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A SEMI-DETAILED SOIL SURVEY,
LAND CAPABILITY/SUITABILITY STUDY FOR OIL PALM CULTIVATION
IN PART OF
SUNGEI SEPUPOK AND SUNGEI GALASAH AREA FOR
SARAWAK OIL PALM SDN BHD

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- 3) LOCATION AND EXTENT
- 4) GEOLOGY
- 5) LANDFORM
- 6) VEGETATION
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A SEMI-DETAILED SOIL SURVEY,
LAND CAPABILITY/SUITABILITY STUDY FOR OIL PALM CULTIVATION

IN PART OF
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Ebor Research
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West Malaysia

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2. TERMS OF REFERENCE

1. INTRODUCTION

A request was made by Sarawak Oil Palm Sdn Bhd to carry out a semi-detailed soil survey and land capability/suitability study for oil palm cultivation in Sungei Sepupok and Sungei Galasah area in the Fourth Division, Sarawak. The survey was carried out by Mr. Chuah Joo Hor of Ebor Research from 10th May to 20th June 1984.

The objective of the survey is to identify and demarcate the various soil units within the survey area. Soil properties were studied in detail, these include physiographical, physical, chemical and morphological properties. Soil limitations which are likely to inhibit good oil palm performance were identified.

- 3) Of the 60 soil pits to be studied, up to 20 pits are to be selected for soil profile sampling and chemical and physical analysis. These will be the representative of the major soil series encountered in the project area. From each selected pit, an average of 4 samples are to be collected from the various soil horizons to the depth of 1.5m.
- 4) In addition, soil water examinations to the depth of 1 meter will be carried out at every 200 meters along each rentice.
- 5) For all the soil pits and soil water examinations, vegetation, landform and slope (actual, in degrees) will be reported.
- 6) Photographic presentation of the major soil series in the Project Area.

2. TERMS OF REFERENCE

The survey was carried out in accordance with the terms of reference given below:

TASK A: Semi-detailed soil survey

1) The maximum distance between rentices is 1 kilometer.

2) About 60 soil examination pits will be studied and described in detail to the depth of 1.5 meter.

3) Of the 60 soil pits to be studied, up to 30 pits are to be selected for soil profile sampling and chemical and physical analysis. These will be the representative of the major soil series encountered in the project area. From each selected pit, an average of 4 samples are to be collected from the various soil horizons to the depth of 1.5m.

4) In addition, soil auger examinations to the depth of 1 meter will be carried out at every 200 meters along each rentice.

5) For all the soil pits and soil auger examinations vegetation, landform and slope (actual, in degrees) will be reported.

6) Photographic presentation of the major soil series in the Project Area.

TASK B: Laboratory analysis

LOCATION Soil samples will be sent for physical and chemical analysis to Ebor Laboratories, Sime Darby Plantations, Klang, Selangor, Peninsular Malaysia.

TASK C: (i) Soil map at "Soil series/Soil Association" level.

(ii) Scale of soil map - 1 : 12,500

TASK D: Reporting

A Full Soil Survey Report including land capability/suitability study for oil palm cultivation will be completed 1 month after the last sample reaches Ebor Laboratory. Six copies will be provided.

Map 1 indicates the location of the blocks.

3. LOCATION AND EXTENT

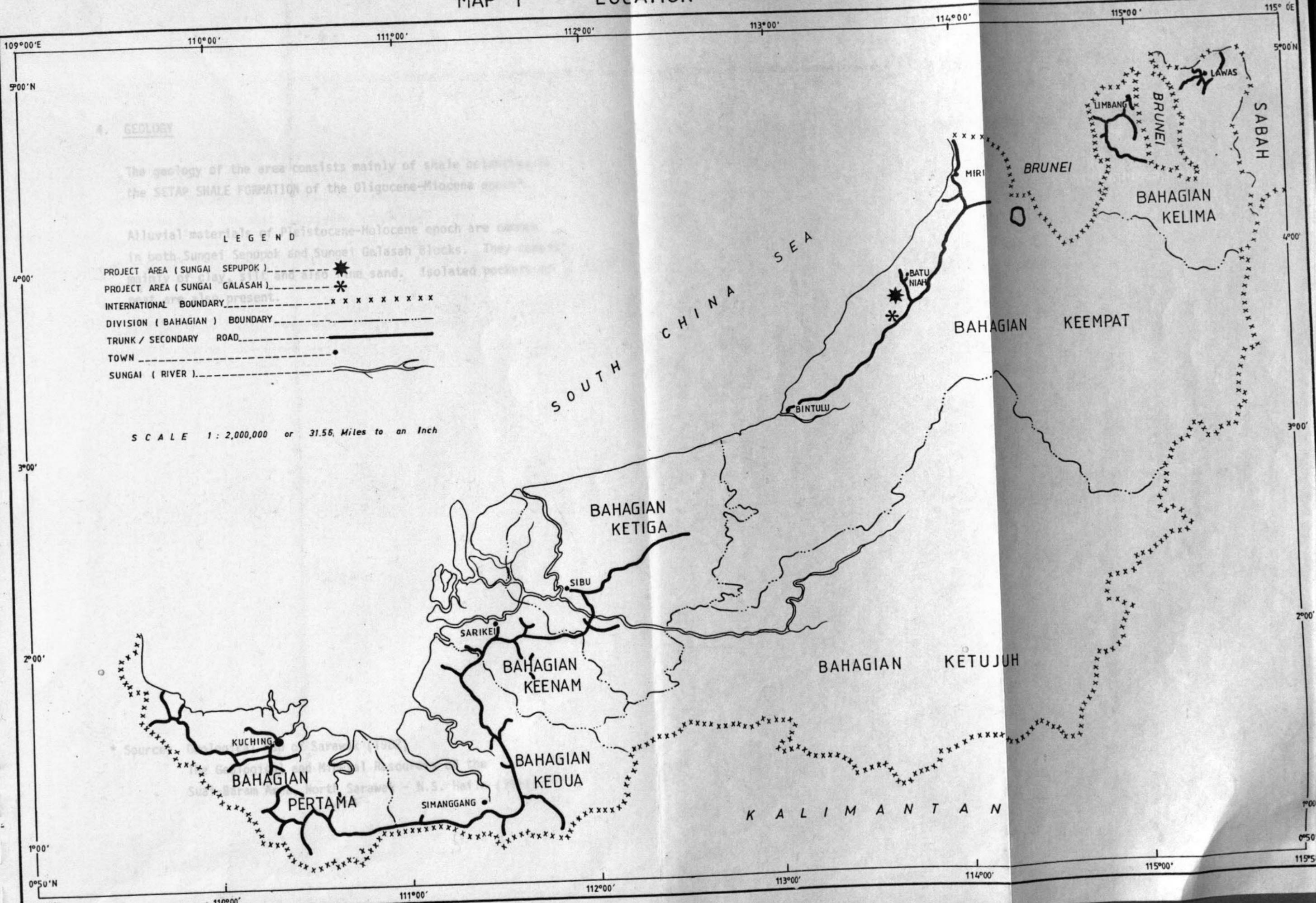
The surveyed area consists of two separated blocks, namely the Sungei Sepupok Block and the Sungei Galasah Block. Both these blocks are situated in the Miri district in the Fourth Division, State of Sarawak.

The Sungei Sepupok Block is 3,720 hectares and is located between latitudes $3^{\circ} 43' N$ and $3^{\circ} 48' N$ and longitudes $113^{\circ} 39' E$ and $113^{\circ} 44' E$. The northern part of the area can be approached via 2nd kilometer Batu Niah - Miri Road from which a stoned road leads to the area. The southern part can be approached via 5th kilometer Batu Niah - Miri Road from where a logging track leads off from the long-house (Rumah Lalat) to the area.

The Sungei Galasah Block is 1,983 hectares and is located between latitudes $3^{\circ} 36' N$ and $3^{\circ} 39' N$ and longitudes $113^{\circ} 38' E$ and $113^{\circ} 43' E$. It is about 86 kilometers from Miri town on the Miri - Bintulu Main Trunk Road which formed a major portion of its South-Eastern boundary. The Sungei Galasah Block is about 9 kilometers south of the Sungei Sepupok Block.

Map 1 indicates the location of the blocks.

MAP 1 LOCATION



4. GEOLOGY

The geology of the area consists mainly of shale or sandstone of the SETAP SHALE FORMATION of the Oligocene-Miocene epoch.

Alluvial materials of the Pleistocene-Holocene epoch are common in both Sungai Sepuok and Sungai Galasah blocks. They consist of fine sand, silt and clay.

LEGEND

- PROJECT AREA (SUNGAI SEPUK)
- PROJECT AREA (SUNGAI GALASAH)
- INTERNATIONAL BOUNDARY x x x x x x x x
- DIVISION (BAHAGIAN) BOUNDARY
- TRUNK / SECONDARY ROAD
- TOWN
- SUNGAI (RIVER)

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

4. GEOLOGY

The geology of the area consists mainly of shale belonging to the SETAP SHALE FORMATION of the Oligocene-Miocene epoch*.

Alluvial materials of Pleistocene-Holocene epoch are common in both Sungei Sepupok and Sungei Galasah Blocks. They consist mainly of clay, silt and also fine sand. Isolated pockets of peat are also present. // clay sh?

Maps 2 and 3 and Table 1 represent the distribution and the extent of the various slope classes.

* Source: Geological Map of Sarawak (1982)
The Geological and Mineral Resources of the
Suai-Baram Area, North Sarawak - N.S. Haile (1962)

5. LANDFORM

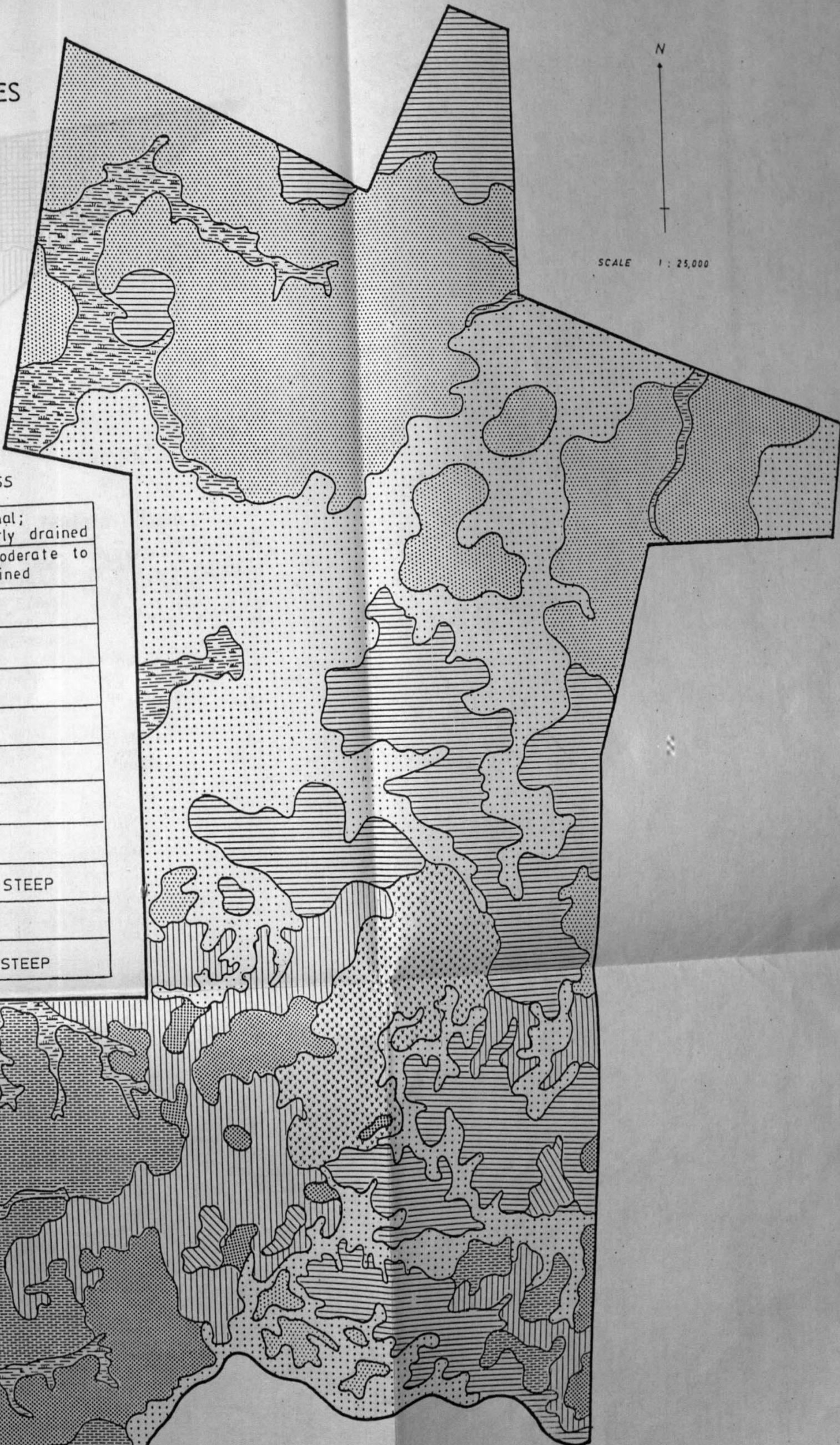
The majority of the surveyed area occurs on undulating to very steep, dissected low hills. Elevation ranges between less than 15 to 110 meters above mean sea level with 15 to 45 meters elevation being the most widespread. Flat low lying valleys are found in both blocks while in the Sungei Sepupok Block, extensive area of old river bed with scattered pitted and grooved rock outcrops are found. *1 km wide*

