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SEMI-DETAILED SOIL SURVEY OF SUNGEI TELABIT AND SENGAH BLOCKS

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SEMI-DETAILED SOIL SURVEY OF SUNGEI TELABIT AND SENGAH BLOCKS

Prepared for
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A DIVISION OF
Sime Darby Berhad

CONTENTS

SUMMARY AND CONCLUSION

1. The surveyed area consists of 4,162 ha and is divided into Sungei Telabit Block (2,125 ha) and Sungei Sengah Block (2,037 ha). They are situated in the Miri District in the Fourth Division, State of Sarawak.

2. Present vegetation is dominantly logged forest with minor regenerated forest and recent secondary growth. About 374 ha (9%) are currently under shifting cultivation. They are mainly located in the northern periphery of the surveyed area. Some 290 ha in Sungei Sengah Block are water-logged with swamp and sedge vegetation.

3. The topography ranges from flat low-lying to very steep hilly. Occasional steep escarpment is the common feature. About 1,776 ha (43%) are on flat to very gently undulating ($<6^{o}$ slope), 1,908 ha (46%) on rolling to steep terrain (6 to 25^{o} slope) and 478 ha on very steep terrain ($>25^{o}$ slope). Most of the terrain is somewhat broken and dissected with narrow ravines and valley floors.

4. Mean monthly rainfall is around 200 mm. Wetter months are from October to January and drier months from March to April. The mean annual temperature is around $26^{o}C$.

5. Dominant soils of the surveyed area are the Merit and Bekenu Series on sedimentary shale and Nyalau Series on sandstones. These upland soils occupy about 3,383 ha (81%) of the area. The low-lying flats are mainly Bijat Series with associated riverine alluvial soils. Together they occupy about 489 ha (12%). Some 290 ha in Sungei Sengah Block are peat with association gley soils of the Samarahan Series.

6. The upland soils generally pose no limitation to oil palm growth except for area with very steep terrain. However, the broken and dissected nature of the terrain may pose some management problem. The low-lying flats require proper drainage system to improve their poor soil drainage. The peat and massive-structured gley soils are considered unsuitable for oil palm.

7. It is estimated that in the Sungei Telabit Block about 2,015 ha (95%) are considered suitable for oil palm cultivation. About 110 ha (5%) consist of very poorly drained shallow soil and are unsuitable for oil palm. In the Sungei Sengah Block only about 1,181 ha (58%) are considered suitable while the remaining 856 ha (42%) have either too steep terrain or too poorly drained and shallow soil depth for oil palm cultivation.

1. ENVIRONMENT

1. ENVIRONMENT

1.1 Location and Extent

The surveyed area is divided into two blocks, namely Sungei Telabit Block (2,125 ha) and Sungei Sengah Block (2,037 ha). These are situated in the Miri District in the Fourth Division, Sarawak.

The area is located between Latitudes 3^{o} 38' N and 3^{o} 42' N and Longitudes 113^{o} 35' E and 113^{o} 40' E. It is adjacent to the Sungei Galasah Block which was surveyed and reported in 1984. It is accessible via Miri-Bintulu Main Trunk Road. At the 83rd kilometre, a private logging road - B.L.D. Road leads to the surveyed area. The eastern boundary of the area is on the B.L.D. Road.

Map 1 indicates the location of the area.

1.2 Geology

The dominant geology of the area is mainly argilaceous and arenaceous shale with minor sandstones belonging to the Setap Shale Formation of the Oligocene-Miocene epoch.

Alluvial materials of Pleistocene-Holocene epoch occupy the low-lying area. They consist mainly of clay and silt with minor sand. Some peat are also present.

1.3 Landform

It is estimated that about 779 ha (19%) of the surveyed area consist of very flat low-lying alluvium with slope not exceeding 2^{o}. These areas have imperfect to very poor drainage. About 997 ha are on raised unfolded sedimentary with slopes ranging from 0 to 6^{o}. They are occasionally broken by deeply incised streams and rivers with steep escarpment. The remaining 2,425 ha consist of rolling to steep hills, of which 478 ha have slopes exceeding 25^{o}.

Map 2 and Table 1 represent the distribution of the various landforms.

1.4 Vegetation

The majority of the surveyed area is covered with logged hills and riverine forests of Dipterocarp species. These constitute about 2,813 ha (68%) of the area. Some 838 ha (20%) are regenerated forest and recent secondary growth, mainly Macaranga species, bushes, short shrubs and sedges. A small area of old rubber holdings can be found in the Sungei Sengah Block.

Present shifting cultivation is to be found mainly in the northern parts of the blocks, particularly that of Sungei Sengah. They are mainly rice (both flat-land and hill rice), pepper and minor cash crops and fruit trees. They constitute about 374 ha (9%) of the area.

Some of the surrounding areas along the Miri-Bintulu Highway have been planted with oil palm and cocoa.

Map 3 and Table 2 represent the generalised distribution of the various types of vegetation in the surveyed area.

1.5 Climate

The climate of the surveyed area is characterised by high rainfall throughout the year, a relatively uniform temperature and a high relative humidity.

1.5.1 Rainfall

A fourteen-year rainfall record of Sungei Niah* is presented in Figure 1a and 1b. The mean monthly rainfall is around 200 mm.

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* Source: Drainage and Irrigation Department, Hydrology Branch, Sarawak

Table 1 : Estimated hectarages of the various landforms and terrain classes

Landform	Terrain Classes	Slope (deg.)	Hectarage		Total
			Sungei Telabit	Sungei Sengah	
Low lying flats	Level - depressional; very poor drained	0- 2	-	290	290
	Level to nearly level - valley floors; very poorly to poorly drained	0- 2	220	190	410
	Nearly level - recent river terrace - moderate to well-drained	0- 2	55	24	79
Low hills	Nearly level to very gently undulating - (on unfolded sediments)	0- 6	885	112	997
	Rolling	6-12	553	377	930
	Hilly to steep	12-25	412	566	978
	Very steep	25-33	-	449	449
	Extremely steep	> 33	-	29	29

Table 2 : Estimated hectarages of the various vegetation in the surveyed area

Vegetation Types	Sungei Telabit Area	Sungei Sengah Area	Total
Primary Vegetation			
Logged forest	1,740	1,073	2,813
Swamp	-	137	137
Secondary Vegetation			
Re-generated forest and recent secondary growth	293	491	784
Abandoned rubber holdings	-	54	54
Under Cultivation			
Rice, pepper and other cash crops	92	282	374
TOTAL:	2,125	2,037	4,162

FIG. 1a

ISOHYETAL PATTERN OF AVERAGE YEARLY RAINFALL DISTRIBUTION

(RECORDS UP TO 1978)

50 mm interval

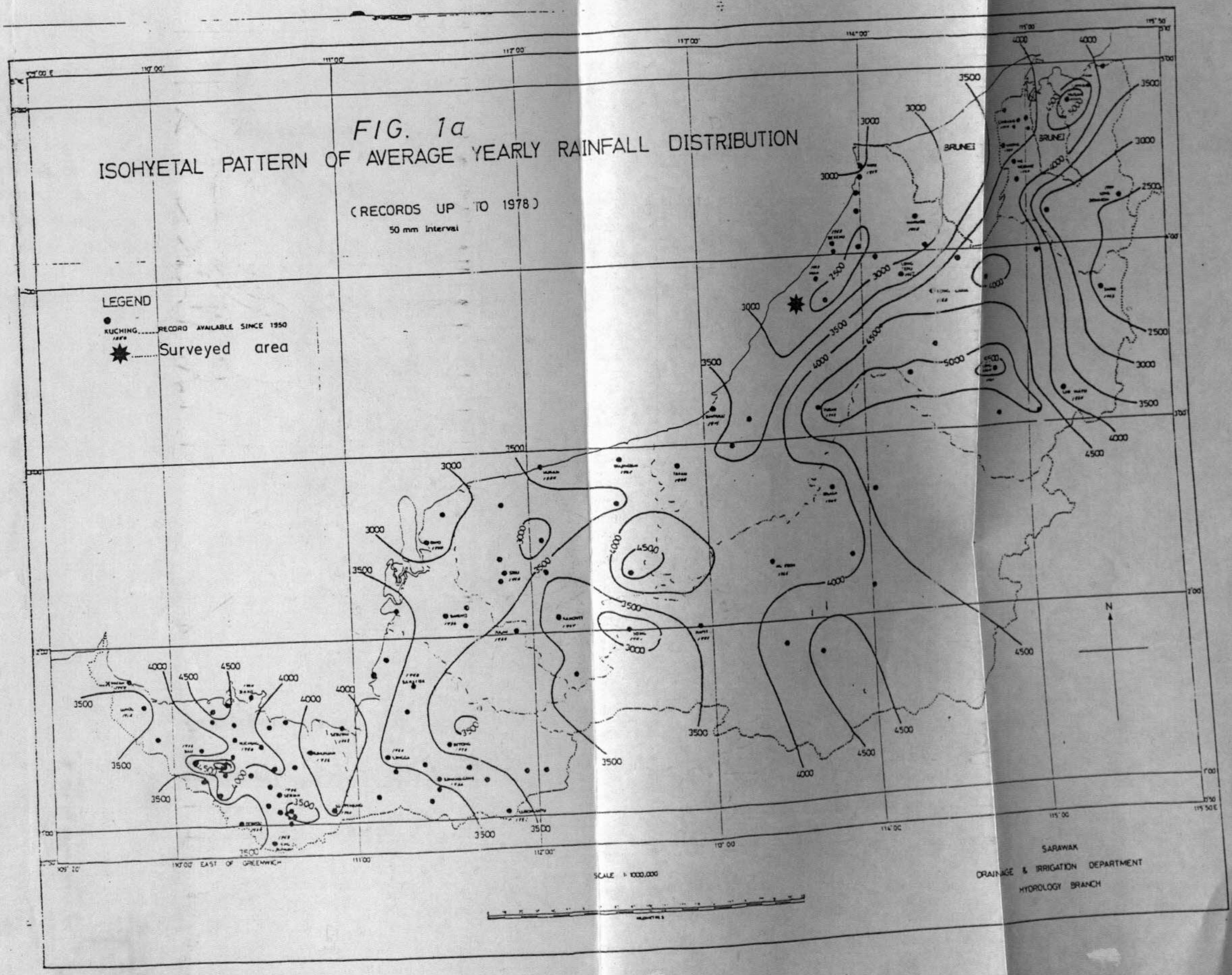
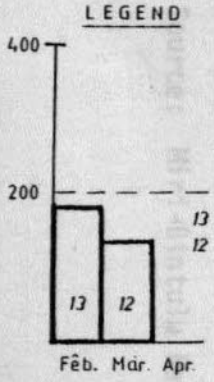
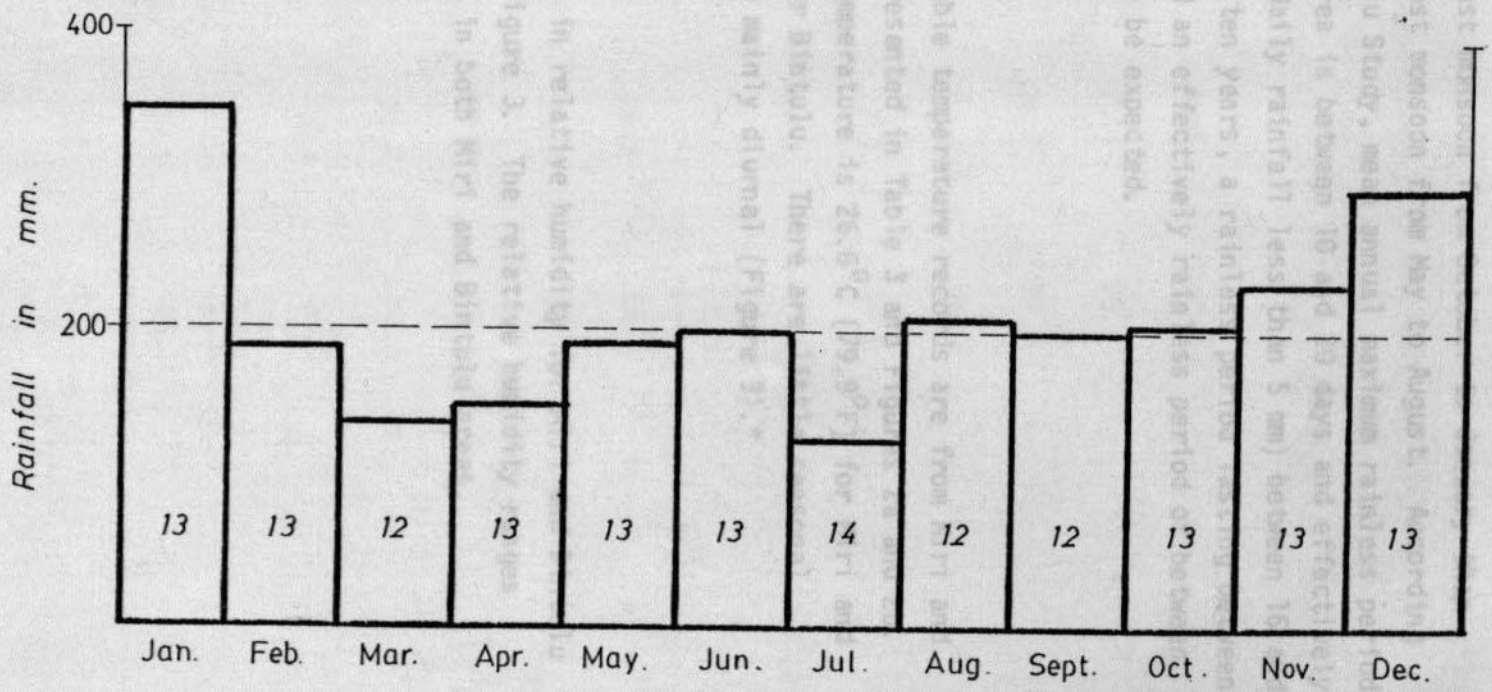


Figure 1b : AVERAGE MONTHLY RAINFALL DISTRIBUTION
SG. NIAH.
(1963 TO 1976 RECORD)





Highest rainfall is recorded in January and the lowest rainfall in March. The monthly precipitation is significantly higher during the Northeast monsoon from October to January than during the Southeast monsoon from May to August. According to the Miri-Bintulu Study, mean annual maximum rainless period in the surveyed area is between 10 and 20 days and effectively rainless period (daily rainfall less than 5 mm) between 16 and 26 days. Once in ten years, a rainless period lasting between 20 and 30 days and an effectively rainless period of between 27 and 45 days can be expected.

1.5.2 Temperature

The nearest available temperature records are from Miri and Bintulu and are presented in Table 3 and Figures 2a and 2b. The mean annual temperature is 26.6°C (79.9°F) for Miri and 26.5°C (79.7°F) for Bintulu. There are little seasonal variations and are mainly diurnal (Figure 3).*

1.5.3 Humidity

Diurnal variations in relative humidity for Miri and Bintulu are presented in Figure 3. The relative humidity ranges between 70 and 95% in both Miri and Bintulu areas.

