered to be unsuitable for cultivation.

9 9. Semilajau-Nyalau Association

The Semilajau-Nyalau Association has been mapped tentatively in the unvisited upper Linei Merah and Linei Puteh valleys where the underlying rock is known to be the arenaceous Belait Formation (Wilford, 1961). The topography consists of low dissected hills, of terrain classes 4 and 5, possibly low terraces of Terrain Class 2 and flat alluvial land, difficult to differentiate on air photographs beneath the primary forest that occurs in these places.

The Nyalau Association is probably dominated by Nyalau Family soils (section 3.1.2) with subordinate Merit soils (section 3.1.1). Associated minor areas of sandy alluvium of a poorly drained nature would be members of the Plan Family (section 3.2.11).

Semilajau Family soils as examined in the lower Linei River valley have the following profile characteristics. Surface litter is in many places absent but may accumulate to depths of about two inches. The A1 horizon is generally a well-rooted, dark yellowish brown sandy loam to loamy sand, very friable to loose with weak crumb to single grain structure. Where recent flooding has occurred buried and layered A1 and O horizons may be visiable in the top 6 inches of soil covered by fresh loose sand. The deep A2 horizon ranges in texture from loamy sand to sandy clay loam and is generally yellowish brown and very friable to firm. Beneath this horizon the texture increases, to a firm sandy clay in places, and is commonly mottled light grey and feddish brown.

Semilajau Family soils are predominantly well to moderately well drained and deep and occur largely on river levees. Analyses of alluvial soils derived from similar rocks elsewhere indicate that plant nutrients are all in short supply below the organic-rich topsoil. Crops grown on these soils elsewhere in the area include coffee, maize, tubers, coconuts, rubber and a variety of tree fruits.

The main physical limitations to cultivation are a risk of periodic flooding of Semilajau soils and of erosion of Nyalau soils. In addition the inherently low chemical fertility of these sandy soils cause the association to be only marginal for cultivation purposes.

2.10 10. Semilajau-Plan Association

The Semilajau-Plan Association is thought to occur principally in the Linei Merah Valley as recent sediments derived from arenaceous Belait Formation rocks. The valley, shortly above its confluence with the Linei Puteh River, is wide, mature and developed above gently dipping massive sandstone 150-300 feet above the nearby Tutoh River.

The main valley has not been examined in the field but from indirect evidence it is probable that the levee soils are predominantly the well-drained Semilajau Family soils as described above and that these grade back to soils of the Plan Family. It is also possible that soils of Malang (section 3.2.2) and Bijat (section 3.2.15) families occur in places and that low hills with Nyalau soils (section 3.1.2) and terraces with Miri soils (section 3.2.1) are intermixed.

The Plan Family is characterized by predominantly sandy textures and pale subsoil colours caused by poor drainage. Little is known about the soil fertility, but since the sand is derived from siliceous rocks it is most likely to be poor in nutrients. An additional limitation to cultivation is expected to be periodic flooding.

.11 11. Semilajau-Malang Association

The Semilajau-Malang Association occurs as a narrow band of recent alluvium in the Linei Puteh, the upper Ridan and in the upper Tutoh and Baram valleys upstream from the Temala-Baram river confluence. The association is found largely where streams drain areas dominated by sandstone formations but in which shale forms a substantial part. The principal soil families are the Semilajau Family, as described above in section 3.2.9, and the Malang Family, as described below in section 3.2.12. Subordinate soils are mainly of the Plan (section 3.2.10) and Bijat (section 3.2.15) families.

The sandy Semilajau soils invariably occur on the high levees and it is possible, in the Baram River particularly, to detect layers of recently deposited sand in the upper subsoil, laid down mainly during the 1962/3 'landas' season.

There is generally a clear break in slope between the high, main river sandy levee and the lower land behind where clayey Malang Family soils occur. The clay soils form a long narrow belt parallel to the river and are succeeded inland, where the alluvium is widespread, by more poorly drained clay soils such as those of the Bijat Family.

This association is considered to be suitable for cultivation, the main limitations being periodic flooding and low soil fertility of the Semilajau soils.

.12 12. <u>Malang Association</u>

The Malang Association consists mainly of moderately well-drained recent alluvial clays and occur as a narrow belt adjacent to the Tutoh River. The association is dominated by soils of the Malang Family with a subordinate component of Bijat (section 2.2.15) soils in low-lying places and Semilajau (section 3.2.9) members on the river levees, particularly in inner meander bends.

Malang soils in this area have the following profile features. The surface litter and humus is generally thin or absent but the Al horizon is a distinct well-rooted dark yellowish brown, friable, crumby clay loam to loam (rarely sandy) between two and six inches thick. Beneath, lie (A) B horizons of clay loam to clay texture with a matrix colour of yellowish brown to reddish yellow, mottled light grey and reddish brown in the deeper subsoils. Dark brown soft mottles, common in places, are thought to indicate ferro-manganese accumulations. Thick root systems penetrate the topsoil and the finer roots extend well into the subsoil where they are usually accompanied by mottling. Gleyed subsoils below 24 inches are common on the lower margins of the association where Bijat Family soils with gleyed subsoils above 24 inches may be intermixed.

Soils of the Malang Family are largely imperfectly to moderately well-drained in this area, and although analyses have not been made it is not expected that the soils will be unduly different from the nearby, better-drained Bijat soils, described in section 3.2.15 below.

Crops grown successfully on Malang soils in the area include rubber (seedling and R.P.S.'A'), bananas, coffee, padi ('tugal'), maize, coconuts, oil palm (Tg. Tahap), citrus, miscellaneous vegetables, tubers, and a variety of tree fruit including durian, rambutan, mangosteen, langsat and illipe nut. The main physical limitation to cultivation is periodic flooding. During the 1962/3 severe floods only well-established tall tree crops survived.

.3 13. <u>Malang-Merit Association</u>

A small area is mapped as the Malang-Merit Association in the Melinau valley where it is not clear how much of the lowlying land consists of low hills with Merit Family soils (section 3.1.1) and how much is Malang Family alluvium (section 3.2.12). It is possible that small limestone outcrops occur in this vicinity (section 3.3.2).