Maps 2 and 3 and Table 1 represent the distribution and the extent of the various slope classes

MAP 2
 SLOPE AND TERRAIN CLASSES
 OF
 SUNGEI SEPUPOK BLOCK



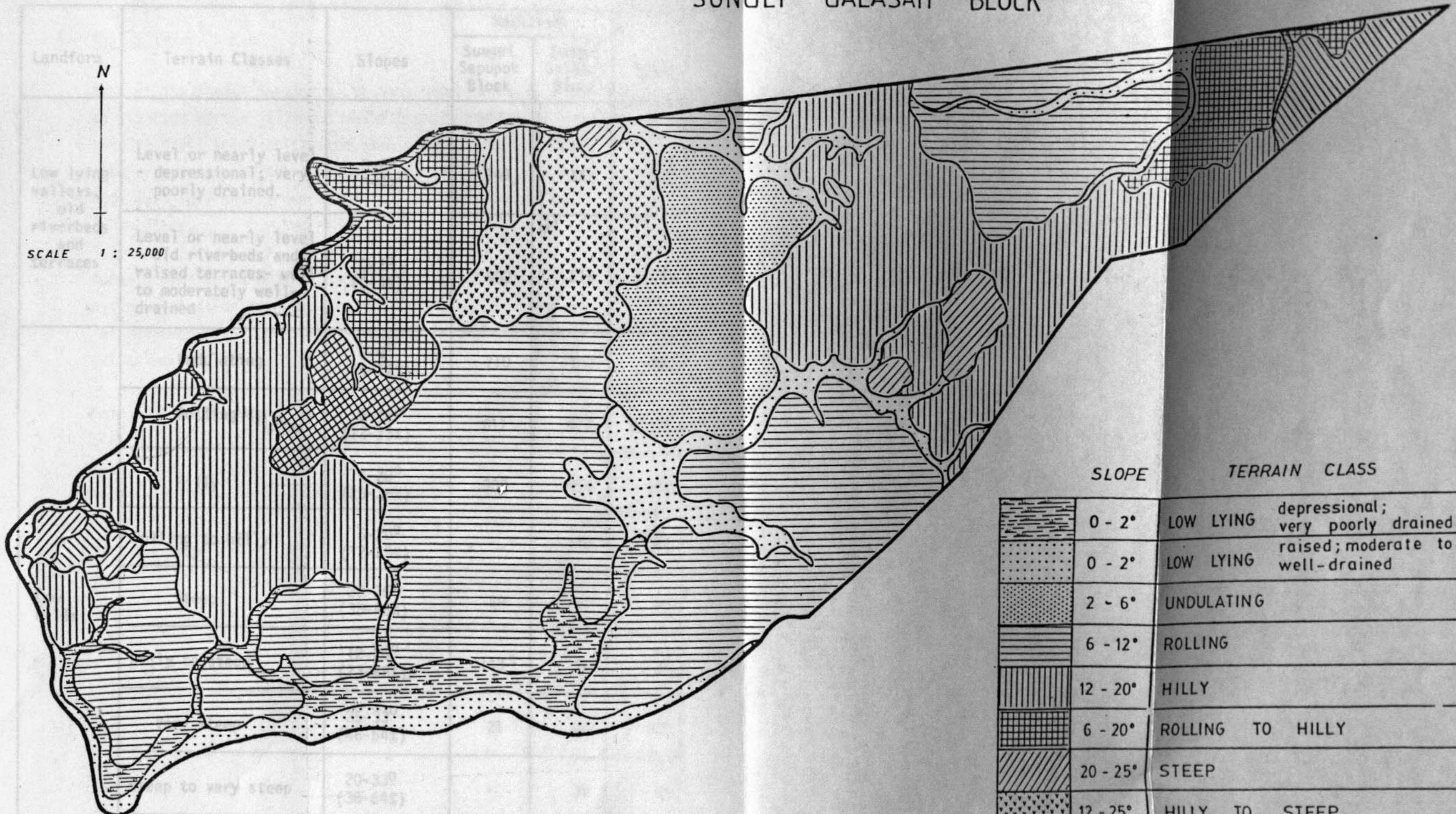
SCALE 1 : 25,000



SLOPE TERRAIN CLASS

SLOPE	TERRAIN CLASS
0 - 2°	LOW LYING <small>depressional; very poorly drained</small>
0 - 2°	LOW LYING <small>raised; moderate to well-drained</small>
2 - 6°	UNDULATING
6 - 12°	ROLLING
12 - 20°	HILLY
6 - 20°	ROLLING TO HILLY
20 - 25°	STEEP
12 - 25°	HILLY TO STEEP
25 - 33°	VERY STEEP
20 - 33°	STEEP TO VERY STEEP
> 33°	EXTREMELY STEEP
25 - > 33°	VERY TO EXTREMELY STEEP

MAP 3 SLOPE AND TERRAIN CLASSES OF SUNGEL GALASAH BLOCK



Landforms
 N
 SCALE 1 : 25,000

SLOPE		TERRAIN CLASS	
	0 - 2°	LOW LYING	depressional; very poorly drained
	0 - 2°	LOW LYING	raised; moderate to well-drained
	2 - 6°	UNDULATING	
	6 - 12°	ROLLING	
	12 - 20°	HILLY	
	6 - 20°	ROLLING TO HILLY	
	20 - 25°	STEEP	
	12 - 25°	HILLY TO STEEP	
	25 - 33°	VERY STEEP	
	20 - 33°	STEEP TO VERY STEEP	

Table 1: Hectarages of the various landforms and terrain classes

Landform	Terrain Classes	Slopes	Hectarage		Total
			Sungei Sepupok Block	Sungei Galasah Block	
Low lying valleys, old riverbeds and terraces	Level or nearly level - depressional; very poorly drained.	0-2° (0-4%)	249	143	392
	Level or nearly level - old riverbeds and raised terraces- well to moderately well-drained	0-2° (0-4%)	902	215	1,117
Low hills	Undulating	2-6° (4-12%)	710	143	853
	Rolling	6-12° (12-23%)	611	677	1,288
	Hilly	12-20° (23-38%)	308	454	762
	Rolling to hilly	6-20° (12-38%)	-	140	140
	Steep	20-25° (38-48%)	59	37	96
	Hilly to steep	12-25° (23-48%)	143	96	239
	Very steep	25-33° (48-64%)	21	40	61
	Steep to very steep	20-33° (38-64%)	-	39	39
	Extremely steep	33° (64%)	307	-	307
	Very steep to extremely steep	25- 33° (48- 64%)	410	-	410
TOTAL:			3,720	1,984	5,704

1178

6. VEGETATION

Most of the Sungei Sepupok Block have undergone shifting cultivation by the natives. While a small portion of the area is still being cultivated with pepper, rice and other cash crops, many of the previously cultivated land have been left idle and re-generation of secondary forest has taken place.

A small area in Sungei Galasah Block is still currently under cultivation with pepper, rice and other cash crops. The remaining area consists of primary forest and has been extracted of timber.

Some of the surrounding areas have been successfully planted with perenial crops, mainly oil palm and cocoa.

Maps 4, 5 and Table 2 represent the distribution and extent of the various types of vegetation (Plates 1-6) in the surveyed area.

MAP 4
VEGETATION OF
SUNGEI SEPUPOK BLOCK

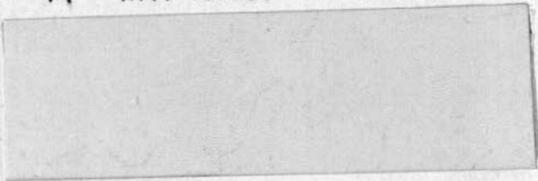


SCALE 1 : 25,000

VEGETATION TYPES

Primary Vegetation

A Hill forest



Secondary Vegetation

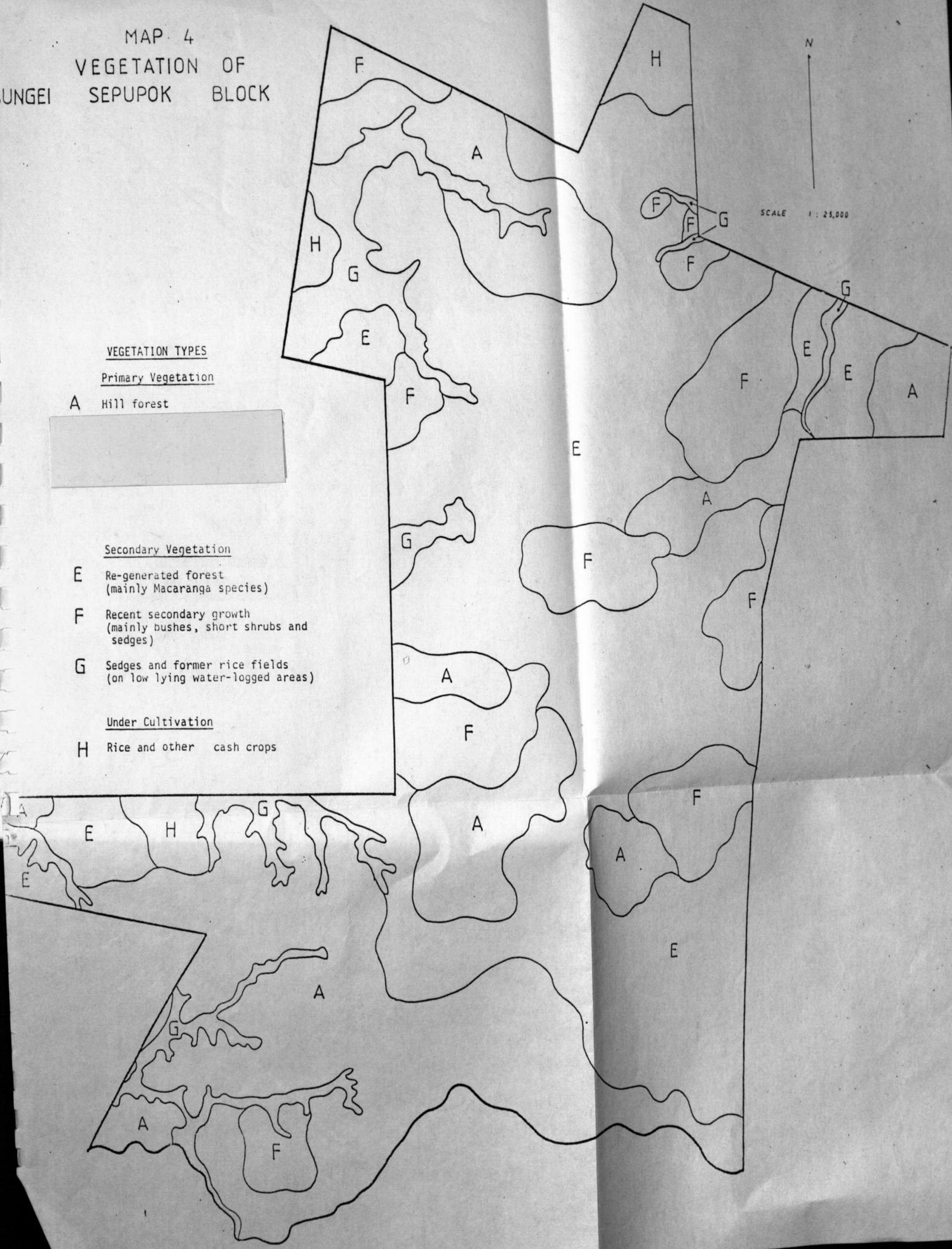
E Re-generated forest
(mainly Macaranga species)

F Recent secondary growth
(mainly bushes, short shrubs and
sedges)

G Sedges and former rice fields
(on low lying water-logged areas)

