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Report No. 35/2

Report on a Semi-Detailed Soil Survey of the LUAK EXPERIMENT STATION

5th. Division

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Soil Survey Division
Research Branch

May,1964

Dept. of Agriculture
Sarawak

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ILLUSTRATIONS

FINAL REPORT ON A SEMI-DETAILED SOIL SURVEY OF LUAK EXPERIMENT STATION

J.R.D. WALL MAY, 1964.

INTRODUCTION

1. This report supersedes the preliminary statements made in Report No. 35/1 in late 1963 (1), the purpose of which was to give an outline of the soils of the area chosen for the station and to indicate suitable sites for oil palm and padi experiments and for buildings.

Soil samples have now been analysed, enabling the completion of the soil classification and the compilation of a soil map at a semi-detailed level. It is the purpose of this report to describe fully the physical background of the area and to give complete descriptions of the soils present. This will enable general planning on the station to proceed and will reduce the task of reporting on a detailed soil survey, which will be possible as soon as a suitable base map is available. A detailed soil map will be essential for the accurate siting of experimental plots as well as for plotting drainage lines and access roads.

The results of this survey support the findings of Report No. 35 (2) - suggesting the possibility of large areas for oil palm cultivation - and of Report No. 35/1 (1) - describing the soils of this station as being morphologically typical of those in large areas of the Sibuti, Niah and Suai river basins.

2. LOCATION

The area, totalling about 1,300 acres, lies in Fourth Division 16 miles South of Miri on the south or true left bank of Sg. Luak. The site is accessible by a re-graded jeep track from the coast, formerly constructed and named the Bulak-Setap road by Shell Company. The future trunk road from Miri to Bintulu is planned to pass close to the east of the station. A spur road joining Bekenu to the trunk road is also planned to pass close to the station.

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Fig. 1.

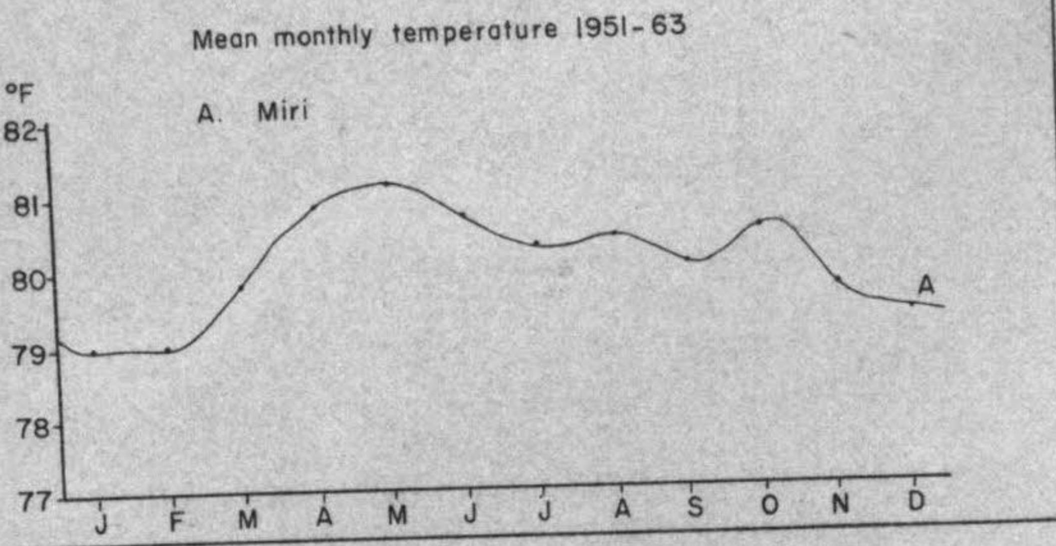


Fig. 2.

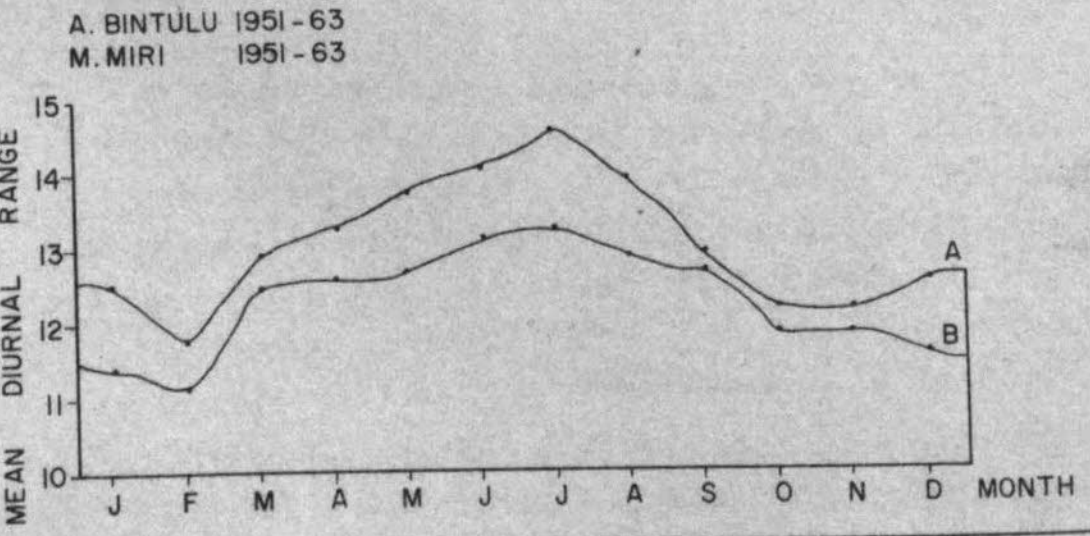
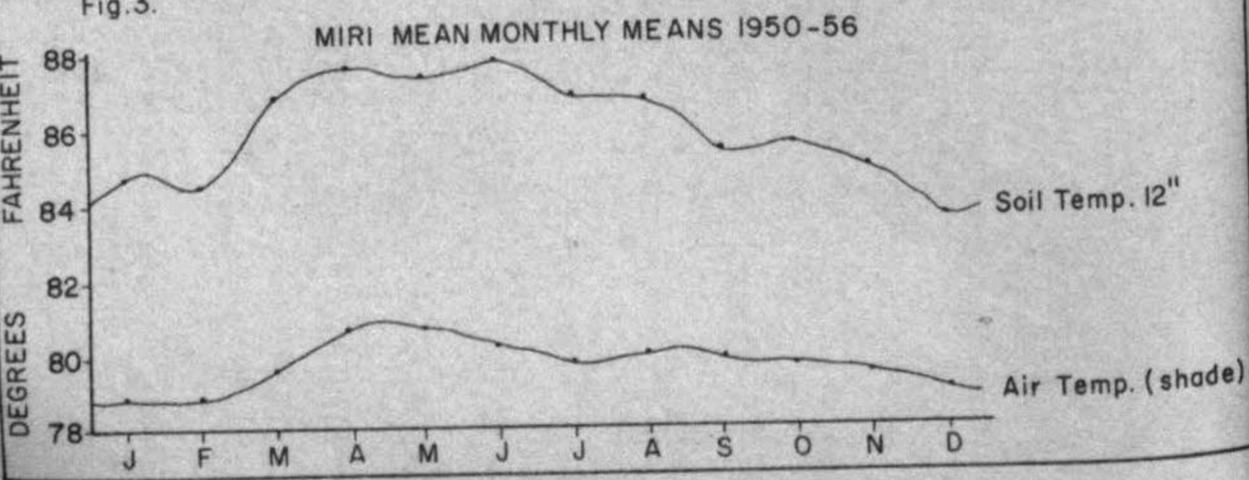


Fig. 3.



PART I GENERAL CHARACTER

1. CLIMATE

Meteorological data is available from Miri, 16 miles to the north (3). Rainfall records start in 1917, full data being recorded from 1951. Miri, although lying on the coast should be reasonably representative of the climate at Luak. A rain gauge has been established at Tiris (Bekenu) since 1958, 12 miles southwest, and during 1962/3 rain gauges have also been set up at Tg. Lobang (Miri), the Miri-Bakong road and at Niah, 24 miles distant.

The mean monthly shade temperature at Miri from 1951-63 is shown in figure 1. It is characterized by a small range greatly exceeded by the monthly mean diurnal range (figure 2). It appears that higher mean temperatures can be expected between March and October with a correspondingly greater range in diurnal temperatures. Extreme maximum and minimum temperatures, exceeding 93° and 68° F respectively, are rare.

Soil temperatures at Miri (in sandy soil) on exposed ground at depths below two to three inches are equable and higher than the air (shade) temperature. At 12 inches depth the monthly mean daily temperature remains between 84° and 88°F, (fig. 3): data from Bintulu in similar soil at 48 inches depth indicate that temperatures vary between extremes by only 1.5°F. the temperature being consistently 5-6°F higher than in the air (shade).

Soil surfaces exposed directly to radiation from the sun probably reach temperatures in excess of 120°F under favourable conditions. Temperature fluctuations on a sunny-with-cloud day at the soil surface exceed 20°F within a few minutes (to judge by experiments carried out at Kuching airport).

The mean annual rainfall at Miri expressed as five year running means from 1917-63 varies between 107 and 155 inches. The mean monthly distribution (fig. 4) reveals a generally wetter season between September and January with a minor peak in June. A similar distribution occurs at Niah, Tiris and the Miri-Bakong road. Extreme monthly rainfalls, also shown in figure 4, indicate the great variability in most months - in January for example, ranging from about 25% to 500% of the mean. Under Mohr and van Baren's (4) classification the climate is 'continuously wet' throughout the year, since the mean rainfall of each month exceeds four inches, and 'continuously very wet' from September to January and in May and June when the mean monthly rainfall exceeds eight inches. The implication is that the soils are normally subject

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Fig.4.

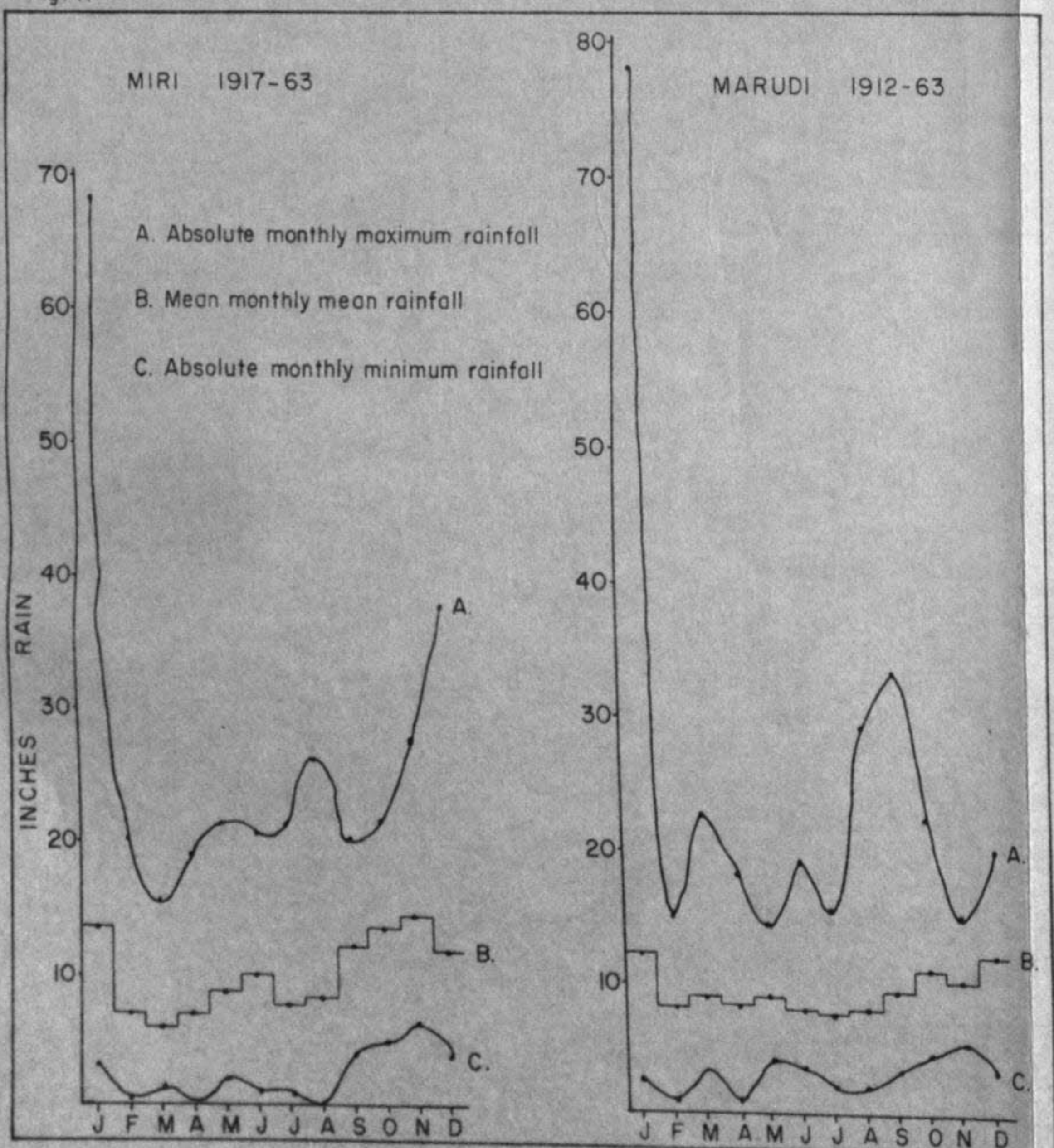
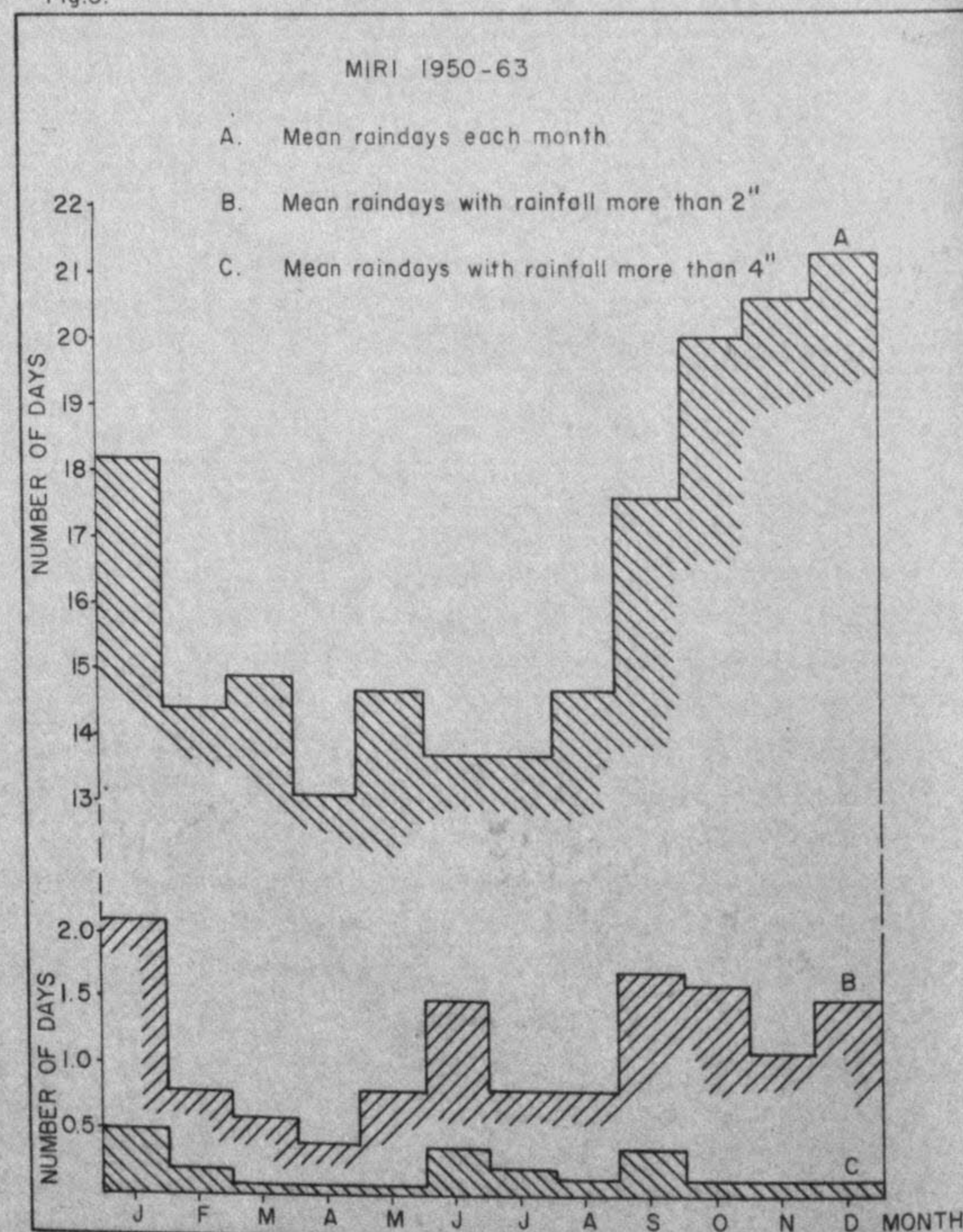

MIRI 1917-63
MARUDI 1912-63
A. Absolute monthly maximum rainfall
B. Mean monthly mean rainfall
C. Absolute monthly minimum rainfall
INCHES RAIN
70
60
50
40
30
20
10
80
A.
B.
C.
J F M A M J J A S O N D

Fig.5.