.14 14. Malang-Bijat Association

The Malang-Bijat Association occupies large areas in the Baram, Apoh and Tutoh valleys. The soils are derived from sedimentary rocks, mainly from the Setap Shale Formation. Malang Family soils, described above in section 3.2.13, occupy positions closest to streams and rivers, and in many cases can be found bordering old ox-bow lakes far from the present main river systems. Bijat Family soils described below in section 3.2.15 occur in the many slightly lower and more poorly drained sites, and in this association are dominant. Subordinate soils of the Mukah (section 3.2.16), Anderson (section 3.3.1) and Semilajau (section 3.2.9) families can be found in places.

The main limitation to cultivation in this association is flooding. This is particularly prevalent in the Melinau valley which receives a large proportion of the rain falling on the Mulu massif.

15 15. Bijat Association

The Bijat Association is most widespread in the Tinjar and lower Baram valleys where it forms a narrow belt of recent alluvial clayey soils between peat swamps. The dominant soils belong to the Bijat Family. Small areas occur with Malang soils (section 3.2.12) close to river banks, and with Anderson (section 3.3.1) and Mukah (section 3.2.16) soils near swamp margins.

The Bijat Family in this area is characterized by the following features. There is usually a thin surface layer of litter and raw humus forming in places a slightly peaty horizon up to six inches thick. Beneath is a dark greyish to yellowish brown A1 horizon of loam to clay loam texture, friable and slightly sticky; there are commonly reddish brown and light grey mottles associated with root channels. The underlying soil lies within or close to the ground water table and varies in colour from light grey to bluish grey and is mottled pale brown, reddish brown and olive brown: the texture ranges from clay loam to silty clay and the soil is characteristically massive, plastic and sticky. In many areas it has been noted that the clay forms with increasing distance from a river an increasingly thin wedge or layer overlying deep peat. Where the clay topsoil is less than 12 inches deep, or gives way to deep peat in patches, the soil is mapped as the Bijat-Anderson Association (section 3.2.18). Bijat soils are all poorly to very poorly drained. The only phase distinguished is an Organic Phase where peat forms a thin topsoil up to 6 inches thick.

Analyses of four profiles (S.4121/24, S.4241/44, S.4112/15, S.4116/23) whose localities are shown on Map 1, Soil, indicate normal 'reserve' levels of nutrients for the family in this region. Phosphorus ranges between 200 and 500 parts per million generally with a peak in the topsoil. Calcium is typically variable; the highest topsoil level slightly exceeds 1,000 parts per million (Melinau Valley), the lowest 200 parts per million. Subsoil levels are lower at between 80 and 240 parts per million. Indications from one profile show that a high proportion of 'reserve' calcium is also exchangeable. 'Reserve' magnesium ranges between 2,000 and 4,600 parts per million, potassium between 6,000 and 8,000 parts per million.

Swamp rice is the chief crop grown and is well adapted to this type of soil. The main physical limitation to cultivation is flooding, which is known to be severe and frequent in the particularly low-lying places such as near the Teru and Lelak rivers and near the Tasong River, tributary of the Baram. In addition, where deep peat lies beneath a thin layer of clay it will be difficult to drain the soil properly.

16 16. Bijat-Mukah Association

The Bijat-Mukah Association is most common in lowlying alluvial land of the Tutoh River and in inner meander bends of the lower Baram and Tinjar rivers. Bijat (section 3.2.15) and Mukah families are dominant with subordinate soils of the Anderson (section 3.3.1) and Malang (section 3.2.12) families.

Mukah Family soils are very poorly drained. The topsoil, which by definition consists of peat or muck between 6 and 36 inches deep, lies over gleyed light grey to brownish or bluish grey plastic clay, mottled olive brown in places. It is known that peat occurs beneath the clay in places, particularly at points farthest from a river. Properties of the clay closely resemble those of the Bijat soils, the peat is similar to that of the Anderson Family except that muck soils, in which inorganic material (mainly clay) is mixed with the peat, are more widespread.

Swamp rice is the main crop grown. Limitations to cultivation are periodic flooding, and a need for controlled drainage, which may be difficult where peat underlies the clay.

17 17. Bijat-Plan Association

The Bijat-Plan Association is found at the foot of hills underlain by sandstone, such as in the Nyambong and Kala Hill areas roughly south of Marudi. At such places there is generally a thin belt of weakly sorted colluvial sand of the Plan Family (section 3.2.10) at foothills sites, which with increasing distance from the foothills grades into gleyed clays of the Bijat Family (section 3.2.15). Subordinate soils found in small patches mainly belong to Malang and Semilajau families (sections 3.2.12 and 3.2.9).

Rubber and fruit trees are cultivated on the slightly better drained Plan soils, and swamp rice is the principal crop on Bijat soils. Flooding of the clayey soils and low fertility in the sandy soils are the chief limitations to cultivation.

18 18. Bijat-Anderson Association

The Bijat-Anderson association occurs largely on peat swamp margins, partly where rivers have deposited a layer of clay above deep peat: in such places the clay if greater than 12 inches deep belongs by definition to the Bijat Family (section 3.2.15) and if less is considered to be a phase of the Anderson Family (section 3.3.1). In addition there are Bijat profiles formed completely of clay (closest to rivers) and Anderson profiles consisting solely of peat (closest to adjacent peat swamps). Subordinate soils are members of the Mukah Family (section 3.2.16), which in places may be widespread, and of the Malang Family where narrow levees of abandoned river meanders occur (section 3.2.12).

This association is considered to be marginal for cultivation due to the probable widespread presence of deep peat.

19 19. Bijat-Rock Association

Wilford reports verbally that parts of the Melinau Valley contain abundant protruding bare limestone pinnacles, which possibly underly the alluvium also at shallow depth. The main area is marked on the soil map as the Bijat-Rock Association.