Under Cultivation

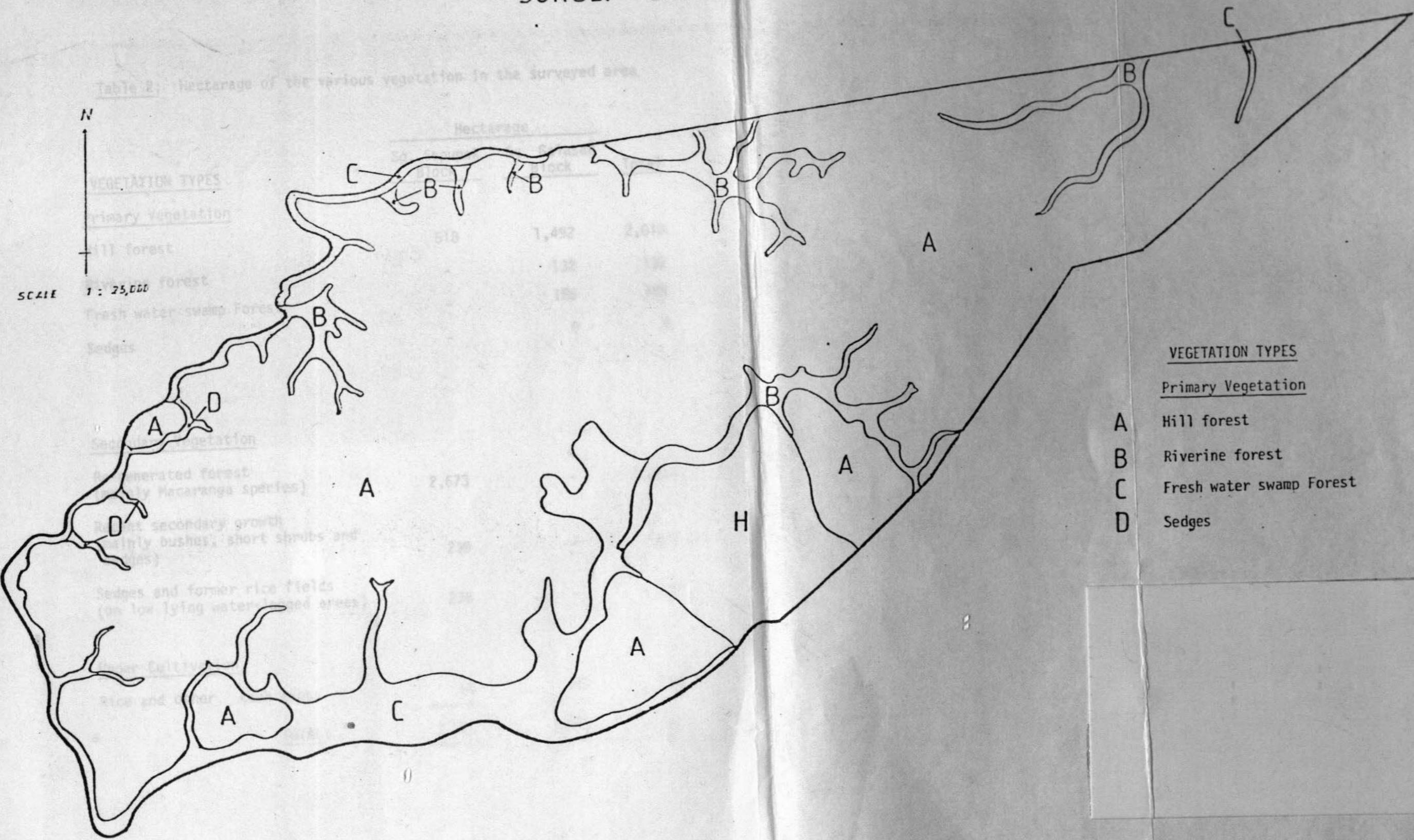
H Rice and other cash crops



MAP 5 VEGETATION OF SUNGEI GALASAH BLOCK

Table 2: Hectarage of the various vegetation in the surveyed area.

N
SCALE 1 : 25,000



VEGETATION TYPES	Hectarage
Primary Vegetation	
Hill forest	510
Riverine forest	1,492
Fresh water swamp Forest	2,010
Sedges	130
Secondary Vegetation	
Regenerated forest (mainly Macaranga species)	2,675
Forest with secondary growth (mainly bushes, short shrubs and vines)	220
Sedges and former rice fields (on low lying water logged areas)	220
Rice Cultivation	
Rice and other cash crops	

- VEGETATION TYPES
- Primary Vegetation
- A Hill forest
 - B Riverine forest
 - C Fresh water swamp Forest
 - D Sedges
-
- Under Cultivation
- H Rice and other cash crops

Table 2: Hectarage of the various vegetation in the surveyed area

<u>VEGETATION TYPES</u>	<u>Hectarage</u>		<u>Total</u>
	<u>Sg. Sepupok Block</u>	<u>Sg. Galasah Block</u>	
<u>Primary Vegetation</u>			
Hill forest	518	1,492	2,010
Riverine forest	-	132	132
Fresh water swamp Forest	-	185	185
Sedges	-	9	9
<u>Secondary Vegetation</u>			
Re-generated forest (mainly Macaranga species)	2,673	-	2,673
Recent secondary growth (mainly bushes, short shrubs and sedges)	239	-	239
Sedges and former rice fields (on low lying water-logged areas)	236	-	236
<u>Under Cultivation</u>			
Rice and other cash crops	54	165	219
<u>TOTAL:</u>	<u>3,720</u>	<u>1,983</u>	<u>5,703</u>



Plate 1 - Hill Forest



Plate 2 - Riverine Forest



Plate 3 - Fresh Water Swam Forest



Plate 4 - Sedges

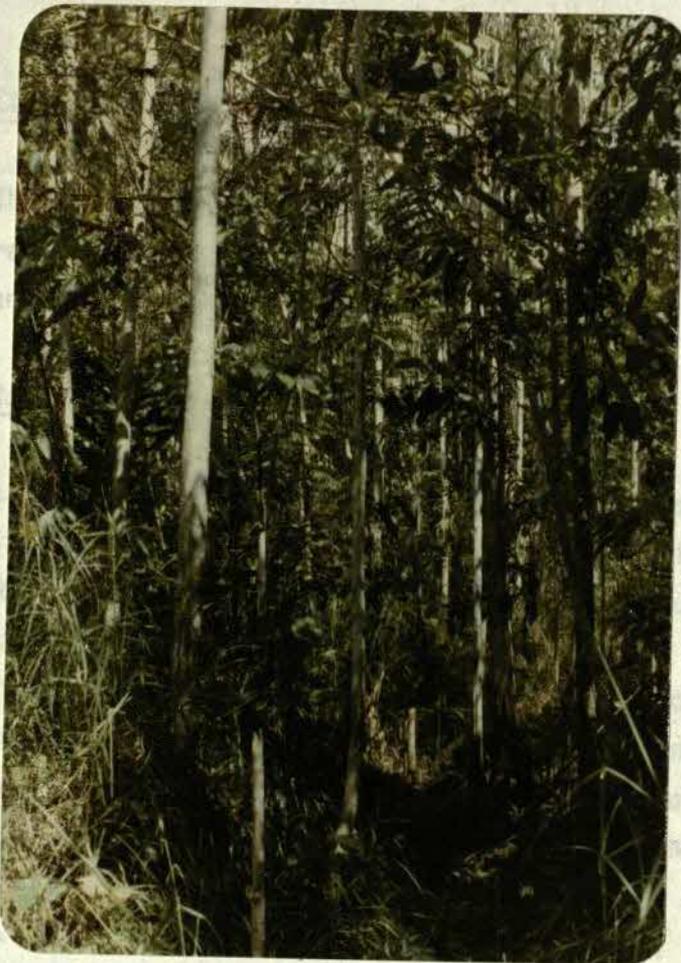


Plate 5 - Re-generated Forest



Plate 6 - Recent Secondary Growth

7. CLIMATE

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

Rainfall

A 14 year rainfall record of Sungei Niah* is presented in Figures 1a, 1b and 1c. The mean monthly rainfall is around 200 mm. Highest rainfall is recorded in January and the lowest rainfall is recorded 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.

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).**

Humidity

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

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

** Source: Miri-Bintulu Regional Study

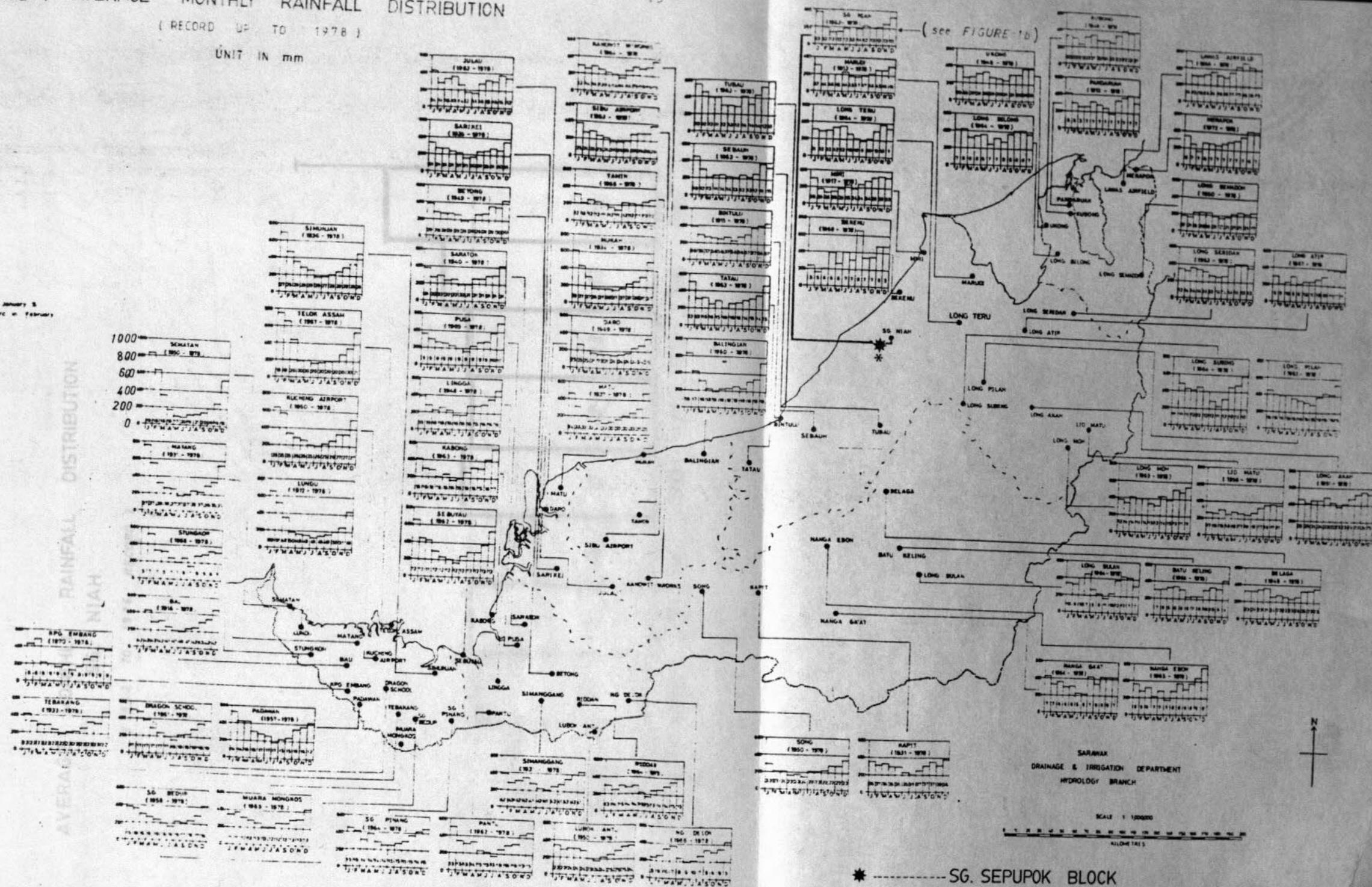
Figure 1a : AVERAGE MONTHLY RAINFALL DISTRIBUTION

(RECORD UP TO 1978)

UNIT IN mm

LEGEND
 10 years record in January &
 11 years record in February

RAINFALL DISTRIBUTION



1000
800
600
400
200
0

SCALE 1:100,000
 ALLOW 1:100,000

* --- SG. SEPUPOK BLOCK
 * --- SG. GALASAH BLOCK

AVERAGE MONTHLY RAINFALL DISTRIBUTION
SG. NIAH.