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* Source: Miri-Bintulu Regional Study

Table 3: Mean Monthly Temperature (^{o}C) for Miri and Bintulu*

Month	Miri	Bintulu
January	25.7	25.7
February	26.1	26.0
March	26.6	26.3
April	27.1	26.9
May	27.3	27.2
June	27.0	26.9
July	26.9	26.8
August	26.9	26.8
September	26.7	26.6
October	26.7	26.6
November	26.4	26.3
December	26.3	26.1
Mean annual	26.6	26.5

*Source: Perkhidmatan Kajicuaca Malaysia,
(records from 1972 - 81)

Figure 2a : MEAN MONTHLY TEMPERATURE DISTRIBUTION

MIRI

10 YEARS RECORD

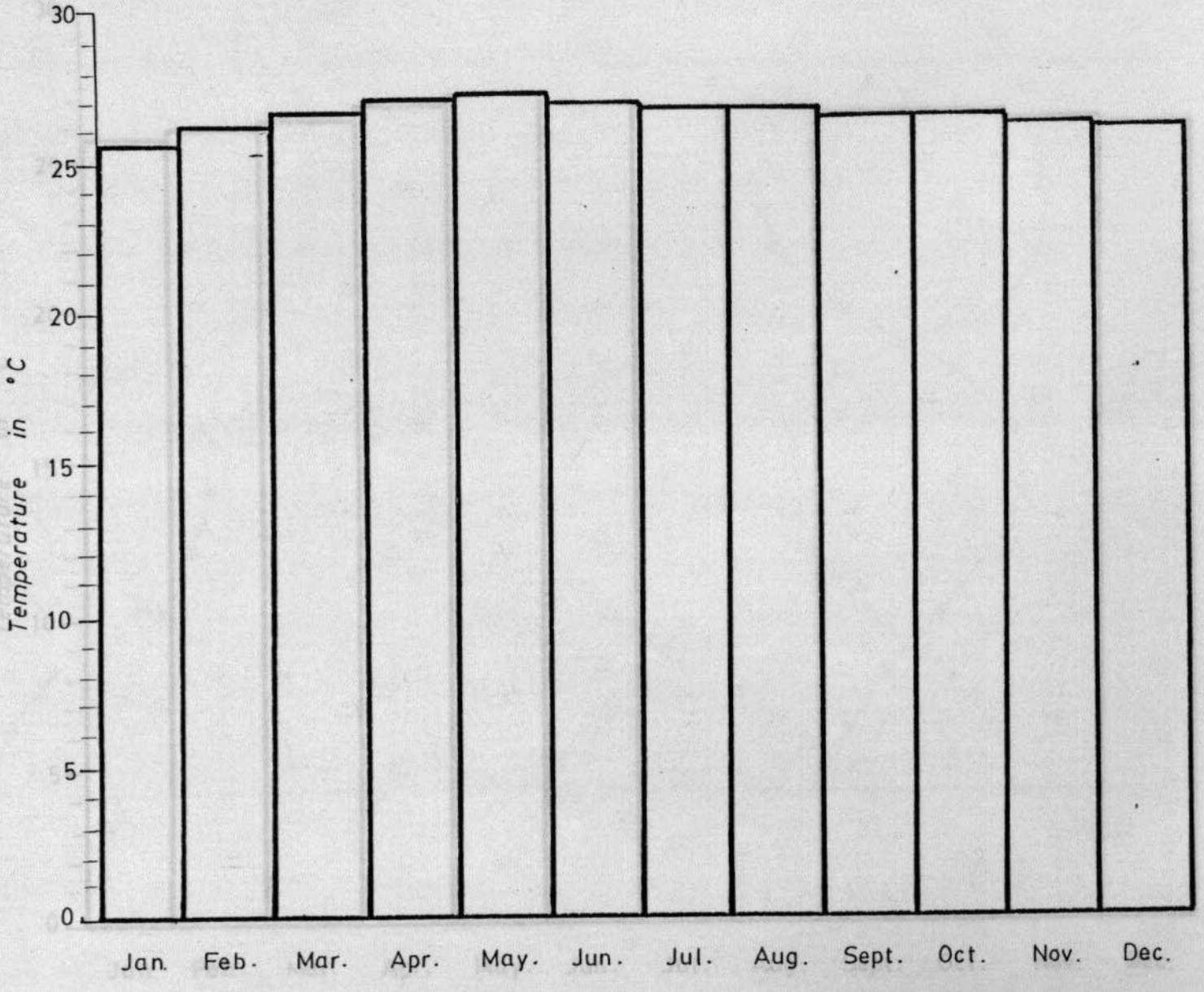


Figure 2b : MEAN MONTHLY TEMPERATURE DISTRIBUTION

BINTULU

10 YEARS RECORD

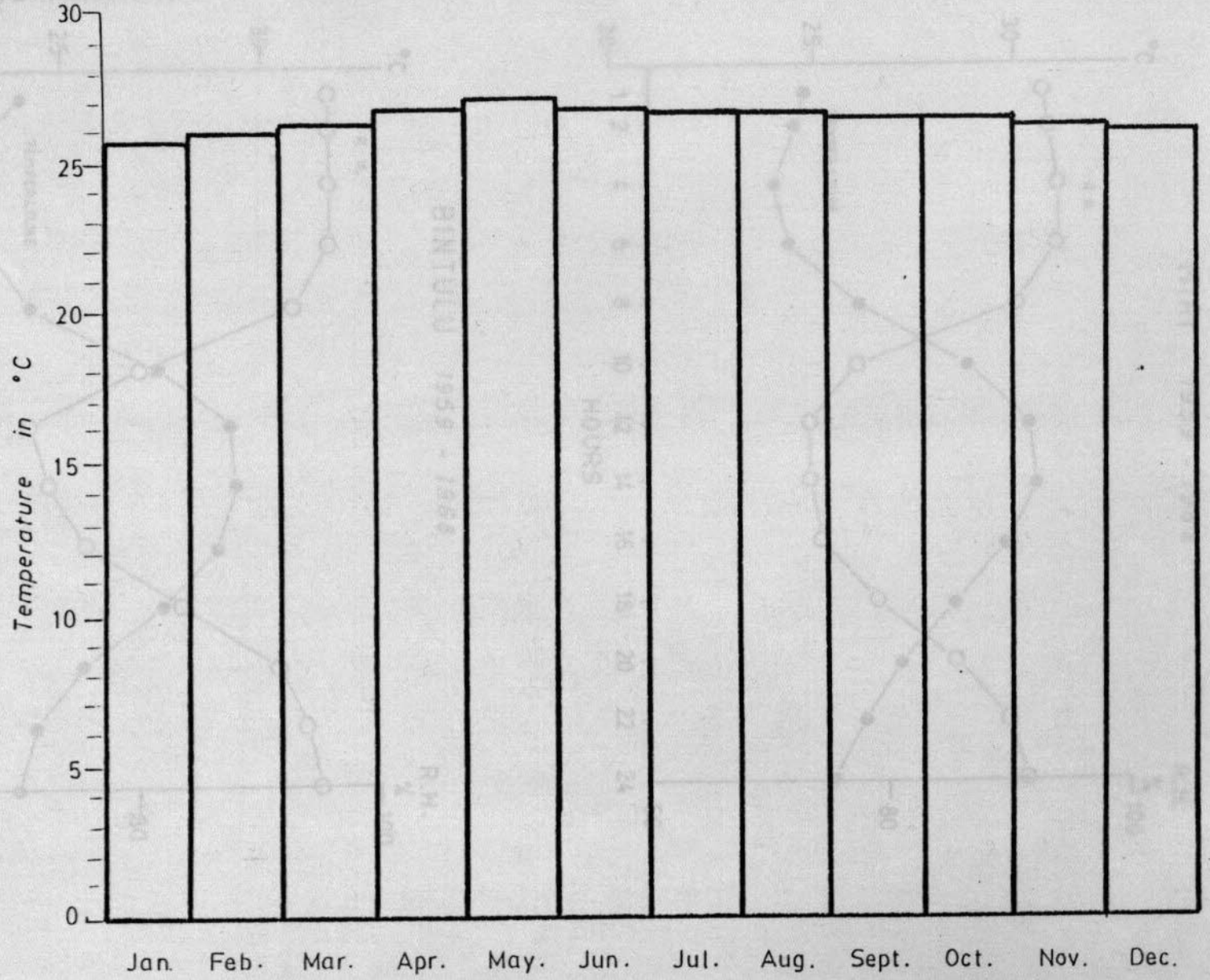
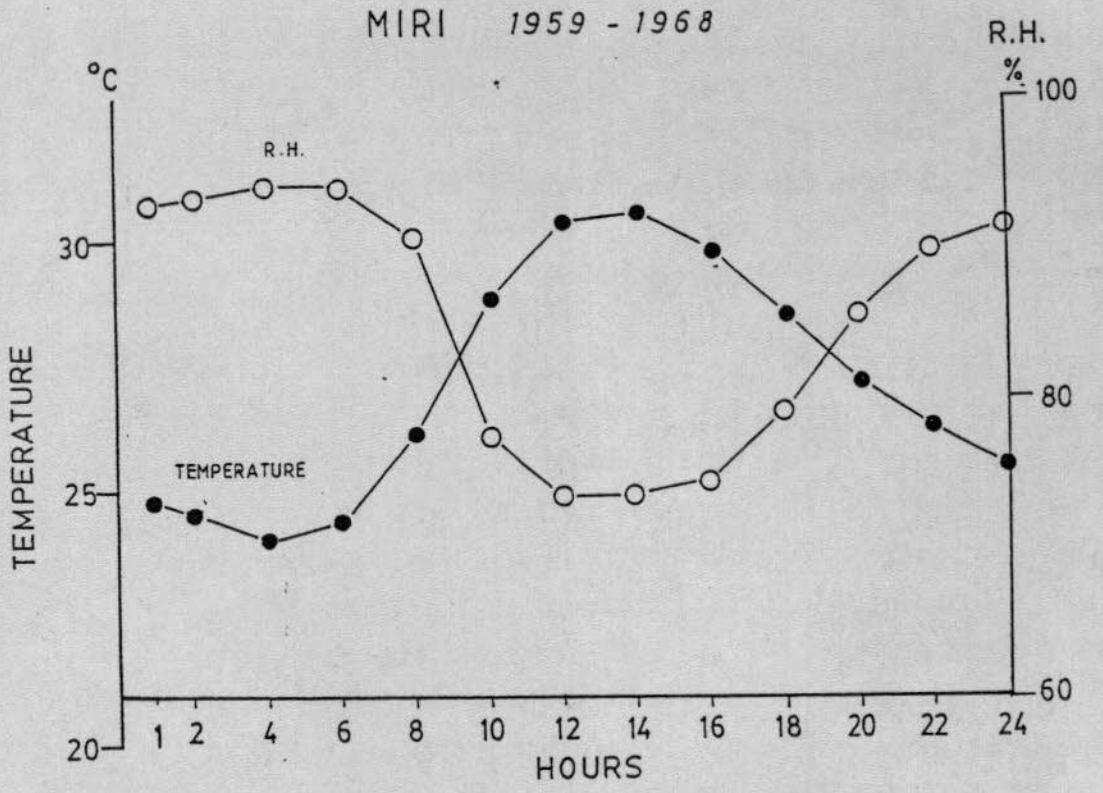
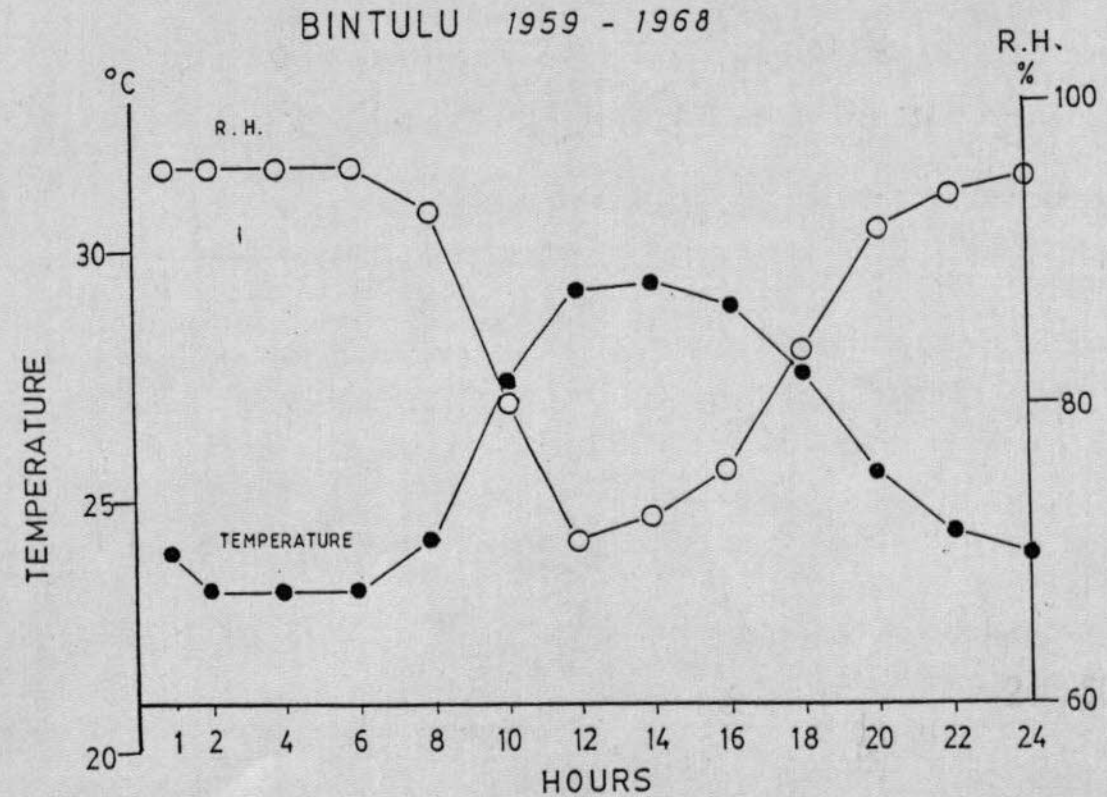


Figure 3 : DIURNAL VARIATION IN TEMPERATURE AND RELATIVE HUMIDITY





2. SOILS

2. SOILS

2.1 Method of Soil Survey

The survey was carried out at a semi-detailed level. Rentices were cut at a spacing of about 1 km apart and were aligned in north-south or east-west direction. A total of 2,041 chain and 1,031 chain of rentices were cut in Sungei Sepupok and Sungei Galasah Blocks respectively.

A total of 52 soil examination profiles were dug and examined. Each soil profile was about 150 cm deep or to the parent rock layer. The soil profiles were located along the rentices throughout the blocks. Soil properties studied in these profiles included soil colour, texture, structure, consistency, porosity, root distribution, etc. In addition to soil profiles, soil auger holes were made and studied at regular intervals of 200 m or less along the rentices. The soils were described according to methods laid down in Handbook No. 18, U.S. Department of Agriculture, Soil Survey Manual (1951).