The alluvium probably consists of soils of the Bijat Family (section 3.2.15), with subordinate Malang soils (section 3.2.12) close to streams. It is likely that the proximity of much limestone will raise the calcium levels in these alluvial soils considerably. The bare limestone is classed as Rock, an arbitrary term including all bare rock outcrops of no agricultural value.

3. ORGANIC SOILS.

Organic hydromorphic soils of the Anderson Family cover approximately one third of the area surveyed and the ratio of areas of deep peat, exceeding 10 feet in depth, to shallower peat is estimated to be about 20:1. That the swamps are deep, domed with 'steep' rims and give way abruptly to inorganic soils on their margins is a characteristic feature of this region. Small areas of non-hydromorphic organic soil occur in patches in the limestone hills near Melinau: these are classed in the Kapor Family.

Peat swamp soils of the Bog Great Soil Group (Thorpe & Smith, 1949) form under almost wholly anaerobic conditions, the ground water table being close to or near the surface throughout the year. The peat is largely poorly decomposed and woody.

1. Anderson Association

The Anderson Association is the most widespread group of soils in this area and occurs in all main river valleys, principally as large peat swamps. Subordinate soils occur in addition to the main Anderson Family on the swamp margins, and are mainly members of the Mukah (section 3.2.6) and Bijat (section 3.2.15) families.

The Anderson Family consists of peat soils exceeding 36 inches in depth. Depth phases of 3-6 feet (Anderson 1), 6-10 feet (Anderson 2) and more than 10 feet (Anderson 3) are tentatively mapped where possible for agricultural recommendations. The peat profile generally appears to be uniform physically both within auger depth and areally. It consists of common hard woody remains of trees in a watery matrix of dark reddish brown partly decomposed roots, leaves and twigs. The peat of 'padang' areas (see section 2.4) appears to differ slightly in having a more fibrous matrix (Anderson, 1964, p.12).

Samples S3477/80, S3481/84 and S3485/89 were taken from beneath the three main peat vegetation zones (section 2.4) near Tg. Pasir, Marudi. Analytical results indicate surface differences mainly in 'reserve' phosphorus distribution - increasing from 195 parts per million in the poor, central 'padang' forest through 320 parts per million in intermediate forest to 540 parts per million under tall 'sengawan' forest on the swamp periphery. Surface peat exchangeable magnesium ranges from 20 parts per million under 'sengawan' forest through 54 parts per million in intermediate forest to 220 parts per million in the 'padang' forest. Phosphorus, magnesium and potassium all show a decrease in value with increasing depth. Carbon: nitrogen ratios range from about 1:10 to 1:30.

The analyses are of the oven-dried peat and consequently the actual concentration of elements in field-wet peat is considerably less, since it consists generally of about one fifth solid matter to four fifths liquid.

The soil provides a poor medium for growth of most cultivated crops. It is acid, chemically poor, waterlogged and gives poor root foundations. Sago can be grown on undrained peat and pineapple, the main crop grown commercially on Malayan peat, requires controlled drainage. The highly-developed swamp in this area could with great expense be drained, burned and manured for crop cultivation but it is thought that timber extraction is a more favourable long term proposition from the point of view of land conservation, particularly in the 'sengawan' forest belt where this tree is gregarious.

.2 2. Kapor-Rock Association

Among the limestone hills the soil pattern is one of vegetative litter accumulation in hollows and crevices among bare limestone rock. The organic Kapor Family soil consists of partly decomposed litter, and humus bound and fed upon by the specialized vegetation, and is of no practicable agricultural value.

AGRICULTURAL SUITABILITY OF THE SOILS AND TOPOGRAPHY OF THE AREA.

The agricultural potential of an area depends primarily on the kind and quality of soils present in conjunction with the type of topography. The soils of this area have been described as associations in section 3 above and are shown on Map 1, Soil; the topography of the area has been described in section 2.2 and is shown on Map 2, Terrain.

The terms unsuitable, marginal and suitable for agriculture are used below in a general sense, since clearly certain crops, such as rubber, are more adaptable to poor soil conditions than others, for example pepper: ideally each crop should be considered separately. The headings below refer broadly to existing soil and topography conditions combined with a purely qualitative estimate of the difficulties and expense involved in modifying and improving existing conditions for the adequate growth of different crops. Thus the unsuitable soils for example consist largely of rocky, shallow, steep and peaty land which would be excessively difficult and costly to reclaim for any crop.

From these consideration of soil and terrain suitability a number of areas have been drawn on Map 3. indicating the land that is thought to have moderate to high agricultural potential. Accessibility from rivers and main population centres is considered and feeder road routes are suggested to serve the selected areas.

1. Soils and Topography Unsuitable for Agriculture.

Land classed here as unsuitable for agriculture is that in which the expense of modification, reclamation or improvement for crop growth is thought to be excessively high.

Soils unsuitable for agriculture due to low fertility are members of the Miri and Bako families, the main soils of the Miri Association and an important part of the Miri-Sabangang and Bako-Nyalau associations. By heavy, continued, complete fertilizer application the soils would probably yield adequately but this would be an economically unsound measure.

Soils with severely restricted rooting depth are members of the Rock, Kapit and part of the Sabangang Families, which are important components of the Kapit and Sabangang Association and of the other associations which are named partly by them (section 3; legend of Map 1, Soil).

Terrain Class 8 is considered to be too steep for any cultivation: Terrain Class 7 also includes many slope facets too steep and high to be used. These areas coincide largely with occurences of the Kapit, Nyalau-Kapit, Merit-Kapit and Kapor-Rock associations, where expensive and difficult terracing may be possible in places but where problems of accessibility in strongly dissected country are equally prohibitive.