MIRI 1950-63
A. Mean raindays each month
B. Mean raindays with rainfall more than 2"
C. Mean raindays with rainfall more than 4"
NUMBER OF DAYS
22
21
20
19
18
17
16
15
14
13
2.0
1.5
1.0
0.5
A
B
C
J F M A M J J A S O N D MONTH

to continuous leaching and never thoroughly dry out - incoming rainfall passing through the soil exceeds the amount evaporated and used by vegetation.

An examination of the length of dry periods with no rainfall (less than 0.1 inch/24 hours) shows that periods of 8 to 15 consecutive dry days are common at Miri, particularly between March and August, the longest dry spell recorded being 23 days. The mean number of rainless days per month is least from October to December at 10 to 11 days and the most from March to August at 18 to 14 days (fig. 5). The actual number of occasions with monthly rains less than 2½, 4 and 8 inches and of rains more than 10, 20 and 30 inches are shown in figure 6.

The Drainage and Irrigation branch of the P.W.D. installed an exposed, class 'A' evaporation pan at Miri in May 1963. The monthly mean, maximum and minimum daily readings are shown in fig. 6. The total monthly rainfall is plotted against total monthly evaporation in figure 7. Although readings are only available for the single year and therefore cannot be used as accurate long-term forecasts the indication is that evaporation is highest from March to July and lowest in December: evaporation exceeded rainfall in March, April, June, August, September and October. These figures can be taken as a measure of the probable maximum evaporation from a free water surface such as in a wet padi field. Evaporation from the soil can be expected to be less than the above figures, particularly under forest where incoming radiation is greatly reduced. On the other hand it has been estimated that incoming rainfall is also reduced, by as much as 15% to 30% under different kinds of vegetation by interception and evaporation (4,5). Further important losses of rainfall can be expected on hill land through surface runoff.

To summarise from the evidence available it is clear that from October to January or February it is cooler and wetter than from March to September. During this latter period a few, long dry spells can be expected in most years during which evaporation probably approaches or even exceeds the rainfall absorbed by the soil. The result may be a deficiency of soil water for certain crops. This facet of the climate is relevant in assessing padi irrigation water requirements. To obtain accurate information it would be essential to install evapo-transpiration recording equipment, various soil water and possibly soil temperature recording devices in addition to the normal meteorological equipment on the station.

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Fig. 6.

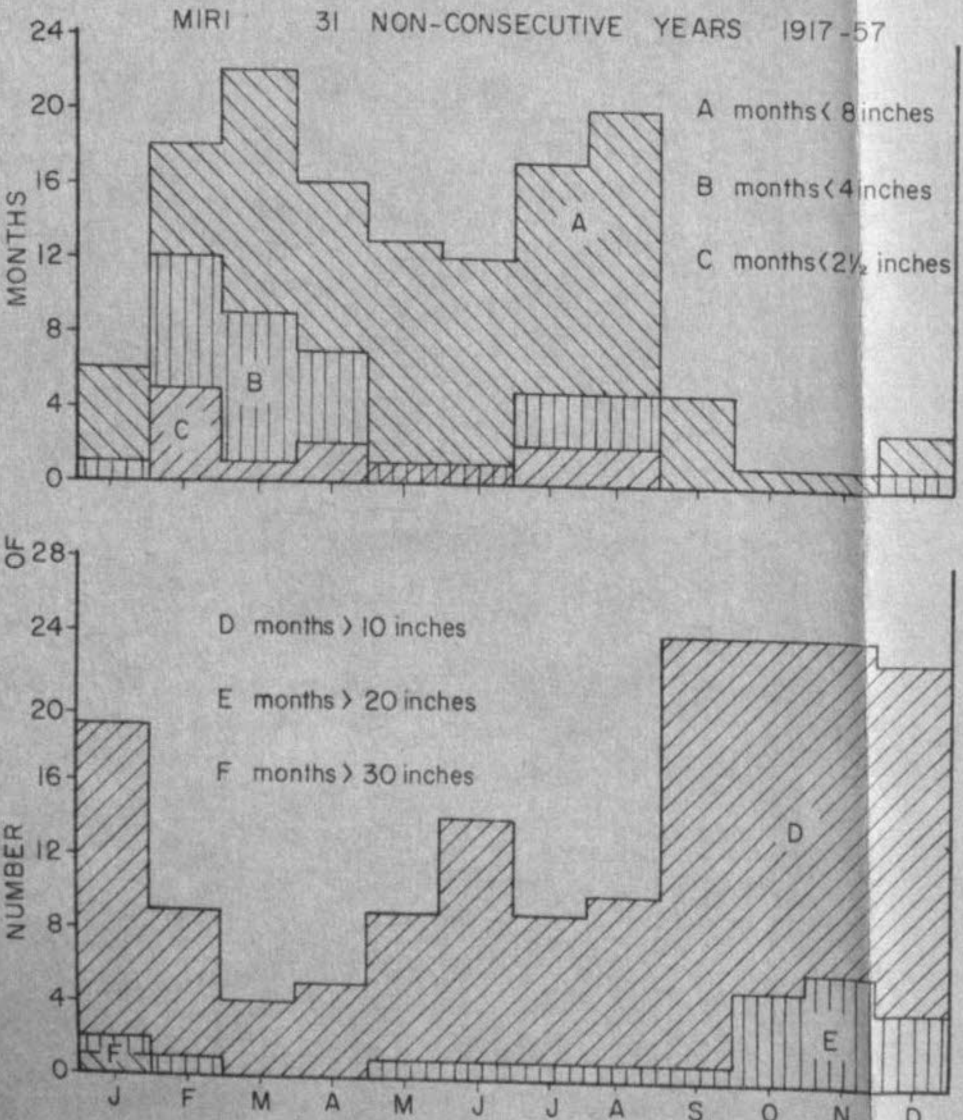
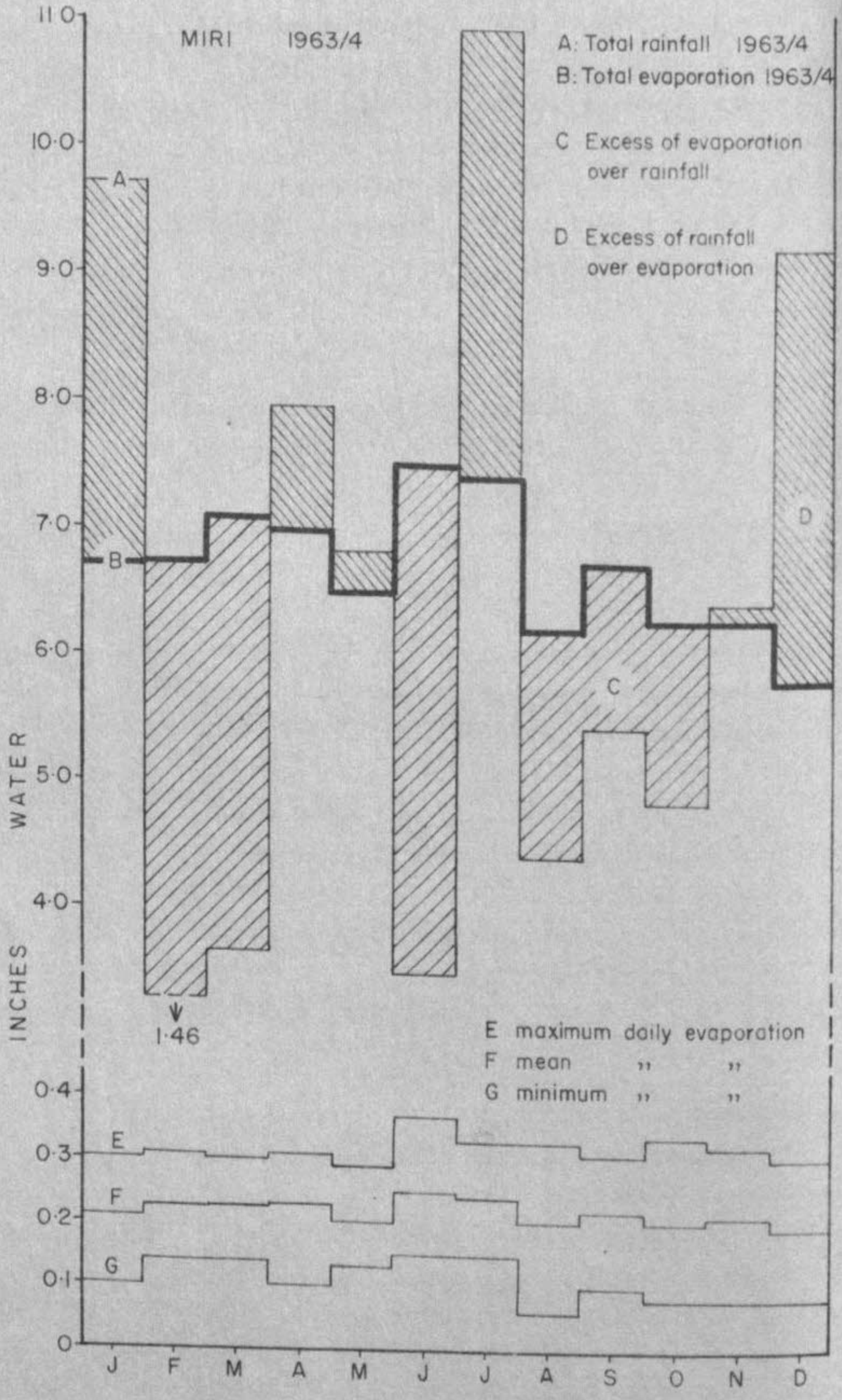

MIRI 31 NON-CONSECUTIVE YEARS 1917-57
A months < 8 inches
B months < 4 inches
C months < 2½ inches
D months > 10 inches
E months > 20 inches
F months > 30 inches
NUMBER OF MONTHS
J F M A M J J A S O N D

Fig. 7.


MIRI 1963/4
A: Total rainfall 1963/4
B: Total evaporation 1963/4
C Excess of evaporation over rainfall
D Excess of rainfall over evaporation
1·46
E maximum daily evaporation
F mean " "
G minimum " "
INCHES WATER
J F M A M J J A S O N D

2. GEOLOGY

A Geological Survey Memoir by Wilford (6) includes descriptions of the geology of this area. Briefly, the land is underlain by sedimentary rocks of Miocene age covered by extensive belts of Quaternary alluvium. In a few places peat is accumulating above the alluvium.

The station lies wholly within but close to the boundary of the Sibuti Formation. The lithology of this formation is described as 'clay and shale with subordinate siltstone, calcareous sandstone, limestone and marl'. Augerings and pits dug during the survey revealed grey to dark grey shale, calcareous shale and mudstone and fine to medium sandstone. The sandstone occurs largely in the northeast as thick beds striking roughly eastwest and dipping north. Shale underlies most of the remaining land and has a weakly expressed eastwest strike. The conformable, younger Lambir Formation outcrops just north of Sg. Luak. It consists of sandstone and shale mainly and it is possible that the sandstone in the northeast of the station is an outlier of this Formation.

The alluvium is predominantly of local origin, clayey and recent. The deeper clay beds, on chemical and geomorphological evidence, can be shown to have affinities with estuarine material. The upper sandier beds, however, have been laid down by existing streams and by colluviation from the hills. The sand is largely siliceous and of fine to medium grade. Almost certainly the sand contains only very low amounts of weatherable minerals: the clay fraction is probably dominated entirely by kaolin. Older, Quarternary, white quartz sand occurs in the centre of the area as a small terrace. Peat is accumulating in the more poorly-drained alluvial areas.

3. TOPOGRAPHY

Of the two broad divisions hill land and flat land, the former can be subdivided into:- ridges of the northeast, terraces, low rolling land and the remaining low hills and ridges. Hills comprise about 60% of the station. Figure 8 gives an outline of the land forms.

Hill land In the northeast corner are the highest hills on the station, but they are only an estimated 40 to 80 feet above adjacent valleys. Their general shape tends to be asymmetrical: they are elongated with the strike of the rocks, which dip north, so that steep scarp slopes face south with gentler dip slopes facing north. A line of almost cliffed slopes marks an abrupt boundary with the lower country to the south. Streams incised into the lower slopes cause a break of slope about 10 to 15 feet above local base level: below this break slopes are steep and stoney; above, the slopes are generally 20-25° on the dip slope and as much as 30° to 50° on the scarp slope. This land is underlain chiefly by thick beds of fine sandstone alternating with shale. Small landslips have taken place on the higher, steep slopes.

Near the centre of the station a small area of terraces occurs, the tops of which are about 15 to 25 feet above local base level. The flat tops are deeply cut into by gullies leaving steep under edges.

Low, gently-rolling land forms the main topography of a fairly large area in the east and smaller patches in the south and west. The amplitude of relief is generally less than 10 feet and slopes are commonly less than 5 to 8°. The land merges imperceptibly into adjacent alluvium and into the lower slopes of the low hills described next. The underlying rock is calcareous shale or mudstone in the east and south.

The remaining hills are characterised by an amplitude of relief of less than 40 feet and slopes between 10° and 30°. The steeper slopes are largely due to stream incision and can be found chiefly in the southeast and south. Many hills are isolated or occur as small groups separated by alluvial land. The rocks beneath consist of shales with subordinate fine sandstone.

<u>Flat land</u> Three distinct types of land characterise the low lying alluvial areas:- the high levees in the northwest, the low basins occurring largely in central areas and the better-drained flat land predominant in the south.

Sg. Luak and its distributary Sg. Luak Damit have produced moderately high levees which grade gently down to adjoining basins. The surface of the levees is gently undulating and their width from the river banks ranges from 200 to more than 500 feet.

The basins of the central areas are practically flat, rising gently to low incipient levees bordering non-permanent streams. This land is separated fairly sharply from hill land by a distinct break of slope. Alluvial basins in the south tend to be less flat; gentle slopes grade away from streams and the footslopes of hills and there is a gradual transition to the low rolling land described above.

The recent geomorphological history of the area can be deduced from evidence of the land forms themselves and from the sequence of events proposed by Liechti and Wilford (7,6). The accordant summits of the lower hills are similar in height to the terrace remnant and almost certainly represent part of the Jerudong Erosion Surface which is of late Middle Pleistocene age. At this time the higher hills in the northeast would have remained as low monadnocks or islands when the rest of the area was largely at or below sea level. It is possible therefore that the whole area, with the exception of the northeast, was subject to alluvial aggradation during the Middle Pleistocene: the only definite evidence of this is the terrace but patches of ridge soils containing pale-coloured, sandy, upper subsoil may represent vestiges of a former, more widespread alluvial covering.