89 soil samples from the 24 selected soil profiles were collected for soil mechanical and chemical analyses in Ebor Laboratories of Sime Darby Plantations, Klang, Selangor.

Map 4 represents the rentice design and location of the soil examination pits in the surveyed area.

Ring samplers were used to obtain undisturbed soil samples for determination of soil bulk density. Three ring samples from each soil horizon of the selected profiles were taken.

2.2 Soil Classification Units

The soils of the surveyed area are classified according to the system used in the revised "Soil Classification in Sarawak" (TIE 1982). The mapping units used are "soil series" which

consist of soils with similar arrangement and characteristics of diagnostic horizons and formed on similar parent materials. Where individual soil series cannot be mapped and shown separately on the map, "soil association" is used. This consists of a group of soil series regularly geographically associated in a defined proportion pattern but are unmappable separately due to the scale of survey and mapping.

2.3 Soils of the Surveyed Area

A total of 7 dominant soil series were identified and demarcated. Map 5 is the semi-detailed soil map of the surveyed area.

2.3.1 Merit Series

This is the most dominant soil series in the surveyed area. It is widespread in both Sungei Telabit and Sungei Sengah Blocks.

Merit Series is classified as red-yellow Podzolic soils that have a fine clayey particle-size class. Clay content for the whole soil is between 35 - 60%. CEC is > 24 meq per 100 g clay in the major part of the B horizon. It is developed from non-calcareous argilaceous shale on gently undulating to steep topography. The soil is characterised by the brownish yellow to yellowish brown well-drained clay with well-developed blocky structures. It is moderately deep to deep with no impervious parent rock occurring within 100 cm depth.

The superficial surface layer consists of both undecomposed and decomposed loose leaf litters and organic debris. This is underlain by a humus rich mineral layer (Ah horizon) which seldom exceeds 5 cm thick. It consists of yellowish brown to dark brown friable sandy clay loam to clay loam. Structures are moderately developed, fine and medium subangular blocky. Crumbs are present and are more prominent in the upper part of the horizon. Where the soil surfaces are exposed and not covered with organic debris, the thickness of the top soil

becomes very thin or even absent. The sub-surface soil (B_1 horizon) lies immediately underneath the top soil and averages about 15 cm thick. It consists of friable sandy clay loam to clay loam with moderate to somewhat strongly developed coarse subangular blocky structures. A prominent feature of this horizon is the presence of many organic acid coatings on soil ped surfaces. The colour of these coatings resembles the soil matrix colour of the overlying top soil. Faunal pedoturbations are evident in the form of fine ($\pm$ 20 mm) scattered "krotovinas" which are very porous and are yellowish brown to dark brown in colour. The B_1 horizon has the maximum illuviation of organic acid from the surface horizon and the soil matrix colour is paler brownish yellow. The Ah and B_1 horizons together have the maximum concentration of both fine and coarse roots ($<$ 1 mm and $>$ 5 mm in diameter). Pores are many and ranges from very fine to coarse sizes.

The horizon with maximum clay content occurs below the B_1 horizon. Most profiles have $>$35% clay in this horizon. Structures are somewhat strongly developed coarse and very coarse subangular blocky and consistency is friable. There is little variation in soil colour amongst profiles and is mainly brownish yellow or reddish yellow to strong brown. Faunal activities are less prominent and krotovinas are found mostly in the upper layer of this horizon. Cutans are common on most of the ped surfaces. They are somewhat continuous, moderate to well-developed, and are paler in colour than the interior of the soil peds. Although both the fine and coarse roots are present, their concentrations are generally lower.

A common feature of some of the Merit Series is the presence of concretions in the lower part of the B horizon. These concretions are mainly iron-coated shale, though very few laterites are also present. They are soft and can easily be broken between the fingers. Most of them are platy in shape and still retain their original sedimentary rock nature.

They are about 5 to 30 mm wide on their widest axis. Some profiles have higher concentration of up to 50% by volume. They are, however, not thick compact and in many of the profiles studied, fine roots have been found to penetrate through this horizon. It is not likely that this concretionary layer will pose any serious limitation to root penetration.

Very common, a BC_R layer may occur, usually at the lower depth of the B horizon. This consists of about 10 to 40% of the stony undecomposed parent rock. The stones are about 10 to 20 cm in size and are spaced at about 15 to 40 cm apart. The interstices are filled with clay of the overlying horizon. Roots are present and the layer poses no limitation to root penetration.

In some of the profiles studied, a transitional layer is present between the B horizon sub-soil and the underlying parent rock. This constitutes the BC or C horizon in which the structures are weakly developed and, in some cases, tending towards massive. Their soil colours are variegated and mottled with grey - a dominant colour of the underlying parent rock. Micro-bio activities are practically absent and the root concentration is usually very low to nil. Underneath this variegated horizon lies the parent rock - shale, with varying degree of weathering and hardness. This impervious layer is not penetrable by roots. It is noted that in many of the profiles and soil auger examinations, the continuous impervious parent rock is not met within 100 cm from the soil surface, even on some of the steeper slopes. Only very few auger examinations have encountered shallower soil depth on slope $> 33^{o}$.

The geomorphic age of the soils of Merit Series is considerably young. This is shown by some of the very steep slopes on low elevation. True laterites are few and gravels are mainly iron-coated parent materials. Pedimentation process is still in its very early stage. These conditions therefore favour the formation of the deeper soils in the surveyed area.

Merit Series soils are acidic with pH ranges from 3.8 to 4.9. Organic carbon is highest in the Ah horizons with values ranging from 2.2 to 5.0%. This is followed by the B_1 illuviated horizons with values ranging from 0.8 to 2.1%. There is an abrupt decrease of organic carbon in the underlying B horizons where most values are below 0.8%. Total exchangeable bases (TEB) are highest in the Ah horizons and lowest in the B horizons. The organic rich Ah horizons have TEB values ranging from 1 to 5 meq/100 gm. Sub-soil B horizons have lower TEB and have values of less than 1 meq/100 gm. Except for the Ah horizons, base saturation of most sub-soils are below 5%. Cation exchange capacity (CEC) for the whole soil is, however, high at $>$ 24 meq/100 gm clay.

A profile description of a typical Merit Series and the analytical data are provided in Appendices I - VI.

2.3.2 Bekenu Series

Bekenu Series is classified as red-yellow Podzolic soils that have a fine loamy or fine silty particle-size class with 35 to 60% clay content for the whole soil. It is developed on fine sandy shale and occur mainly on the steeper terrain in the surveyed area. It is mapped in association with soils of the Merit Series.

The superficial surface layer consists of both undecomposed and decomposed loose litters. Underneath this A_o horizon is a humus rich thin Ah mineral layer, usually less than 5 cm thick. It consists of yellowish brown to dark brown very friable fine sandy clay loam. Structures are moderately developed, fine and medium subangular blocky and some crumbs. The B_1 horizon lies immediately underneath the top soil and consists of brownish yellow fine sandy loam to fine sandy clay loam. Structures are moderately developed with medium and some coarse subangular blocky structures and very friable consistency. Coatings of organic acid are common on most of the ped surfaces. Both the Ah and B_1 horizons have the highest concentrations of fine to coarse roots.

Sub-soil B_2 horizon is usually deep, extending to below 100 cm deep. It consists of brownish-yellow to reddish-yellow to strong brown fine sandy clay loam to fine clay loam. Structures are moderately developed with coarse subangular blocky structures and friable to very friable consistency. Faunal activities are present and krotovinas are common up to the upper layer of the B_2 horizon. The structures are less developed as compared to the corresponding horizons in the associated Merit Series. Structures are easily broken down into fine, medium or coarse subangular blocky. Micro-bio activities are present and krotovinas are observed up to the upper part of the B_2 horizon. Cutans are common, and pores and roots are concentrated more towards the upper B horizon and decrease with depth.

Gravels of laterites and platy laterised (iron-coated) shale and undecomposed stony parent rocks may be present, usually in the lower part of the B horizon. Their occurrences are similar to those of the Merit Series in terms of their amount, distribution and compactness. They are considered not a serious limitation to root penetration.

The major chemical properties of Bekenu Series are quite similar to those of the Merit Series. The soils are strongly to extremely acid. Organic acid is highest in the Ah horizon and decreases abruptly in the B horizon. Total cations are lower than those of the Merit Series. Total exchangeable bases are very low at below 0.5% in most of the sub-soil. The CEC for the whole soil is more than 24 meq/100 gm clay.

A profile description of a typical Bekenu Series and the analytical data are provided in Appendices VII - X.

2.3.3 Nyalau Series

Nyalau Series is classified as red-yellow Podzolic soils that have a yellow-coloured coarse loamy particle-size class. It is developed on sandstone and occurs on very gently undulating topography.

The top soil consists of a thin layer of yellowish brown friable sandy loam with moderately developed fine and medium structures. Sub-soil consists of brownish yellow fine sandy loam. Structures are friable with medium blocks becoming coarser with depth. The soil is deep but soft decomposing sandstone gravels may be encountered at depth below 75 cm. These gravels, however, pose no limitation to root penetration. The soil is somewhat excessively drained and high leaching loss of plant nutrient can be expected.

Nyalau Series is strongly acidic with pH between 4.5 to 4.8. This sandy soil is very low in its available plant nutrients, with total exchangeable bases for sub-soil at below 0.3 meq %. Due to the low clay content, the CEC is low at less than 10 meq/100 gm soil.

A profile description and the analytical data of the Nyalau Series are provided in Appendix XI.

2.3.4 Bemang Series

Bemang Series is classified as Alluvial soils that have a fine loamy particle-size class with 18 to 25% clay content for the whole soil. It is formed in alluvium derived from non-calcareous sedimentary rocks.

The soil is limited in its occurrence and is confined mainly along the banks of some tributaries. The organic A_0 horizon consists of leaf litters and may organic debris. The Ah horizon is only about 2 cm thick and consists of dark brown friable loam. The underlying B_1 horizon is dark yellowish brown loam with medium blocky structures and friable consistency. The sub-soil B_2 horizon is deep with yellowish brown friable loam. Mottles may be present at depth below 75 cm. The soil is moderately well-drained and may be subject to short-duration flooding during the rainy period.

Bemang Series is acidic in the top soil with pH between 5.4 to 5.5 while sub-soil is strongly acidic with pH 4.4. Total exchangeable bases are higher in the surface 20 cm soil with values between 3 to 7 meq % while sub-soil value is below 1 meq %. The higher exchangeable bases of the surface soil are mainly due to the higher exchangeable Mg and Ca values.

A profile description of a typical Bemang Series and the analytical data are provided in Appendix XII.

2.3.5 Bijat Series

Bijat Series is classified as Gley soils that have developed in marine or accreting riverine alluvium from non-calcareous sedimentary rocks and have a clayey particle-size class. The soils have white to grey colour within 50 cm of the mineral soil surface.

It is found in both broad and narrow valley floors with sedges and poor riverine forest being the dominant vegetation. The top soil consists of about 5 cm thick very dark greyish brown friable silt loam. Sub-soil colour is light brownish grey changing to light grey with depth. Prominent mottles of yellowish brown, strong brown and yellowish red are common and occur immediately below the Ah horizon. At depth below 75 cm the soil is massive with very poor soil structural development. Bijat Series is poorly drained and is subject to frequent flooding during the rainy months.

The soil is strongly acidic throughout with pH between 4.6 to 5.1. Total exchangeable bases range from 1.4 to 3.2 meq % with generally higher exchangeable Mg and Ca.

A profile description and the analytical data of Bijat Series are provided in Appendix XIII.

Note: Majority of the auger examination of Bijat Series have clayey texture.

2.3.6 Samarahan Series

Samarahan Series is classified as Gley soils that have developed in marine or accreting riverine alluvium from non-calcareous sedimentary rocks and have a clayey particle-size class. The soils have a greenish grey colour within 50 cm of mineral soil surface.

It occurs on depressional back swamp and valley floors and is often associated with peat soils of Mukah Series.

The surface horizon is usually covered with sedges or debris of organic matters at various degrees of decomposition. The top soil consists of about 5 cm thick dark reddish brown clay loam. This is followed by a weakly developed to massive structured light grey silty clay loam. Mottles are very few or absent. Few inclusions of organic debris are found in the upper part of the horizon. Samarahan Series is very poorly drained with stagnant water at or near the soil surface. It is easily flooded especially during the rainy season.

The soil is strongly acidic with pH between 4.2 and 4.3. Total exchangeable bases range from 3 to 5 meq % with higher exchangeable Ca and Mg.

A profile description and the analytical data of Samarahan Series are provided in Appendix XIV.

2.3.7 Mukah Series

Mukah Series is classified as Organic soils that have 50 to 150 cm of organic soil materials resting on clayey, non-sulphidic substratum. The organic soil materials are autochthonous and have a low ash content.

Mukah Series is found in the depressional back swamp basin of Batang Suai River. The organic materials consist of slightly decomposed fragments of plant tissues, many of which still retain the recognisable structures of the plants. A massive gleyed horizon of clayey texture is met between 50 to 150 cm

from the soil surface. The soil is very poorly drained and is water-logged in most parts of the year. Swamp forest is the dominant vegetation.

A profile description of Mukah Series is provided in Appendix XV.

A summary of some salient soil properties of the 7 soil series and their estimated hectarages is provided in Tables 4a and 4b.

2.4 General Soil Properties of the Surveyed Area

- Sub-soil clay content for most soils is above 20%, except for Nyalau and Bemang Series.

- Sub-soil silt content for most soils is above 30%, except for Nyalau Series.

- Gravels and stones may be present in small amount in soils derived from sedimentary rocks. They are not likely to pose limitation to root penetration.

- Most of the alluvial soils are poorly to very poorly drained and are subject to flooding during rainy days.

- All the soils are considered strongly acidic with pH generally below 5.2.

- CEC/100 gm soil is generally medium to low but CEC/100 gm clay for all soils generally exceeds 40 meq %, except for Nyalau Series.

- Total exchangeable bases (TEB) for top soil are higher than those of sub-soil, with values ranging from 1 to 6 meq %. However, TEB for the sub-soil are very low at <1 meq % for sedimentary soil of Merit, Bekenu and Nyalau Series and higher for alluvial soil of Bijat and Samarahan Series where values range from 1 to 3 meq %. Higher TEB are mainly due to higher exchangeable Ca and Mg.