Although peat can be drained, burned, fertilized and planted with shallow-rooted tolerant crops, such as pineapple, coffee, sago sundry small fruit trees, maize and vegetables it is thought that the Anderson Family peats of this area are unsuitable for agriculture due to poor chemical properties, lack of suitable support for some tall tree crops (coconuts) and inherently poor drainage. Schemes for draining peripheral areas of the domed Tinjar-Baram swamp have been proposed in detail (White, 1956), and there is sufficient surface gradient near the margins of the larger swamps for this to be practicable. Peat drainage however should be integrated on a large scale to be effective and sufficiently little is known of the problems of factors such as shrinkage rate, irreversible drying of peat, the effect on the height of water tables of undrained neighbouring areas, besides the eventual problem of the drained peat level shrinking below the general water table level, for the magnitude of such schemes to cause them to be all but impossible at the present time (Andriesse, 1964). Crop yields on the dominant, raised, central 'padang' peats would almost certainly be low, judging by their stunted natural vegetation, without heavy, continued manurial applications. Timber extraction from the peripheral, sloping, 'sengawan' and mixed swamp forest belts is a profitable venture and one that least affects the delicate natural balance of soil-soil water relationships.

Anderson family soils cover approximately 27% of the surveyed area and an additional 10%, approximately, is occupied by the hill land described above, together making about 37% of the area unsuitable for agriculture.

2. Soils and Topography Marginal for Agriculture

Land classed here as marginal for agriculture is that in which the expense of modification, reclamation or improvement for crop growth is thought to be moderate to high.

Soils with poor nutrient status (excluding those described in section 4.1) are members of the Matang, Nyalau, Sabangang, Semilajau and Plan families. They are the principal soils in the Nyalau and Sabangang Associations and form important parts of those associations in which their names are included (section 3; legend of Map 1, Soil). The soils are sandy (siliceous), leached, have low nutrient and water holding capacities and low levels of both exchangeable and 'reserve' nutrients compared to equivalent hill or valley clay soils: the sandy soils, being more permeable, have superior rooting qualities however, and generally have sufficient rooting depth.

Terrain Class 7 is considered to be marginal for cultivation since the steepnees and length of slope combine to make terracing both difficult and expensive. Terrain Class 7 and in many places Terrain Class 6 coincide in distribution with the Nyalau and Sabangang soils and gullying with landslides in such areas is common under cultivated land, such as on the Peninjau hills near Marudi, and outside this survey area at Berop where large areas were devasted in 1962/3. For this reason annual crops are not suitable for such a combination of topography and soil. To help prevent erosion under perennial crops clean weeding should be avoided and cover crops established. Erosion is most likely in these areas during the first few years of cultivation and the establishment of new crops, particularly where terracing is practised. In many cases the crop can be established successfully but in others erosion on a large scale may leave the land unfit for even hill rice.

The marginal alluvial soils of the Semilajau and Plan families will probably require heavy complete fertilizing for optimum crop yields.

It is estimated that about 28% of the surveyed area consists of land marginal for agriculture that requires moderate to high expenditure in improvements.

3. Soils and Topography Suitable for Cultivation

Land classed here as suitable for agriculture is that in which the expense of modification, reclamation or improvement for crop growth is thought to be nil to moderate.

Hill soils suitable for agriculture are principally those of the Merit Family, where it is the main component of soil associations such as the Merit, Merit-Nyalau, Merit-Nyalau-Sabangang associations. Merit soils have average to low fertility by comparison with shale-derived soils elsewhere in the country; it is probable that phosphorus is the main deficient major nutrient (Bailey, 1965) and potassium the least deficient. Although the textures are clayey the soil is moderately permeable and well to moderately well drained. Surface water run off is high by comparison with Nyalau soils and sheet erosion prevails over gully erosion. Rooting depth is normally adequate.

The soils are stable under most slope conditions in terrain classes 3, 4, 5 and parts of 6, which are the most common classes where the above soil association are found. Terraces will be required generally on slopes exceeding about 15°. An additional amount of land, where Nyalau and Sabangang soils (section 4.2) combine with low, gently sloping topography, can also be classed as suitable but terracing would need to be more stringent and fertilizing more frequent.

With appropriate fertilizer and cultivation practices it is thought that a wide variety of annual and perennial crops can be grown satisfactorily on this hill land with moderate expenditure. It is estimated that about 22% of the surveyed area consists of hill land suitable for cultivation.

Present day floodplains with recent alluvial soils contain large areas of soils suitable for agriculture. These are principally members of the Malang, Bijat and Mukah families which are dominant or important soils in associations containing their names.

The soils have in common clayey textures, moderate chemical fertility, moderate nutrient and water holding capacities and a susceptibility to periodic flooding due to the flat or gently sloping land being at or close to ground water level. The Mukah, and to a lesser extent the Bijat, soils require drainage for most crops. Malang soils are suitable for a wide variety of annual and perennial crops, the Bijat and Mukah soils are possibly more suited to shallow-rooted crops due to poor soil drainage.

It is estimated that about 18% of the surveyed area consists of recent alluvial land suitable for cultivation, and requiring low to moderate expenditure in improvements (excepting that required for severe flood control).

.4 4. Areas with Best Agricultural Potential

For brevity the relevant data is presented in tabular form as far as possible. Acreage figures are measured by planimeter from 1:50,000 maps, therefore in deeply dissected hill land the figures will be appreciably less than the surface ground area.

.4.1 1. LINEI PUTEH BLOCK

Total acreage: 5,400. The area could possibly be extended east into the Buang River system.

Acreage under primary forest: 4,300

Acreage under title: nil .

Present cultivation: mainly hill rice, some swamp rice and seedling rubber close to rivers.

Main soils: the Nyalau Family of soils is dominant in hill areas, with subordinate Merit Family soils in places. River levees contain Semilajau soils and river basins Malang soils.

Dominant topography: low to moderately high and steep ridges and hills of terrain classes 4 and 6. Slope facets of Terrain Class 8 are common and small areas of Terrain Class 1 probably occur in places.

Main hazards to cultivation: low soil fertility and strong risk of gully erosion with Nyalau soils on slopes exceeding 15-20°, areas which should be avoided where possible.

Land suitability: many small hill areas are too steep for agriculture, large areas are marginal: alluvial valleys and low hills are the most suitable for agriculture. A semi-detailed soil survey would be necessary to delimit the small areas of steep land with shallow soils.

.4.2 2. KUALA TINJAR BLOCK

Total acreage: 9,700. The area could be extended down the Baram River slightly.