Either prior to or following the establishment of the Jerudong Erosion Surface there were eustatic changes resulting in down-cutting by rivers to depths of as as much as 250 feet below present sea level in coastal areas; this phase of active erosion, which caused the formation of deep, wide valleys, was followed by aggradation to heights just above present base level: the deposited material was both fluviatile and marine. In more recent times a phase of down-cutting has been responsible for the formation of low terraces, about 10 - 15 feet above local base level, such as those near Sibuti (2). This sequence of events explains the presence of large belts of alluvium containing misfit streams, the chemical affinities of the clay soils with estuarine material and the comparatively good internal drainage of the alluvium compared with that in other areas which are rapidly collecting peat.

4. DRAINAGE

The whole station lies within the drainage system of Sg. Setap (see soil map). Two main, true right-bank tributaries of this river drain the station. Sg. Luak flows along the northern boundary and Sg. Kabuloh runs just within the southeast corner: both are permanent streams with fresh water whose sources lie in the nearby Lambir Hills.

Sg. Luak Damit is a permanent distributary of Sg. Luak running a meandering course through the northwest corner. Sg. Pintasah, a small, misfit, non-permanent tributary of this stream derives from and drains most of the northeast part of the station.

Low hills straddled eastwest across the centre form a low watershed between the Sg. Luak system and that of a small semi-permanent, misfit stream which is probably a tributary of Sg. Kabuloh. This stream derives from low rolling land in the east and drains most of the southern part of the station, except in the southeast corner where a number of non-permanent streams drain independently to Sg. Kabuloh.

The presence of the old Bulak-Setap road has caused the formation of one or two boggy patches near the road within the station, presumably due to a lack of or collapse of culverts. Adequate drainage at these points would ameliorate such conditions.

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Floods occur fairly regularly on the alluvial land, mainly during the 'landas.' Local Iban, however, say that they are of short duration and rarely deep. During the 1962/3 exceptional 'landas', floods were three to four feet deep, while rain persisted, but drained away rapidly afterwards. (2).

The banks of Sg. Luak and Sg. Luak Damit are sandy, which, together with the predominantly argillaceous nature of soils and rocks of the area, suggests that the river is subject to flash floods following heavy thunderstorms in the Lambir Hills. The small misfit streams in the rest of the station have nearby sources and even during prolonged heavy rain will probably collect insufficient water to spread more than a thin sheet of water over the large expanses of alluvium through which they flow. There is no tidal backing-up of water in Sg. Luak or Sg. Kabuloh and flood water has few impediments in escaping downstream.

As stressed in Report No.35/1 (1) and in section 2 above detailed investigations of stream behaviour coupled with rainfall, soil lysimeter and evaporation work would be required in assessing the soil water balance, likelihood of flooding, irrigation requirements and plant-soil water relationships.

5. VEGETATION

Referring to the vegetation map (map 1) it can be seen that large areas are covered by old (estimated at over 15 years) secondary vegetation. This is forest characterised by a thick undergrowth of saplings, young trees, abundant creepers and a few large trees. It is possible that this is a special type of Riparian Forest since it is distributed chiefly on alluvial land. Local Iban, however, say that parts of the station were used by nearby Rh. Bedit for hill padi 'a long time ago'.

More recent secondary forest, also following from hill padi cultivation by Rh. Bedit, occurs alongside the Bulak-Setap road, Sg. Luak and in a re-entrant in the south. Tall grasses, ferns, saplings and young trees are dominant, estimated at less than 15 years old and in some places less than five years. Seedling rubber has been planted in the southern re-entrant.

The primary forest is good quality Lowland Dipterocarp. The lower hills contain common large girth trees identified by local people as 'paji' (a type of kapor), 'tapang', 'kelampai' (Iban), 'ubah merah', 'kemadu' (Ib.), 'resak' (Ib.), 'mere-Kubong' (Ib.), 'jeruit' (Ib.) and 'barun' (Ib.). The 'paji' may be the tree with light crowns identified on air photographs and mentioned in Report No. 35 (2). The higher hills in the northeast contain less thick forest which includes

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'bindang', a palm commonly found on rather poor, shallow soils derived from fine sandstone.

PART II - SOILS

1. METHODS OF SURVEY

The manner in which semi-detailed surveys are conducted is now becoming standardized in Sarawak. Air photograph interpretation had to be used in this case to produce a base map showing as much topographic detail as possible in the absence of any suitable large scale map. Normally air photograph interpretation cannot be used to any great extent in semi-detailed surveys unless the photographs are of large scale and good quality.

In the field, with a base at the junction of Sg. Luak and the Bulak-Setap road, a parallel rentis grid was cut at a 500 foot interval, along which auger descriptions were made at least every 500 feet in significant locations. From these a tentative soil classification and soil map were produced. Pit and auger samples were taken in representative sites, analyses of which allowed the retention or amendment of the classification and map. The total area is slightly more than 100 acres, the total rentis length is about 29 miles and 63 samples were collected for survey analysis and 130 samples for agronomy analysis.

The rentis grid was found to be inaccurate at lengths exceeding half a mile. A field party returning to the area cut two precise check rentises which has enabled the completion of a reasonably exact base map. The soil boundaries are correct along rentis lines but due to the difficulty of access between rentises the inter-rentis boundaries are less reliable in places. The map will therefore be satisfactory for preliminary general planning but can be no substitute for an accurate, detailed soil map prepared with a 5 to 10 foot contoured base map at a scale no smaller than 1:5,000.

2. SOIL CLASSIFICATION

Prior to 1964 the emphasis on soil mapping lay heavily on reconnaissance surveys with the aim of covering large areas in comparatively short times. The units used for mapping and descriptive work were Soil Associations, which are simply groups of soils, easily recognised in the field and on air photographs and which are preferably, but not necessarily, genetically related.

During 1964, however, the need and opportunity has arisen for the use of the basic soil unit, the Soil Series, with an increasing number of detailed and semi-detailed surveys being requested. It is possible to map a series only after much detailed ground work and individual series are not generally recognisable on air photographs. Many series are established already, while a number of new series have been named provisionally.

The grouping together of similar kinds of series related genetically forms the next higher class of soil, the Soil Family, of which a number have been established provisionally. A further grouping of families, again based on pedogenesis leads to the Great Soil Groups: this is the lowest class of soils in general use in international comparisons while the class of Soil Family or Soil Series is normally used at a national level. (Table 1).

TABLE 1

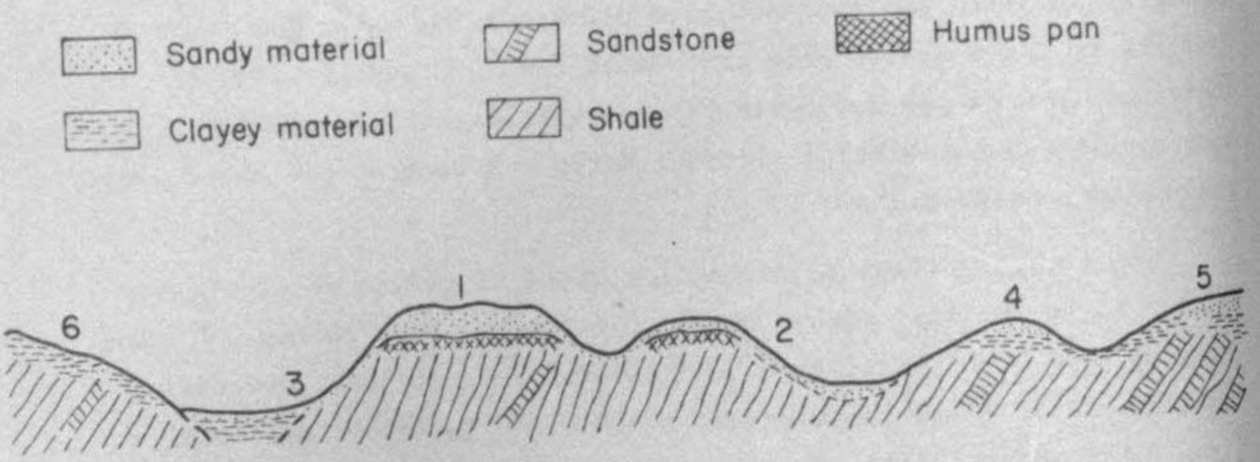
Scheme of Soil Classification

ORDER	SUBORDER	GREAT SOIL GROUP	FAMILY	SERIES
ZONAL	PODSOL	RED-YELLOW PODSOLIC	'NYALAU'	'LIKAU' 'LABANG' 'LUAK' 'KABULOH' 'PINTASAH'
		HUMUS PODSOL	'MIRI'	MIRI
INTRAZONAL	HYDROMORPHIC	YELLOW-BROWN HYDROMORPHIC	'MALANG'	MALANG
			'SEMILAJAU'	SEMILAJAU
		LOW-HUMIC GLEY	'PLAN'	SALITUT
			'SAMARAHAN'	SAMARAHAN
		HALF BOG	'ABON'	'ABON'
AZONAL	-	LITHOSOL	NOT MAPPED	
		RECENT ALLUVIAL	UNDIFFERENTIATED	

Inverted commas indicate that the name is provisionally established.

Above the level of the Great Soil Groups and increasingly broader in scope and definition are Soil Suborders and Orders, based on pedogenesis. The precise definitions of Great Soil Groups through to the Orders has never been uninamously agreed upon by soil scientists and various schemes crop up regularly year after year with only limited

Fig. 9. RELATIONSHIP BETWEEN MIRI SERIES AND OTHER ASSOCIATED SERIES



1 MIRI SERIES

2 MIRI SERIES shallow phase

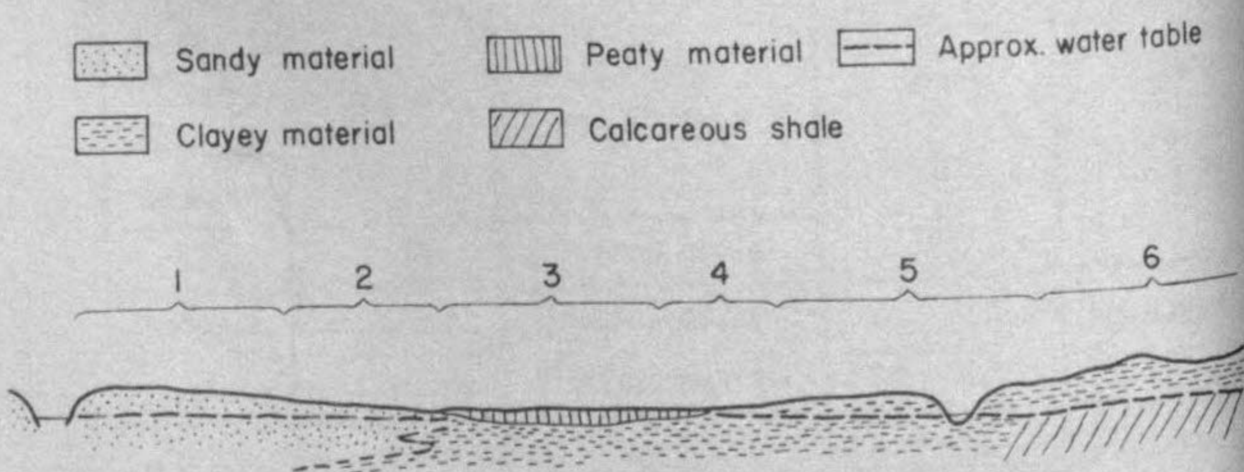
3 Undifferentiated colluvium/alluvium

4 'LABANG SERIES'

5 'LIKAU SERIES'

6 'LUAK SERIES'

Fig. 10. RELATIONSHIP BETWEEN ASSOCIATED LOWLYING SOILS



1 SEMILAJAU SERIES

2 SALITUT SERIES

3 'ABON SERIES'

4 SAMARAHAN SERIES

5 MALANG SERIES

6 KABULOH SERIES

acceptance. The scheme and definitions adopted in Table 1 and the following paragraphs follows that at present used in Sarawak.

3. GENERAL CHARACTER OF THE SOILS.

The parent material from which most of the residual soils is developed is predominantly argillaceous with subordinate fine, and rare medium, arenaceous material. The shales are largely grey to dark grey, probably carbonaceous, in some cases calcareous, and contain moderate amounts of iron. The climate is typical of the humid tropics with a uniformly high temperature and a high annual mean but erratic monthly rainfall. During the greater part of the year the rainfall is probably sufficient to maintain an overall leaching process, but it is likely, between March and September in particular, that there will be lengthy periods when leaching is negligible or even absent and the soils begin to dry out.

The predominant soil-forming process is therefore podsolization and by the definitions suggested by Harris (8) the residual soils are provisionally considered as Zonal and belonging to the Red-Yellow Podsolic Great Soil Group (Table 1); further analytical data however, may reveal features common to Latosols, particularly in the shale-derived soils. The more sandy and siliceous the parent material, the more obviously the podsolization process is expressed in downward translocation of sesquioxides, clay and soluble bases. This results in light-coloured and light-textured A2 horizon in comparison with the underlying B2 horizon.

Red-Yellow Podsolics. The 'Likau Series' is the most strongly podsolized residual soil and consists of brownish yellow sandy loam increasing with depth to brownish yellow or yellowish brown sandy clay loam to sandy clay. The depth to weathering rock is generally less than 30 inches.

The least clearly podsolized residual series are the 'Luak', 'Pintasah' and Kabuloh Series. All comprise yellow to yellowish brown clay loams on clays with an indistinct A2 horizon. The B3 and C horizons tend to be mottled light grey and reddish brown to strong brown, due to impeded soil drainage above the more or less impermeable parent rock. Iron accumulates as thin skins around and impregnated within weathering shale and fine sandstone fragments. Yellow mottles within the A and B horizons are commonly associated with weathering rock fragments of lighter texture than the matrix. Such spots provide localized situations for water retention and incipient gleying. Similarly, root channels commonly become filled with coarser material than the matrix after the root has died and this material can exhibit pale, gley colours surrounded by a reddish yellow halo. This is due either to depletion (centre) and an accumulation (halo) of iron through leaching process and/or localized gleying due to such channels being preferential conductors for all incoming rain. Soil depths generally range between 20 and 40 innhes, roots being only slightly impeded by stoniness.

The 'Labang Series' shows a clear textural increase from the A2 to B3 horizons. The A2 resembles that of the 'Likau Series', the B horizons those of the 'Luak Series'. It is presumed that the parent rock includes fine sandstones with shale; it is also possible that colluviation has had some effect. Since the hills with 'Likau Series' have a similar geomorphological history to the terrace the sandy nature of their profiles may also reflect the former presence of sandy terrace material that has since largely been eroded.

In most residual soils an examination of profile faces showed only weak structural development of a blocky nature. Clay illuviation into the B horizon however is evident as clear clay skins coating the few, deep, vertical cracks. Permeability is highest in the 'Likau Series', lowest in 'Luak', 'Pintasah' and 'Kabuloh Series.'

The risk of erosion is not great, except in 'Labang' and 'Likau Series' where slopes exceed 15° to 20°. Clearing and burning will expose the surface to heavy rainfall and since roots no longer bind the topsoil the upper sandy horizons will be prone to removal.

Humus Podsols belonging to the Podsol World Soil Group (Table 1) occupy only a small area. Conditions for this extreme podsolization are ideal; a heavy rainfall, a highly porous solum, highly siliceous minerals, level topography, weakly permeable substrata and availability of humus in the topsoil. It is felt that the formation of the soil took place largely before it was stranded as a terrace when the area was more or less at base level during mid Pleistocene times. In other words the soil probably formed initially as a Ground Water Podsol, the main barrier to complete leaching being the ground water table, which held up illuviated humus compounds and particles to form the characteristic dark brown B2 horizon. It is also possible that the B horizon formed over more or less impermeable substrata such as shale, either in the presence of the ground water table (possibly perched) or without it altogether. Normal residual soils occupy the lower flanks of the terraces and nearby hills thus the thickness of terrace material is probably less than 10 to 15 feet before shale is reached. (fig.9).

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The profile consists of deep, white, single grain quartz sand in the A2 lying over a dark brown, loamy sand B2 at 30 to 40 inches depth. The profile is the same as the Miri Series and it is therefore presumed that the terrace is marine and not riverine. Riverine terraces generally consist of less well-sorted material than the present example, while marine terraces are almost invariably well-graded and well-sorted quartz sands.