Table 4a : Summary of some salient soil properties

SOIL SERIES		SOIL CHARACTERISTICS
Mrt	Merit	on shale; texture is clay loam to clay to silty clay loam; with 35 to 60% clay; brownish yellow to reddish yellow to strong brown; moderately deep to deep; stony and non-stony; well-drained; nearly level to very steep.
Bku	Bekenu	as above but texture is clay loam to clay; with 18 to 35% clay.
Nlu	Nyalau	on sandstone; texture is fine sandy loam; with less than 18% clay; brownish yellow; deep; stony and non-stony; somewhat excessively drained; nearly level to very gently undulating.
Bmg	Bemang	on alluvium; texture is loam; yellowish brown; moderately deep to deep; non-stony; moderately well-drained; nearly level.
Bjt	Bijat	on alluvium; texture is silty clay loam; light brownish grey with mottles; moderately deep; massive clay at below 75 cm soil depth; imperfect to poorly drained; nearly level to level.
Smn	Samarahan	on alluvium; texture is silty clay loam; light grey; very shallow; massive clay within 25 cm soil surface; very poorly drained; level.
Mkh	Mukah	on organic debris; peat and much 50 to 150 cm thick overlying massive clay; very poorly drained; depressional.

Table 4b : Estimated hectarages of the various soil units

Soil Unit	Slope (Degree)	Sungei Telabit (ha)	Sungei Sengah (ha)	Total
Merit/Bekenu 5ab	0 - 6	791	73	864
Merit/Bekenu 5c	6 - 12	553	377	930
Merit/Bekenu 5de	12 - 25	412	566	978
Merit/Bekenu 45f	25 - 33	-	449	449
Merit/Bekenu 45g	>33	-	29	29
Nyalau/Bekenu 5ab	0 - 6	94	39	133
Bemang 4	0 - 2	55	24	79
Bijat 3a	0 - 2	110	102	212
Samarahan 1a	0 - 2	110	88	198
Mukah/Samarahan 1a	0 - 2	-	290	290
		2125	2037	4162

3. LAND CAPABILITY CLASSIFICATION

3. LAND CAPABILITY CLASSIFICATION

3.1 Method and Criteria

The method and criteria used in assessing the land capability classes of the surveyed area is in accordance to the "Sarawak Land Capability Classification and Evaluation for Agricultural Crop" by E. F. Maas et al (1979).

In assessing the land capability classes, various factors which affect crop growth are considered. These are:-

- Depth to impervious rock layer
- Depth to massive clay
- Depth to sulphidic layer (if any)
- Depth of organic layer
- Depth to groundwater table
- Erosion hazard
- Inundation hazard
- Fertility status
- Fertility of organic layer
- Degree of humification
- Moisture-holding capacity
- Slope
- Wetness
- Texture of mineral sub-soil at 50 - 100 cm
- Stoniness (within top 25-cm soil).

Factors limiting crop growth have been separated into the following five levels of severity ranging from none to very serious.

a) None: No crop restrictions attributable to soil, water or terrain criteria.

b) Minor: Limitations that reduce the productivity of only a few specific crops or that can be easily corrected by proper management.

c) Moderate: Soil, water and terrain limitations that restrict the range of crops or require moderate conservation practices.

d) Serious: Soil, water and terrain limitations that will seriously inhibit or even preclude the growing of some crops but which may be well suited to others.

e) Very serious: Soil and terrain limitations that will not only hinder but may totally inhibit the use of this land for crop production.

Tables 5a and 5b present the limiting factors for crop growth and the degree of limitation.

3.2 Land Capability Classes

Land is grouped into various capability classes based on the presence and/or absence and the severity of crop growth limitation. The capability classes of mineral soils and organic soils are as follows:-

Capability Classes of Mineral Soils

Class 1: Land with no limitations or only one minor limitation to crop growth.

Land in Class 1 imposes no significant limitation to plant growth and is suitable for the widest range of climatically adapted upland crops. The soils are deep with level to very gently sloping topography.

Table 5a: Limitations to Crop Suitability on Mineral Soils

Symbol	Type of Limitation	Degree of Limitation				
		None	Minor	Moderate	Serious	Very Serious
a	Depth to sulphidic layer (cm)	>100	75 - 100	50 - 75	<50	-
c	Depth to massive clay (cm)	>75	50 - 75	25 - 50	<25	-
d	Soil depth to impervious layer or 50% rock fragments (cm)	>100	75 - 100	50 - 75	25 - 50	<25
e	Erosion hazard	None	Low	Medium	High	Very high
f	Fertility	Medium	-	Low fertility, low retention	Acute deficiency, very low retention	-
i	Inundation hazard (frequency and duration)	None	Infrequent, short	Frequent, short	Infrequent, long	Frequent and long or submerged
m	Moisture-holding capacity	High (loam to clay)	-	Medium (sandy loam)	Low (fine and medium sands)	Very low (coarse sand)
o	Depth of organic layer (cm)	<25	-	25 - 50	-	-
r	Stoniness (% rock fragments or stone within top 25 cm)	<0.1	0.1 - 3	3 - 15	15 - 50	>50
t	Slope (topography)	0 - 6°	6 - 12°	12 - 25°	25 - 33°	>33°
w	Wetness	Well drained	Mod. well drained	Imperfectly drained	Poorly to very poorly drained	-

Table 5b: Limitations to Crop Suitability on Organic Soils

Symbol	Type of Limitation		Degree of Limitation				
			None	Minor	Moderate	Serious	Very Seriou
a	Depth to sulphidic layer* (cm)		>100	75 - 100	50 - 75	-	-
f	Fertility of the organic layer		Medium (loamy** muck)	-	-	Very low (peat or sandy muck)	-
g	Depth to ground-water table (cm)	Natural	-	-	30 - 60	0 - 30	-
		drained	60 - 100	-	30 - 60	>100	-
h	Degree of humification		Hemic-sapric	-	-	Fibric	-
i	Inundation hazard (frequency and duration)		None	Infrequent, short	Frequent, short	Infrequent, long	Frequent and long, or submerged
n	Nature (texture of mineral sub-soil at 50 - 100 cm		Fine loamy to clayey	-	-	Sandy to coarse loamy	-
o	Depth of organic layer (cm)		-	-	50 - 100	>100	-

* Depth after reclamation; allow 25 cm more for subsidence of virgin organic soil

** The clay component must be greater than 18%

They are well to moderately well-drained and have good water and nutrient-holding capacities. They are easily maintained in good tilth and productivity. Mineral drainage or soil conservation measures are required.

Class 2: Land with two or three minor limitations or one moderate limitation that restricts the range of crops and/or requires moderate drainage or some conservation practices.

Land in Class 2 is incapable of supporting quite as wide a range of annual and perennial crops as that in Class 1. The soils are deep, level to moderately sloping and have good to imperfect drainage. If flooding occurs, it is of short duration. The soils can be managed and cropped with little difficulty.

Class 3: Land with two or three moderate limitations or one serious limitation that restricts the range of crops, the degree of possible mechanisation, or requires special conservation practice.

Land in Class 3 has more pronounced or more kinds of limitations than that in Class 2 and conservation practices are more difficult to apply and maintain. In this class the limitations that restrict the ease of tillage, planting and harvesting, the choice of crops and the application and maintenance of conservation practices may include moderately severe effects of erosion, low fertility correctable with consistently high applications of fertilizers, hilly terrain, frequent over flow accompanied by crop damage, poor drainage, moderate salinity, restricted rooting zone, low water-holding capacity or stoniness sufficiently severe to hinder cultivation.

Class 4: Land with several moderate or two or three serious limitations that severely restrict the range of crops or require special conservation practices, or both.

Land in Class 4 has such limitations that it is only suitable for a few crops, the yield is low or the risk of crop failure is high. The limitations may seriously affect such farm practices as the timing, ease of tillage, planting, harvesting and the application and maintenance of conservation practices. Limitations include very low water-holding capacity, low fertility which is difficult or unfeasible to correct, steep slopes, severe erosion, frequent flooding with severe effects on crops or very restricted rooting zone over bedrock.

Class 5: Land with such severe limitations that, with a few limited exceptions, precludes the use of the area for agriculture. Limitations include very steep slopes (greater than 33^{o}), very severe erosion hazard, frequent floods of long duration, excessive salinity, shallow soils over bedrock or extremely low nutrient and moisture-retaining capacity.

Capability Classes of Organic Soils

Class 05: Land consisting of peat greater than 100 cm deep or shallow peat over sand. Class 05 land has four or more serious limitations in its original state that, with the exception of sago, precludes the use of the area for agriculture without major improvement. Limitations may include low fertility, undecomposed surface peat, high water table, inundation and deep accumulation of raw peat.

Class 04: Land suitable without drainage for only sago and rice. This land has two or three serious limitations that restrict the range of crops and requires special management practices. In its unimproved state, Class 04 land may have such serious limitations as salinity, high water table, low fertility and an undecomposed fabric surface layer.

Classes 03 and 02: These are good soils for wet-land rice or sago and dry-season crops such as vegetable, maize and soyabeans. They have one serious limitation in the undrained state, i.e. wetness. If already drained, they may have two or three moderate limitations or one serious limitation such as low fertility or muck more than 100 cm deep. These limitations restrict the range of crops or require considerable improvement before the range of crops can be extended.

3.3 Land Capability Subclasses

The land capability subclasses are subdivisions within the capability classes. They are formed on the basis of the kinds of limitation encountered and hence provide specific guidelines in the choice of suitable crops and the management required. These limitations are designated on the capability map by letter symbols after the capability class rating. Fifteen possible limitations are recognised and are given below:-

	Limitation	Symbol
a) Mineral soils:	Depth to massive clay	c
	Depth to impervious layer	d
	Erosion hazard	e
	Moisture-holding capacity	m
	Stoniness	r
	Slope (topography)	t
	Wetness	w

		Limitation	Symbol
b)	Mineral or organic soils:	Depth to sulphidic layer (potential acid-sulphate)	a
		Fertility	f
		Inundation hazard	i
		Depth of organic layer	o
		Salinity of ground water	s
c)	Organic soils:	Depth to groundwater table	g
		Degree of humification	h
		Nature (texture) of mineral sub-soil	n

3.4 Land Capability of Surveyed Area

Terrain, physiographical, soil physical and chemical properties of the surveyed area are examined. The land capability classes of the various soils are provided below:-

Soils of Merit and Bekenu Series

These are deep to moderately deep well-drained soils. Textures range from clay loam to clay in the Merit Series to sandy clay loam in the Bekenu Series. The structures are moderately to well-developed. They occur on flat to extremely steep terrain.

These soils generally pose no major limitation to plant growth except where they occur on steep terrain. The gravels (laterised shale), if present, are loosely packed in thin horizon and constitute less than 50% of the soil volume. Stones of parent rock are mostly encountered below 50 cm soil depth. They are widely spaced with interstices filled with soils from the overlying horizon. These concretionary layers are considered not a serious limitation to plant performance. The main limiting

factor for these soils is the terrain. Slope with $> 25^{o}$ is likely to have serious soil erosion hazard. It also affects the movement in the field for land preparation, planting, field maintenance, etc. and lower efficiency in harvesting and crop removal.

The land capability class for this group of soils is as follows:-

Class 1 Land with no limitations

Class 2 t Land with minor limitation on slope ($6 - 12^{o}$)

Class 3 te Land with moderate limitations due to slope ($12 - 25^{o}$) and has high erosion hazard

Class 4 te Land with serious limitations due to slope ($25 - 33^{o}$) and erosion hazard.

Soils of Nyalau Series

This is a sandy soil derived from sandstone. It occurs on nearly level to very gently undulating terrain. The soil is deep with moderately developed structures. Drainage is somewhat excessive and leaching loss is expected to be high. Total exchangeable bases are considered low.

The land capability class for the soils of Nyalau Series is as follows:-

Class 2 f Land with moderate limitation due to low soil fertility.

Soils of Bemang Series

Soils of the Bemang Series occur on raised river banks. The soil is moderately deep with loamy texture throughout. It is moderately well-drained and water table usually fluctuates

around 75 cm soil depth. Floodings may occur on this levee soil but they are usually of short duration.

The land capability class for soils of the Bemang Series is as follows:-

Class 2 i Land with minor limitations due to infrequent, short inundation hazard and moderate soil drainage.

Soils of Bijat Series

This alluvial soil is found mainly in both broad and narrow valley floors. It has a clayey sub-soil texture and is strongly mottled, indicating a fluctuating water table during the dry/wet period. The soil is imperfect to poorly drained. Massive clay is only encountered at depth below 75 cm.

The land capability class for soils of the Bijat Series is as follows:-

Class 3 wi Land with limitation due to inundation hazard and poor drainage.

Soils of Samarahan Series

This soil is found in the low-lying valley floors. It is characterised by very poor soil drainage and massive gley sub-soil. The massive clay horizon is encountered within 25 cm from the soil surface. It is water-logged in most parts of the year.

The land capability class for soils of the Samarahan Series is as follows:-

Class 4 cw Land with serious limitations due to poor drainage, inundation hazard and shallow effective soil depth to massive clay horizon (<25 cm).

Soils of Mukah Series

Mukah Series is an organic soil with 50 to 150 cm of peat overlying clayey, non-sulphidic substratum. It is very poorly drained and is water-logged almost throughout the year.

The land capability class for the soils of the Mukah Series is as follows:-

Class 04 gf — Land with serious limitations due to very low soil fertility and shallow depth to groundwater table (< 30 cm).

4. SUITABILITY FOR OIL PALM CULTIVATION

4. SUITABILITY FOR OIL PALM CULTIVATION

In formulating the suitability for oil palm cultivation, the climate and soil requirements of the crop and the land capability have to be taken into consideration.

4.1 Climatic Requirement for Oil Palm Cultivation

Climate is an important factor in the assessment of environmental condition for oil palm cultivation. Ideal climate for oil palm cultivation should have an annual rainfall of about 1,800 mm (70 inches) per year, well distributed throughout the year. Mean monthly rainfall should be 127 mm (5 inches). Mean monthly temperature for oil palm should be between 27 to 32^{o}C.

4.2 Soil Requirement for Oil Palm Cultivation

Oil palm requires $\geq$ 50 cm effective soil depth with sandy loam to clay texture (except massive clay). Structures should be moderate to strongly developed and consistency friable to firm. The soil should be well-drained to imperfectly drained. Terrain should be level to steep and slope not exceeding 25^{o}.

4.3 Suitability for Oil Palm Cultivation in the Surveyed Area

4.3.1 Climatic Suitability for Oil Palm Cultivation

The surveyed area has high rainfall with mean monthly precipitation of around 200 mm. Mean annual temperature is about 26.5^{o}C. These are considered suitable for oil palm cultivation.

4.3.2 Suitability for Oil Palm Cultivation

The suitability for oil palm cultivation has been evaluated and is presented in Table 6. A summary of their hectarage statistics is presented in Table 7.