Acreage under primary forest: 5,000. Some is possible old secondary forest.

Acreage under title: 315

Present cultivation: mainly swamp and hill rice; scattered fruit and vegetable gardens near villages; small patches of seedling rubber close to rivers.

Main soils: the Bijat Family of soils is dominant except on the levees of main rivers and ox-bow lakes where Malang soils occur. Patches of Anderson Family peat, both at the surface and beneath the clay soils may be present in the Tasong area.

Dominant topography: flat to gently sloping alluvial basins of Terrain Class 1.

Main hazards to cultivation: periodic flooding and the presence of deep peat.

Land suitability: most is suitable for the cultivation of mainly irrigated crops; the patches of deep peat, are unsuitable for cultivation and are probably most common in the Tasong area. A thorough appreciation of the flooding, drainage and irrigation problems is required before development.

4.3 3. KUALA TUTOH BLOCK

Total acreage: 6,300. The area could be extended considerably up the Tutoh River.

Acreage under primary forest: 300. Some is possible old secondary forest.

Acreage under title: 279.

Present cultivation: mainly swamp and hill rice; scattered fruit and vegetable gardens near villages; a few small seedling rubber gardens close to rivers.

Main soils: Bijat and Malang Family soils are dominant with possibly small patches of surface peat, and sandy levee soils of the Semilajau Family.

Dominant topography: flat to gently sloping alluvial land of Terrain Class 1.

Main hazard to cultivation: periodic flooding.

Land suitability: most is suitable for cultivation, partly of irrigated crops, partly for dry land crops. A thorough appreciation of the flooding, drainage and irrigation problems is required before development.

4.4 4. KUALA PEKING BLOCK

Total acreage: 5,700. There is little scope for extension.

Acreage under primary forest: 2,000. Small areas are possibly old secondary forest.

Acreage under title: nil.

Present cultivation: mainly swamp rice and small scattered seedling rubber gardens close to rivers.

Main soils: Bijat family soils are dominant with the possibility of shallow surface peat and deep peat beneath shallow clay south of the Peking River.

Dominant topography: flat to gently sloping alluvial land of Terrain Class 1.

Main hazards to cultivation: periodic flooding.

Land suitability: most land is suitable for the cultivation of irrigated crops. Areas south of the Peking River may be marginal or unsuitable due to the presence of peat. A thorough appreciation of the floodings drainage and irrigation problems is required before development.

4.5 5. IKANG BLOCK

Total acreage: 7,500. The area could be extended up the Baram River considerably.

Acreage under primary forest: 200. Small areas are possibly old secondary forest.

Acreage under title: nil.

Present cultivation: mainly swamp rice with vegetable, fruit and rubber gardens adjacent to rivers.

Main soils: Bijat and Malang family soils are dominant, the latter on river banks and close to streams. Patches of Anderson Family peat soils may occur, particularly close to swamp margins.

Dominant topography: flat to undulating alluvial land of Terrain Class 1.

Main hazard to cultivation: periodic flooding.

Land suitability: most land is suitable for cultivation, partly of irrigated crops, partly of dry land crops. There are possibly patches of peat unsuitable for cultivation. A thorough appreciation of the flooding drainage and irrigation problems is required before development.

4.6 6. TERU BLOCK

Total acreage: 3,000. The area could be extended west considerably into the upper Karap River.

Acreage under primary forest: 400. Some is possibly old secondary forest.

Acreage under title: nil.

Present cultivation: mainly swamp rice and a few seedling rubber gardens close to rivers.

Main soils: Bijat soils are dominant with subordinate Mukah, and probably Anderson family peat, in places.

Dominant topography: flat to gently sloping alluvial land of Terrain Class 1.

Main hazards to cultivation: periodic flooding and the presence of deep peat close to swamp margins.

Land suitability: much land is suitable for the cultivation of irrigated crops mainly; patches of unsuitable deep peat may be present. A thorough appreciation of the flooding, drainage and irrigation problems is required before development.

4.4.7 7. PEKING BLOCK

Total acreage: 10,000. There is a little scope for extension of the block onto low hills on all margins.
Acreage under primary forest: 5,000
Acreage under title: nil.

Present cultivation: mainly hill rice, and seedling rubber gardens close to villages.

Main soils: Merit Family soils are dominant with subordinate Malang, Bijat and Anderson soils in small valleys.

Dominant topography: low to moderately high, gentle to steeply sloping hills. Small slope facets of Terrain Class 8 are probably common.

Main hazards to cultivation: low soil fertility and sheet erosion on unprotected steep slopes. Shallow soils in places.

Land suitability: most of this block is thought to be suitable, or in places marginal for the cultivation of dry land, annual or perennial crops.

4.4.8 8. BAIN-LAMA BLOCK

Total acreage: 21,700. The area could be extended onto rather high hill land mainly in the south.
Acreage under primary forest: 11,500
Acreage under title: nil.

Present cultivation: largely hill rice with a few small seedling rubber gardens close to villages.

Main soils: Merit Family clayey soils are dominant, with locally Nyalau soils and Merit soils with sandy upper subsoils. Small valleys contain Malang and Bijat family soils with a few patches of Anderson Family peat.

Dominant topography: low to moderately high hills and ridges with gentle to steep slopes of terrain classes 4 and 6: Many small slope facets occur of Terrain Class 8.

Main hazards to cultivation: low soil fertility and sheet and gully erosion on unprotected steep slopes. Shallow soils in places.

Land suitability: most of this block is thought to be suitable for the cultivation of dry land, annual and perennial crops, although many small patches may be marginal or unsuitable due to steep slopes and shallow soils.

4.4.9 9. SELEMEN-AROH BLOCK

Total acreage: 8,600. There is little extra hill land available but much alluvial land adjacent to the Baram River.
Acreage under primary forest: 2,400
Acreage under title: nil.

Present cultivation: mainly hill rice with seedling rubber gardens close to villages.

Main soils: Merit Family soils are dominant with subordinate Nyalau soils mainly on the crests of high ridges. Malang and Bijat soils have been noted in small valleys.