Erosion has stripped sand from the terrace flanks causing the profile to be shallow in places. Neighbouring ridges with pale, sandy upper subsoils are possibly remnants of a former terrace cover, but since the overall profile is similar to the 'Labang' or 'Likau Series' they are mapped as such. A perched water table lies over or within the B2 horizon.

In the lowlying alluvial land are Intrazonal Soils representative of the Low Humic Gley, Yellow-Brown Hydromorphic and Half Bog Great Soil Groups (Table 1). All owe their origin to alluvial deposition in a more or less hydromorphic environment. The influence of climate on their formation is indirect, the main influence being topographic situation, hence the Intrazonal classification.

The <u>Half Bog Soils</u> occupy the flat, lowlying, most poorly drained patches (fig. 10). Peat has developed under anaerobic conditions to depths not exceeding 36 inches over gleyed clays. The main soil is the 'Abon Series'. <u>Low Humic Gley Soils</u> are more widespread and occupy slightly better drained positions (fig. 10). Characteristically they have a greyish brown to yellow brown clay loam to clay topsoil and upper subsoil overlying, within 24 inches gleyed and mottled subsoil clays which are often waterlogged. It is possible that the clays underlying Half Bog and those in the Low Humic Gley Soils are partially of estuarine origin (see section 5). The principal soil is the Samarahan Series.

<u>Yellow-Brown Hydromorphic Soils</u> are also widespread in the better-drained sites of levees and footslopes (fig. 10). The water table is deep and by definition heavily gleyed horizons do not occur within 24 inches of the surface, which is predominantly yellowish brown to yellow in colour. Waterlogging may occur periodically during floods but is of sufficiently short duration to leave only a few permanent traces of gleying in the upper subsoil. The sandy variety has a better internal drainage and is termed Semilajau Series, the clayey variety is called Malang Series and contains more distinct mottling in the deeper horizons.

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<u>Azonal Lithosols</u> (Table 1) can be found in a few small patches in the northeast where landslides and steep slopes occur. Due to their very limited distribution they are not mapped. Azonal Recent Alluvial Soils of mixed colluvial/alluvial origin have also been noted among the steeper gullies in the hills ranging from sands to stony sandy clay loam but with little or no genetic profile differentiation apart from a shallow A1 horizon. These soils are mapped and classed as undifferentiated, unnamed alluvium.

4. SOIL SERIES DESCRIPTIONS

The following descriptions enable the characterization and easy recognition of the series; they should also facilitate differentiation between similar series. Some have been established elsewhere and are known to have a wide distribution; others, however, are described for the first time in this report and it is not certain yet whether the provisional range of characteristics described below will be adequate after having encountered the same soil elsewhere.

A few series have a very limited distribution within the station. Samples have not been analysed of these soils and in cases where detailed descriptions are available from their type areas these are included with notes on the degree of variation to be expected in the station.

1. 'LIKAU SERIES' (provisional)

This soil is classified as a member of the Nyalau Family in the Red-Yellow Podsolic Great Soil Group.

It is derived from sandstone, predominantly fine, with subordinate shale and consists of yellow to brownish yellow (fine) sandy loam on (fine) sandy clay loam grading to (fine) sandy clay. Light grey and reddish brown mottles occur in places in the deeper subsoil. There is a distinctive plastic yet friable consistency in well-moistened soil.

<u>GENERAL DESCRIPTION</u>

Horizon	Depth	
O	2 to 0 - 0	Impersistent, but commonly as thick as two inches.
A1	0-2 to 4"	Grayish brown to dark yellowish brown (fine) sandy loam to (fine) sandy clay loam; very friable; well-rooted.
A2	- 8 to 2"	Yellow to brownish yellow (fine) sandy loam to (fine) sandy clay loam, friable; moderately well-rooted.

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B	- 30 to 48"+	Brownish yellow (fine) sandy clay loam to (fine) sandy clay; weakly mottled light grey and reddish brown; firm to very firm; poorly rooted.
C	generally within 48"	White to brownish yellow parent material.

RANGE OF CHARACTERISTICS

Parent material: Tertiary, fine to medium siliceous sandstone, in Fourth Division largely of Miocene age. Shale may be present but it is always subordinate.

Topography: generally on moderately high to high hills; dissected, with slopes largely greater than 20°. This series commonly occurs on ridges, with more clayey soils on the lower slopes, and on shelves of scarp slopes.

Occurrence: established in Fourth Division where it is known to be widespread. It is probably present in all Divisions but has only been mapped as a series in Third and Fourth Divisions. In the station the soil does not have a wide distribution.

Diagnostic Horizons: within auger depth (48 inches) the following genetic horizons are generally present.

O1 - 2 Commonly ½ to 2 inches, but generally absent after cultivation.

A1 Thin but distinct. Cultivation combined with erosion may remove or obscure it.

A2 Usually a clear contrast to lower horizons. Variable thickness.

B2 Generally deep.

C Commonly present and merges with the B horizons.

In Third Division the soil appears to be deeper with a more uniform profile and a less clear change between A2 and B2 horizons.

Colour: The colour throughout is a fairly uniform brownish-yellow to yellowish brown and largely of 10YR hue, although deeper subsoils may grade towards 7.5YR. The A1 is dark where present. Mottling is not generally present in the upper subsoil but may appear as faint to distinct, pale yellow to light grey and reddish yellow to reddish brown in the B2 or C horizons.

Texture: fine to medium sand grades predominate. There is always an increase in clay from A to B horizons, generally from sandy loam or sandy clay loam through to sandy clay at depth.

Structure and consistence: the topsoil commonly exhibits a weak crumb structure and is always friable to very friable. The A2 horizons show little or no structural development while B horizons may have weak indications of blockiness. The consistence of horizons with fine sandy clay loam textures is distinctive. When moist to wet the soil is friable to firm yet plastic and non sticky. The plasticity seems to be connected with a high proportion of very fine sand and silt.

Inclusions: only in the B and C horizons are stones commonly present. Generally they consist of pieces of soft to hard sandstone, although it is not unusual to find iron-coated shale fragments.

Drainage: internal drainage is good, external drainage ranges between rapid and slow.

Rooting depth: no appreciable impediment to roots occur within the solum until the C horizon is reached at depths varying from about 30 to 48 inches plus. The soil is not well rooted below the A1 horizon however.

Phases: a shallow phase of less than 24 inches to weathering rock is present but not common. More poorly-drained phases also occur in which mottling in the subsoil is more pronounced but these are not common.

CHEMICAL AND MINERALOGICAL DATA

Clay minerals: Kaolin dominant (one profile).

Sand fraction: quartz dominant. Heavy fraction consists of a Zircon Association in which tourmaline, garnet and rutile also occur. (one profile).

Silica/sesquioxide ratio:

Cation exchange capacity (milli equivalent %): less than 8 generally. A peak in the A1 and commonly in the B horizon.

Base saturation (%): generally less than 3 to 5 except in the A1.

Acidity: between pH 4.0 and 5.0 throughout.

'Reserve' phosphorous (ppm): about 150 in the A1, uniformly less than 100 in the subsoil.

'Reserve' cations (ppm):-

calcium - widely variable in the A1, 50 to 150 in subsoil.
magnesium - lowest in the A1 at 200 to 1000, rising steadily to a peak of 1,500 to 2,000 in B horizon.
potassium - lowest in the A1 at 800 to 1,500, rising steadily to a peak of 3,000 to 6,000 in B horizon.

Group III elements: less than 5% in the A1 rising to a peak in the B horizon of 10% to 12%.

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Remarks: the soil characteristically has a low base exchange capacity and low base saturation, reflecting the dominance of kaolin and quartz and the lack of weatherable minerals in the parent rock. Strong leaching is reflected in the 'reserve' figures of potassium and magnesium and in the group III elements.

FEATURES DISTINGUISHING LIKAU SERIES FROM SIMILAR SERIES:

1. Nyalau Series: is closely similar but has a bright reddish yellow B horizon and tends to be slightly more sandy.

2. 'Labang Series': the A horizons are closely similar but this has a clay loam or clay B horizon.

3. Pasai Series: has similar textures but is mottled well into the A2 horizon; colours are more reddish yellow.

4. Tebakang Series: has similar textures but is derived from Triassic sandstones and is found so far only in First Division. The deeper subsoil is more reddish yellow.

2. ' LABANG SERIES ' (provisional)

This series is provisionally established hence the inverted commas. It is classified as a member of the 'Nyalau Family' in the Red-Yellow Podsolic Great Soil Group.

The soil is derived from Tertiary shales and fine sandstones. It consists of yellow to yellowish brown fine sandy loam to fine sandy clay loam overlying clay loam, then clay of a brownish yellow verging to reddish yellow colour. The deeper subsoil is slightly mottled and commonly contains iron-rich shale fragments. The descriptions below deliberately cover a wide range since the nature of the soil development itself is more complicated than normal.

GENERAL DESCRIPTION

HORIZON	DEPTH	
O	1-½ - 0	Impersistent but commonly ½ to 1 inch humus.
A1	0 - ½ to 5"	Dark greyish brown to yellowish brown fine sandy loam to fine sandy clay loam; very friable, crumby; well rooted.
A2	- 12 to 24"	Yellow to yellowish brown fine sandy clay loam; friable; moderately well rooted.
B2	- 48"+	Brownish yellow to reddish yellow clay loam to clay distinctly mottled light grey to pale yellow and reddish yellow to reddish brown; firm to very firm and dense; moderately well rooted; common iron-rich and iron-coated stones.

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C	Generally beyond auger depth. Light grey to dark grey shale with fine sandstone, above which may be heavily mottled light grey clay.

RANGE OF CHARACTERISTICS

Parent material: strongly weathered shale and fine siliceous sandstone of Tertiary age, so far within the Plio-Miocene period only. The sandstone is generally fine in grade and is sufficiently common to give a distinctly sandy upper subsoil.

Topography: generally low to moderately high hills with gentle to steep slopes as much as 35.

Occurrence: established in Fourth Division where it is known to be widespread from Btg. Tatau northwards. Also occurs in Fifth Division. It has a fairly wide distribution in the station.

Diagnostic horizons

O1 - 2	Impersistent and commonly absent altogether.
A1	Thin and distinct but commonly absent after cultivation.
A2	By definition this horizon should be distinct and in clear contrast to lower horizons. Should be at least 12 inches deep.
B2	Generally deep.
C	Commonly present and merges to parent material.

Colour: the range is from 10Yr to 7.5YR in the A and upper B horizons - usually ranging from yellow, brownish yellow and yellowish brown to reddish yellow. Mottling in the B3 and C horizons is distinct to prominent and ranges from light grey to yellow and red. The light grey commonly becomes sufficiently prominent to form the matrix colour. The shale is generally light to dark grey.

Texture: by definition the A1 and A2 should have sufficient sand to be classed (fine) sandy loam to (fine) sandy clay loam: combined, they should be at least 12 inches deep. The B horizons should be clay loam to clay.

Structure and consistence: the A1 is generally weakly crumby and very friable; the A2 is structureless, friable to firm but plastic and non sticky when moist to wet - possibly due to the high proportion of very fine sand to silt. The B2 is firm to very firm and weakly blocky.

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Inclusions: in the B and C horizons it is usual to find stones but they vary in quantity from few to abundant. They generally consist of weathering fragments of shale or fine sandstone, coated and impregnated with iron.

Drainage: internally, the series varies from imperfectly to well drained. In this area it is generally imperfectly to moderately well drained. External drainage, or run off, is medium to rapid depending on slope.

Rooting depth: the only impediment to rooting is when stones become abundant in the lower subsoil. The soil is generally moderately well rooted in the subsoil and well rooted in the topsoil.

Phases: the shallow phase of less than 24 inches to weathering rock occurs but is not common. All drainage phases from well to imperfectly drained have been noted in the station.

CHEMICAL AND MINERALOGICAL DATA

Clay minerals: not analysed but probably dominated by kaolin.

Sand fraction: not analysed but probably dominated by quartz and others resistant to weathering.

Silica/sesquioxide ratio:

Cation exchange capacity (milli-equiv.%): between 5 and 15 in the topsoil, 5 to 8 in the A2 and increasing slightly within the B horizons.

Base saturation (%): generally between 2 to 8 with a definite peak in the topsoil.

Acidity: between 4.0 and 4.8 throughout.

'Reserve' phosphorous (ppm): 100 to 150 in topsoil, uniformly less than 100 in subsoil with a slight rise in the C horizon.

'Reserve' cations (ppm):

calcium	-	widely variable in topsoil, 100 to 200 in subsoil with a distinct peak in the B horizon.
magnesium	-	about 500 to 700 in the topsoil rising steadily with increasing depth to 2,000 to 3,000.
potassium	-	lowest in the topsoil at about 2,000 rising with depth as much as 9,000 with fairly wide variations.

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FEATURES DISTINGUISHING LABANG SERIES FROM SIMILAR SERIES:

1. Nyalau Series: is similar, but has a sandy clay loam to sandy clay lower subsoil and is less stony and less mottled.

2. 'Likau Series': is similar, but has a sandy clay loam to sandy clay lower subsoil and is less stony and less mottled.

3. 'Luak Series': is similar, but does not have the sandy upper subsoil.

4. Pasai Series: is similar, but has a sandier lower subsoil and is more strongly mottled throughout.

5. 'Ri 'i' and Bedup Series: have similar lower subsoils but are derived from Triassic rocks of First Division.

3. 'LUAK SERIES' (provisional)

This soil is classified as a member of the 'Nyalau Family' in the Red-Yellow Podsolic Great Soil Group. Its structure and degree of expression of the argillic horizon (9) however give it affinities with Harris's (8) Latosolic Podsolic Great Soil Group.

It is derived from shale with subordinate fine sandstone and consists of yellow to yellowish brown clay loam on clay. Light grey and reddish brown mottles commonly occur in the deeper subsoil.

GENERAL DESCRIPTION

Horizon	Depth	
O	2 - 0 - 0"	Impersistent, but commonly as much as two inches thick.
A1	0 - ½ to 4"	Brown to dark yellowish brown loam to clay loam, crumby, friable; well-rooted.
A2/B1	- 6 to 12"	Yellow to brownish yellow clay loam, firm, slightly-blocky; moderately well drained.
B	24 to 40"	Brownish yellow to yellowish brown clay, clearly mottled light grey to pale yellow and reddish yellow to red; very firm to firm; slightly blocky; stony; moderately well-rooted.
C	generally within 48"	Light grey to dark grey shale.

RANGE OF CHARACTERISTICS

Parent material: Tertiary shales, mainly of Plio-Miocene age in Fourth and Fifth Divisions. Light grey to dark grey, carbonaceous, slightly calcareous in places.

Topography: generally on low to moderately high hills: dissected with slopes ranging from less than 10° to more than 30°.

Occurrence: first established in Fourth Division where it has a wide distribution. It is also known to occur in Fifth and probably in parts of Third Division. The soil is widespread in the station.

Diagnostic horizons: within auger depth the following horizons are generally present.

O1 - 2	Commonly absent, but under primary forest may be fairly thick.
A1	Thick but distinct.
A2/B1	There is a contrast between this horizon and subjacent horizons but it is an indistinct and gradual change.
B2	Usually thick and contrasts strongly in colour to the B3, C1 weathering rock zone.
C	Commonly present and merges with the lower B horizon.

Colour: the colour is a fairly uniform yellow to yellowish brown of 7.5YR to 10YR hue throughout until the zone of weathering rock is reached. This is always mottled light grey but may be faint to prominent to become the matrix colour.

Texture: the topsoil may be slightly sandy but clay loam to clay is the main texture throughout. Small patches of sandy clay occur in places if sandstone is present in the parent material, but these are not important. Stones vary from few to abundant in the B horizon.

Structure and consistence: the topsoil has generally a weak to moderate crumb structure and is friable. Beneath, the structure is weak blocky and the moist consistence firm to very firm. The B3 - C1 horizons may be plastic and massive.

Inclusions: yellow to reddish brown iron-rich and iron-impregnated stones vary from few to abundant in the B horizon. They are largely shale with subordinate fine sandstone.