Table 6: Suitability for Oil Palm Cultivation in Sungei Telabit/Sungei Sengah Blocks

Mapping Unit	Soil Series	Effective Soil Depth (cm)	Slope (degree)	Soil Drainage	Land Capability Class	Suitability for Oil Palm	Hectarage		
							Sungei Telabit	Sungei Sengah	Total
Mrt/Bkn 5ab	Merit Bekenu	>100	0 - 6	Well-drained	Class 1	Suitable	791	73	864
Mrt/Bkn 5c	Merit Bekenu	>100	6 - 12	Well-drained	Class 2t	Suitable	553	377	930
Mrt/Bkn 5de	Merit Bekenu	>100	12 - 25	Well-drained	Class 3te	Suitable	412	566	978
Mrt/Bkn 45f	Merit Bekenu	75 - >100	25 - 33	Well-drained	Class 4te	Unsuitable	-	449	449
Mrt/Bkn 45g	Merit Bekenu	75 - >100	>33	Well-drained	Class 5te	Unsuitable	-	29	29
Nlu/Bkn 5ab	Nyalau Bekenu	>100	0 - 6	Somewhat excessively well-drained	Class 2f Class 1	Suitable Suitable	94	39	133
Bmg 4a	Bemang	75 - 100	0 - 2	Moderately well-drained	Class 2i	Suitable	55	24	79
Bjt 3a	Bijat	50 - 75	0 - 2	Poorly drained	Class 3wi	Suitable	110	102	212
Sma 1a	Samarahan	<25	0 - 2	Very poorly drained	Class 4cw	Unsuitable	110	88	198
Mkh/Sma 1a	Mukah Samarahan	<25	0 - 2	Very poorly drained Very poorly drained	Class 04gf Class 4cw	Unsuitable	-	290	290
							2,125	2,037	4,162

Table 7: Hectarage Statistics of Land Suitability for Oil Palm Cultivation in Sungei Telabit/Sungei Sengah Blocks

	Suitable	Unsuitable	Total
Sungei Telabit	2,015 (95%)	110 (5%)	2,125
Sungei Sengah	1,181 (58%)	856 (42%)	2,037
	3,196 (77%)	966 (23%)	4,162

APPENDICES

Soil profile no.:	5
Soil series:	Merit
Elevation:	-
Landform:	Hilly
Physiography at site:	Mid-slope
Slope at site:	15^{o}
Soil drainage:	Well-drained
Soil erosion	Severely eroded
Presence of surface stones or rock outcrops:	-
Effective soil depth:	>150 cm
Vegetation:	Logged forest
Moisture conditions in profile:	Moist

Profile Description

Ah	0- 5 cm	Very dark brown 10YR 2/2; clay loam; moderate, fine SBK and granules; friable; common coarse pores; abundant medium and fine roots; clear boundary.
B_1	5- 25 cm	Yellowish brown 10YR 5/6; clay loam; moderately strong, medium SBK; friable; common coarse and medium pores; some fauna activities; many fine roots; gradual boundary.
B_t	25- 70 cm	Brownish yellow 10YR 6/8; clay loam; moderately strong, coarse and medium SBK; friable; common medium pores; few fauna activities; many medium roots; patchy organic acid coatings; gradual boundary.
B_{tcn}	70- 95 cm	Brownish yellow 10YR 6/8; clay loam; moderate, coarse and very coarse SBK; slightly firm; few coarse pores; few platty laterised shale; few coarse roots; clear boundary.
BC	95-150 cm	Brownish yellow 10YR 6/8; clay loam; moderate, coarse and very coarse SBK; friable; frequent soft gravelly mudstone; few fine roots.

SOIL ANALYTICAL DATA

Soil profile no.: 5
Soil series:

Horizon	Depth in cm	pH (1:2.5)	Elect cond umho/cm	Percentage							Bulk density	Free Co_3	$CaCo_3$	OC	OM	N	C/N
				Clay	Silt	Very fine sand	Fine sand	Medium sand	Coarse sand	Very coarse sand							
	0-5	4.20	18	37.0	43.0	13.7	4.6	0.7	0.6	0.4	0.65	ND	ND	3.25	5.59	0.36	9.03
	5-25	4.40	68	36.2	42.2	16.6	4.0	0.4	0.4	0.2	1.16	ND	ND	0.78	1.34	0.12	6.50
	25-70	4.75	24	39.7	40.8	13.9	4.1	0.4	0.4	0.7	1.41	ND	ND	0.44	0.76	0.08	5.50

Horizon	Perchloric Digestable ppm			Perchloric Digestable ppm				ppm			meq %	Exchangeable Cation				
	K	Mg	Ca	P	Cu	Mn	Zn	Total S	Av P	H_2O soluble B	CEC in NH_4OAC	K	Mg	Ca	Na	Al
	3500	1438	48.00	128	10	53	43	125	13	55	20	0.22	0.52	0.93	0.09	1.28
	4500	1525	13.50	75	9	22	39	375	7	12	17	0.15	0.32	0.005	0.11	1.50
	5000	1700	15.00	74	11	33	51	125	9	ND	15	0.12	0.14	0.001	0.10	2.84

ND = Not detected
N = Negligible

Soil profile no.:	7
Soil series:	Merit
Elevation:	-
Landform:	Hilly
Physiography at site:	Mid-slope
Slope at site	18^{o}
Soil drainage:	Well-drained
Soil erosion:	Severely eroded
Presence of surface stones or rock outcrops:	-
Effective soil depth:	>150 cm
Vegetation:	Logged forest
Moisture conditions in profile:	Moist

Profile Description

Ah	0- 3 cm	Brown to dark brown 10YR 4/3; silty clay loam; moderate, fine SBK and crumbs; friable; common coarse pores; abundant fine and medium roots; clear boundary.
B_1	3- 20 cm	Yellowish brown 10YR 5/4-5/6; silty clay; moderately strong, medium SBK; friable; common coarse and fine pores; many fauna activities; many fine and few coarse roots; many organic acid coatings; gradual boundary.
B_{t1}	20- 70 cm	Strong brown 7.5YR 5/6; silty clay loam; moderately strong, medium and coarse SBK; friable; many medium and coarse pores; few fauna activities; many coarse, medium and fine roots; few organic acid coatings; gradual boundary.
B_{t2}	70-105 cm	Reddish yellow 7.5 YR 6/6; clay, moderate, coarse and very coarse SBK; slightly firm; few medium and fine pores; few fine roots; clear boundary.
BC	105-150 cm	Yellowish red 5YR 5/8; clay; common red 2.5YR 4/8 and very pale brown 10YR 7/4 fine mottles; moderately

weak, very coarse SBK; slightly firm; very few fine roots.

Soil profile no.: 7
Soil series:

Horizon	Depth in cm	pH (1:2.5)	Elect cond umho/cm	Percentage							Bulk density	Free Co_3	$CaCo_3$	OC	OM	N	C/N
				Clay	Silt	Very fine sand	Fine sand	Medium sand	Coarse sand	Very coarse sand							
	0-3	4.00	217	34.6	47.9	8.3	5.3	1.9	1.3	0.7	0.52	ND	ND	4.95	8.51	0.42	11.79
	3-20	4.40	74	40.5	50.0	7.5	1.3	0.4	0.4	0.4	0.67	ND	ND	1.50	2.58	0.21	7.14
	20-70	4.70	32	42.1	48.4	7.0	1.2	0.5	0.5	0.3	0.78	ND	ND	0.57	0.98	0.12	4.75
	70-105	4.60	34	49.6	37.7	6.3	1.4	1.0	2.5	1.5	0.69	ND	ND	0.38	0.65	0.09	4.22

Horizon	Perchloric Digestable ppm			Perchloric Digestable ppm				ppm			meq %						
								Total S	Av P	H_2O soluble B	CEC in NH_4OAC	Exchangeable Cation					
	K	Mg	Ca	P	Cu	Mn	Zn					K	Mg	Ca	Na	Al	
	4800	1538	50	175	10	73	42	450	16	52	24	0.30	0.58	1.02	0.10	1.26	
	6100	1788	18	108	9	27	33	525	9	15	18	0.16	0.32	0.02	0.08	2.34	
	5800	1788	16	73	11	67	39	225	8	5	16	0.13	0.14	0.006	0.10	2.81	
	7000	2025	12	83	15	158	60	450	8	3	18	0.15	0.07	ND	0.10	2.67	

ND = Not detected
N = Negligible

Soil profile no.:	15
Soil series:	Merit
Elevation:	-
Landform:	Steep hill
Physiography at site:	Lower slope
Slope at site:	22^{o}
Soil drainage:	Well-drained
Soil erosion:	Severely eroded
Presence of surface stones or rock outcrops:	-
Effective soil depth:	>160 cm
Vegetation:	Logged forest
Moisture conditions in profile:	Moist

Profile Description

Ah	0- 3 cm	Brown to dark brown 10YR 4/3; clay loam; moderate, fine and medium SBK and crumbs; friable; common medium and coarse pores; many fine, medium and coarse roots; clear boundary.
B_1	3- 15 cm	Yellowish brown 10YR 5/4-5/6; silty clay; moderate, medium SBK; friable; common, medium and fine pores; many fauna activities and organic acid coatings; many medium and very coarse roots; clear boundary.
B_t	15- 70 cm	Brownish yellow 10YR 6/6-6/8; clay; moderately strong, medium and coarse SBK; slightly firm; few coarse pores; few organic acid coatings; many medium and coarse roots; some clay cutans; gradual boundary.
B_3	70-110 cm	Brownish yellow 10YR 6/6-6/8; silty clay; common medium reddish yellow 7.5YR 6/6 and pale yellow 2.5Y 7/4 mottles; moderate, coarse and very coarse SBK; slightly firm; few fine pores; few medium and coarse roots; few clay cutans; gradual boundary.
BC	110-160 cm	Variegated brownish yellow 10YR 6/6-6/8; reddish yellow 7.5YR 6/6-6/8; pale yellow 2.5Y 7/4; silty

clay; moderately weak, very coarse SBK; slightly massive; few medium roots.

SOIL ANALYTICAL DATA

Appendix IIIb

Soil profile no. : 15
Soil series:

Horizon	Depth in cm	pH (1:2.5)	Elect cond umho/cm	Percentage							Bulk density	Free Co_3	$CaCo_3$	OC	OM	N	C/N
				Clay	Silt	Very fine sand	Fine sand	Medium sand	Coarse sand	Very coarse sand							
	0-3	3.80	25	32.0	44.5	12.6	6.0	2.0	1.6	1.3	0.83	ND	ND	2.97	5.11	0.28	10.61
	3-15	4.30	87	40.2	44.4	11.5	2.1	0.6	0.5	0.7	1.09	ND	ND	1.20	2.06	0.16	7.50
	15-70	4.15	59	50.2	39.4	6.8	1.4	0.9	0.9	0.4	1.37	ND	ND	0.49	0.84	0.10	4.90
	70-110	4.70	38	51.7	40.2	5.5	1.2	0.6	0.4	0.4	1.32	ND	ND	0.38	0.65	0.10	3.80

Horizon	Perchloric Digestable ppm			Perchloric Digestable ppm				ppm			meq %	Exchangeable Cation				
	K	Mg	Ca	P	Cu	Mn	Zn	Total S	Av P	H_2O soluble B	CEC in NH_4OAC	K	Mg	Ca	Na	Al
	4000	975	25	108	10	26	28	125	10	76	19	0.18	0.47	0.08	0.09	2.20
	4500	1584	22	85	11	27	31	325	8	15	16	0.14	1.41	0.001	0.10	1.89
	6000	1500	18	83	15	30	45	25	9	5	19	0.12	0.05	0.001	0.10	0.37
	7500	1688	17	75	15	38	47	275	8	ND	20	0.15	0.04	0.003	0.11	3.34

ND = Not detected
N = Negligible

Soil profile no.:	17
Soil series:	Merit
Elevation:	-
Landform:	Nearly level (unfolded sediment)
Physiography at site:	Nearly level
Slope at site:	$<2^{o}$
Soil drainage:	Well-drained
Soil erosion:	Slightly eroded
Presence of surface stones or rock outcrops:	-
Effective soil depth:	>150 cm
Vegetation:	Secondary forest
Moisture conditions in profile:	Moist

Profile Description

Ah	0- 2 cm	Brown to dark brown 10YR 4/3; silty clay loam; moderate, fine and medium SBK; friable; common medium and coarse pores; abundant medium roots; clear boundary.
B_1	2- 25 cm	Yellowish brown 10YR 5/6; silty clay; moderately strong, medium and some coarse SBK; friable; many coarse and medium pores; many fauna activities; many fine, medium and coarse roots; many organic acid coatings; gradual boundary.
B_{t1}	25- 60 cm	Brownish yellow 10YR 6/6; silty clay; moderately strong, coarse and very coarse SBK; friable to slightly firm; common medium and coarse pores; few organic acid coatings; many fine and medium roots; patchy clay cutans; gradual boundary.
B_{t2}	60-105 cm	Brownish yellow 10YR 6/6; silty clay; moderate, very coarse SBK; slightly firm; few fine and medium pores; few fine roots; patchy clay cutans; gradual boundary.

B_3 105-140 cm Brownish yellow 10YR 6/6 to reddish yellow 7.5YR 6/6; silty clay; common light grey 10YR 7/2 coarse shale fragments; moderately weak; very coarse SBK; slightly firm; very few fine roots; few clay cutans.

Soil profile no.: 17
Soil series:

Horizon	Depth in cm	pH (1:2.5)	Elect cond umho/cm	Percentage													
				Clay	Silt	Very fine sand	Fine sand	Medium sand	Coarse sand	Very coarse sand	Bulk density	Free Co_3	$CaCo_3$	OC	OM	N	C/N
	0-2	4.70	109	34.9	55.1	2.9	2.6	2.0	1.9	0.6	0.78	ND	ND	2.18	3.75	0.39	5.59
	2-25	4.40	64	40.5	56.0	2.3	0.6	0.3	0.2	0.1	1.13	ND	ND	0.90	1.55	0.16	5.63
	25-60	4.40	87	47.2	49.3	1.8	0.8	0.2	0.4	0.3	1.20	ND	ND	0.67	1.15	0.14	4.79
	60-105	4.20	87	44.4	52.0	2.3	0.8	0.2	0.2	0.1	1.32	ND	ND	0.32	0.55	0.09	3.56

Horizon	Perchloric Digestable ppm			Perchloric Digestable ppm				ppm			meq %					
								Total S	Av P	H_2O soluble B	CEC in NH_4OAC	Exchangeable Cation				
	K	Mg	Ca	P	Cu	Mn	Zn					K	Mg	Ca	Na	Al
	6300	2075	100	258	18	354	74	225	12	32	22	0.34	1.22	3.56	0.11	0.95
	6700	2000	20	145	15	152	58	125	7	7	17	0.16	0.02	0.06	0.11	1.81
	6800	2050	22	130	11	19	65	175	8	7	12	0.15	0.18	0.02	0.13	1.81
	6500	1925	29	155	16	128	54	125	16	3	17	0.16	0.21	0.012	0.11	1.83

ND = Not detected
N = Negligible

Soil profile no.:	19
Soil series:	Merit
Elevation:	-
Landform:	Hilly
Physiography at site:	Mid-slope
Slope at site:	20^{o}
Soil drainage:	Well-drained
Soil erosion:	Severely eroded
Presence of surface stones or rock outcrops:	Nil
Effective soil depth:	>150 cm
Vegetation:	Logged forest
Moisture conditions in profile:	Moist

Profile Description

Ah (eroded) 0- 1 cm Dark yellowish brown 10YR 4/4; silty loam; moderate, fine SBK; friable; many fine and coarse roots; clear boundary.