Dominant topography: low to moderately high, gentle to steep hills and ridges of terrain classes 4 and 6. Many small slope facets of terrain class 8 occur.

Main hazards to cultivation: low soil fertility and sheet and gully erosion in unprotected steep slopes. Shallow soils in places.

Land suitability: most of the block is thought to be suitable for the cultivation of dry land, annual and perennial crops, although many small patches may be marginal or unsuitable due to steep slopes and shallow soils.

4.10 10. MALOI-TABIH BLOCK

Total acreage: 7,500. The area could be extended slightly on to higher hill land mainly to the south.
Acreage under primary forest: 6,800
Acreage under title: nil.

Present cultivation: mainly hill rice and rubber. In the Tabih (Bemang) area R.P.S.'A' rubber has been planted successfully.

Main soils: Merit Family soils are probably dominant with Nyalau soils being confined largely to the higher ridges. Valleys contain both Semilajau and Malang soils and on the northern margin Anderson Family peat occupies some valleys.

Dominant topography: low to moderately high, gentle to steep hills and ridges of terrain classes 4 and 6. Many small slope facets of Terrain Class 8 occur and patches of Terrain Class 7 may be common.

Main hazards to cultivation: low soil fertility and sheet and gully erosion on steep slopes. Shallow soils in places.

Land suitability: much of the block is thought to be suitable or marginal for the cultivation of dry land, perennial and annual crops; small areas are likely to be unsuitable due to steep slopes and shallow soils. A semi-detailed survey may be necessary to delimit the worst areas.

4.11 11. TERAWAN-WEST BLOCK

Total acreage: 3,300. There is a little scope for extension on the northern margins onto hill land, possibly containing poor terrace soils and alluvial land.
Acreage under primary forest: 2,900. Timber is being extracted in the north.
Acreage under title: nil.

Present cultivation: mainly hill rice in the north.

Main soils: mixed Merit and Nyalau family soils occur and possibly gravelly Sabangang soils in the north. The Nyalau members are confined mainly to high ridges. Minor patches of deep peat occur in marginal valleys.

Dominant topography: moderately high to high, moderately steep to steep ridges of Terrain Class 6 occur in the north. Dissected, rather lower hills of terrain classes 4 and 6 occupy the southern parts. Slope facets of Terrain Class 8 are probably most common in the ridges to the north.

Main hazards to cultivation: low soil fertility, sheet and gully erosion on higher steep hills and ridges and shallow soils.

Land suitability: much of the land is marginal to suitable for the cultivation of dry land, perennial and annual crops. There are probably many small areas of unsuitable land on steep slopes. A semi-detailed soil survey may be necessary to delimit the worst areas.

4.4.12 12. TERAWAN-EAST BLOCK

Total acreage: 2,500. It may be possible to extend the area eastwards onto higher hills and westwards onto alluvial land.
Acreage under primary forest: 2,400
Acreage under title: nil.

Present cultivation: a small patch of land is cultivated for hill rice in the north.

Main soils: mixed Merit-Nyalau family soils are dominant with long narrow belts of Malang and Semilajau soils in the few valleys.

Dominant topography: low to moderately high hills and ridges with gentle to steep slopes of terrain classes 4 and 6. Slope facets of Terrain Class 8 may be common.

Main hazards to cultivation: low soil fertility, sheet and gully erosion on high steep hills and shallow soils.

Land suitability: much of the land is marginal or suitable for the cultivation of dry land annual and perennial crops. A semi-detailed soil survey may be necessary to delimit the worst areas.

4.4.13 13. GAK BLOCK

Total acreage: 3,600. It may be possible to extend the area north and south into higher hills.
Acreage under primary forest: 3,400. Part of the area is being exploited for timber
Acreage under title: nil.

Present cultivation: nil

Main soils: mixed Merit and Nyalau family soils with Bijat and Malang soils in the valleys.

Dominant topography: low to moderately high hills and ridges with gentle to steep slopes of terrain classes 4 and 6. There are probably many slope facets of Terrain Class 8 and small areas of Terrain Class 7.

Main hazards to cultivation: low soil fertility, sheet and gully erosion on steep slopes and shallow soils.

Land suitability: much of the land is marginal or suitable for the cultivation of dry land perennial and annual crops. Many small areas consist of slopes too steep for cultivation. A semi-detailed soil survey may be required for the delimitation of the worst areas.

4.4.14 14. BEREI SELAMAT-WEST BLOCK

Total acreage: 7,200. There is little scope for expansion of this area.

Acreage under primary forest: 6,100
Acreage under title: nil.

Present cultivation: part of the area is planted with hill rice in the west.

Main soils: Merit family soils are dominant. Small valleys on the margins contain Anderson Family peat.

Dominant topography: low to moderately high hills and ridges with gentle to steep slopes in terrain classes 4 and 6. Many slope facets of Terrain Class 8 occur and there may be some hills of Terrain Class 7.

Main hazards to cultivation: low soil fertility, sheet erosion on unprotected steep slopes, shallow soils.

Land suitability: most of this block is considered to be suitable for agriculture although many small areas of marginal and unsuitable land occurs, mainly on steep slopes.

4.4.15 15. BEREI SELAMAT-EAST BLOCK

Total acreage: 1,500. There is little scope for extending this block.

Acreage under primary forest: all.
Acreage under title: nil.

Present cultivation: nil

Main soils: Merit Family soils are thought to occur throughout the area with subordinate Kapit soils on steep slopes.

Dominant topography: low to moderately high, gentle to steep hills and ridges of terrain classes 4 and 6. Many slope facets of Terrain Class 8 occurs.

Main hazards to cultivation: low soil fertility, erosion on unprotected steep slopes, shallow soils.

Land suitability: most of the land is marginal to suitable for the cultivation of dry land, perennial and annual crops. Further field investigations may prove that the steep land is extensive.