Drainage: internally the drainage is imperfect to moderate, externally it is medium to rapid depending on slope.

Rooting depth: despite the common presence of stones in the B horizon roots do not seem to be hampered. The A1 horizon is the best-rooted.

Phases: a shallow phase of less than 24 inches to weathering rock is fairly common in the station, the main drainage phases found are the moderately well-drained to imperfectly-drained phases. This seems to be a typical picture wherever the series occurs.

CHEMICAL AND MINERALOGICAL DATA

Clay minerals: not analysed, but kaolin probably dominant.

Sand fraction: not analysed, but quartz probably dominant with other minerals resistant to weathering.

Silica/sesquioxide ratio:

Cation exchange capacity (milli equiv. %): a low of 8 to 10 in the A2 is common otherwise fairly uniform between 10 to 15 with the highest value in the B horizon.

Base saturation (%): varies from nil to 5 in the subsoil with between 5 and 10 in the A1. The exceptions are where more calcareous parent material occur and high calcium-with-magnesium values cause the base saturation to be as high as 70 to 80%.

Acidity: ranges from 4.0 to 5.0 with a tendency to increase in value with depth.

'Reserve' phosphorous (ppm): 200 to 300 in the A1, decreasing to a uniform 50 to 150 in the subsoil. A peak can generally be detected in the B2.

'Reserve' cation (ppm):

Calcium	-	very variable. Ranges from 1,500 to 400 in the A1 decreasing to as little as 30 in the B2 then rising to 300 to 700 in the upper C horizon.
magnesium	-	lowest in the A1 at 1,000 to 2,000 rising steadily to 2,000 to 5,000 in the lower subsoil.
potassium	-	lowest in the A2 horizon at 1,000 to 4,000 rising to a peak in the B2 of 3,000 to 8,000, then decreasing slightly in the C horizon.

Group III elements (%): lowest at 5 to 10 in the topsoil rising to a uniform 10 to 18.

Remarks: the soil has low exchangeable bases except calcium and magnesium which are variable. The exchange capacity is medium. The 'reserve' cations show common high values of calcium, magnesium and to a lesser extent potassium. Leaching of bases is not conspicuous.

FEATURES DISTINGUISHING LUAK SERIES FROM SIMILAR SERIES:

1. 'Labang Series': is similar, but has a more sandy A2 horizon.
2. Beaup and 'Ri'i Series': are closely similar but are developed over Triassic rock and have a reddish yellow B horizon. 'Reserve' calcium and magnesium tend to be lower.
3. Pasai Series: is similar, but is more sandy and is mottled throughout.
4. 'Pintasah Series': is closely similar, but is a rich reddish yellow colour in the B horizon.

4. 'PINTASAH SERIES' (provisional)

This soil is classed as a member of the 'Nyalau Family' in the Red-Yellow Podsolic Great Soil Group. Its structure and degree of expression of the argillic horizon (9) however give it affinities with Harris's (8) Latosolic Podsolic Great Soil Group.

The soil is derived from shale with subordinate fine sandstone in places and consists of yellow to yellowish brown clay loam overlying reddish yellow to yellowish red, mottled clay.

The descriptions below are provisional since the soil has not yet been fully examined and it may prove to be the same as the 'Ri'i Series'.

GENERAL DESCRIPTION

Horizon	Depth	
O	2 - 0 - 0	Impersistent, but commonly as much as two inches thick.
A1	0 - ½ to 6"	Grayish brown to dark yellowish brown loam; crumby; friable; well-rooted.
A2/B1	- 8 to 20"	Yellow to yellowish brown clay loam to clay, with weak red to strong brown mottles from weathering iron-rich shale; friable to firm; moderately well-rooted.
B	- 24 to 48"+	Reddish-yellow to yellowish red clay loam to clay, with red yellow and light grey mottles partly from weathering iron-rich shale; firm to very firm; moderately well-rooted; stony in places.
C	generally within auger depth	Light grey to dark grey shale.

RANGE OF CHARACTERISTICS

Parent material: Tertiary shales, in Fourth and Fifth Divisions largely of Plio-Miocene age. Fine sandstone may be present but is always subordinate. The shale is thought to be iron-rich.

Topography: generally on low to moderately high hills, dissected, with slopes ranging from less than 10° to more than 30°.

Occurrence: the series is provisionally established in Fourth Division where it is known to occur widely but generally in association with the Luak Series. It has also been noted in Fifth Division on the same parent rock, and possibly occurs in Third Division. It does not have a wide distribution on the station.

Diagnostic horizons: within auger depth (48 inches) the following genetic horizons are normally present:

O1 - 2	Commonly absent, particularly after cultivation. May be present under primary forest.
A1	Generally thin but distinct. Cultivation combined with erosion on steeper slopes may have caused its removal.
A2/B1	Usually a fairly clear contrast with lower horizons in texture and particularly in colour but generally thin. Gradual change to underlying horizons.
B	Generally deep.
C	Commonly present and merges with the lower B horizon.

Colour: the topsoil, if present, is always dark and predominantly of 10YR hue. The A2(B1) horizon varies from yellow to yellowish brown, largely of 10YR hue, while the B2 horizon contrasts fairly strongly in being reddish yellow to yellowish red, chiefly of 7.5YR and 5YR hue; strong brown - 7.5YR hue - is also common. Subsoil mottles vary widely from light grey through yellow to dark reddish brown: light grey may be the main matrix colour in the B3, C1 horizons in places.

Texture: clay loam to clay are dominant but the topsoil may contain sufficient sand for a loam texture. Stones may give a stony clay texture in the B2.

Structure and consistence: the topsoil is generally weak to moderate crumb and friable. Beneath, the structure is weak blocky and firm to very firm when moist. The deeper subsoil in the B3, C1 horizons may be plastic under field conditions.

Inclusions: in the B and C horizons iron-coated and iron-rich shale and fine sandstone fragments vary from few to abundant.

Drainage: the internal drainage is chiefly imperfect to moderate; the external drainage is medium to rapid depending on slope.

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Rooting depth: the topsoil is always the best-rooted, but a few fine to medium roots extend well down into the subsoil following structural faces. Stones do not appreciably impede rooting.

Phases: a shallow phase of less than 24 inches occurs on the station but is not common.

CHEMICAL AND MINERALOGICAL DATA

Clay minerals: not analysed, but probably dominated by kaolin.

Sand fraction: not analysed, but quartz probably dominant with other minerals resistant to weathering.

Silica/sesquioxide ratio: analyses not available.

Cation exchange capacity (milli equiv. %): as high as 40 in the A1 and between 10 to 20 in the subsoil.

Base saturation (%): between 5 and 10 in the A1 and between nil and 5 in the subsoil except where calcareous strata form part of the parent rock.

Acidity: ranges from pH 4.0 to 5.0 with a tendency to increase in value with depth.

'Reserve' phosphorous (ppm): 100 to 300 in the A1 and a uniform 50 to 150 in the subsoil.

'Reserve' cations (ppm):

- calcium - ranges between 50 and 250 throughout with peaks in the A1 and B2 horizons.
- magnesium - 1,000 to 2,500 in the A1 dropping slightly in the A2 then rising steadily to 1,500 to 3,000 in the subsoil.
- potassium - lowest in the A1 and A2 between 1,500 and 2,000 then rising steadily to as much as 7,000 in the lower subsoil.

Group III elements (%): less than 10 in the A1 and between 10 and 20 in the B2.

Remarks: the above figures are all from sites in the Bintulu-Tatau area where the Pintasah Series is common. It is likely that calcium and magnesium figures are slightly higher in the station. Leaching is not pronounced due to the heavy texture. There is a close resemblance to the Luak Series chemically.

FEATURES DISTINGUISHING PINTASAH SERIES FROM SIMILAR SERIES:

1. 'Luak Series': is closely similar but has a brownish yellow to yellowish brown B horizon. These two series commonly occur together.

2. 'Ri'i Series': is closely similar in morphological properties but appears to have a superior structure and is possibly poorer in 'reserve' calcium and magnesium. Later investigations may prove the two to be sufficiently similar to warrant abolishing the Pintasah Series. 'Ri'i Series' is derived from Triassic rocks.

3. Bedup Series: is closely similar but has within auger depth a light grey, red-mottled B3, C1 horizon.

4. Pasai Series: is similar to the imperfectly-drained phase but is mottled in the A horizon and is slightly sandy throughout.

5. KABULOH SERIES (code number 3401)

This soil is classified as a member of the 'Nyalau Family' in the Red-Yellow Podsolic Great Soil Group. Its structure and degree of expression of the argillic horizon (9), however, give it close affinites with Harris's (8) Latosolic Podsolic Great Soil Group.

It is derived from calcareous shale and marl and consists of a moderately deep, pale yellow to light yellowish brown clay containing dark brown ferro-manganese concretions, particularly in the deeper subsoil. It is possible that the soil may be partially derived from alluvium.

GENERAL DESCRIPTION

Horizon	Depth	
O	2 - 0 to 0"	Impersistent, where present less than two inches thick.
A1	0 - 2 to 3"	Dark greyish brown loam to clay loam; friable but slightly plastic when moulded; crumby; well rooted.
A2	- 6 to 9"	Light yellowish brown clay loam to clay; firm; slightly blocky; well rooted.
B	- 20 to 40"	Light yellowish brown clay, very firm, dense; slightly blocky; moderately well rooted; distinctly mottled dark brown by ferro-manganese concretions.
C	- 40 to 48"+	Light grey to dark grey shale above which may be a light grey clay mottled brownish yellow and dark brown.

RANGE OF CHARACTERISTICS

Parent material: Tertiary shales, predominantly of Plio-Miocene age in Fourth Division, calcareous. Limestone in places.

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Topography: gently undulating low hills; slopes less than 10°, amplitude of relief less than 15 feet. Commonly merges into Malang Series alluvium.

Occurrence: principally in Fourth Division south of the Lambir Hills. Occurs in three small areas in the station.

Diagnostic horizons: within auger depth (48 inches) the following horizons are generally present:

O	Thin or absent
A1	Thin but distinct
A2	Indistinct and commonly not detectable in the field.
B	Deep and uniform
C	Not always within auger depth: may be hard to soft.

Colour: beneath the dark topsoil the colour is a fairly uniform pale yellow to light yellowish brown (2.5Y to 10YR). Dark brown and to a lesser extent light grey mottles occur in the deeper subsoil. Above the C horizon there may be a greyish brown to light grey clay mottled brownish yellow to dark brown.

Texture: there is little sand present and clay is the dominant texture throughout except in the topsoil which varies from loam to clay loam.

Structure and consistence: a moderate crumb structure may be present in the topsoil which grades to a blockiness lower down. The consistence is uniformly firm to very firm. In the B3 to C1 horizon may be slightly plastic clay.

Inclusions: rare except in the zone of weathering rock.

Rooting depth: above the B3 horizon the soil is moderately well to well rooted.

Phases: a shallow phase of less than 24 inches to weathering rock has been noted. The main drainage phase in the station is moderately well drained.

CHEMICAL AND MINERALOGICAL DATA

Clay minerals: not analysed but probably dominated by kaolin.

Sand fraction: only 5 to 20% of total and probably dominated by quartz and other minerals resistant to weathering (one profile).

Silica/sesquioxide ratio:

Cation exchange capacity (milli equiv. %): about 30 to 50 in the A1 and 25 to 35% in A/B horizon compared to 10 to 12 in the C horizons. Unusually high for an inorganic soil in Sarawak.

Base saturation (%): ranges from 50% in the A2 to 100% in the B/C horizons due to high calcium and magnesium levels.

Acidity: the pH level at 5.5 to 6.5 in the A1, decreases slightly in the A2 then increases steadily to 7.0 to 7.5 in the B horizons and 7.4 to 7.7 in the C horizons. Unusually high for a residual soil in Sarawak.

'Reserve' phosphorous (ppm): 300 in the A1 decreasing to 200 in the B2 then rising to 350 in the C horizon. (one profile).

'Reserve' cations (ppm): (one profile)

calcium	-	lowest in the A2 at 4,500 then increasing remarkably in the B3 to 27,000 and 98,000 in the C1.
magnesium	-	fairly uniformly around 4,000 except in the C horizons which rise through 7,000 to 10,000
potassium	-	fairly uniform throughout between 5,000 and 7,000
manganese	-	ranges from 10 to 25.

Group III elements (%): 10 in the A1 rising to 19 in the B2 and decreasing to 10 in the C. (one profile).

Remarks: this series has a notably high C.E.C., pH, manganese, and 'reserve' calcium and magnesium which can be attributed to its parent material.

FEATURES DISTINGUISHING KABULOH SERIES FROM OTHER SIMILAR SERIES

1. Malang Series: is morphologically similar but is a stronger yellow and does not have weathering marl parent material. The two series common in the same area grading imperceptibly together.

6. MIRI SERIES (code number 4108)

This soil is classed as a member of the 'Miri Family' in the Humus Podsol World Soil Group.

The soil is developed in loose alluvial sands and consists of a thick, dark greyish brown topsoil overlying deep white sand which rests in turn on dark brown loamy sand.

GENERAL DESCRIPTION

Horizon	Depth	
O	6 - 2 to 0"	Generally thick, very dark grayish brown humus; well rooted.
A1	0 - 2 to 8"	Dark greyish brown loamy sand to sandy loam, with many clean quartz grains; loose; weak crumb to single grain; moderately well rooted.

A2	- 20 to 40"	Light grey to white sand to loamy sand, with faint very pale brown streaky mottles; loose; single grain; very few roots.
B	- 48"+	Dark brown loamy sand to sandy loam; wet and structureless.
IIC		Not usually within auger depth: probably shale in the station.

RANGE OF CHARACTERISTICS

Parent material: Quaternary sands, quartzose and predominantly of fine to medium grade.

Topography: flat-topped to gently undulating terraces with steep upper terrace flanks. Associated particularly with the coastal component of the Jerudong Erosion Surface.

Occurrence: widespread throughout coastal and sub coastal Sarawak. In the Station only a small area occurs.

Diagnostic Horizons: within auger depth the following horizons are generally present:

O1 - 2	Generally thick and distinct compared with most soils.
A1	Fairly thick and distinct.
A2	Deep and a strong contrast with overlying and underlying horizons.
B2	Generally thick and not necessarily within auger depth. Should be well developed.
C	Generally beyond auger depth.

Colour: strong contrasts in colour occur. The O horizons are dark, varying in hue from 2.5YR to 10YR with low value and chroma; the A1 is also dark with common, clean, white quartz grains. Beneath, the A2 is light grey to white in 7.5YR to 2.5Y hues, lightly mottled pale yellow (2.5Y) to very pale brown (10YR). The B horizons vary from dark greyish brown to very dark brown in 10YR hues.

Texture: throughout, the texture is sand through to sandy loam which is most common in the A1 and B2 horizons.

Structure and consistence: the topsoil possesses a very weak crumb to single grain structure and is loose to very friable. The A2 is structureless to single grain and loose. Depending on the degree of development of the humus pan the B2 ranges from structureless to slightly platy and from very friable to very firm.

Inclusions: absent, with the rare exception of few soft to hard quartz pebbles.

Drainage: internally well drained to excessive, externally slow to very slow.

Rooting depth: the only impediment to rooting is where the B horizon is firm to very firm; nevertheless almost all roots remain in A1 and O horizons.

Phases: a deep phase occurs (rarely in the station) where the B2 is beyond auger depth. The shallow phase is where the C horizon lies within 24 inches of the surface and generally can be found on terrace margins. Other phases are suggested for weakly and strongly cemented B2 horizons. In the station the B2 is not strongly cemented.

CHEMICAL AND MINERALOGICAL DATA

Clay minerals: insignificant amounts of clay present.

Sand fraction: predominantly quartz: heavy minerals from Zircon and Zircon - Tourmaline Associations, including rutile and anatase with a moderately high proportion of opaque and alterites (one profile only).

Silica/sesquioxide ratio: not analysed.

Cation exchange capacity (milli equiv. %): the A1 ranges between 5 and 25, the A2 is less than 5, the B2 largely between 5 and 10.

Base saturation (%): ranges from 3 to 20 in the A1 and less than 3 to 5 in the subsoil.