(1963 TO 1976 RECORD)

LEGEND

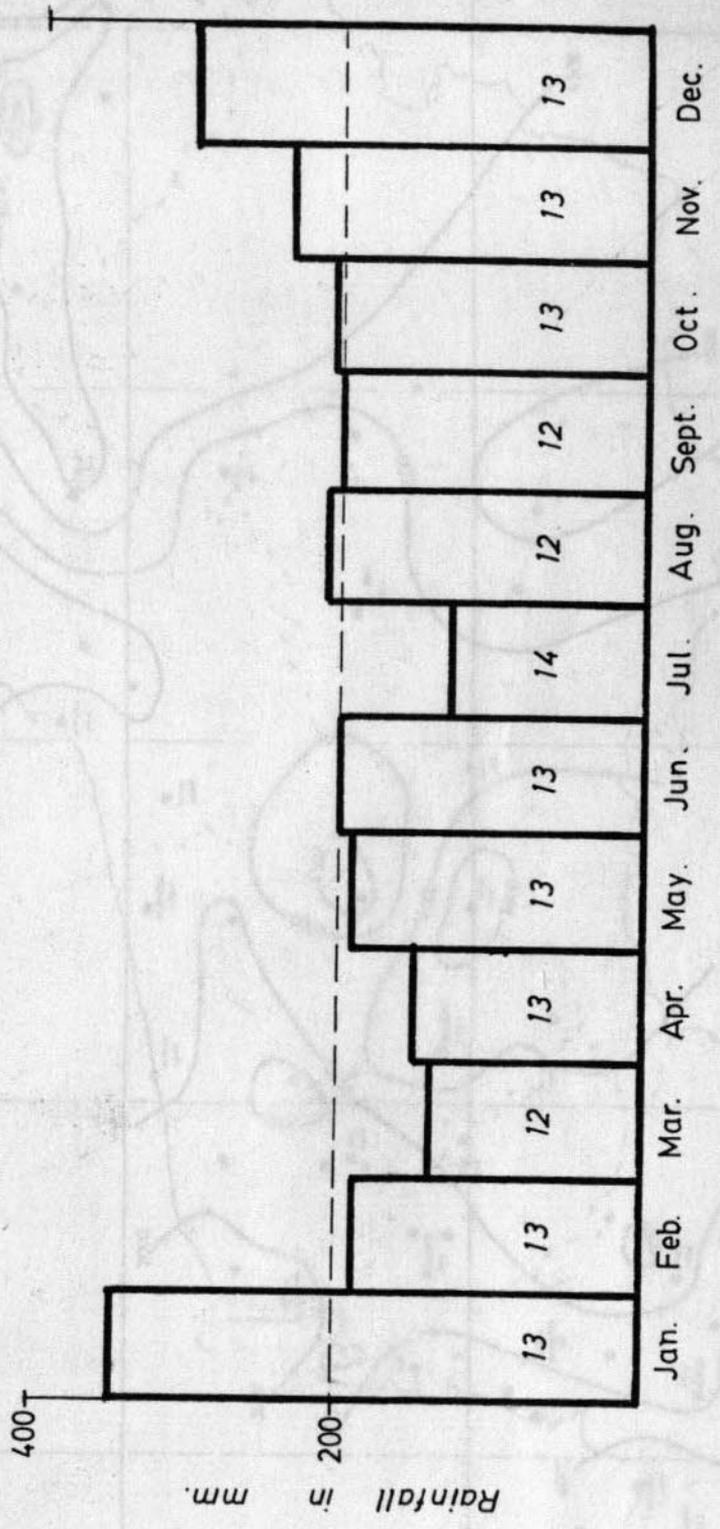
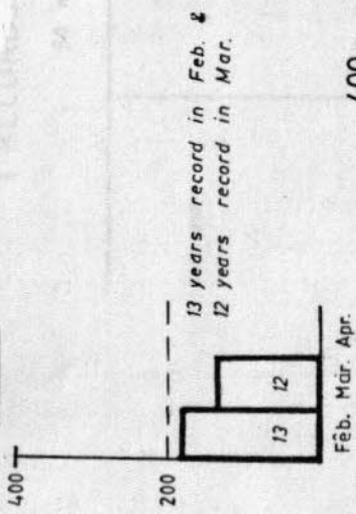
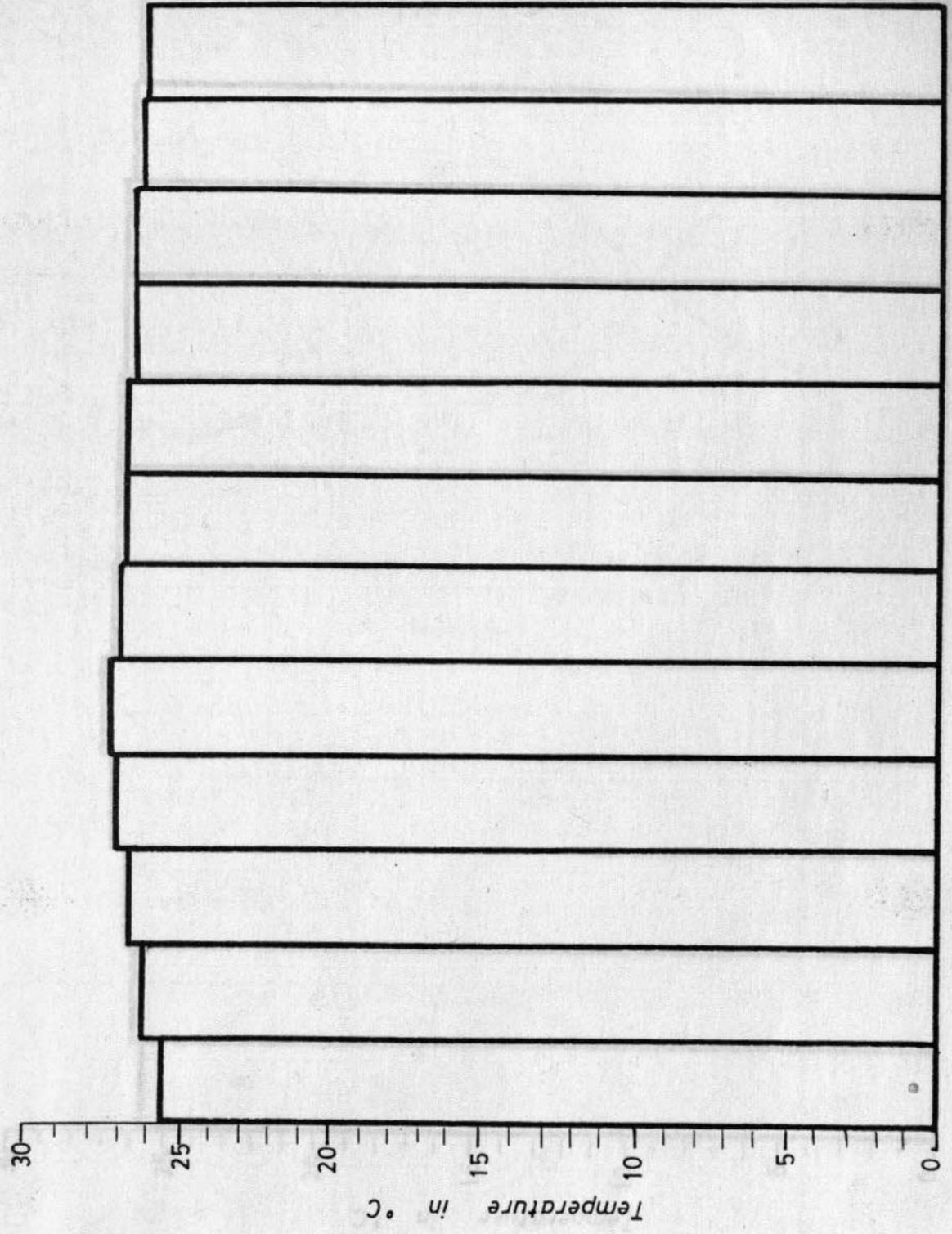


Table 3: Mean Monthly Temperature ($^{\circ}\text{C}$) for Miri and Bintulu*

<u>Month</u>	<u>Miri</u>	<u>Bintulu</u>
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
<u>Mean annual</u>	<u>26.6</u>	<u>26.5</u>

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

Figure 2a : MEAN MONTHLY TEMPERATURE DISTRIBUTION
MIRI
10 YEARS RECORD



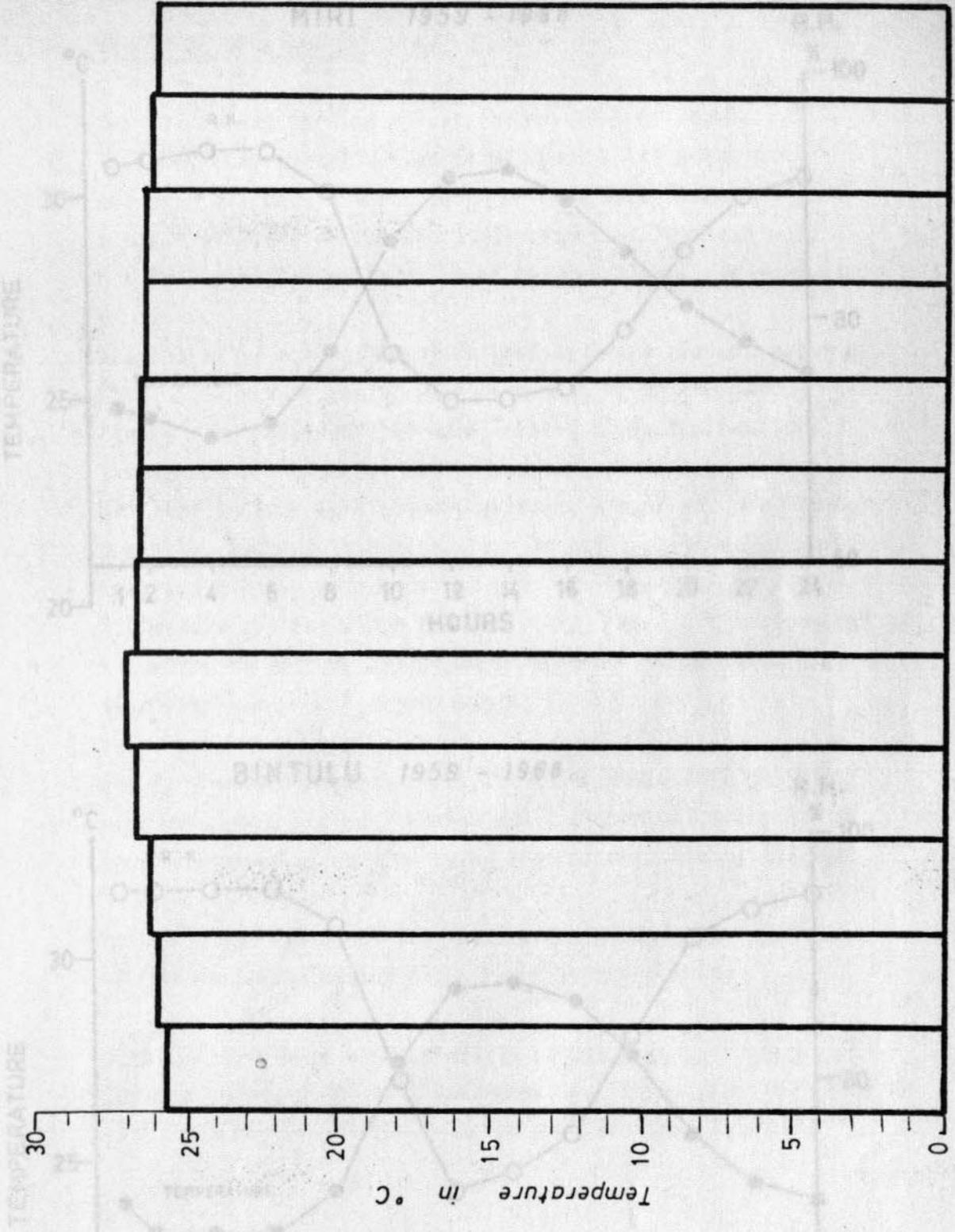
Jan. Feb. Mar. Apr. May. Jun. Jul. Aug. Sept. Oct. Nov. Dec.