.4.16 16. ULU TERAWAN BLOCK

Total acreage: 2,200. Extensions to this block might be made to the north on alluvial and/or peat land.
Acreage under primary forest: all.
Acreage under title: nil

Present cultivation: nil

Main soils: it is thought that Bijat and Malang family soils are dominant but it is possible that many parts contain deep surface peat or peat beneath shallow clay.

Dominant topography: flat alluvial land.

Main hazards to cultivation: periodic flooding and presence of deep peat.

Land suitability: land suitable for the cultivation of irrigated crops is probably dominant, although the possible presence of much peat unsuitable for cultivation must not be discounted. A semi-detailed survey would be required to delimit the unsuitable land, and a thorough appreciation of the flooding, drainage and irrigation problems is required before any development takes place.

.4.17 17. ULAT-NORTH BLOCK

Total acreage: 1,200. It may be possible to extend this area north to higher hilly land.
Acreage under primary forest: nil
Acreage under title: nil

Present cultivation: nil.

Main soils: Merit Family soils are thought to be dominant probably with Malang and Bijat soils in the small valleys.

Dominant topography: low to moderately high, gentle to steep hills and ridges of terrain classes 4 and 6. Many slope facets of Terrain Class 8 occur.

Main hazards to cultivation: low soil fertility, sheet erosion on unprotected steep slopes, shallow soils.

Land suitability: most of the land is marginal to suitable for the cultivation of dry land, perennial and annual crops. Further field investigations may prove that the steep land is extensive.

4.4.18 18. ULAT-SOUTH BLOCK

Total acreage: 2,000. It may be possible to extend this block north among higher hill land.
Acreage under primary forest: all.
Acreage under title: nil.

Present cultivation: nil

Main soils: Merit Family soils are dominant. Small valleys on the margins contain Anderson Family peat.

Dominant topography: low to moderately high hills and ridges with gentle to steep slopes in terrain classes 4 and 6. Many slope facets of Terrain Class 8 occur and there may be some hills of Terrain Class 7.

Main hazards to cultivation: low soil fertility, sheet erosion on unprotected steep slopes, shallow soils.

Land suitability: most of this block is considered to be suitable for agriculture although many small areas of marginal and unsuitable land occur, mainly on steep slopes.

4.4.19 19. BEMANG BLOCK

Total acreage: 3,600. It may be possible to extend this block southwards among higher hill land.
Acreage under primary forest: all.
Acreage under title: nil.

Present cultivation: small areas in the north are in use for hill rice cultivation.

Main soils: Merit Family soils are thought to be dominant with Anderson Family peat and Malang and Bijat soils in the valleys on the margins.

Dominant topography: low to moderately high, gentle to steep hills and ridges of terrain classes 4 and 6. Many small slope facets of Terrain Class 8 occur and patches of Terrain Class 7 may be present.

Main hazards to cultivation: low soil fertility and sheet and gully erosion on steep slopes. Shallow soils in places.

Land suitability: much of the block is thought to be suitable or marginal for the cultivation of dry land, perennial and annual crops; small areas are likely to be unsuitable due to steep slopes and shallow soils. A semi-detailed survey may be necessary to delimit the worst areas.

4.4.20 20. LAHAI BLOCK

Total acreage: 4,000. This block could probably be extended to the east and south among higher hill land if necessary.
Acreage under primary forest: all (?)
Acreage under title: nil

Present cultivation: it is probable that small parts are used for hill rice cultivation (none in 1951 air photographs).

Main soils: Merit Family soils are dominant with subordinate Nyalau soils in a few places on the higher ridges.

Dominant topography: low to moderately high, gentle to steep hills and ridges of terrain classes 4 and 6. Many small slope facets of Terrain Class 8 occur and patches of Terrain Class 7 may be present.

Main hazards to cultivation: low soil fertility and sheet and gully erosion on steep slopes. Shallow soils in places.

Land suitability: much of the block is thought to be suitable or marginal for the cultivation of dry land, perennial and annual crops; small areas are likely to be unsuitable due to steep slopes and shallow soils. A semi-detailed survey may be necessary to delimit the worst areas.

4.4.21 21. NYALIN BLOCK

Total acreage: 14,500. Extensions to this block could probably be made to the south and possibly to the west among higher hills.
Acreage under primary forest: 7,300.
Acreage under title: nil.

Present cultivation: parts in the east are used for hill rice cultivation. Small fruit, coffee and rubber gardens, some R.P.S. 'A', are located near rivers.

Main soils: Merit Family soils are dominant, and Nyalau Family soils are thought to occur also in the west, mainly in higher hills. Small valleys contain Malang and Bijat soils mainly.

Dominant topography: low to moderately high, gently to steep hills and ridges of terrain classes 4 and 6. Many small slope facets of Terrain Class 8 occur and patches of Terrain Class 7 may be present.

Main hazards to cultivation: low soil fertility and sheet and gully erosion on steep slopes. Shallow soils in places.

Land suitability: much of the block is thought to be suitable or marginal for the cultivation of dry land, perennial and annual crops; small areas are likely to be unsuitable due to steep slopes and shallow soils. A semi-detailed survey would be necessary to delimit the worst areas.

4.4.22 22 ATIP BLOCK

Total acreage: 1,400. Extensions to this block can only be made into alluvial land on the margins.
Acreage under primary forest: 100
Acreage under title: nil.

Present cultivation: almost wholly hilly rice.

Main soils: Merit soils are dominant with subordinate Bijat and Mukah soils in the common minor valleys.

Dominant topography: low to moderately high, gentle to moderately steep hills of Terrain Class 4. Slope facets of Terrain Class 8 are few.

Main hazards to cultivation: soil fertility, sheet erosion on uprotected steep slopes, shallow soil.

Land suitability: most of this block is considered to be suitable for cultivation of dry land, perennial and annual crops. Small patches of marginal land may occur where there are steep slopes.

4.4.23 23. MELANA BLOCK

Total acreage: 2,500. Slight extensions to this block can be made to the east.

Acreage under primary forest: 200

Acreage under title: nil.

Present cultivation: mainly hill rice cultivation, with fruit, coffee and seedling rubber gardens close to rivers.