Acidity: ranges from pH 4.0 in the A1 to pH 5.0 in the subsoil.

'Reserve' phosphorous (ppm): not analysed but probably low.

'Reserve' cations (ppm): not analysed but probably low.

Group III elements (%): not analysed but probably low.

Remarks: highly siliceous, strongly leached and nutritionally poor except in the topsoil.

FEATURES DISTINGUISHING MIRI SERIES FROM OTHER SIMILAR SERIES:

1. Bako Series: closely similar but found on dip slopes of hills lying at shallow depth on hard sandstone.
2. Penian Series: closely similar but found in beaches and with the ground water table occurring in or below the B2 which is chiefly weakly developed.

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7. MALANG SERIES (code number 4350)

This soil is classified as a member of the 'Malang Family' in the Yellow-Brown Hydromorphic Great Soil Group. The term Yellow-Brown Hydromorphic has been coined due to the lack of any suitable compartment in the scheme outlined by Harris (8). It is characterized by weak to moderate hydromorphism in contrast to the strong hydromorphism of the Grey Hydromorphic Great Soil Group.

The soil consists of a yellow to yellowish brown loam to clay, at least 24 inches deep and only lightly mottled, overlying a predominantly light grey, mottled reddish brown, gley horizon. It is derived from riverine alluvium.

GENERAL DESCRIPTION

Horizon	Depth	
O	2 - 0 to 0"	Impersistent, but may be as much as 2 inches of litter and leaves.
A1	0 - 2 to 3"	Dark yellowish brown loam to clay loam, crumby; well rooted.
A2	- 6 to 12"	Yellow to yellowish brown clay loam to clay; well rooted; merges to B horizon.
B	- 24 to 48"+	Yellow to yellowish brown clay, lightly mottled with light grey to dark reddish brown; slightly blocky; moderately well rooted.
Cg	deeper than 24", in places beyond auger depth	Grey clay to silty clay, mottled reddish brown to olive brown. The water table usually occurs within this zone.

RANGE OF CHARACTERISTICS

Parent material: recent riverine alluvium, still accumulating, derived predominantly from shale and sandstone with subordinate additions from igneous rock in First Division.

Topography: flat to gently undulating with slopes not exceeding approximately 5°.

Occurrence: the series is known to be widespread throughout Sarawak in the middle to upper reaches of rivers.

Diagnostic Horizons: within auger depth the following horizons are generally present:

O1 - 2	Mainly litter and leaves, commonly absent.
A2	Indistinct and merges with B horizons.
B	Deep, forming main part of profile; uniform.
Cg	Contrasts strongly with overlying horizons. May be beyond auger depth.

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Colour: beneath the dark topsoil the colour is a uniform yellow to yellowish brown, hue 10YR. Mottles near the Cg horizon and the water table are generally distinct, dark reddish brown to yellow and light grey. The Cg horizon has a matrix colour of light grey to greenish grey in the 5Y - 5GY range mottled with reddish brown to olive.

Texture: the topsoil is commonly loam, which increases with depth to clay loam then clay and in places silty clay in the Cg horizon.

Structure and consistence: the topsoil is generally moist, friable and crumby. The A2 and B horizons are uniformly structureless to weakly blocky and friable to firm when moist. The gleyed Cg horizon is generally within the water table, wet, plastic and sticky to slightly sticky.

Inclusions: stones are rare but ferro-manganese concretions are common in places.

Drainage: the series includes well-drained to imperfectly-drained phases depending on the depth to the gleyed horizon and degree of mottling. In the station the series is chiefly moderately well-drained to imperfectly drained. External drainage is slow.

Rooting depth: no impediment to rooting occurs above the water table.

Phases: drainage phases only have been established.

CHEMICAL AND MINERALOGICAL DATA

Clay minerals: not analysed but kaolin probably dominant.

Sand fraction: not analysed but quartz probably dominant.

Silica/sesquioxide ratio:

Cation exchange capacity (milli equiv. %): A1 variable between 10 to 30. Subsoil ranges from 5 to 12.

Base saturation (%): variable and ranges from 10 to 30 with a peak in the A1.

Acidity: ranges from pH 4.5 to 5.5 with a tendency to increase in value with depth.

'Reserve' phosphorous (ppm): generally a peak in the A1 of 150 to 250 decreasing to a uniform 60 to 120 in the subsoil.

'Reserve' cations (ppm):

- calcium - A1 variable between 500 and 900; subsoil fairly uniform between 150 and 350.
- magnesium - rather variable throughout, ranging from 800 to 2,000.
- potassium - fairly uniform throughout ranging between 2,000 to 4,000.

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Group III elements (%):

Remarks: the soil is characteristically uniform above the water table.

FEATURES DISTINGUISHING MALANG SERIES FROM OTHER SIMILAR SERIES:

1. Kabuloh Series: is morphologically similar, but is derived from calcareous shale and should have weathering parent material within auger depth.

8. SEMILAJAU SERIES (code number 4311)

This is classified as a member of the 'Semilajau Family' in the Yellow-Brown Hydromorphic Great Soil Group: where the soil is deep it has close affinities with the Red-Yellow Podsolics. The term Yellow-Brown Hydromorphic has been coined due to the lack of any suitable compartment in the scheme outlined by Harris (7). It is characterised by weak to moderate hydromorphism in contrast to the strong hydromorphism of the Grey Hydromorphics.

The soil consists of deep yellow to brownish yellow sandy loam in the upper subsoil increasing to sandy clay loam in the deeper subsoil where mottling generally occurs.

GENERAL DESCRIPTION

Horizon	Depth	
O	2 - 0 to 0"	Impersistent, where present no more than two inches thick.
A1	0 - 1 to 5"	Dark brown to yellowish brown sandy loam to loamy sand; loose to very friable; single grain to weak crumb, well rooted.
A2	- 20 to 40"	Yellow to brownish yellow sandy loam; very friable; moderately well rooted.
B	- 48" +	Yellow to brownish yellow sandy loam to sandy clay loam, with light grey and reddish brown mottles; friable to firm; moderately well rooted.
Cg		Pale yellow to light grey sandy loam to sandy clay loam, mottled reddish brown to brownish yellow.

RANGE OF CHARACTERISTICS

Parent material: recent riverine alluvium, still accumulating, derived chiefly from sandstone, siliceous.

Topography: narrow levee strips which slope gently but noticeably towards basins behind the rivers.

Occurrence: the series is known to occur throughout Sarawak in the upper reaches of rivers, particularly where sandstone is dominant.

Diagnostic horizons: within auger depth (48 inches) the following horizons are generally present:

O	Mainly litter and leaves, commonly absent.
A1	Thin but distinct.
A2	Distinct and deep; grades gradually to the underlying horizon.
B	Fairly distinct and deep.
Cg	Contrasts strongly with overlying horizon. Not everywhere present. Must be more than 24 inches from the surface.

Colour: the topsoil is generally dark with low value and chroma. The main part of the profile is largely uniform between pale yellow and brownish yellow (2.5Y to 10YR) with a tendency to increase in chroma in the B horizon. Mottles in the deeper subsoil range from reddish brown through pale brown to light grey. The C horizon varies from pale yellow to light grey and is faintly mottled as above.

Texture: sand predominates, largely of medium to fine grade, but becomes admixed with clay with increasing depth. Sandy clay textures are not met with, the main range being from loamy sand to sandy clay loam.

Structure and consistence: structure is weak to absent throughout, the consistence mainly very friable to friable, although loose and firm grades occur in places.

Inclusions: nil.

Drainage: the series ranges from well drained to imperfectly drained depending on the depth to the water table and gleyed zone. In the station the soil is largely moderately to imperfectly drained. Periodic flooding occurs.

Rooting depth: no impediment occurs above the water table.

Phases: three drainage phases only have been established.

CHEMICAL AND MINERALOGICAL DATA

Clay minerals: not analysed but probably dominated by kaolin.

Sand fraction: not analysed but quartz and other minerals resistant to weathering probably dominant.

Silica/sesquioxide ratio:

Cation exchange capacity (milli equiv. %): the A1 varies between 5 and 10, the subsoil between 2 and 8, the higher values occurring at depth.

Base saturation (%): varies between 5 and 10.

Acidity: fairly uniform between 4.5 and 5.0.

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'Reserve' phosphorous (ppm): a peak in the A1 or about 150 decreasing to 80 - 100 in the subsoil with a slight rise in the gleyed horizon. (one profile only).

'Reserve' cations

calcium	- a peak in the A1 of 200 to 500 decreasing to less than 100 in the A2 then rising to 170 in the B horizons. (one profile only).
magnesium	- less than 250 in the A1 rising steadily through 700 to 1,000 in the A2 and 1,500 in the gleyed horizon. (one profile only).
potassium	- fairly uniform between 2,000 and 3,500 throughout. (one profile only).

Group III elements: not analysed.

Remarks: the soil has a low exchange complex and a low base saturation. 'Reserve' levels show that leaching occurs.

9. SALITUT SERIES (code number 4312)

This soil is classified under the 'Plan Family' in the Low Humic Gley Great Soil Group. There are affinities with both the Latosolic Regosols and with the Yellow-Brown Hydromorphics.

The soil consists of light greyish brown to yellowish brown sandy loam to sandy clay loam mottled light grey and reddish brown, overlying within 24 inches grey to light grey loamy sand to sandy clay loam, mottled reddish brown.

GENERAL DESCRIPTION

Horizon	Depth	
O	6 to 2 - 0"	Impersistent in drier areas but generally present and in places peaty.
A1	0 - 3 to 6"	Dark greyish brown to dark yellowish brown sandy loam to loamy sand; friable to very friable; well rooted.
A-B	- 24"	Yellowish brown to greyish brown sandy loam to sandy clay loam, mottled light grey and reddish brown; friable.
B-Cg	within 24"	Grey to light grey loamy sand to sandy loam mottled reddish to olive brown. Wet, slightly sticky and slightly plastic to plastic.

RANGE OF CHARACTERISTICS

Parent material: recent riverine alluvium, still accumulating, mainly fine to medium sand with subordinate clay, siliceous; derived from sandstone and shale largely.

Topography: flat to gently sloping land near rivers.

Occurrence: this series occurs chiefly in association with Semilajau Series but is not widespread. It has a fairly wide distribution in the northwest of the station.

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Diagnostic Horizons

O1 - 2	Distinct and commonly as much as 6 inches thick.
A1	Distinct and quite thick.
A - B	Distinct from the above horizons but may merge with the horizons below.
Cg	Contrasts with above horizon only if water table is low.

Colour: beneath the dark topsoil the colours are largely of 10YR or 2.5 hue. The chroma and value should be fairly high to give grayish brown to slightly yellow colours. Mottles vary from reddish brown to light grey. The gley horizons are noticeably pale.

Texture: the upper subsoil should be sandy loam to loamy sand. The lower subsoil is more variable ranging from sandy loam to sandy clay loam. In places sedimentary discontinuities occur when clay-loamy sand bands can be found, particularly deep in the solum.

Structure and consistence: subsoil structure is weak or absent; the consistence, if moist, is very friable to firm, if wet non plastic to plastic and non sticky to slightly sticky. The topsoil tends to be crumby and friable.

Inclusions: nil.

Drainage: internal drainage is poor to very poor depending on the depth to the gleyed horizons, external drainage is slow. Periodic flooding occurs.

Rooting depth: no impediment to rooting above the water table.

Phases: drainage phases only have been established, these being poorly and very poorly drained.

CHEMICAL AND MINERALOGICAL DATA

No analyses available.

FEATURES DISTINGUISHING SALITUT SERIES FROM OTHER SIMILAR SERIES:

1. Semilajau Series: similar but is deeper to the watertable, richer in colour and better drained.
2. Bawang Series: closely similar but occurs in marine sands. Textures are lighter and colours greyer than in the Salitut Series.

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10. SAMARAHAN SERIES (code number 4306)

This soil is classified as a member of the 'Samarahan Family' in the Low Humic Gley Great Soil Group.

It consists of dark peaty topsoil overlying grey clay which in places gives way to dark grey clay with depth. The upper subsoil is generally mottled yellow to reddish brown.

GENERAL DESCRIPTION

Horizon	Depth	
O - A1	6 to 2 - 0"	Dark grayish brown peaty loam.
Bg	0 - 2 to 4"	Grayish to brown clay loam to clay mottled reddish brown and light grey.
Cg	- 48" +	Light grey to greenish grey clay, in places dark grey. Reddish brown to olive mottles in top part of horizon. The water table lies within this horizon.

RANGE OF CHARACTERISTICS

Parent material: recent riverine alluvium, still accumulating, predominantly clay, derived largely from shale. There is a possibility that the lower horizons are slightly brackish.

Topography: flat basin land between streams.

Occurrence: the series is widespread throughout Sarawak in small inland valleys.

Diagnostic horizons:

O - A1	Everywhere present; distinct, thick and commonly peaty.
Bg	Not everywhere present. Occurs chiefly in the poorly-drained phase.
Cg	Distinct and clear in contrast with the A1; everywhere present.

Colour: the topsoil is very dark in colour and contrasts strongly with the Cg horizons which are invariably pale and of high value and low chroma. The Bg horizon where present is fairly dark with little hue at all. Mottles range from reddish brown to olive shades.

Texture: the topsoil is commonly peaty; the subsoil is chiefly clay to silty clay.

Structure and consistence: the subsoil is massive, and generally wet, plastic and sticky. The topsoil is at times moist rather than wet and exhibits a weak crumb structure.

Inclusions: nil.

Drainage: internally poor to very poor: externally very slow. Periodic flooding.

Rooting depth: no impediment to rooting occurs above the water table.

Phases: two drainage phases have been established which are poorly and very poorly drained.

CHEMICAL AND MINERALOGICAL DATA

Clay minerals: not analysed but probably dominated by kaolin.

Sand fraction: insignificant but quartz and other minerals resistant to weathering probably dominant. Heavy minerals form a Zircon Association with subsidiary tourmaline, rutile and anatase. A fairly high proportion of opaques and alterites (one sample only).

Silica/sesquioxide ratio:

Cation exchange capacity (milli equiv. %): topsoil variable, depending on amount of peat present, between 20 and 40. Subsoil between 10 and 18 throughout.

Base saturation (%): varies from 2 to 5 normally.

Acidity: fairly uniform throughout at 3.8 to 4.5.

'Reserve' phosphorous (ppm): topsoil about 550; subsoil ranges from 200 to 350 and is fairly uniform.

'Reserve' cations (ppm):

calcium - about 1,200 in the topsoil and between 600 and 800 in the subsoil tending to decrease with depth.

magnesium - about 3,000 in the topsoil dropping to 2,500 in the Bg. and rising steadily with depth to 3,700.

potassium - about 6,000 in the topsoil rising steadily to 8,600 in the Cg.

Group III elements %: between 10 and 15 in the topsoil rising to 15 to 20 in the subsoil.

Remarks: The 'reserve' nutrients described above are typical of the series as found in the station. It is probable however that lower levels are more general in areas located further from the coast.

FEATURES DISTINGUISHING SAMARAHAN SERIES FROM OTHER SERIES:

1. Bijat Series: is closely similar but occurs alongside large rivers; chemically it should be richer in nutrients than the Samarahan Series, particularly in magnesium and calcium.
2. Pendam Series: is similar but occurs in estuarine alluvium and is richer in nutrients than Samarahan Series.
3. Kakai Series: is similar but the parent material is basic igneous rock. Iron and manganese levels are higher.
4. Simuja Series: is similar but the parent material is limestone, sedimentary, and igneous rocks; it occurs alongside large rivers and is richer than Samarahan Series.

11. 'ABON SERIES' (provisional)

This soil is classified as a member of the 'Abon Family' in the Half Bog Great Soil Group.

It consists of peaty to mucky topsoil overlying light grey clay.

GENERAL DESCRIPTION

Horizon	Depth	
O	0 - 6 to 36"	Dark grayish brown peat or muck.
Cg	- 48" +	Light grey, grey and in places greenish grey clay.

RANGE OF CHARACTERISTICS

Parent material: recent riverine alluvium, not actively accumulating, chiefly clay derived from shale. Peat forms the topsoil and has accumulated in situ.

Topography: flat basin land between streams.