Figure 3 - DIURNAL VARIATION IN TEMPERATURE AND RELATIVE HUMIDITY

Figure 2b: MEAN MONTHLY TEMPERATURE DISTRIBUTION

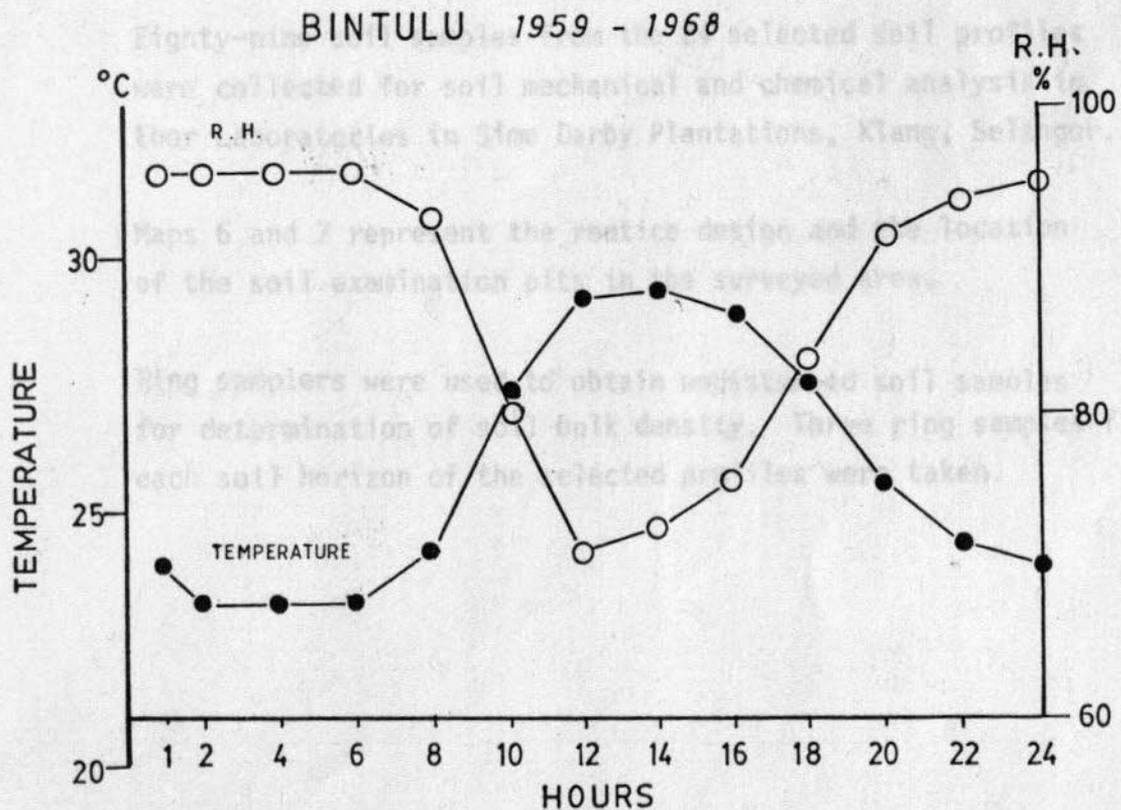
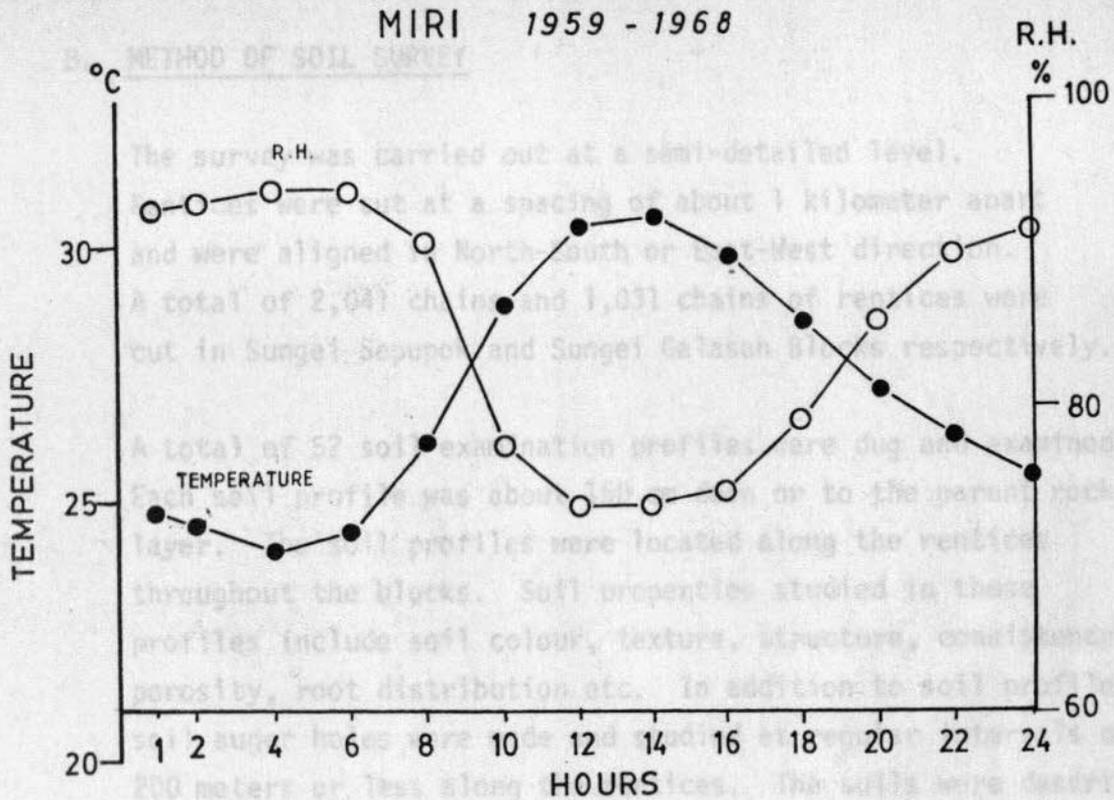
BINTULU

10 YEARS RECORD



Jan. Feb. Mar. Apr. May. Jun. Jul. Aug. Sept. Oct. Nov. Dec.

Figure 3 : DIURNAL VARIATION IN TEMPERATURE AND RELATIVE HUMIDITY



8. METHOD OF SOIL SURVEY

The survey was carried out at a semi-detailed level. Rentices were cut at a spacing of about 1 kilometer apart and were aligned in North-South or East-West direction. A total of 2,041 chains and 1,031 chains of rentices were cut in Sungei Sepupok and Sungei Galasah Blocks respectively.

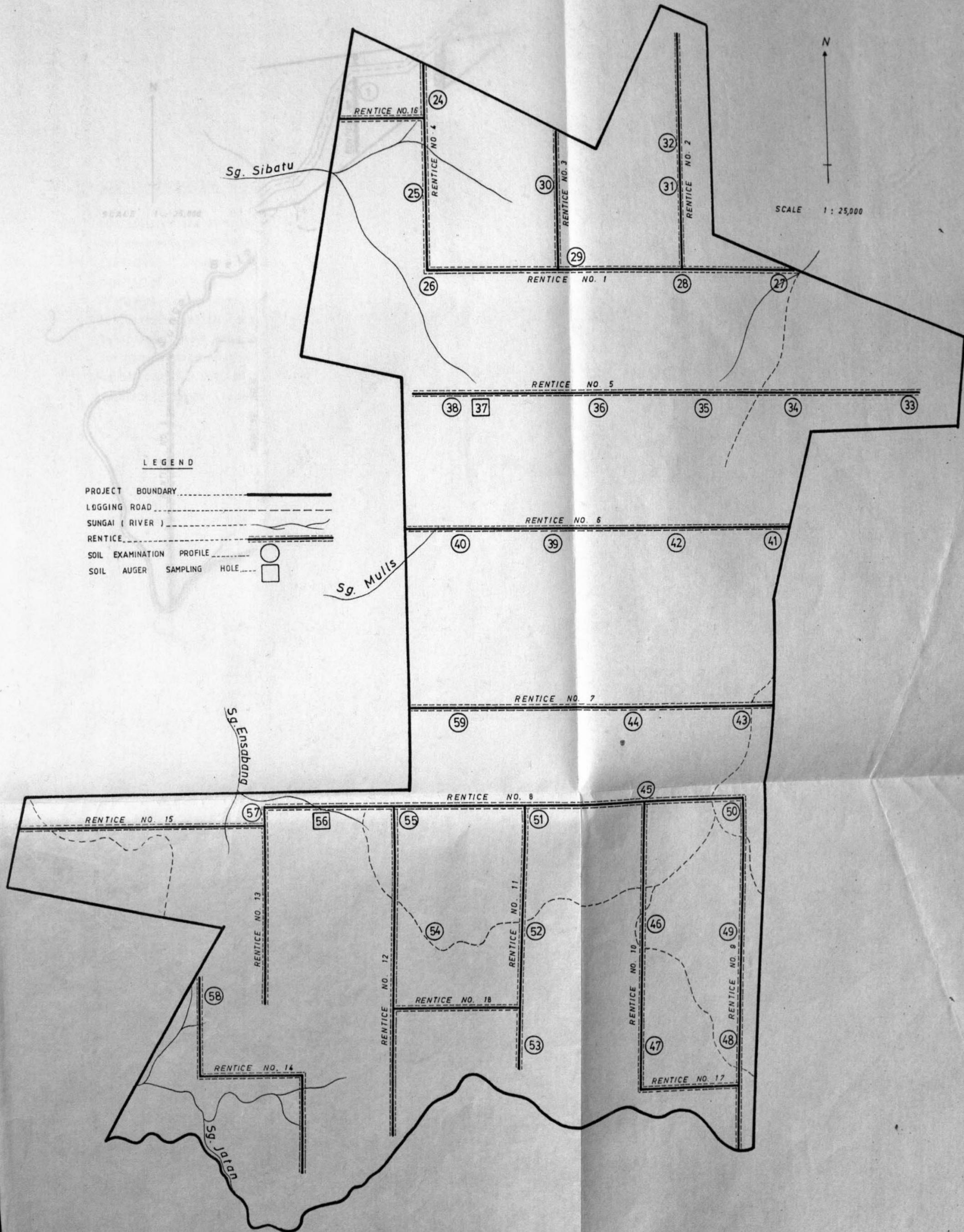
A total of 52 soil examination profiles were dug and examined. Each soil profile was about 150 cm deep or to the parent rock layer. The soil profiles were located along the rentices throughout the blocks. Soil properties studied in these profiles include soil colour, texture, structure, consistency, porosity, root distribution etc. In addition to soil profiles, soil auger holes were made and studied at regular intervals of 200 meters 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)

Eighty-nine soil samples from the 24 selected soil profiles were collected for soil mechanical and chemical analysis in Ebor Laboratories in Sime Darby Plantations, Klang, Selangor.

Maps 6 and 7 represent the rentice design and the 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.

MAP 6 - RENTICE DESIGN & SOIL PROFILES LOCATION



LEGEND

- PROJECT BOUNDARY
- LOGGING ROAD
- SUNGAI (RIVER)
- RENTICE
- SOIL EXAMINATION PROFILE
- SOIL AUGER SAMPLING HOLE



SCALE 1 : 25,000

SCALE 1 : 25,000

9. 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.

Table 4: Soil Groups And Families Separation

Soil Group	Family	Family Criteria	Series	Series Differentiae	Soil Taxonomy (U.S.D.A.)*
Red-Yellow Podzolic Soils	BEKENU	Red-Yellow Podzolic soils that have a fine loamy or fine silty particle-size class and are derived from sedimentary rocks	Bekenu	BEKENU soils that have a yellow colour class; a fine loamy particle-size class; and are residual	Typic/(Orth) Oxic Paleudults/Dystrupepts
	KABULOH	Red-Yellow Podzolic soils that have a calcareous or non-acid reaction	Tukau Kabuloh	BEKENU soils that have developed in non-accreting alluvium KABULOH soils that have a hue of 2.5Y within a depth of 50 cm or throughout the control section.	Typic/Aquic/(Orth) Oxic Paleudults/Dystrupepts Typic/Aquic Tropudalfs/Eutropepts
	MERIT	Red-Yellow Podzolic soils that have a fine clayey particle-size class	Merit	MERIT soils that have a CEC of > 24 meq. per 100 gm clay in the major part of the B horizon and have a yellow colour class	Typic Paleudults/Dystrupepts
Alluvial Soils	NYALAU	Red-Yellow Podzolic soils that have a coarse loamy or coarse silty particle-size class	Bedup Sabangang	MERIT soils that have a yellow colour class and low C.E.C. NYALAU soils that have developed in non-accreting alluvium	Orthoxic Paleudults/Oxic Dystrupepts Typic/(Orth) Oxic Paleudults/Dystrupepts
	SEDUAU	Alluvial soils that have a clayey particle-size class	Seduau	SEDUAU soils that have formed in alluvium derived from non-calcareous sedimentary rocks and have a yellow colour class	Tropofluvents, Typic/Aquic/Oxic Dystrupepts

*Tentative correlation

cont...

Soil Group	Family	Family Criteria	Series	Series Differentiae	Soil Taxonomy (U.S.D.A)*
Gley Soils	BIJAT	Gley soils that have developed in marine or accreting riverine alluvium and have a clayey particle-size class	Bijat	BIJAT soils that have developed in riverine alluvium derived from non-calcareous sedimentary rocks and have a white to grey colour within 50 cm of mineral soil surface	Tropic (Histic) Fluvaquents
Skeletal Soil	TUTOH	Skeletal soils that have developed in colluvium	Mundai	BIJAT soils that have developed in riverine alluvium derived from calcareous sedimentary rocks	Tropic (Histic) Fluvaquents
	BINATANG	Skeletal soils that have developed in alluvium or alluvium overlying residuum	Tutoh	TUTOH soils derived from non-calcareous sedimentary rocks	Typic Troporthents
Organic Soil	MUKAH	Organic soils that have 50-100 cm of organic materials resting on clayey, non-sulphidic substratum	Binatang	BINATANG soils that have a drainage class of 4 or more	Lithic Tropofluvents
			Mukah	MUKAH soils that have autochthonous organic soil materials with a low ash content	Terric Tropofibrists

10.1 Merit series

This is the most dominant soil series in the surveyed area. It occupies the major portion of both Sungei Senupok and Sungei Galasah Blocks.

Merit series is classified as Red-Yellow Podzolic soils that have a fine clayey particle-size class and that have a CEC of > 24 meq per 100 g clay in the major part of the B horizon on non-calcareous argillaceous shale. It occurs on gently undulating to steep topography. It is characterised by the brownish yellow to yellowish brown well-drained clay with well-developed blocky structures. The soil is moderately deep to deep and impervious parent rock usually occurs below 100 cm depth.