B_1 1- 10 cm Yellowish brown 10YR 5/4-5/6; silty clay loam; moderately strong, medium SBK; friable; common fine and medium pores; few organic acid coatings; many fine and medium roots; gradual boundary.

B_{t1} 10- 30 cm Yellowish brown 10YR 5/6; silty clay; moderately strong, medium and coarse SBK; friable; common medium and fine, and few coarse pores; few organic acid coatings; many fine and few coarse roots; gradual boundary.

B_{t2} 30- 60 cm Reddish yellow 5YR 6/8; silty clay; moderate, coarse and very coarse SBK; slightly firm; few fine and coarse pores; few medium roots; patchy clay skins; clear boundary.

B_{t3} 60-115 cm Red 2.5YR 5/8; clay; few fine yellow 10YR 7/6 mottles; moderate, coarse and very coarse SBK; slightly firm and massive; very few gravelly laterised shale; very

few fine and medium roots; patchy clay skins; gradual boundary.

BC 115-150 cm Red 2.5YR 5/8; clay; many fine and medium yellow 10YR 7/6 mottles; moderately weak, very coarse SBK; slightly massive; few gravelly laterised shale; very few fine roots.

SOIL ANALYTICAL DATA

Soil profile no.: 19
Soil series:

Horizon	Depth in cm	pH (1:2.5)	Elect cond umho/cm	Percentage							Bulk density	Free Co_3	$CaCo_3$	OC	OM	N	C/N
				Clay	Silt	Very fine sand	Fine sand	Medium sand	Coarse sand	Very coarse sand							
	0-1	4.75	138	22.9	61.2	5.4	3.4	3.5	2.9	0.7	-	ND	ND	3.54	6.09	0.36	9.83
	1-10	4.85	35	34.4	55.8	4.7	2.5	1.7	0.6	0.3	1.11	ND	ND	1.15	1.98	0.16	7.19
	10-30	4.05	198	44.1	46.4	4.3	2.4	1.2	0.9	0.7	1.09	ND	ND	0.76	1.31	0.15	5.07
	30-60	4.20	90	49.8	42.8	3.9	1.8	0.8	0.5	0.4	1.36	ND	ND	0.45	0.77	0.72	3.75
	60-115	4.85	26	51.8	37.5	3.1	1.6	1.5	2.2	2.3	1.26	ND	ND	0.43	0.74	0.07	6.14

Horizon	Perchloric Digestable ppm			Perchloric Digestable ppm				ppm			meq %	Exchangeable Cation				
	K	Mg	Ca	P	Cu	Mn	Zn	Total S	Av P	H_2O soluble B	CEC in NH_4OAC	K	Mg	Ca	Na	Al
	5100	1950	77	175	8	593	50	400	12	30	16	0.37	1.51	2.10	0.09	0.44
	6600	2050	21	114	17	314	60	25	7	5	14	0.18	0.33	0.02	0.07	1.15
	7300	2750	19	111	12	138	60	125	8	20	19	0.16	0.34	0.01	0.10	1.61
	7800	3000	15	96	14	60	59	125	8	5	18	0.16	0.36	0.01	0.10	1.56
	8500	3250	16	114	13	61	65	75	8	ND	19	0.15	0.47	0.001	0.09	1.89

ND = Not detected
N = Negligible

Soil profile no.:	24
Soil series:	Merit
Elevation:	-
Landform:	Hilly
Physiography at site:	Mid-slope
Slope at site:	15^{o}
Soil drainage:	Well-drained
Soil erosion:	Severely eroded
Presence of surface stones or rock outcrops:	-
Effective soil depth:	>150 cm
Vegetation:	Secondary forest
Moisture conditions in profile:	Moist

Profile Description

Ah	0- 4 cm	Dark yellowish brown 10YR 4/4; silty clay; moderate, fine and medium SBK; friable; few coarse and medium pores; many coarse and medium roots; clear boundary.
B_1	4- 15 cm	Yellowish brown 10YR 5/4-5/6; silty loam; moderately strong, coarse SBK; friable; many coarse and medium pores; many fauna activities; many coarse and medium and some fine roots; many organic acid coatings; gradual boundary.
B_{t1}	15- 40 cm	Yellowish brown 10YR 5/6; silty clay loam; moderately strong, coarse and very coarse SBK; friable; few medium and fine pores; few fauna activities; few medium and coarse roots; patchy organic acid coatings; gradual boundary.
B_{t2}	40- 95 cm	As above but colour is yellowish brown 10YR 5/8 to strong brown 7.5YR 5/8.
B_3	95-150 cm	Reddish yellow 5YR 6/8; silty clay loam; common very pale brown 10YR 7/4 mottles; moderately weak, very coarse SBK; friable; few gravelly laterised shale; few fine roots.

SOIL ANALYTICAL DATA

Soil profile no.: 24
Soil series:

Horizon	Depth in cm	pH (1:2.5)	Elect cond umho/cm	Percentage							Bulk density	Free Co_3	$CaCo_3$	OC	OM	N	C/N
				Clay	Silt	Very fine sand	Fine sand	Medium sand	Coarse sand	Very coarse sand							
	0-4	4.70	67	41.2	52.3	4.3	1.2	0.4	0.3	0.3	-	ND	ND	3.45	5.93	0.28	12.32
	4-15	4.35	120	26.8	51.2	11.1	5.5	1.8	2.5	1.1	-	ND	ND	2.06	3.54	0.24	8.58
	15-40	4.40	112	34.1	52.1	9.9	2.5	0.7	0.5	0.2	-	ND	ND	0.82	1.41	0.13	6.31
	40-95	4.40	56	39.3	47.3	10.2	1.7	0.6	0.5	0.4	-	ND	ND	0.38	0.65	0.09	4.22

Horizon	Perchloric Digestable ppm			Perchloric Digestable ppm				ppm			meq %					
								Total S	Av P	H_2O soluble B	CEC in NH_4OAC	Exchangeable Cation				
	K	Mg	Ca	P	Cu	Mn	Zn					K	Mg	Ca	Na	Al
	6900	3188	69	245	15	87	76	375	20	5	17.9	0.11	1.23	1.78	0.13	0.42
	5200	1550	23	118	8	107	52	300	9	30	12.1	0.19	0.30	0.25	0.06	1.00
	5100	1400	16	88	8	32	43	125	7	12	12.7	0.15	0.22	0.02	0.11	1.00
	3500	1388	15	75	9	22	41	175	8	ND	14.3	0.12	0.15	0.003	0.07	1.17

ND = Not detected
N = Negligible

Soil profile no.:	2
Soil series:	Bekenu (stony)
Elevation:	-
Landform:	Hilly
Physiography at site:	Upper slope
Slope at site:	18^{o}
Soil drainage:	Well-drained
Soil erosion:	Severely eroded
Presence of surface stones or rock outcrops:	-
Effective soil depth:	>60 cm
Vegetation:	Secondary forest
Moisture conditions in profile:	Moist

Profile Description

Ah	0- 5 cm	Dark greyish brown 10YR 4/2; clay loam; moderate, fine SBK and crumbs; friable; common coarse pores; abundant fine and medium roots; clear boundary.
B_{t1}	5- 25 cm	Light yellowish brown 10YR 6/4 to brownish yellow 10YR 6/6; clay loam; moderate, medium SBK; friable; common fine and coarse pores; many fauna activities; many fine, medium and coarse roots; many organic acid coatings; gradual boundary.
B_{t2}	25- 60 cm	Brownish yellow 10YR 6/6-6/8; silty clay loam; moderately strong, medium and some coarse SBK; friable; common fine and coarse pores; many medium roots; few organic acid coatings; clear boundary.
BC_R	60 cm+	Brownish yellow 10YR 6/6-6/8; silty clay loam; moderate, coarse SBK; friable; very frequent stony shale; few fine roots.

SOIL ANALYTICAL DATA

Appendix VIIb

Soil profile no.: 2
Soil series:

Horizon	Depth in cm	pH (1:2.5)	Elect cond umho/cm	Percentage													
				Clay	Silt	Very fine sand	Fine sand	Medium sand	Coarse sand	Very coarse sand	Bulk density	Free Co_3	$CaCo_3$	OC	OM	N	C/N
	0-5	4.40	18	30.3	49.4	17.3	1.4	0.4	0.6	0.6	0.81	ND	ND	3.54	6.09	0.28	12.64
	5-25	4.60	45	27.7	42.2	27.9	1.5	0.4	0.2	0.1	1.13	ND	ND	0.80	1.38	0.12	6.67
	25-60	4.35	57	28.7	52.5	15.3	2.1	0.7	0.3	0.4	1.37	ND	ND	0.33	0.57	0.10	3.30

Horizon	Perchloric Digestable ppm			Perchloric Digestable ppm				ppm			meq %	Exchangeable Cation				
	K	Mg	Ca	P	Cu	Mn	Zn	Total S	Av P	H_2O soluble B	CEC in NH_4OAC	K	Mg	Ca	Na	Al
	2800	975	17.40	138	14	71	28	325	16	46	18	0.26	1.38	3.86	0.11	0.58
	3000	989	18.50	81	13	27	33	75 ?	8	5	12	0.19	0.23	0.03	0.11	1.00
	3300	1363	14.00	67	8	25	36	450	8	3	12	0.21	0.08	0.002	0.09	1.33

ND = Not detected
N = Negligible

Soil profile no.:	6
Soil series:	Bekenu (stony)
Elevation:	-
Landform:	Very gently undulating (unfolded sediment)
Physiography at site:	Gentle slope
Slope at site:	3^{o}
Soil drainage:	Well-drained
Soil erosion:	Moderate
Presence of surface stones or rock outcrops:	-
Effective soil depth:	65 cm
Vegetation:	Logged forest
Moisture conditions in profile:	Moist

Profile Description

Ah	0- 2 cm	Yellowish brown 10YR 5/4; loam; moderate, fine SBK; friable; few coarse pores; many medium roots; clear boundary.
B_1	2- 10 cm	Yellowish brown 10YR 5/6; clay loam; moderate, medium and fine SBK; friable; common medium and coarse pores; many medium roots; many organic acid coatings; gradual boundary.
B_t	10- 40 cm	Brownish yellow 10YR 6/6-6/8; clay loam; moderate, medium and coarse SBK; friable; common medium and fine pores; few fauna activities; many fine and medium roots; few organic acid coatings; clear boundary.
B_{cn}	40- 65 cm	Brownish yellow 10YR 6/6-6/8; clay loam; moderate, coarse and medium SBK; friable; few medium pores; frequent platty laterised shale; few medium roots; distinct boundary.
Cu	65-150 cm	Dominant shale parent rock; impenetrable; no roots.

SOIL ANALYTICAL DATA

Soil profile no.: 6
Soil series:

Horizon	Depth in cm	pH (1:2.5)	Elect cond umho/cm	Percentage													
				Clay	Silt	Very fine sand	Fine sand	Medium sand	Coarse sand	Very coarse sand	Bulk density	Free Co_3	$CaCo_3$	OC	OM	N	C/N
	0-2	4.80	65	25.2	41.4	23.9	5.9	0.7	2.5	0.4	1.05	ND	ND	2.16	3.72	0.19	11.37
	2-10	4.60	36	28.4	40.9	24.4	4.5	0.5	0.8	0.5	1.27	ND	ND	0.94	1.62	0.11	8.55
	10-40	4.60	30	28.9	40.4	20.1	5.6	1.7	2.4	0.9	1.23	ND	ND	0.55	0.95	0.09	6.11

Horizon	Perchloric Digestable ppm			Perchloric Digestable ppm				ppm			meq %					
								Total S	Av P	H_2O soluble B	CEC in NH_4OAC	Exchangeable Cation				
	K	Mg	Ca	P	Cu	Mn	Zn					K	Mg	Ca	Na	Al
	1700	869	49	90	8	22	25	225	11	15	15	0.34	0.37	0.24	0.10	0.72
	1900	925	16	80	9	13	26	225	10	5	11	0.10	0.09	0.005	0.09	1.42
	2800	1350	12	65	10	19	41	125	7	5	12	0.10	0.07	ND	0.08	1.42

ND = Not detected
N = Negligible

Soil profile no.:	11
Soil series:	Bekenu (stony)
Elevation:	-
Landform:	Hilly
Physiography at site:	Upper slope
Slope at site:	16^{o}
Soil drainage:	Well-drained
Soil erosion:	Severely eroded
Presence of surface stones or rock outcrops:	-
Effective soil depth:	>120 cm
Vegetation:	Secondary forest
Moisture conditions in profile:	Moist

Profile Description

Ah	0- 2 cm	Dark brown 10YR 3/3; loam; moderate, fine SBK; friable; few coarse pores; many fine and coarse roots; clear boundary.
B_1	2- 10 cm	Yellowish brown 10YR 5/4; clay loam; moderately strong, medium SBK; friable; common medium and coarse pores; many fauna activities; many fine and coarse roots; many organic acid coatings; gradual boundary.
B_t	10- 25 cm	Yellowish brown 10YR 5/6 to light olive brown 2.5Y 5/6; clay loam; moderately strong, medium and some coarse SBK; friable; common fine and medium pores; very few gravelly soft concretions; few fauna activities; many fine and medium roots; few organic acid coatings; clear boundary.
B_{cn1}	25- 75 cm	Colour as above; clay loam; few medium pores; very frequent stony, hard shale; few fine and medium roots; gradual boundary.
B_{cn2}	75-120 cm	Colour as above; clay loam; dominant, stony and boundary shale; very few medium roots.

SOIL ANALYTICAL DATA

Soil profile no. : 11
Soil series:

Horizon	Depth in cm	pH (1:2.5)	Elect cond umho/cm	Percentage							Bulk density	Free Co_3	$CaCo_3$	OC	OM	N	C/N
				Clay	Silt	Very fine sand	Fine sand	Medium sand	Coarse sand	Very coarse sand							
	0-2	5.30	73	19.1	43.6	22.6	8.1	3.3	2.5	0.8	1.02	ND	ND	2.21	3.80	0.31	7.13
	2-10	4.55	55	29.4	47.0	21.2	0.9	0.5	0.7	0.3	1.18	ND	ND	0.96	1.65	0.14	6.86
	10-25	4.20	14	29.6	45.2	21.3	2.0	0.7	0.9	0.3	1.44	ND	ND	0.60	1.03	0.10	6.00

Horizon	Perchloric Digestable ppm			Perchloric Digestable ppm				ppm			meq %						
								Total S	Av P	H_2O soluble B	CEC in NH_4OAC	Exchangeable Cation					
	K	Mg	Ca	P	Cu	Mn	Zn					K	Mg	Ca	Na	Al	
	3500	1825	180	145	12	183	48	125	14	25	16	0.23	0.97	3.89	0.08	0.59	
	3900	1875	63	90	13	118	66	25	8	7	13	0.19	0.25	0.29	0.18	1.33	
	3900	1938	17	75	10	121	47	300	8	12	12	0.15	0.10	0.01	0.11	1.89	

ND = Not detected
N = Negligible

Soil profile no.:	25
Soil series:	Bekenu (stony)
Elevation:	-
Landform:	Hilly
Physiography at site:	Mid-slope
Slope at site:	15^{o}
Soil drainage:	Well-drained
Soil erosion:	Severely eroded
Presence of surface stones or rock outcrops:	-
Effective soil depth:	85 cm
Vegetation:	Logged forest
Moisture conditions in profile:	Moist

Profile Description

Ah	0- 10 cm	Brown to dark brown 10YR 4/3; loam; moderate, medium and fine SBK and many crumbs; friable; common coarse and medium pores; abundant coarse and medium roots; clear boundary.
B_1	10- 25 cm	Pale brown 10YR 6/3 to light yellowish brown 10YR 6/4; loam; moderate, coarse and medium SBK; very friable; common medium and fine and few coarse pores; some fauna activities; many organic acid coatings; many medium and few coarse roots; gradual boundary.
B_t	25- 60 cm	Brownish yellow 10YR 6/8; loam; moderate, coarse SBK; friable; common fine pores; many medium and fine roots; very few organic acid coatings; gradual boundary.
B_{3cn}	60- 85 cm	As above but with frequent gravelly laterised shale.
C	85 cm+	A layer of somewhat impervious parent rock - sandstone.