Occurrence: the series is widespread throughout Sarawak in inland areas in poorly drained valleys.

Diagnostic horizons:

O Everywhere present and must be between 6 and 36" thick.

Cg Everywhere present and is a prominent contrast to the O horizon.

Colour: the O horizon is general dark grayish brown in 10YR hue. It always has low value and chroma. In contrast the Cg is gleyed and pale. The colours range from white to grey and greenish grey and are of 10YR hue, in places 2.5 and 5Y or 5GY, of high value and low chroma.

Texture: the top horizon is organic and may contain a fairly high proportion of partially-rotted wood. Inorganic material may be admixed with the material forming peaty or mucky clay for example. The Cg horizon is clay to silty clay.

Structure and consistence: the peat is wet and consists of material ranging from soft, rotted organic material to hard wood. The clay is massive, wet, sticky and plastic.

Inclusions: excepting the wood, nil.

Drainage: internally very poor since the water table is permanently at or near the surface. Externally very slow. Periodic flooding.

Rooting depth: most roots probably remain near the surface or in the top few inches of clay where the peat is shallow.

Phases: none established.

CHEMICAL AND MINERALOGICAL DATA

Clay minerals: not analysed but probably dominated by kaolin.

Sand fraction: not analysed but probably dominated by quartz and other minerals resistant to weathering.

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Silica/sesquioxide ratio:

Cation exchange capacity (milli equiv. %): topsoil between 50 and 100. The underlying clay between 10 and 18.

Base saturation (%): the clay varies from 2 to 5 normally, in the peat however it may rise to 10 to 15.

Acidity: the peat generally has a pH of 3 to 3.8, the clay ranges between pH. 3.8 and 4.5.

'Reserve' phosphorous (ppm): the peat ranges from about 500 to 1,000, while the underlying clay varies from 200 to 500.

'Reserve' cations (ppm):

calcium - the peaty horizons range from 300 to 500, the clay increases to 500 to 700.

magnesium - throughout the solum the level is fairly uniform between 2,500 and 3,000.

potassium - the organic material contains between 5,500 and 7,000. It is not certain whether the clay layer contains more or less on the basis of samples analysed so far.

Group III elements (%): the peat has not been analysed but probably contains less than 5 to 10. The clay level is uniform between 15 and 20.

Remarks: the two parts of the solum are different in most respects. The organic horizons resemble the Anderson Series, the inorganic part the Samarahan Series.

FEATURES DISTINGUISHING ABON SERIES FROM OTHER SERIES:

1. An unnamed Series occurring in the middle reaches of large rivers is closely similar and probably differs only in having higher nutrient levels, in the clay in particular.
2. Mukah Series: is closely similar and differs only in having higher nutrient levels and a more bluish or greenish clay as subsoil.

12. UNDIFFERENTIATED ALLUVIUM

These soils are situated in only small parts of the station and are of minor importance. They consist of pale-coloured sands to sandy clay loams which have been deposited in narrow valleys by mixed colluvial-alluvial activity. In the northeast corner they may be stony.

13. BOG SOIL

In only three places does this type of soil occur: it is of limited importance and it is thought that after drainage, the soil will be closely similar to the Abon Series. It consists of thoroughly waterlogged peaty muck two to three feet deep, in one or two spots four feet. The water content is sufficiently high to cause the soil to be unstable to walk on and the soil does not really resemble the true peat of Anderson Series.

14. LITHOSOL

Only in the northeast corner is this soil at all common. It is found as small patches of stony, shallow, yellow sandy loam to clay loam, in places giving way to bare rock on landslides and scarp slopes. It is of minor importance.

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PART III CONCLUSIONS

1. GENERAL.

The climate in this part of Sarawak is typical of the humid tropics. There is a uniformly high temperature and humidity and the rainfall produces the main seasonal variations. There is a wet season, the 'landas', from September to January or February, during which rainfall is more than sufficient for plant growth. During the rest of the year, except in May and June, the rainfall penetrating the ground may be insufficient to overcome losses by runoff, vegetation interception and particularly evaporation. It is not known how far this is typical of Sarawak due to lack of pertinent data, but it is thought to be indicative of a fairly pronounced dry season in the coastal areas of Fourth Division as far as soil climate is concerned.

The parent rock of the soils in the station is predominantly shale with subordinate fine sandstone. This type of lithology is known to be extensive in this part of Fourth Division coinciding largely with the Sibuti, Tangap and Setap Formations: the Setap Formation is also extensive in Fifth Division. Calcareous strata, although not common, have a pronounced effect on some soils.

The low hills in the station are typical of those found further south in large parts of the Sibuti, Niah and Suai river basins. This type of topography coincides with shale lithology.

Most patches of primary vegetation on the station include many large trees, notably 'kapor' ('paji') and 'tapang'. Those parts containing poorer forest are situated either in the northeast corner or where there has been padi cultivation many years ago. Both types of primary vegetation are widespread to the south of the station and coincide with shale-dominated and fine sandstone-dominated lithology respectively.

In most general respects the station is representative of the areas selected for development both in the immediate neighbourhood and in the upper Sibuti, Sibuti-Niah and Niah-Suai areas.

2. SOILS

Soils described in the preceeding section are, with one exception, found widely in this section of Fourth Division and many are widespread throughout the country. Experiments undertaken on the station therefore will be applicable in many other areas where these soils occur.

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The Kabuloh Series is known to have a restricted distribution since it is related directly to the occurrence of calcareous shale, marl or limestone. During a previous reconnaissance survey (2) this soil was noted only at Sg. Mulis (Btg. Suai) and around Batu Niah. During the survey of the station, however, it was found to have a wider distribution than expected and it is possible that during the reconnaissance survey it was largely overlooked since it closely resembles the Malang Series.

3. TOPSOIL CHEMICAL FERTILITY

The following remarks are based on analyses of samples taken specifically for agronomy purposes in conjunction with analyses of samples used primarily for classification purposes. The latter comprise profile samples of genetic horizons while the former are taken by auger from the top six inches of soil representing the zone of maximum rooting. The agronomy samples are taken in representative sites of soil series in a close pattern of nine or ten samples in about one acre.

In order to determine the uniformity of the topsoil of a soil series in a small area agronomy samples from a number of sites were analysed individually. Samples from other sites were bulked, mixed thoroughly and split - one sub sample only being analysed.

The methods of analysis give 'reserve' values of nutrients. This approximates to the total amount of any one element in the soil. The Chemistry Division have found in a number of experiments that this correlates with plant growth more closely than with the more conventional 'available' or 'exchangeable' analyses.

Since insufficient data is available from most series to calculate reliable means the remarks below are generalised and are open to revision.

1. <u>Luak and Pintasah Series</u> (nine sites)

The two are closely related and in many respects resemble Bedup and Ri'i Series.

<u>Phosphorous (ppm)</u>: varies over small distances largely between 50 and 300.

<u>Calcium (ppm)</u>: widely variable over small distances between about 100 and 1,000: the presence of thin beds of shale parent material rich in calcium help to account for the variation, also the amount of organic matter in the topsoil.

<u>Magnesium (ppm)</u>: widely variable over small distances between about 500 and 2,000.

<u>Potassium (ppm)</u>: varies largely between 1,000 and 6,000.

<u>Nitrogen (%)</u>: varies largely between 0.15 and 0.25 in one site.

Remarks: The levels accommodate those in the A1 horizon; the higher the content of organic matter the higher the levels tend to be of nitrogen phosphorous and calcium in particular and to a lesser extent of magnesium and potassium. There is as much variation within sites as between sites. Subsoil analyses reveal lower levels of phosphorous and calcium (nitrogen not analysed) pointing to the need for topsoil conservation. These soils appear to be of average nutritional value for Sarawak.

2. Kabuloh Series (two sites)

Phosphorous (ppm): varies within a fairly narrow range of about 250 to 450.

Calcium (ppm): varies within a high range of about 4,000 to 8,000. More than a 10% increase in the C horizons.

Magnesium (ppm): ranges from 2,500 to 4,500 and is higher where the organic matter is high.

Potassium (ppm): a narrow range between 4,000 and about 6,500.

Nitrogen (%): varies between about 0.30 and 0.55.

Remarks: The influence of the parent material is marked in the overall levels of calcium, magnesium and phosphorous. Nitrogen levels are uniformly higher than in most residual soils and subsoils are less leached. The variation between sites is similar to that within a site. The soil is richer in nutrients than the average in Sarawak.

3. Labang and Likau Series (ten sites)

Phosphorous (ppm): largely between 50 and 200, not widely variable in one site.

Calcium (ppm): varies widely from 100 to 660 in small areas.

Magnesium (ppm): varies widely between 350 and 2,000 in small areas.

Potassium (ppm): a wide range between 700 and 3,500.

Nitrogen (%): a wide range from 0.15 to 0.78.

Remarks: The presence of organic matter and the amount of clay in the topsoil strongly influence the amount of phosphorous, calcium, magnesium and nitrogen present. The variation between sites is similar to that within sites. Bands of calcareous strata in the parent material also affect the amount of calcium in particular. Topsoil conservation is important in retaining the existing levels of phosphorous and calcium since subsoil amounts are lower. These soils are of low to average nutritional value for Sarawak.

4. Miri Series (five sites)

Phosphorous (ppm): a narrow range from 60 to 120 between sites.

Calcium (ppm): a fairly narrow range between sites from 80 to 350.

Magnesium (ppm): ranges widely from 200 to 1,500 between sites.

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Potassium (ppm): a fairly narrow variation ranging from 1,300 to 5,500 between sites.
Nitrogen (%): not analysed.

Remarks: This soil is strongly leached; it retains the bulk of its nutrients in the topsoil, which is predominantly organic. The removal of the topsoil therefore would render the soil infertile. The range between sites is greater than that within a site. It is of low to very low nutritional value for Sarawak.

5. Malang Series (six sites)

Phosphorous (ppm): a narrow range within a site from about 170 to 250; the range extends from 80 to 300 between sites.
Calcium (ppm): a narrow range within a site from 200 to 400; this widens appreciably to 130 to 1,100 between sites.
Magnesium (ppm): within a site the range is narrow between 1,300 and 2,000; different sites vary widely from 120 to 2,700.
Potassium (ppm): from 2,100 to 4,100 within a site, but from 800 to 6,700 between sites.
Nitrogen (%): fairly uniform between 0.17 to 0.25.

Remarks: The topsoil, in contrast to the hill soils, remains uniform in small areas, but has a wide range in nutrient value in different parts of the station. This probably reflects the varying sources of the alluvium, proximity to the calcareous Kabuloh Series, susceptibility to flooding and clay content as much as difference in organic matter content. The range is much greater between sites than within a site. The soil appears on the whole to be of average nutritional value for Sarawak.

6. Semilajau and Salitut Series (four sites)

Phosphorous (ppm): uniformly between 140 and 204 within a site but ranging from 90 to 240 between sites.
Calcium (ppm): ranges from 60 to 330 both within and between sites.
Magnesium (ppm): ranges widely from about 500 to 2,500 both within and between sites.
Potassium (ppm): a fairly narrow range between 1,800 and 3,300 between and within sites.
Nitrogen (%): between 0.15 and 0.26.
Remarks: Within a site only the magnesium levels vary widely. Between sites the magnesium and calcium contents are most variable. The amount of organic matter, susceptibility to flooding and proximity to sources of calcium (the Kabuloh Series) all will effect levels at various sites. The soil appears to be less than average to average in nutritional value by Sarawak standards.

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7. Samarahan and Abon Series (eight sites)

Phosphorous (ppm): uniform at one site between 110 and 140 but fluctuates widely from about 110 to 1,000 between sites.
Calcium (ppm): a rather wide variation from 20 to 150 in one site with extreme ranges of about 200 to 12,600 Between other sites.
Magnesium (ppm): a fairly narrow range in a site from about 300 to 800 which increase from 800 to 4,600 between other sites.
Potassium (ppm): uniform at one site at about 2,000 to 2,800 but increases to 8,900 in other sites.
Nitrogen (%): at one site a uniform 0.11 to 0.15.

Remarks: The wide fluctuations between sites can be attributed largely to the amount of organic matter present - the Abon Series having a higher organic topsoil than the Samarahan Series - and to the proximity of the calcareous parent material of the Kabuloh Series. Susceptibility to flooding and the addition of fresh alluvium will also have a noticeable effect. The variation between sites is much greater than with a site.

By Sarawak standards this soil is above average in nutritional value and in the station itself appears to be slightly richer than average for Samarahan Series.