The superficial surface layer consists of both undecomposed and decomposed loose leaf litters and organic debris. It is about 4 to 6 leaf thick and covers about 60% of the soil surface. This is underlain by a humus rich mineral layer (A_h 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 present of many organic acid coatings on soil ped surfaces. The colour of these coatings resemble the soil matrix colour

Very common, a $3C_2$ layer may occur, usually at the lower depth of the overlying top soil. Faunal pedoturbations are evident in the form of fine (± 20 mm) scattered "krotovinas" which are very porous and are yellowish brown to dark brown in colour. The B1 horizon has the maximum illuviation of organic acid from the surface horizon and the soil matrix colour is paler brownish yellow. The A_h and the B1 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.

Weakly developed and in some cases tending towards massive. Their The horizon with maximum clay content occurs below the B1 horizon. Most profiles have $>35\%$ clay in this horizon. Structures are toward 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 concentration are generally lower.

The geomorphic age of the soils of Merit series are considerable. 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 its 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 not 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.

exchangeable bases (TEB) are highest in the A_h horizons and lowest in the B horizons. The organic rich A_h horizons have TEB values ranging from 2 to 5 meq/100 gm.

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 are mottled with grey - a dominant colour of the underlying parent rock. Micro-bio activities is 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 are 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°.

The geomorphic age of the soils of Merit series are considerable 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 favoured the formation of the deeper soils in the surveyed area.

Merit series soils are acidic with pH ranges from 3.8 to 4.5. Organic carbon is highest in the A_h horizons with values ranges from 1.8 to 3.8%. This is followed by the B₁ illuviated horizons with values ranging from 0.6 to 1.1%. There is an abrupt decrease of organic carbon in the underlying B horizons, where most values are below 0.4%. Total exchangeable bases (TEB) are highest in the A_h horizons and lowest in the B horizons. The organic rich A_h horizons have TEB values ranging from 2 to 8 meq./100 gm.

Typical Profile (Profile No. 2)

Merit series

Sub-soil B horizons have lower TEB and have values between 1.0 to 0.3 meq./100 gm. Except for the A_h horizons, base saturation of most horizons are below 10%.

A_h 0-5 cm Yellowish brown (10YR 5/4) clay loam, moderate.

A profile description of a typical Merit series and the analytical data is provided herewith. Plates 7 represents soils of the Merit series.

B₁ 5-20 cm Brownish yellow (10YR 6/6); clay loam, moderately strong, medium and coarse subangular blocky, friable; many very fine pores; frequent fine and medium roots; with brown (10YR 5/3) organic acid coatings on some ped surfaces and along few channels; some krotovinas; gradual boundary

B₂ 1 20-60 cm Reddish yellow (7.5YR 6/8) to strong brown (7.5YR 5/6) clay loam, moderately strong, coarse subangular blocky breaking into moderately strong, coarse and some medium subangular blocky; friable to slightly firm; common fine pores; few, fine and medium roots; moderately developed cilia on most ped surfaces; few krotovinas; gradual boundary

B₂ 2 50-85 cm Similar to the horizon above but with very few fine and medium roots; texture is clay; clear boundary

B₂ 3ca 85-115 cm Reddish yellow (7.5YR 6/8); clay loam, moderately strong, coarse and very coarse subangular blocky; friable to stiffly firm; few fine pores; very few fine and medium roots; with few 5-30 cm gravels of laterites and silts; laterised chert; gravels are loosely packed; clear boundary

Typical Profile (Profile No. 2)

BC	115-145 cm	Merit series (7.5YR 6/8), strong brown (7.5YR 5/8) brownish yellow (10YR 6/5) and 6/4); clay loam;
A ₀		Leaf litter, 3 to 5 leaves thick.
A _h	0-5 cm	Yellowish brown (10YR 5/4); clay loam; moderate, medium and fine subangular blocky and crumbs; friable; many fine pores; abundant fine and coarse roots; clear boundary.
B ₁	5-20 cm	Brownish yellow (10YR 6/6); clay loam, moderately strong, medium and coarse subangular blocky; friable; many very fine pores; frequent fine and medium roots; with brown (10YR 5/3) organic acid coatings on some ped surfaces and along few channels; some krotovinas; gradual boundary
B ₂ 1	20-60 cm	Reddish yellow (7.5YR 6/8) to strong brown (7.5YR 5/8) clay loam; moderately strong, coarse subangular blocky breaking into moderately strong, coarse and some medium subangular blocky; friable to slightly firm; common fine pores; few, fine and medium roots; moderately developed cutans on most ped surfaces; few krotovinas; gradual boundary
B ₂ 2	60-85 cm	Similar to the horizon above but with very few fine and medium roots; texture is clay; clear boundary
B ₂ 3cn	85-115 cm	Reddish yellow (7.5YR 6/8); clay loam; moderately strong, coarse and very coarse subangular blocky; friable to slightly firm; few fine pores; very few fine and medium roots; with few 5-30 mm gravels of laterites and platy laterised shale; gravels are loosely packed; clear boundary

BC 115-145 cm Reddish yellow (7.5YR 6/8), strong brown (7.5YR 5/8), brownish yellow (10YR 6/6) and 6/8); clay loam; moderately strong, coarse and medium subangular blocky; friable; few medium pores; very few, very fine roots; some scattered decomposing parent rocks (5 to 20 mm) spaced at 5 to 40 mm apart; interstices are filled with clay loam; tongue boundary

CR 145 cm + A continuous layer of undecomposed parent material shale

Soil profile No. 2
Soil name: Airt's series

Depth (cm)	Moisture (%)	Temp (°C)	pH	Clay (%)	Silt (%)	Loam (%)	Coarse sand (%)	Fine sand (%)	Very fine sand (%)	Organic matter (%)	Carbon (%)	Nitrogen (%)	Phosphorus (ppm)	Potassium (ppm)	Calcium (ppm)	Magnesium (ppm)	Sulfur (ppm)	Zinc (ppm)	Copper (ppm)	Manganese (ppm)	Iron (ppm)	Barium (ppm)	Strontium (ppm)	Sodium (ppm)	Lithium (ppm)	Boron (ppm)	Fluorine (ppm)	Chlorine (ppm)	Iodine (ppm)	Other (ppm)
0-5	2.5	19	5.5	28.5	27.7	12.0	1.1	0.6	1.0	1.53	0.18	0.18	0.25	0.25	0.25	0.25	0.25	0.25	0.25	0.25	0.25	0.25	0.25	0.25	0.25	0.25	0.25	0.25	0.25	0.25
5-10	2.6	19	5.5	28.5	27.7	12.0	1.1	0.6	1.0	1.53	0.18	0.18	0.25	0.25	0.25	0.25	0.25	0.25	0.25	0.25	0.25	0.25	0.25	0.25	0.25	0.25	0.25	0.25	0.25	0.25
10-15	2.6	19	5.5	28.5	27.7	12.0	1.1	0.6	1.0	1.53	0.18	0.18	0.25	0.25	0.25	0.25	0.25	0.25	0.25	0.25	0.25	0.25	0.25	0.25	0.25	0.25	0.25	0.25	0.25	0.25
15-20	2.6	19	5.5	28.5	27.7	12.0	1.1	0.6	1.0	1.53	0.18	0.18	0.25	0.25	0.25	0.25	0.25	0.25	0.25	0.25	0.25	0.25	0.25	0.25	0.25	0.25	0.25	0.25	0.25	0.25
20-25	2.6	19	5.5	28.5	27.7	12.0	1.1	0.6	1.0	1.53	0.18	0.18	0.25	0.25	0.25	0.25	0.25	0.25	0.25	0.25	0.25	0.25	0.25	0.25	0.25	0.25	0.25	0.25	0.25	0.25
25-30	2.6	19	5.5	28.5	27.7	12.0	1.1	0.6	1.0	1.53	0.18	0.18	0.25	0.25	0.25	0.25	0.25	0.25	0.25	0.25	0.25	0.25	0.25	0.25	0.25	0.25	0.25	0.25	0.25	0.25
30-35	2.6	19	5.5	28.5	27.7	12.0	1.1	0.6	1.0	1.53	0.18	0.18	0.25	0.25	0.25	0.25	0.25	0.25	0.25	0.25	0.25	0.25	0.25	0.25	0.25	0.25	0.25	0.25	0.25	0.25
35-40	2.6	19	5.5	28.5	27.7	12.0	1.1	0.6	1.0	1.53	0.18	0.18	0.25	0.25	0.25	0.25	0.25	0.25	0.25	0.25	0.25	0.25	0.25	0.25	0.25	0.25	0.25	0.25	0.25	0.25
40-45	2.6	19	5.5	28.5	27.7	12.0	1.1	0.6	1.0	1.53	0.18	0.18	0.25	0.25	0.25	0.25	0.25	0.25	0.25	0.25	0.25	0.25	0.25	0.25	0.25	0.25	0.25	0.25	0.25	0.25
45-50	2.6	19	5.5	28.5	27.7	12.0	1.1	0.6	1.0	1.53	0.18	0.18	0.25	0.25	0.25	0.25	0.25	0.25	0.25	0.25	0.25	0.25	0.25	0.25	0.25	0.25	0.25	0.25	0.25	0.25
50-55	2.6	19	5.5	28.5	27.7	12.0	1.1	0.6	1.0	1.53	0.18	0.18	0.25	0.25	0.25	0.25	0.25	0.25	0.25	0.25	0.25	0.25	0.25	0.25	0.25	0.25	0.25	0.25	0.25	0.25
55-60	2.6	19	5.5	28.5	27.7	12.0	1.1	0.6	1.0	1.53	0.18	0.18	0.25	0.25	0.25	0.25	0.25	0.25	0.25	0.25	0.25	0.25	0.25	0.25	0.25	0.25	0.25	0.25	0.25	0.25
60-65	2.6	19	5.5	28.5	27.7	12.0	1.1	0.6	1.0	1.53	0.18	0.18	0.25	0.25	0.25	0.25	0.25	0.25	0.25	0.25	0.25	0.25	0.25	0.25	0.25	0.25	0.25	0.25	0.25	0.25
65-70	2.6	19	5.5	28.5	27.7	12.0	1.1	0.6	1.0	1.53	0.18	0.18	0.25	0.25	0.25	0.25	0.25	0.25	0.25	0.25	0.25	0.25	0.25	0.25	0.25	0.25	0.25	0.25	0.25	0.25
70-75	2.6	19	5.5	28.5	27.7	12.0	1.1	0.6	1.0	1.53	0.18	0.18	0.25	0.25	0.25	0.25	0.25	0.25	0.25	0.25	0.25	0.25	0.25	0.25	0.25	0.25	0.25	0.25	0.25	0.25
75-80	2.6	19	5.5	28.5	27.7	12.0	1.1	0.6	1.0	1.53	0.18	0.18	0.25	0.25	0.25	0.25	0.25	0.25	0.25	0.25	0.25	0.25	0.25	0.25	0.25	0.25	0.25	0.25	0.25	0.25
80-85	2.6	19	5.5	28.5	27.7	12.0	1.1	0.6	1.0	1.53	0.18	0.18	0.25	0.25	0.25	0.25	0.25	0.25	0.25	0.25	0.25	0.25	0.25	0.25	0.25	0.25	0.25	0.25	0.25	0.25
85-90	2.6	19	5.5	28.5	27.7	12.0	1.1	0.6	1.0	1.53	0.18	0.18	0.25	0.25	0.25	0.25	0.25	0.25	0.25	0.25	0.25	0.25	0.25	0.25	0.25	0.25	0.25	0.25	0.25	0.25
90-95	2.6	19	5.5	28.5	27.7	12.0	1.1	0.6	1.0	1.53	0.18	0.18	0.25	0.25	0.25	0.25	0.25	0.25	0.25	0.25	0.25	0.25	0.25	0.25	0.25	0.25	0.25	0.25	0.25	0.25
95-100	2.6	19	5.5	28.5	27.7	12.0	1.1	0.6	1.0	1.53	0.18	0.18	0.25	0.25	0.25	0.25	0.25	0.25	0.25	0.25	0.25	0.25	0.25	0.25	0.25	0.25	0.25	0.25	0.25	0.25
100-105	2.6	19	5.5	28.5	27.7	12.0	1.1	0.6	1.0	1.53	0.18	0.18	0.25	0.25	0.25	0.25	0.25	0.25	0.25	0.25	0.25	0.25	0.25	0.25	0.25	0.25	0.25	0.25	0.25	0.25
105-110	2.6	19	5.5	28.5	27.7	12.0	1.1	0.6	1.0	1.53	0.18	0.18	0.25	0.25	0.25	0.25	0.25	0.25	0.25	0.25	0.25	0.25	0.25	0.25	0.25	0.25	0.25	0.25	0.25	0.25
110-115	2.6	19	5.5	28.5	27.7	12.0	1.1	0.6	1.0	1.53	0.18	0.18	0.25	0.25	0.25	0.25	0.25	0.25	0.25	0.25	0.25	0.25	0.25	0.25	0.25	0.25	0.25	0.25	0.25	0.25
115-120	2.6	19	5.5	28.5	27.7	12.0	1.1	0.6	1.0	1.53	0.18	0.18	0.25	0.25	0.25	0.25	0.25	0.25	0.25	0.25	0.25	0.25	0.25	0.25	0.25	0.25	0.25	0.25	0.25	0.25
120-125	2.6	19	5.5	28.5	27.7	12.0	1.1	0.6	1.0	1.53	0.18	0.18	0.25	0.25	0.25	0.25	0.25	0.25	0.25	0.25	0.25	0.25	0.25	0.25	0.25	0.25	0.25	0.25	0.25	0.25
125-130	2.6	19	5.5	28.5	27.7	12.0	1.1	0.6	1.0	1.53	0.18	0.18	0.25	0.25	0.25	0.25	0.25	0.25	0.25	0.25	0.25	0.25	0.25	0.25	0.25	0.25	0.25	0.25	0.25	0.25
130-135	2.6	19	5.5	28.5	27.7	12.0	1.1	0.6	1.0	1.53	0.18	0.18	0.25	0.25	0.25	0.25	0.25	0.25	0.25	0.25	0.25	0.25	0.25	0.25	0.25	0.25	0.25	0.25	0.25	0.25
135-140	2.6	19	5.5	28.5	27.7	12.0	1.1	0.6	1.0	1.53	0.18	0.18	0.25	0.25	0.25	0.25	0.25	0.25	0.25	0.25	0.25	0.25	0.25	0.25	0.25	0.25	0.25	0.25	0.25	0.25
140-145	2.6	19	5.5	28.5	27.7	12.0	1.1	0.6	1.0	1.53	0.18	0.18	0.25	0.25	0.25	0.25	0.25	0.25	0.25	0.25	0.25	0.25	0.25	0.25	0.25	0.25	0.25	0.25	0.25	0.25
145-150	2.6	19	5.5	28.5	27.7	12.0	1.1	0.6	1.0	1.53	0.18	0.18	0.25	0.25	0.25	0.25	0.25	0.25	0.25	0.25	0.25	0.25	0.25	0.25	0.25	0.25	0.25	0.25	0.25	0.25
150-155	2.6	19	5.5	28.5	27.7	12.0	1.1	0.6	1.0	1.53	0.18	0.18	0.25	0.25	0.25	0.25	0.25	0.25	0.25	0.25	0.25	0.25	0.25	0.25	0.25	0.25	0.25	0.25	0.25	0.25
155-160	2.6	19	5.5	28.5	27.7	12.0	1.1	0.6	1.0	1.53	0.18	0.18	0.25	0.25	0.25	0.25	0.25	0.25	0.25	0.25	0.25	0.25	0.25	0.25	0.25	0.25	0.25	0.25	0.25	0.25
160-165	2.6	19	5.5	28.5	27.7	12.0	1.1	0.6	1.0	1.53	0.18	0.18	0.25	0.25	0.25	0.25	0.25	0.25	0.25	0.25	0.25	0.25	0.25	0.25	0.25	0.25	0.25	0.25	0.25	0.25
165-170	2.6	19	5.5	28.5	27.7	12.0	1.1	0.6	1.0	1.53	0.18	0.18	0.25	0.25	0.25	0.25	0.25	0.25	0.25	0.25	0.25	0.25	0.25	0.25	0.25	0.25	0.25	0.25	0.25	0.25
170-175	2.6	19	5.5	28.5	27.7	12.0	1.1	0.6	1.0	1.53	0.18	0.18	0.25	0.25	0.25	0.25	0.25	0.25	0.25	0.25	0.25	0.25	0.25	0.25	0.25	0.25	0.25	0.25	0.25	0.25
175-180	2.6	19	5.5	28.5	27.7	12.0	1.1	0.6	1.0	1.53	0.18	0.18	0.25	0.25	0.25	0.25	0.25	0.25	0.25	0.25	0.25	0.25	0.25	0.25	0.25	0.25	0.25	0.25	0.25	0.25
180-185	2.6	19	5.5	28.5	27.7	12.0	1.1	0.6	1.0	1.53	0.18	0.18	0.25	0.25	0.25	0.25	0.25	0.25	0.25	0.25	0.25	0.25	0.25	0.25	0.25	0.25	0.25	0.25	0.25	0.25
185-190	2.6	19	5.5	28.5	27.7	12.0	1.1	0.6	1.0	1.53	0.18	0.18	0.25	0.25	0.25	0.25														