SOIL ANALYTICAL DATA

Soil profile no.: 25
Soil series:

Horizon	Depth in cm	pH (1:2.5)	Elect cond umho/cm	Percentage													
				Clay	Silt	Very fine sand	Fine sand	Medium sand	Coarse sand	Very coarse sand	Bulk density	Free Co_3	$CaCo_3$	OC	OM	N	C/N
	0-10	4.10	185	25.1	35.5	31.8	5.5	0.8	0.7	0.6	-	ND	ND	3.15	5.42	0.31	10.16
	10-25	4.45	60	18.7	40.1	30.9	8.0	1.0	0.7	0.6	-	ND	ND	1.08	1.86	0.11	9.82
	25-60	4.50	34	21.2	39.1	30.9	1.4	0.7	0.8	0.5	-	ND	ND	0.40	0.69	0.06	6.67

Horizon	Perchloric Digestable ppm			Perchloric Digestable ppm				ppm			meq %						
								Total S	Av P	H_2O soluble B	CEC in NH_4OAC	Exchangeable Cation					
	K	Mg	Ca	P	Cu	Mn	Zn					K	Mg	Ca	Na	Al	
	1800	738	36	90	3	18	11	600	14	46	14	0.22	0.52	0.59	0.08	0.95	
	2000	744	13	55	3	12	15	475	6	12	8	0.16	0.10	0.05	2.10	0.83	
	2300	694	13.5	45	2	16	16	50	7	3	9	0.06	0.03	ND	0.08	1.22	

ND = Not detected
N = Negligible

Soil profile no.:	1
Soil series:	Nyalau
Elevation:	-
Landform:	Very gently undulating (unfolded sediment)
Physiography at site:	Very gentle slope
Slope at site:	3^{o}
Soil drainage:	Somewhat excessively drained
Soil erosion:	Slightly eroded
Presence of surface stones or rock outcrops:	-
Effective soil depth:	>110 cm
Vegetation:	Logged forest
Moisture conditions in profile:	Moist

Profile Description

Ah	0- 2 cm	Yellowish brown 10YR 5/4; fine sandy loam; moderate, fine and medium SBK; friable; few coarse pores; abundant fine and medium roots; clear boundary.
B_{21}	2- 40 cm	Brownish yellow 10YR 6/8; fine sandy loam; moderate, medium SBK; friable; common fine and medium pores; many fauna activities; abundant fine roots; many organic acid coatings; gradual boundary.
B_{22}	40- 95 cm	Brownish yellow 10YR 6/6-6/8; fine sandy loam; moderate, coarse and medium SBK; friable; few fine and medium pores; few fine roots; few organic acid coatings; clear boundary.
BC	95-110 cm	Brownish yellow 10YR 6/6-6/8; fine sandy loam; moderately weak, coarse SBK; friable; frequent gravelly soft decomposing sandstones.

SOIL ANALYTICAL DATA

Soil profile no.: 1
Soil series:

Horizon	Depth in cm	pH (1:2.5)	Elect cond umho/cm	Percentage							Bulk density	Free Co_3	$CaCo_3$	OC	OM	N	C/N
				Clay	Silt	Very fine sand	Fine sand	Medium sand	Coarse sand	Very coarse sand							
	0- 2	4.60	55	15.9	23.2	16.2	42.9	1.2	0.2	0.3	0.83	ND	ND	1.40	2.41	0.10	14.00
	2-40	4.50	32	19.5	19.0	15.3	45.0	0.6	0.2	0.4	1.30	ND	ND	0.38	0.65	0.08	4.75
	40-95	4.80	20	18.6	20.6	15.4	44.5	0.6	0.1	0.2	1.60	ND	ND	3.10	5.33	0.04	77.50

Horizon	Perchloric Digestable ppm			Perchloric Digestable ppm				ppm			meq %						
								Total S	Av P	H_2O soluble B	CEC in NH_4OAC	Exchangeable Cation					
	K	Mg	Ca	P	Cu	Mn	Zn					K	Mg	Ca	Na	Al	
	1300	688	14.00	48	5	12	14	75	9	12	10.5	0.10	0.12	0.010	0.07	1.03	
	1500	644	9.50	38	6	13	12	150	8	5	6.4	0.06	0.04	0.003	0.07	0.78	
	1800	756	12.00	26	5	12	13	125	10	3	4.9	0.07	0.04	0.006	0.09	0.78	

ND = Not detected
N = Negligible

Soil profile no.:	18 (soil auger examination)
Soil series:	Bemang
Elevation:	-
Landform:	River bank
Physiography at site:	Nearly level
Slope at site:	$<2^{o}$
Soil drainage:	Moderately well-drained
Soil erosion:	Slightly eroded
Presence of surface stones or rock outcrops:	-
Effective soil depth:	>100 cm
Vegetation:	Secondary forest
Moisture conditions in profile:	Moist

Profile Description

Ah	0- 2 cm	Dark brown 10YR 3/3; loam; moderate, medium and fine SBK and some crumbs; friable.
B_1	2- 20 cm	Dark yellowish brown 10YR 4/6; loam; friable.
B_2	20-100 cm	Yellowish brown 10YR 5/6; loam; friable; many very pale brown 10YR 7/3 mottles at depth.

SOIL ANALYTICAL DATA

Appendix XIIb

Soil profile no. : 18
Soil series:

Horizon	Depth in cm	pH (1:2.5)	Elect cond umho/cm	Percentage								Free Co_3	$CaCo_3$	OC	OM	N	C/N
				Clay	Silt	Very fine sand	Fine sand	Medium sand	Coarse sand	Very coarse sand	Bulk density						
	0-2	5.50	110	15.9	36.8	26.3	17.9	1.4	1.4	0.3	-	ND	ND	2.93	5.04	0.32	9.16
	2-20	5.35	43	16.2	34.5	25.4	17.8	3.5	2.0	0.6	-	ND	ND	1.23	2.12	0.20	6.15
	20-100	4.35	111	22.3	36.8	26.0	13.7	0.6	0.4	0.2	-	ND	ND	0.35	0.60	0.07	5.00

Horizon	Perchloric Digestable ppm			Perchloric Digestable ppm				ppm			meq %						
								Total S	Av P	H_2O soluble B	CEC in NH_4OAC	Exchangeable Cation					
	K	Mg	Ca	P	Cu	Mn	Zn					K	Mg	Ca	Na	Al	
	3100	975	317	215	15	471	43	600	20	15	13	0.32	0.76	6.19	0.10	0.37	
	2600	988	65	128	5	258	27	575	12	17	8	0.16	1.21	1.34	0.08	0.44	
	3300	969	32	76	3	120	62	225	9	10	8	0.08	0.06	0.17	0.07	0.83	

ND = Not detected
N = Negligible

Soil profile no.:	22
Soil series:	Bijat
Elevation:	-
Landform:	Alluvial flat
Physiography at site:	Nearly level
Slope at site:	$<2^{o}$
Soil drainage:	Imperfect to poorly drained
Soil erosion:	Nil
Presence of surface stones or rock outcrops:	-
Effective soil depth:	80 cm
Vegetation:	Logged riverine forest
Moisture conditions in profile:	Wet

Profile Description

Ah	0- 6 cm	Very dark greyish brown 10YR 3/2; silty clay loam; moderate, medium and some fine SBK; friable; many medium and coarse roots; clear boundary.
B_{1g}	6- 20 cm	Light brownish grey 10YR 6/2; silty clay loam; common medium and coarse dark yellowish brown 10YR 3/6 mottles; moderate, coarse and medium SBK; slightly sticky; few coarse roots; gradual boundary.
B_{2g}	20 - 80 cm	Light grey 10YR 7/1; silty clay loam; common medium and coarse strong brown 7.5YR 5/8 and yellowish red 5YR 5/8 mottles; few coarse roots; clear boundary.
Cg	80 cm+	Massive, gleyed silty clay.

Soil profile no.: 22
Soil series:

Horizon	Depth in cm	pH (1:2.5)	Elect cond umho/cm	Percentage							Bulk density	Free Co_3	$CaCo_3$	OC	OM	N	C/N
				Clay	Silt	Very fine sand	Fine sand	Medium sand	Coarse sand	Very coarse sand							
	0-6	5.00	128	28	56.5	6.1	6.2	2.1	0.9	0.2	-	ND	ND	2.46	4.23	0.31	7.94
	6-20	4.60	67	32	51.1	5.0	4.9	3.7	2.3	0.7	-	ND	ND	0.85	1.46	0.14	6.07
	20-80	5.10	66	34	49.5	8.5	4.1	1.5	1.8	0.3	-	ND	ND	0.46	0.79	0.10	4.60

Horizon	Perchloric Digestable ppm			Perchloric Digestable ppm				ppm			meq %	Exchangeable Cation				
	K	Mg	Ca	P	Cu	Mn	Zn	Total S	Av P	H_2O soluble B	CEC in NH_4OAC	K	Mg	Ca	Na	Al
	5300	2075	34	200	8	1986	59	325	11	17 ?	16	0.32	1.66	1.14	0.11	0.28
	6300	2500	19	125	8	1256	48	225	10	ND	14.3	0.14	1.04	0.09	0.08	0.44
	5500	1863	136	90	13	582	46	275	10	3	10.4	0.15	1.55	1.08	0.12	0.28

ND = Not detected
N = Negligible

Soil profile no.:	27
Soil series:	Samarahan
Elevation:	-
Landform:	Alluvial flat
Physiography at site:	Level
Slope at site:	$<2^{o}$
Soil drainage:	Very poorly drained
Soil erosion:	Nil
Presence of surface stones or rock outcrops:	-
Effective soil depth:	<25 cm
Vegetation:	Sedges
Moisture conditions in profile:	Wet

Profile Description

Ah	0- 5 cm	Dark reddish brown 5YR 3/2; loam; moderately weak to somewhat massive.
Cg	5-100 cm	Massive, structureless bluish grey silty clay loam; no mottles; few organic debris.

SOIL ANALYTICAL DATA

Appendix XIVb

Soil profile no.: 27
Soil series:

Horizon	Depth in cm	pH (1:2.5)	Elect cond umho/cm	Percentage													
				Clay	Silt	Very fine sand	Fine sand	Medium sand	Coarse sand	Very coarse sand	Bulk density	Free Co_3	$CaCo_3$	OC	OM	N	C/N
	0-5	4.15	269	32.9	32.3	2.4	7.6	9.8	11.1	3.9	-	ND	ND	12.20	20.98	0.64	19.00
	35-75	4.30	240	33.3	50.2	10.9	2.4	1.1	1.4	0.7	-	ND	ND	5.04	8.67	0.36	14.00

Horizon	Perchloric Digestable ppm			Perchloric Digestable ppm				ppm			meq %					
								Total S	Av P	H_2O soluble B	CEC in NH_4OAC	Exchangeable Cation				
	K	Mg	Ca	P	Cu	Mn	Zn					K	Mg	Ca	Na	Al
	3300	2063	131	300	22	126	14	1075	12	26	34	0.18	2.06	2.76	0.14	0.78
	4500	1350	75	145	7	133	19	30	16	71	18	0.42	0.91	1.79	0.09	1.00

ND = Not detected
N = Negligible

Soil profile no.:	26
Soil series:	Mukah
Elevation:	-
Landform:	Back swamp
Physiography at site:	Level
Slope at site:	$<1^{o}$
Soil drainage:	Very poorly drained
Soil erosion:	Nil
Presence of surface stones or rock outcrops:	-
Effective soil depth:	<5 cm
Vegetation:	Swamp forest
Moisture conditions in profile:	Wet

Profile Description

Ao_1	0- 5 cm	Leaf litter.
Ao_2	5-150 cm	Peat/muck.

MEMORANDUM

CLIC

Your Ref: 2048/600
Our Ref: SOP 311(a)

Date: 3 November 1989

- 6 NOV 1989

To: NR Dept.
London

From: RO (SEA)
Kuala Lumpur

Attn: John Varley

SIMILAJAU SEMI-DETAILED SOIL SURVEY REPORT

Enclosed is a copy of the final semi-detailed soil survey report on Similajau undertaken by Sime Darby Services for your attention and retention.

Please advise if there is any major deviation from the TOR that were agreed prior to the commencement of the survey. Please indicate what samples you would require for checking purposes.

Regards.