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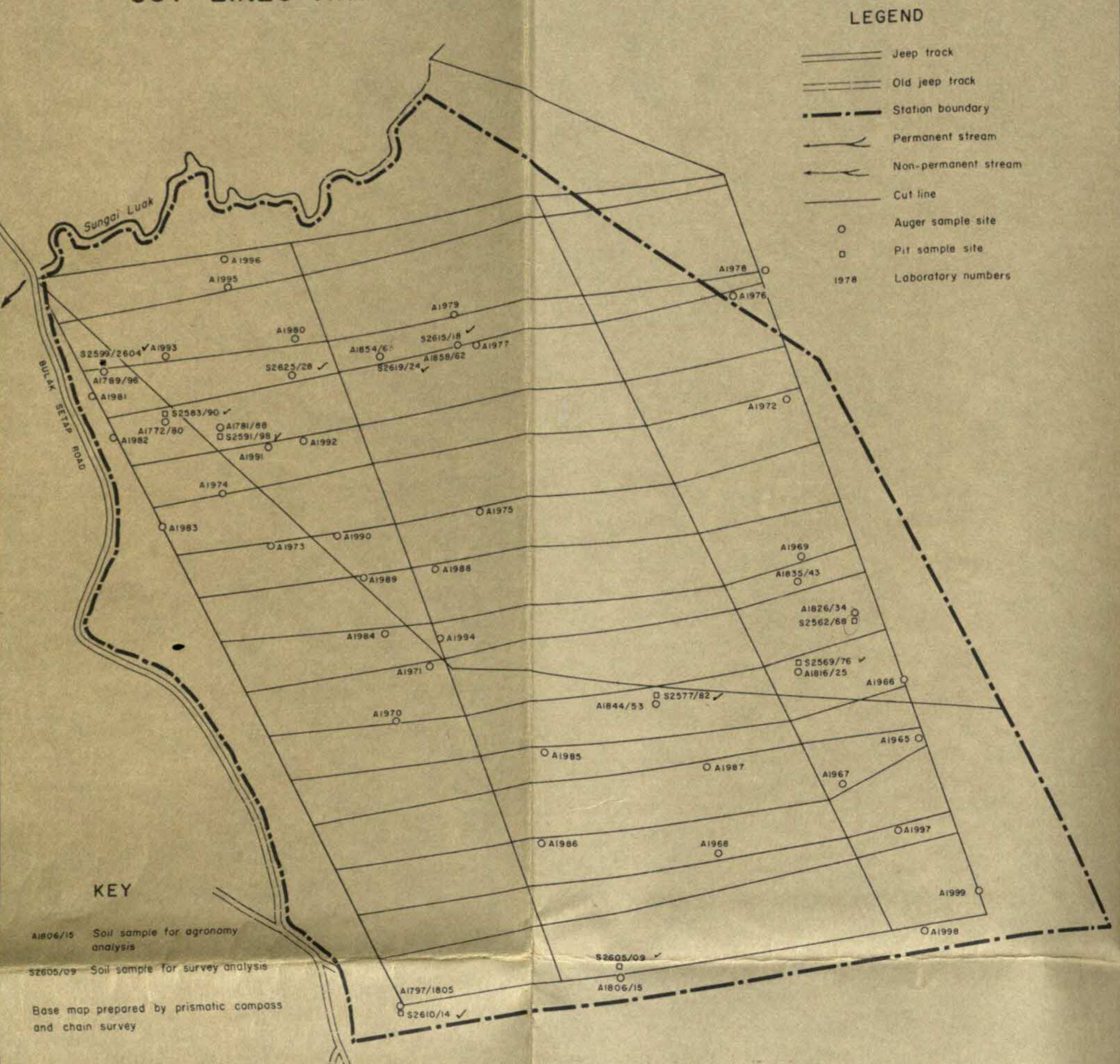
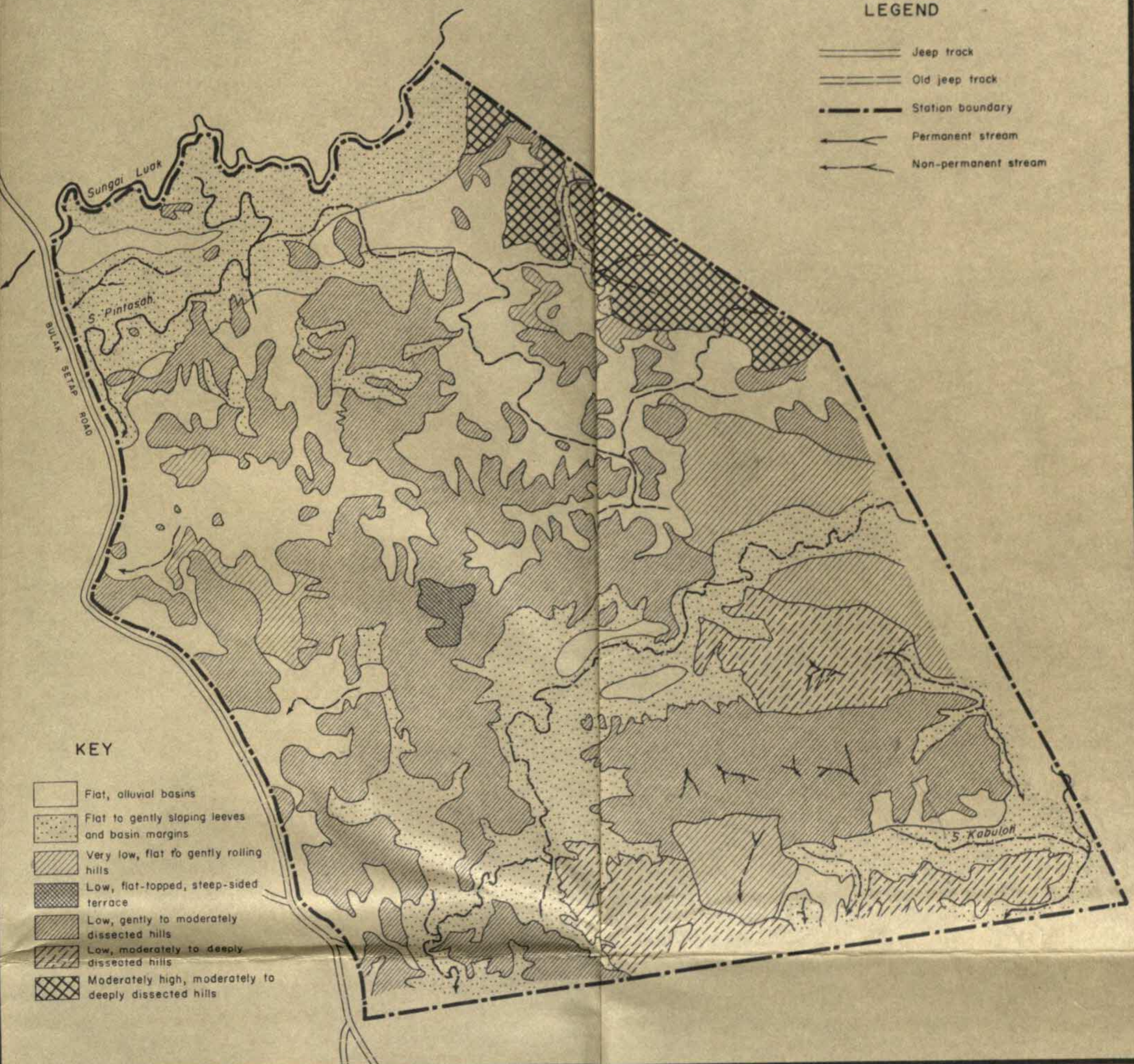
MAP 15

LUAK EXPERIMENT STATION

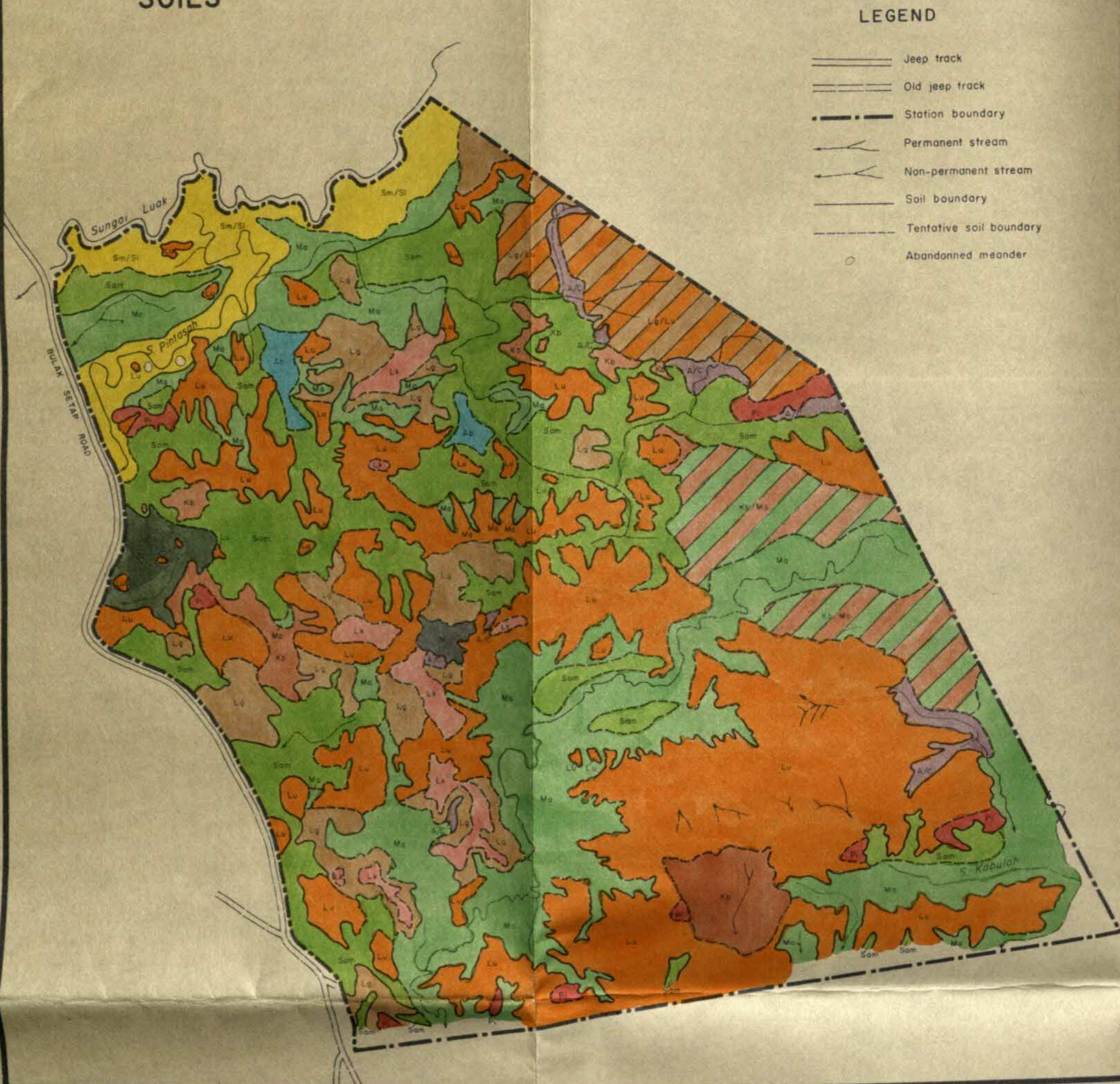
MAP 15a CUT LINES AND SAMPLE SITES



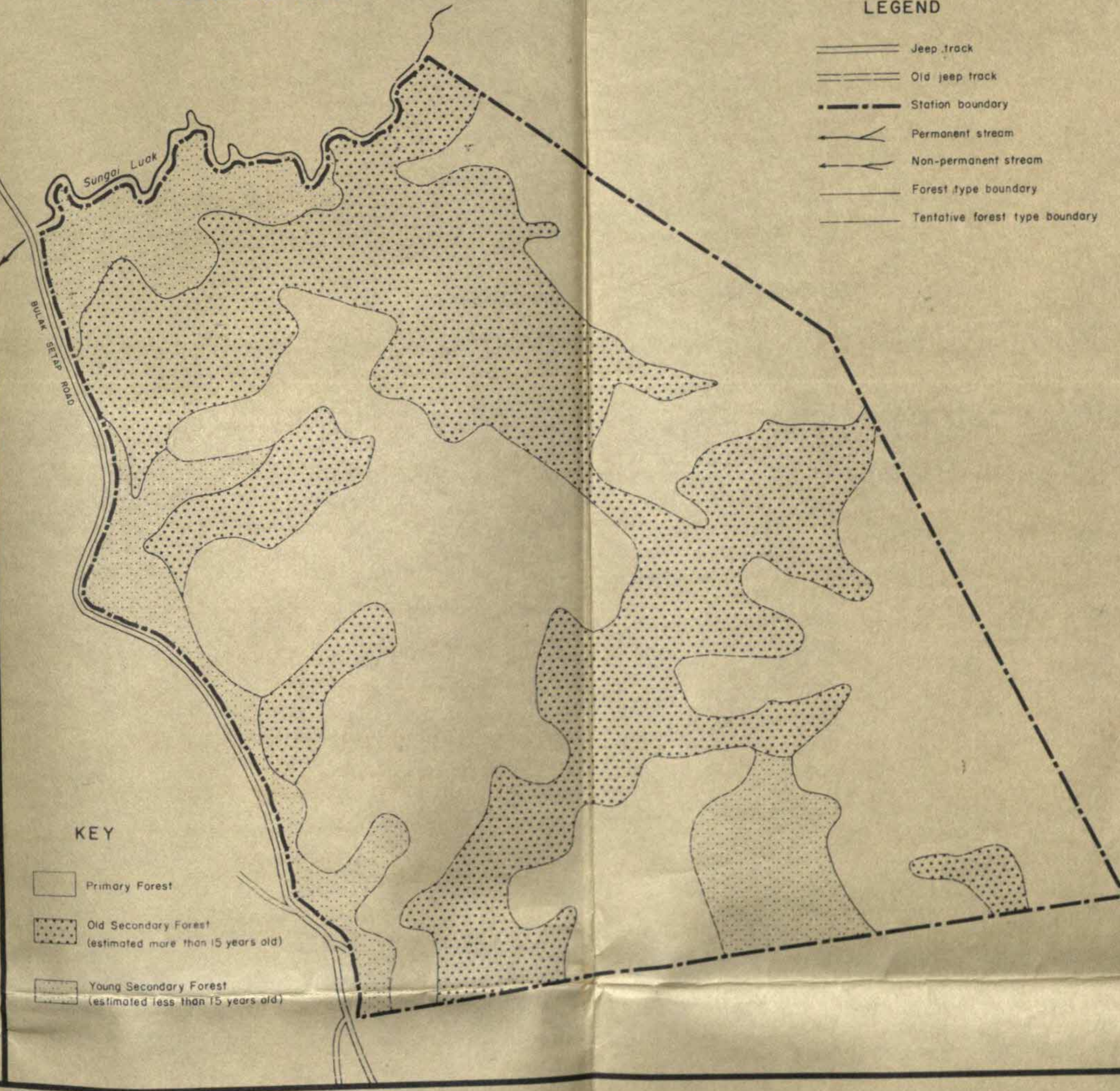
MAP 15b LANDFORMS



MAP 15c SOILS



MAP 15d VEGETATION



KEY TO SOILS

SOIL FAMILY	SOIL SERIES	MAIN CHARACTERISTICS	TOPOGRAPHY	PARENT MATERIAL	REMARKS
NYALAU	Lk LIKAU	Thin to thick humic O horizon overlying dark yellowish to dark grayish brown sandy loam A1 horizon. Shallow to moderately deep brownish yellow fine sandy loam A2 on similarly coloured fine sandy clay loam B2. Well to moderately well drained.	Low hills and ridges, less than 40 feet amplitude; gentle to moderately steep slopes, 10°-30°	Sibuti Formation fine sandstone and subordinate shale.	Associated in places with former terraces. Subject to erosion. Minor inclusion of Labang Series
BEKENU	Lb LABANG	Sporadic thin O horizon, overlying thin dark yellowish brown loam A1 horizon. Thin yellowish brown fine sandy clay loam A2 horizon over yellowish brown clay loam to clay B2 horizon. Moderately well drained.		Sibuti Formation fine sandstone and shale.	Susceptible to topsoil erosion. Includes small areas of Likau and Luak Series.
MERIT	Lu LUAK	Sporadic thin O horizon on thin dark yellowish brown A1 horizon. Moderately deep yellowish brown clay loam A2 horizon over yellowish brown clay B2 horizon. Moderately well drained.		Sibuti Formation shale	Commonly stony within 36 inches of surface. Includes many small areas of Pintasah Series.
	Pt PINTASAH	As Luak Series but with reddish yellow to yellowish red B2 horizon. Moderately well drained.			Commonly stony within 36 inches of surface. Mapped areas schematic.
KABULOH	Kb KABULOH	Rare thin O horizon on thin yellowish to dark yellowish brown clay loam A1 horizon. Moderately deep light yellowish brown clay B horizon mottled light grey in lower part and abruptly overlying C horizon shale. Moderately well drained.	Gently rolling land with slopes less than 15°	Sibuti Formation marl and calcareous shale.	Includes small areas of, and merges with, Malang Series.
MIRI	Mi MIRI	Thick dark reddish brown O horizon on dark greyish brown loamy sand A1 horizon. Moderately deep to deep light grey sand A2 over dark brown loamy sand B2 horizon. Well drained.	Flat topped terrace	Pleistocene sand	Subject to erosion on terrace flanks.
MALANG	Ma MALANG	Moderately thick dark yellowish brown loam A1 horizon over deep yellowish brown clay loam to clay B horizon merging to strongly light grey and reddish brown mottled CG horizon. Moderately well drained.	Flat to gently sloping alluvial basins	Recent clayey alluvium.	Merges with Kabuloh Series.
BIJAT	Sam SAMARAHAN	Thin dark yellowish to dark greyish brown clay loam A1 horizon overlying light grey clay CG horizon, mottled yellowish to reddish brown. Poorly drained.	Flat alluvial basins and small swamps		Merges with Abon and Malang Series. Very poorly drained patches in places.
MUKAH	Ab ABON	10-40 inches mucky peat overlying gleyed clay. Very poorly drained.		Organic accumulations and clayey alluvium.	Merges with Samarahan Series. Deeper peaty material in small patches.
Undifferentiated	A/C Alluvium/Colluvium	Pale coloured sands and sandy clay loam. Poorly drained, to imperfectly drained.	Narrow valleys and flatland close to intermittent streams.	Recent alluvial-colluvial deposits.	Of minor importance
	O Organic Soil	Loose, waterlogged muck and peat deeper than 40 inches.	Flat, small swamps.	Organic accumulations and recent alluvium.	Can probably be converted to Abon Series by drainage.
Associations of Series	Lb/Lu LABANG/LUAK	Refer to individual series.	Low to moderately high hills, amplitude up to 80 feet; slopes 20°-35°	Sibuti Formation sandstone and shale.	Occupies higher land in northeast.
	Kb/Ma KABULOH/MALANG		Low, gently rolling land	Recent clayey alluvium and Sibuti Formation calcareous shale and marl.	Includes small pocket of Samarahan and Luak Series.
SEMILAJAU	Sm/Sl SEMILAJAU	Sporadic O horizon and dark yellowish brown A1 horizon. Deep brownish yellow loamy sand A2 over sandy clay loam B horizon. Moderately well drained.	Flat to gently sloping levees and margins of alluvial basins	Recent sandy alluvium.	About equal proportions of both units
PLAN	SALITUT	Thin peaty topsoil in places overlying thin, yellowish brown then light yellowish brown sandy loam, mottled pale yellow reddish brown and light grey. Poorly drained.