SOIL ANALYTICAL DATA

Soil profile No: 2

Soil name: Merit series

Depth in cm	pH	Elect. cond. $\mu\text{mho/cm}$	Percentage		Very fine sand	Fine sand	Medium sand	Coarse sand	Very coarse sand	Bulk density	Free CO_2	CaCO_3	Organic carbon	Organic matter	N	C/N ratio
			Clay	Silt												
Ah	3.75	191	30.8	28.8	20.7	11.0	6.3	1.1	0.6	1.02	N	0.5	1.53	2.63	0.18	8.5
B1	3.75	148	30.8	26.2	25.8	7.9	7.3	0.8	0.3	1.28	N	ND	0.57	0.98	0.11	5.18
B2 1	4.00	95	38.8	25.3	21.5	6.9	5.9	0.4	0.4	1.34	N	ND	0.22	0.38	0.08	2.75
B2 2	4.00	77	42.1	24.0	22.0	5.8	4.1	0.4	0.8	1.43	N	ND	0.20	0.34	0.09	2.22
B2cm	4.25	33	37.3	26.3	19.9	5.7	3.8	1.4	2.8	1.52	N	0.3	0.16	0.28	0.06	2.67
BC	4.25	36	26.9	27.4	24.2	6.9	6.2	1.6	2.7	1.48	N	ND	0.11	0.19	0.05	2.2

Horizon	Perchloric Digestible				Total S	Av P	H_2O soluble B	meq CEC in NH_4OAC	Exchangeable Cation			TEB		
	K	Mg	Ca	p					Cu	Mn	Zn		K	Mg
Ah	0.49	0.09	0.02	105	325	12	3.7	9.3	0.15	0.35	0.06	0.11	1.30	0.67
B1	0.50	0.10	0.02	95	47	8	1.3	9.2	0.18	0.07	0.01	0.11	1.98	0.37
B2 1	0.60	0.13	0.02	95	188	8	0.6	7.1	0.10	0.05	0.02	0.11	2.06	0.28
B2 2	0.63	0.14	0.02	90	ND	10	0.6	13.1	0.13	0.04	0.02	0.09	2.17	0.28
B2cm	0.77	0.16	0.02	89	ND	8	0.4	12.4	0.13	0.03	0.01	0.09	1.79	0.26
BC	0.90	0.16	0.02	70	63	9	0.9	7.7	0.15	0.03	0.01	0.11	1.32	0.30

N: Negligible
 ND: Not Detected

10.2. Baduy Series

Baduy series is classified as red-yellow Podzolic soils that have a fine clayey particle-size class and that have a CEC of



Effective soil depth
> 100 cm

Plate 7 - Merit Series

Typical Profile (Profile No. 4)

10.2 Bedup series

Bedup series

Bedup series is classified as Red-yellow Podzolic soils that have a fine clayey particle-size class and that have a CEC of < 24 meq/100 gm clay in the major part of the B horizon and have a yellow colour class.

Ah 0-4 cm Brown (10YR 5/3); clay loam; moderately strong

This soil is similar in most respect to Merit series except that it has a lower CEC of below 24 meq/100 gm clay in the major part of the B horizon. In the surveyed areas, most of the horizons of Bedup series have CEC of between 16 to 22 meq per 100 gm clay.

B1 Brownish yellow (10YR 5/5 to 6/5); clay loam; moderately strong; medium subangular blocky

Bedup series has been mapped in association with the soils of the Merit series.

roots; many weakly developed pale brown (10YR 6/4) organic acid coatings on some ped surfaces; gradual

A profile description of a typical Bedup series and the analytical data is provided herewith. Plate 8 represents soils of Bedup series.

B2 Brownish yellow (10YR 6/5) to yellow (10YR 6/6); clay, moderately strong, coarse and some medium subangular blocky; friable; many fine pores; very few 5-15 cm laterites and medium platy lateritised shale; many fine and few coarse roots; few patchy weakly developed light yellow brown (10YR 6/6) organic acid coatings on ped surfaces; some cutans; gradual boundary

B3g 45-80 cm Reddish yellow (7.5YR 6/8); clay; moderate coarse and some very coarse subangular blocky; friable; few fine pores; very few 5-10 cm laterites; few scattered undecomposed xerolite roots (3 to 20 cm diameter) spaced at 5 to 10 cm apart; interstitial and filled with clay; gradual boundary

Typical Profile (Profile No. 4)

	80-150 cm	Brownish yellow (10YR 6/8); clay; moderately friable; and very coarse subangular blocky; fine pores; very few fine roots; about 70-80% gravelly and stony undecomposed parent
A _o		Leaf litter, 6 to 8 leaves thick.
A _h	0-4 cm	Brown (10YR 5/3); clay loam; moderately strong, medium and fine subangular blocky and crumbs; friable; many fine and medium pores; abundant fine and coarse roots; clear boundary
B ₁	4-15 cm	Brownish yellow (10YR 6/6 to 6/8); clay loam; moderately strong, medium subangular blocky; friable; many fine pores; many fine and medium roots; many weakly developed pale brown (10YR 6/4) organic acid coatings on some ped surfaces; gradual boundary
B ₂	15-45 cm	Brownish yellow (10YR 6/8) to reddish yellow (7.5YR 6/8); clay; moderately strong, coarse and some medium subangular blocky; friable; many fine pores; very few 5-15 mm laterites and medium platy laterised shale; many fine and few coarse roots; few patchy weakly developed light yellow brown (10YR 6/4) organic acid coatings on ped surfaces; some cutans; gradual boundary
BC _{R1}	45-80 cm	Reddish yellow (7.5YR 6/8); clay; moderate coarse and some very coarse subangular blocky; friable; few fine pores; very few 5-10 mm laterites; few scattered undecomposed parent rocks (3 to 20 cm diameter) spaced at 5 to 40 cm apart, interstices are filled with clay; gradual boundary

BCR₂

80-150 cm

Brownish yellow (10YR 6/8); clay; moderately weak, coarse and very coarse subangular blocky; friable; fine pores; very few fine roots; about 20-30% gravelly and stony undecomposed parent rocks (3-20 cm diameter) spaced at 5-30 cm apart; interstices are filled with clay.

Note: Both BCR₁ and BCR₂ layer pose no limitation to root penetration

SOIL ANALYTICAL DATA

Soil profile No: 4

Soil name: Bedup Series

Depth in cm	pH	Elect. cond. $\mu\text{mho/cm}$	Percentage					Bulk density	Free CaCO_3	Organic carbon	Organic matter	N	C/N ratio			
			Clay	Silt	Very fine sand	Fine sand	Medium sand							Coarse sand	Very coarse sand	
A ₁ 0-4	3.85	232	34.0	30.0	11.7	8.7	9.1	1.0	1.0	0.98	N	ND	2.15	3.70	0.26	8.27
B ₁ 4-15	4.00	119	39.4	23.3	16.3	9.5	9.4	1.0	0.8	1.18	N	0.1	0.90	1.55	0.10	9
B ₂ 15-45	4.20	75	47.9	23.0	11.4	6.9	6.1	1.8	2.3	1.35	N	0.1	0.85	1.46	0.09	9.44
BCR ₁ 45-80	4.25	72	48.8	28.6	6.5	3.4	5.1	3.1	3.8	1.32	N	0.3	0.32	0.55	0.14	2.29

Depth in cm	Perchloric Digestible				ppm Total S	Av P	H ₂ O soluble B	meq CEC in NH ₄ OAC	Exchangeable Cation			TEB		
	K	Mg	Ca	P					K	Mg	Ca		Na	Al
A _n	0.73	0.14	0.03	185	125	12	4.4	7.1	0.21	0.61	0.25	0.08	0.99	1.15
B ₁	0.84	0.15	0.02	150	ND	8	2.5	8.0	0.15	0.42	0.03	0.11	1.28	0.71
B ₂	1.10	0.19	0.02	140	16	8	0.2	10.4	0.15	0.33	0.03	0.09	1.27	0.60
BCR ₁	1.58	0.26	0.02	160	63	10	1.3	13.1	0.26	0.34	0.01	0.08	1.80	0.69

N: Negligible
 ND: Not Detected

10.3 Bekon series

Bekon series is classified as red-yellow Podzolic soils that have a fine loamy or fine silty particle-size class and is derived from sedimentary rocks. It is developed on fine sandy shale and occur mainly on the steeper terrain in the surveyed areas. It is mapped in association with soils of the Merit



← Stones are spaced at 15 to 40 cm apart

Plate 8 - Bedup Series

moderately developed and some angular blocky structures and fine roots are present, and ... up to the upper layer of the B₂ horizon. The structures are less developed as compared to the corresponding horizons in the associated Merit series. Structures are easily broken up into fine, medium or coarse subangular blocky, micro-bio activities are present, and krotovinas are observed up to the upper part of the B₂ horizon. Cotans are common, and pores and roots are concentrated more towards the upper B horizon and decreases with depth.