Main soils: Merit Family soils are dominant, in places Kapit Family soils occur.

Dominant topography: low to moderately high hills and ridges with gentle to steep slopes in terrain classes 4 and 6. Many slope facets of Terrain Class 8 occur and there may be some hills of Terrain Class 7.

Main hazards to cultivation: low soil fertility, sheet erosion on unprotected steep slopes, shallow soils.

Land suitability: much of this block is considered to be marginal to suitable for cultivation. Many small areas may be unsuitable due to steep slopes. A semi-detailed soil survey would be required to delimit the worst areas.

4.5 5. ROAD ROUTES.

A number of generalized road routes are suggested on Map 3, Agricultural Potential. The routes tap the best agricultural land and although not avoiding all steep high land in detail, the most obvious blocks of difficult road-building country are avoided. Floodable alluvial land and peat swamp are avoided as far as possible. The route proposed from Marudi to Linei is by far the best possibility from the agricultural point of view since it does not pass through areas of poor soils and links together the well-populated farming land of the Selijau valley. This road extends alongside the Tutoh River as far as the Temasok area, at which point a crossing of the Tutoh River can be made to join the hill land of the Terawan area. Further extension of the route through blocks proposed for development in the Apoh River area brings the road to the Baram River near Long Lama. The suggested route to the Long Teru area from Long Lama follows dissected low hills as far as the Lelak River, from where alluvial land subject to flooding has to be followed.

Sites of gravel, sand and limestone used in road building are indicated where they occur close to the routes.

5. CONCLUSIONS.

This report covers an area of approximate 980 square miles and was surveyed principally to determine its agricultural potential.

The residual soils as shown on Map 1, Soil, are developed over Tertiary sandstone-shale successions with subordinate limestone, and under the prevailing climate most are podsolized to a greater or lesser degree. These soils, classed as Red-Yellow Podsolics, are characterized by largely normal nutrient levels, by Sarawak standards, moderately good drainage and moderately good rooting depth. In general, the soils support good stands of Dipterocarp forest. The topography of these areas consists mainly of deeply dissected hills, in places more than 1,000 feet high, with moderately steep to steep slopes.

Alluvial soils shown on Map 1, Soil, are predominantly clayey, with variable drainage and are of slightly better than average fertility by Sarawak standards. Gravel terraces are common in the Tutoh River valley. Most forest alongside the main rivers has been cleared for the cultivation of swamp rice.

Organic, peat swamp soils are widespread in all lower main valleys. The peat is deep, poorly endowed with nutrients and waterlogged. The swamps are almost entirely covered by specialized primary vegetation.

Land suitable for agriculture is here defined by a purely qualitative estimate as that requiring no to moderate expense in modification, reclamation or improvement for crop growth. It is estimated that about 17% of the surveyed area consists of land with residual soils and topography suitable for agriculture, and about 18% of the area consist of land with alluvial soils suitable for agriculture. A further 28% of the area contains land marginal for agriculture, which requires moderate to high expense in improvement.

Twenty three blocks of land are indicated on Map 3, Agricultural Potential, ranging in size from 1,200 acres to 21,700 acres which contain appreciable areas of land suitable to marginal for agriculture. These largely lie within a belt of low hill country on the margins of the deep peat swamps or at main river confluences where wide alluvial belts occur. Many blocks require more detailed surveying to determine the extents of suitable soils or to assess the difficulties of flood control and drainage.

Road routes are drawn in a generalized manner on Map 3, Agricultural Potential, to link the suggested development blocks.

REFERENCES CITED IN TEXT.

Anderson, J.A.R. (1964). The Structure and Development of the Peat Swamps of Sarawak and Brunei. Journal of Tropical Geography, Vol. 18, 1964.

Andriesse, J.P. (1962). Field Classification of Sarawak Soils. Department of Agriculture, Technical Paper No.1, 1962.

Andriesse, J.P. (1964). Report on a Semi-Detailed Soil Survey of Nonok Coastal Area, 1st Division. Dept. of Agriculture, Soil Survey Report No.60, 1964.

Bailey, J.M. (1965). Chemistry Division Report. Annual Report of the Department of Agriculture, 1963-4 (in press).

Haile, N.S. (1962) The Geology and Mineral Resources of the Suai-Baram Area, North Sarawak, Brit. Borneo Geol. Survey Mem., 13, 1962.

Liechti, P. et. al (1962). The Geology of Sarawak, Brunei and the Western Part of North Borneo. Brit. Borneo. Geol. Survey Bull., 3, 1962.

Rainfall Statistics of the British Borneo Territories, 1896-1957 Department of Civil Aviation and Meteorological Services, 1961. Also unpublished meteorological data from the same department and from Drainage and Irrigation Branch, Public Works Department.

Thorpe, J. and Smith, G.D. (1949) Higher categories of soil classification: order, suborder and great soil groups. Soil Science Vol. 67, 1949.

Wall, J.R.D. (1964, a) Report on a Semi-Detailed Soil Survey of Luak Experiment Station, Fourth Division, Department of Agriculture, Soil Survey Report No.35/2.

Wall, J.R.D. (1964, b) Report on a Reconnaissance Soil Survey of the Sualai Area, Fifth Division. Department of Agriculture, Soil Survey Report No.66, 1964.

Wall, J.R.D. (1964, c) Report on a Reconnaissance Soil Survey of the Lubai Area, Fifth Division. Dept. of Agriculture, Soil Survey Report No.65, 1964.

Wall, J.R.D. (1964, d) Report on a Reconnaissance Soil Survey of the Sabangang Area, Fifth Division. Department of Agriculture, Soil Survey Report No.71, 1964.

White, Sir Bruce Wolfe Barry & Partners, (1956). Report to the Government of Sarawak on the Baram-Tinjar Area, Fourth Division, 1956.

Wilford, G.E. (1961). The Geology and Mineral Resources of Brunei and Adjacent Parts of Sarawak. Brit. Borneo Geol. Survey Mem., 10, 1961.

Printed by Department of Agriculture, Sarawak.