Ng Ah Lek
For Regional Controller (SEA)

Enc

3973

MAP 1 - Location

MAP 2 - Landform

MAP 3 - Vegetation

MAP 4 - Rentis Design & Soil Pits Location

MAP 5 - Semi-detailed soil map

Sungei Sengah/Sungei Telabit
Suai - Sarawak

MAP 1 LOCATION

LEGEND

PROJECT AREA

INTERNATIONAL BOUNDARY

DIVISION (BAHAGIAN) BOUNDARY

TRUNK / SECONDARY ROAD

TOWN

SUNGAI (RIVER)

SCALE 1 : 2,000,000 or 31.56 Miles to an Inch

SOUTH CHINA SEA

BRUNEI

SABAH

BRUNEI

LAWAS

LIMBANG

MIRI

BATU NIAH

BINTULU

BAHAGIAN KELIMA

BAHAGIAN KEEMPAT

BAHAGIAN KETIGA

SIBU

SARIKEI

BAHAGIAN KEENAM

BAHAGIAN KETUJUH

KUCHING

BAHAGIAN PERTAMA

SIMANGGANG

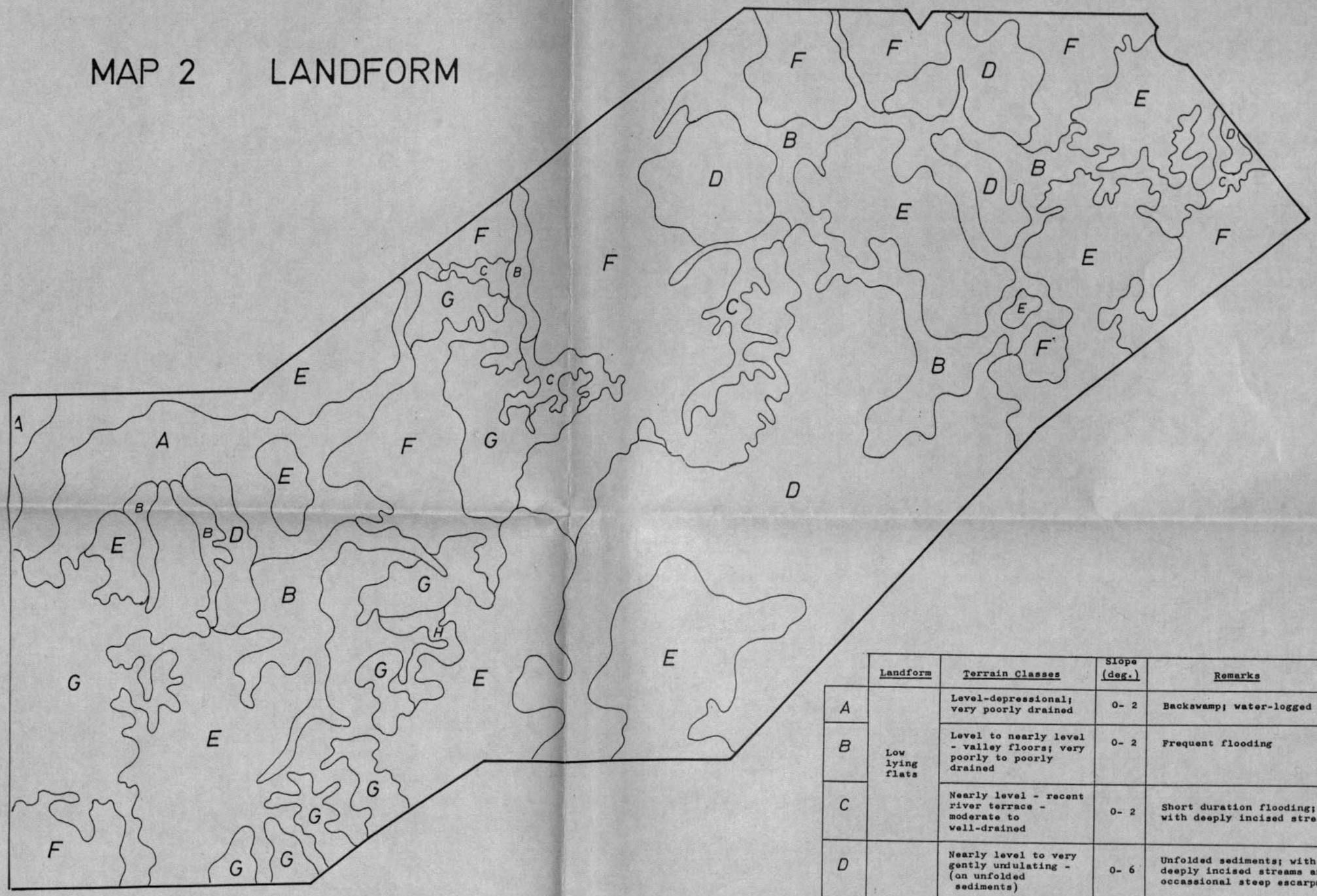
BAHAGIAN KEDUA

KALIMANTAN

109°00'E 110°00' 111°00' 112°00' 113°00' 114°00' 115°00' 115°50'E

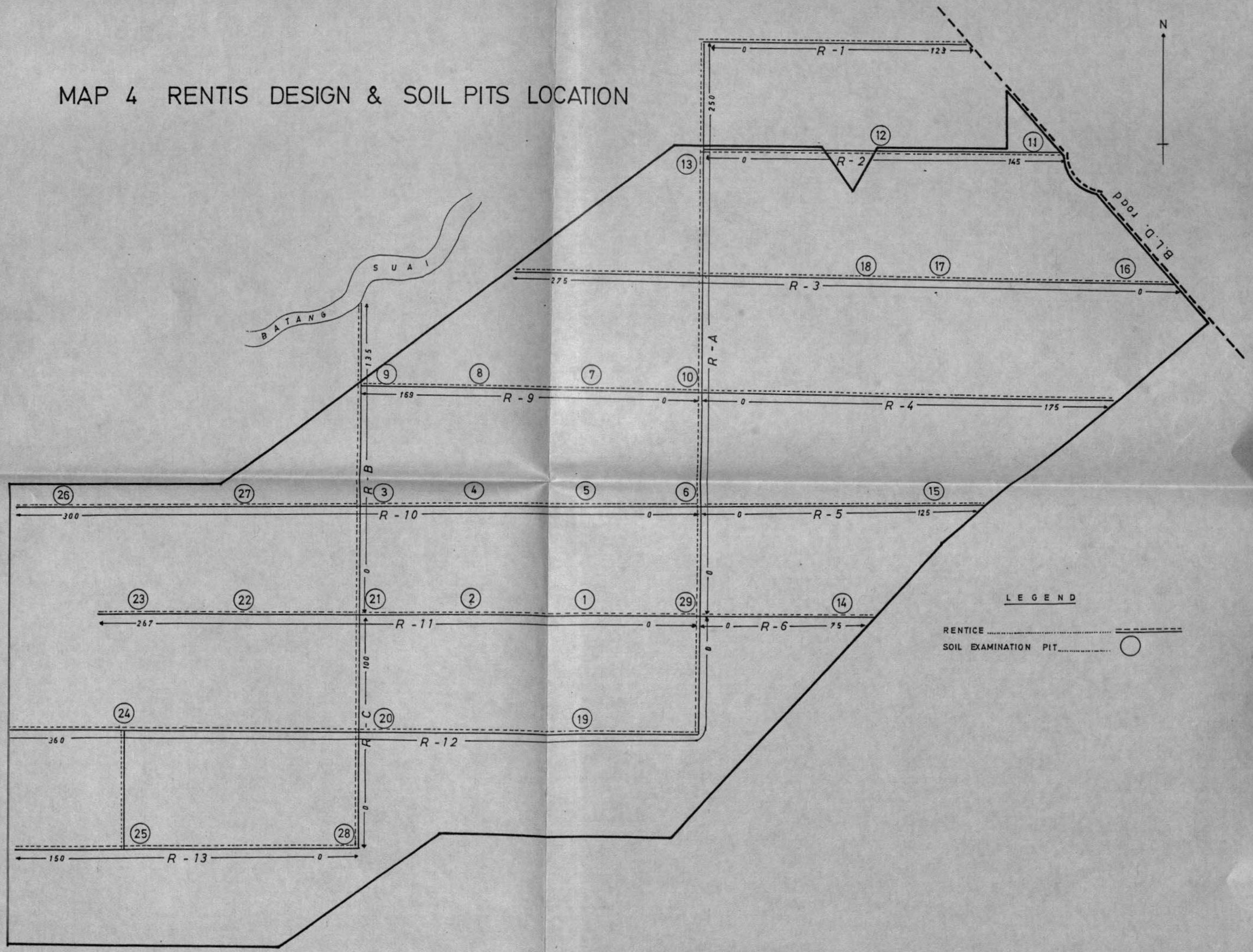
5°00'N 4°00' 3°00' 2°00' 1°00' 0°50'N

MAP 2 LANDFORM

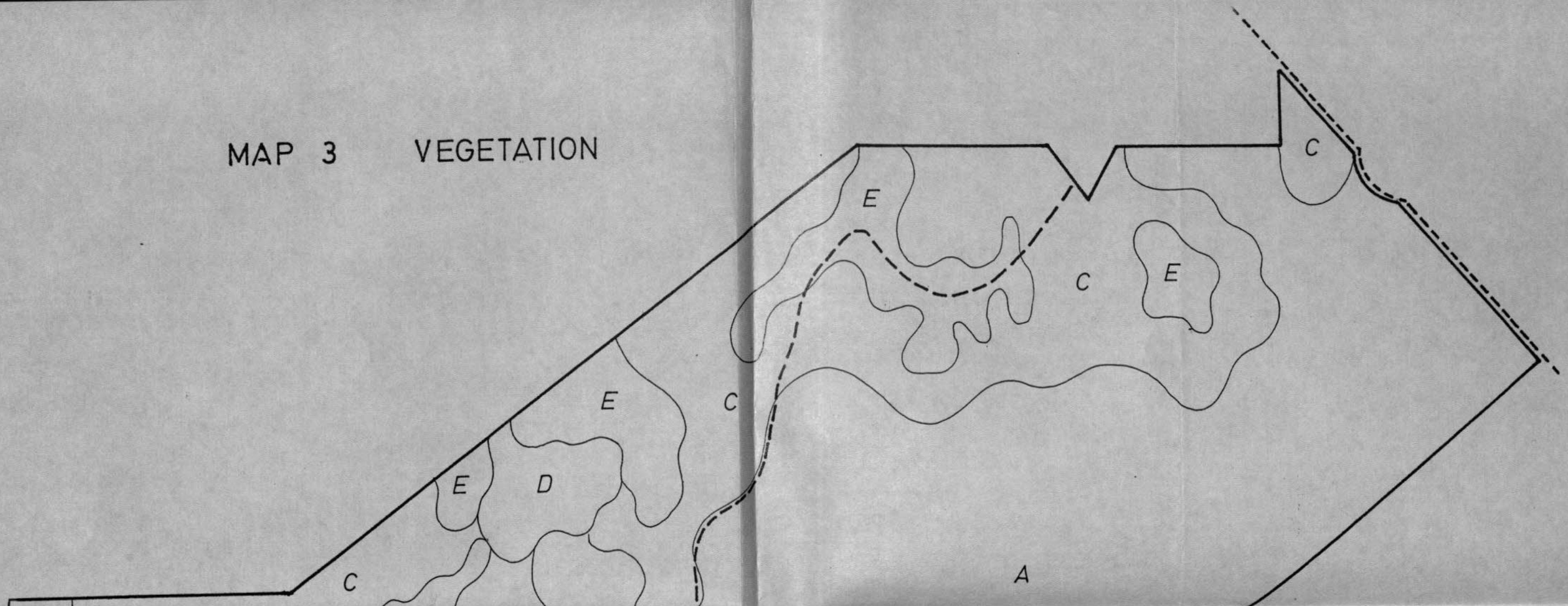


	Landform	Terrain Classes	Slope (deg.)	Remarks
A	Low lying flats	Level-depressional; very poorly drained	0- 2	Backswamp; water-logged
B		Level to nearly level - valley floors; very poorly to poorly drained	0- 2	Frequent flooding
C		Nearly level - recent river terrace - moderate to well-drained	0- 2	Short duration flooding; with deeply incised streams
D	Low hills	Nearly level to very gently undulating - (on unfolded sediments)	0- 6	Unfolded sediments; with deeply incised streams and occassional steep escarpments
E		Rolling	6-12	Slightly dissected
F		Hilly to steep	12-25	Broken and moderate to strongly dissected terrain; occassional steep to very steep escarpment
G		Very steep	25-33	
H		Extremely steep	> 33	

MAP 4 RENTIS DESIGN & SOIL PITS LOCATION



MAP 3 VEGETATION



VEGETATION TYPES

Primary Vegetation

A Logged forest (hill forest & riverine forest)

B Swamp (with sedges)

Secondary Vegetation

C Re-generated forest & recent secondary growth (with Macaranga species, short shrubs, bushes. Sedges on former rice fields)

D Abandoned rubber holdings

Under Cultivation

E Rice, pepper and other cash crops

MAP 5

SEMI-DETAILED SOIL MAP
SUNGEI SENGAH / SUNGEI TELABIT
SUAI - SARAWAK

SCALE 1 : 12,500

N

SUNGEI SENGAH BLOCK

Mrt/Bku-5de
Bmg-4a
Bjt-3a
Mrt/Bku-4.5f
Mrt/Bku-5de
Mrt/Bku-5c
Mkh/Smn-1a
Mrt/Bku-5c
Mrt/Bku-5de
Smn-1a
Mrt/Bku-5c
Smn-1a
Mrt/Bku-5ab
Bjt-3a
Mrt/Bku-4.5f
Mrt/Bku-4.5g
Mrt/Bku-4.5f
Mrt/Bku-5c
Mrt/Bku-4.5f
Mrt/Bku-4.5f
Mrt/Bku-4.5f
Mrt/Bku-5de

Mrt/Bku-5de
Mrt/Bku-5de
Mrt/Bku-5ab
Smn-1a
Mrt/Bku-5ab
Mrt/Bku-5c
Mrt/Bku-5c
Mrt/Bku-5ab
Mrt/Bku-5c
Mrt/Bku-5de
Mrt/Bku-5de
Bmg-4a
Mrt/Bku-5de
Bmg-4a
Mrt/Bku-5c
Bjt-3a
Mrt/Bku-5de
Mrt/Bku-4.5f
Nlu/Bku-5ab
Mrt/Bku-5ab
Mrt/Bku-5c
Mrt/Bku-5c
Mrt/Bku-5ab

SUNGEI TELABIT BLOCK

Key to mapping unit

eg. Mrt/Bku-5c
- slope class
- effective soil depth
- soil series
- soil association

effective soil depth* (cm)	slope class
1 ..... <25	a ..... 0 - 2°
2 25-50	b ..... 2 - 6°
3 ..... 50 - 75	c ..... 6 - 12°
4 ..... 75 -100	d ..... 12 - 20°
5 ..... >100	e ..... 20 - 25°
	f ..... 25 - 33°
	g ..... > 33°

* depth to impervious rock, permanent water table, massive clay etc.

Block boundary

SOIL SERIES		SOIL CHARACTERISTICS
Mrt	Merit	on shale; texture is clay loam to clay to silty clay to silty clay loam; with 35 to 60 % clay; brownish yellow to reddish yellow to strong brown; moderately deep to deep; stony and non-stony; well-drained; nearly level to very steep.
Bku	Bekenu	as above but texture is clay loam to clay; with 18 to 35 % clay
Nlu	Nyalau	on sandstone; texture is fine sandy loam; with less than 18 % clay, brownish yellow; deep; stony and non-stony; somewhat excessively drained; nearly level to very gently undulating
Bmg	Bemang	on alluvium; texture is loam; yellowish brown; moderately deep to deep; non-stony; moderately well-drained; nearly level
Bjt	Bijat	on alluvium; texture is silty clay loam; light brownish grey with mottles; moderately deep; massive clay at below 75 cm soil depth; imperfect to poorly drained; nearly level to level
Smn	Samarahan	on alluvium; texture is silty clay loam; light grey; very shallow; massive clay within 25 cm from soil surface; very poorly drained, level
Mkh	Mukah	on organic debris; peat and muck 50 to 150 cm thick overlying massive clay; very poorly drained; depressional