10.3 Bekenu series

Bekenu series is classified as Red-yellow Podzolic soils that have a fine loamy or fine silty particle-size class and is derived from sedimentary rocks. It is developed on fine sandy shale and occur mainly on the steeper terrain in the surveyed areas. It is mapped in association with soils of the Merit series.

The superficial surface layer consists of both undecomposed and decomposed loose litters about 4 to 6 leaf thick and covers about 60% of the soil surface. Underneath this A_0 horizon is a humus rich thin A_h 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 A_h and B_1 horizons have the highest concentrations of fine to coarse roots.

Sub-soil B_2 horizons are 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 decreases 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 that of the Merit series in terms of their amount, distribution and compactness. They are therefore considered not a serious limitation to root penetration.

The major chemical properties of Bekenu series are quite similar to that of the Merit series. The soils are acidic. Organic acid are highest in the A_h horizon and decrease abruptly in the B horizons. Total cations are lower than that of the Merit and Bedup series. Total exchangeable bases are very low at below 10% in most of the sub-soil. The C.E.C. in the sub-soil ranges from 20 to 39 meq/100 gm clay. (No series differentiae has yet been established based on C.E.C. values, unlike soils of Merit and Bedup series).

A profile description of a typical Bekenu series and the analytical data is provided herewith. Plate 9 represents soil of Bekenu series.

0-5 cm 5.5R 5/8; clay; moderate, very coarse and coarse subangular blocky structure; friable to slightly firm; few very fine pores; few very fine and coarse roots; few root channels; many krotovinas (4-15 mm); many moderately developed cutans; clear boundary.

5-15 cm 5.5R 5/8; clay; moderate, coarse and very coarse subangular blocky structure; friable; few fine pores; few very fine roots; about 20-30% gravels (5-30 mm) of soft iron-coated shale and laterites; gravels are loosely-packed; with 5-15% light yellowish brown (10YR 5/6) and light grey (10YR 7/2) patches.

Typical Profile (Profile No.18)

Bekenu series

A ₀		Leaf litter, 4 to 6 leaves thick
A _h	0 - 4 cm	Brown to dark brown (10YR 4/3-5/3); sandy clay loam; moderate, medium and fine subangular blocky and some crumbs; friable; many fine pores; abundant; fine and coarse roots; clear boundary
B ₁	4 - 25 cm	Brownish yellow (10YR 6/6-6/8); fine sandy clay; loam moderate, coarse and very coarse subangular blocky breaking into moderately strong, coarse and medium subangular blocky structure; friable; many very fine and few medium pores; many very fine and coarse roots; many organic stains on ped surfaces; many fine krotovinas (< 15 mm); gradual boundary
B ₂	25 - 90 cm	Brownish yellow (10YR 6/8) to strong brown (7.5YR 5/8); clay loam; moderate; very coarse and coarse subangular blocky structures; friable to slightly firm; few very fine pores; few very fine and coarse roots; few root channels; many krotovinas (< 15 mm); many moderately developed cutans; clear boundary.
B ₂ cn	90 - 150 cm	Brownish yellow (10YR 6/8) to strong brown (7.5YR 5/8); clay; moderate, coarse and very coarse subangular blocky structures; friable; few fine pores; few very fine roots; about 20-30% gravels (5-30 mm) of soft iron-coated shale and laterites; gravels are loosely-packed; with <5% light yellowish brown (10YR 6/4) and light grey (10YR 7/2) blotches

SOIL ANALYTICAL DATA

Soil profile No: 18

Soil name: Bekenu series

Depth in cm	pH (1:2.5)	Elect. cond. $\mu\text{mho/cm}$	Percentage				Bulk density	Free CO_3	CaCO_3	Organic carbon	Organic matter	N	C/N ratio			
			Clay	Silt	Very fine sand	Fine sand								Medium sand	Coarse sand	Very coarse sand
Ah	4.05	235	23.7	21.8	9.8	11.0	27.1	5.4	0.8	1.05	N	ND	2.40	4.13	0.24	10.00
B1	4.00	135	27.9	24.3	12.4	5.2	25.3	3.8	0.3	1.36	N	ND	0.68	1.17	0.10	6.80
B2	3.95	115	35.1	25.2	11.0	5.6	20.1	0.6	1.9	1.52	N	ND	0.26	0.45	0.07	3.71
B2c	4.30	57	33.5	23.7	9.4	4.8	19.6	3.3	5.3	1.51	N	ND	0.17	0.29	0.06	2.83

Horizon	Perchloric Digestable			Perchloric Digestable			ppm Total S	ppm Av P	H_2O soluble B	meq CEC in NH_4OAC	Exchangeable Cation			TEB		
	K	Mg	Ca	P	Cu	Mn					Zn	K	Mg		Ca	Na
Ah	0.44	0.09	0.04	140	9	58	26	18	2.5	13.3	0.18	1.66	1.75	0.12	0.48	3.71
B1	0.52	0.10	0.02	100	8	20	27	7	2.6	9.3	0.13	0.24	0.01	0.11	1.10	0.49
B2	0.65	0.13	0.02	145	9	24	35	7	ND	10.4	0.13	0.12	0.01	0.12	1.54	0.38
B2c	0.83	0.14	0.02	145	15	36	44	15	ND	7.7	0.13	0.46	0.04	0.13	0.51	0.76

ND = Not Determined
N = Negligible

B.4 Kabuluh series

Kabuluh series is classified as Red-yellow Podzolic soils that have a calcareous or non-acid reactive clays and have a hue of 2.5Y within a depth of 10 cm or throughout the control section.



Plate 9 - Bekenu Series

variable and is uniform in all the profiles studied. Coatings of iron and manganese are present. This horizon has few roots as compared to the overlying A₁ horizon. They are mainly fine roots with 1-3 mm diameter.

The major part of the B₂ horizon commences at about 15 to 30 cm from the soil surface. The dominant colours are pale yellow, light yellowish brown and light olive brown (of 2.5Y hue) with many blotches of brownish yellow, yellowish brown, reddish yellow

10.4 Kabuloh series

Kabuloh series is classified as Red-yellow Podzolic soils that have a calcareous or non-acid reaction class and have a hue of 2.5Y within a depth of 50 cm or throughout the control section.

The soil is formed on flat, somewhat extensive old river beds and is moderately well-drained. It is confined mainly in Sungei Sepupok Blok, particularly the upper section

Towards the lower part of the B horizon, the soil colours of 2.5Y HUE become more dominant and distinct. These horizons

A thick layer of leaf litters and organic debris have been observed in soils of Kabuloh series. It is usually about 6 to 8 leaves thick and is in the various stages of decomposition. The mineral top soil is about 8 cm thick and is generally thicker than those of the upland soils. It consists of dark brown to yellowish brown moderately developed medium and fine subangular blocky and crumb structures. Texture varies from loam to silty loam to sandy loam. Clay content is less than 20%, while silt and very fine sand contribute to between 40 to 50%. Roots are many, and are fine to coarse sizes (1-20 mm diameter). The underlying B₁ horizon consists of olive brown to light yellowish brown loam to clay loam with a higher clay content of 23 to 33%. Structures are well-developed with very coarse and coarse subangular easily breaking down into well-developed coarse and medium subangular. Consistency is friable and is uniform in all the profile studied. Coatings of organic acid are found on many of the ped surfaces and krotovinas are present. This horizon has less roots as compared to the overlying A_h horizon. They are mainly fine roots with 1 - 5 mm diameter.

The major part of the B₂ horizon commence at about 15 to 30 cm from the soil surface. The dominant colours are pale yellow, light yellowish brown and light olive brown (of 2.5Y HUE) with many blotches of brownish yellow, yellowish brown, reddish yellow

and strong brown. Textures are mainly clay loam to clay and clay contents in the horizon are highest at 35 to 40%. Structures are well formed with coarse and very coarse subangular and angular blocky and consistency is friable to slightly firm. Coatings of organic acid are very few and very weakly developed. They are mainly found in the upper layer of the horizon. Few krotovinas are present throughout the B₂ horizon. Well formed cutans are common features on most of the ped surfaces. They appear to be "waxy" and are mainly of 2.5Y HUE colours.

Towards the lower part of the B horizon, the soil colours of 2.5Y HUE become more dominant and distinct. These horizons have been designated as B₃ or BC horizons. Structures are weakly developed and tending towards massive. In some of the profile and soil auger examinations, a BC_g or C_g gleyed horizon have been encountered at depth around 75 cm from the soil surface. It is likely that water-table is met at this horizon at some part of the year, especially during the rainy period. Micro-bio activities are absent and roots are nil.

Pitted and rounded boulders of limestone can be found both on the soil surfaces and in the soil profiles. When present on the soil surfaces (estimated at ± 20% of this soil unit), the boulders are distributed haphazardly without any definite pattern of spacing

Kabuloh series has a similar soil nutrient distribution within profile as soils of the Merit, Bekenu and Bedup series. The A_h horizons have the highest organic carbon, nitrogen and total exchangeable bases and these decrease abruptly in the sub-soil. Values for organic carbon, nitrogen, total phosphorus and exchangeable potassium are similar to those of the upland soils while slightly higher values are observed in available phosphorus. Values for total cations (except for Ca which is higher) are similar to those of Merit and Bedup series, and are higher than those of the Bekenu series. The major differences are the soil pH and the total exchangeable bases. Soil pH values are between

Typical Profile (Profile No. 4)

5.0 to 6.6 and are generally less acidic as compared to soils of Merit, Bedup and Bekenu series. Values for total exchangeable bases are higher, ranging from 10 to 29 meq/100 gm with higher exchangeable Ca.

A profile description of a typical Kabuloh series and the analytical data is provided herewith. Plates 10a and 10b represent soils of Kabuloh series.

- 0-5 cm Light yellowish brown (2.5Y 6/4) to olive brown (2.5Y 4/3); loam; moderate to strong, coarse subangular blocky breaking into moderately strong, medium and coarse subangular block structures; friable; common fine pores; many fine and coarse roots; many moderately developed organic acid coatings on ped surfaces; many protocones; clear boundary
- 5-20 cm Pale yellow (2.5Y 7/4), olive yellow (2.5Y 6/4), and strong brown (2.5YR 5/6); clay loam; moderate to strong and very coarse subangular and angular blocky breaking into moderately strong, coarse subangular and angular block structures; slightly friable; some very fine pores; few fine roots; many well-developed pale yellow (2.5Y 7/4) cutans on ped surfaces; few protocones; gradual boundary
- 20-120 cm Dark yellow (2.5Y 7/4) and strong brown (2.5YR 5/6); clay; strong to very strong; clay in above horizon; few very fine pores; very few fine roots; many well-developed pale yellow (2.5Y 7/4) cutans on ped surfaces; presence of 2 to 5 mm dark reddish brown (5YR 3/4) manganese concretions (4.5 cm diameter)

Typical Profile (Profile No. 40)

Kabuloh series

A ₀		Leaf litters, 6 to 8 leaves thick
A _h	0-5 cm	Yellowish brown (10YR 5/4); loam; moderate, medium and fine subangular blocky and some crumbs; friable; common fine pores; many fine and coarse roots; clear boundary
B ₁	5-30 cm	Light yellowish brown (2.5Y 6/4) to olive brown (2.5Y 6/6); loam; moderately strong, coarse subangular blocky breaking into moderately strong, medium and coarse subangular block structures; friable; common fine pores; many fine and coarse roots; many moderately developed organic acid coatings on ped surfaces; many krotovinas; clear boundary
B ₂₁	30-80 cm	Pale yellow (2.5Y 7/4), olive yellow (2.5Y 6/6), and strong brown (7.5YR 5/8); clay loam; moderate, coarse and very coarse subangular and angular blocky breaking into moderately strong, coarse subangular and angular blocky structures; slightly firm; many very fine pores; few fine roots; many well-developed pale yellow (2.5Y 7/4) cutans on ped surfaces; few krotovinas; gradual boundary
B ₂₂	80-120 cm	Pale yellow (2.5Y 7/4) and strong brown (7.5YR 5/6); clay; structures are as above horizon; few very fine pores; very few fine roots; many well-developed pale yellow (2.5Y 7/4) cutans on ped surfaces; presence of 2 to 5% dark reddish brown (5YR 3/4) manganese concretions (< 5 mm diameter)



Plate 10a - Kabuloh Series



→ Rounded
Boulder

Plate 10b - Kabuloh Series With Boulder

SOIL ANALYTICAL DATA

Soil profile No: 40

Soil name: Kabuloh series

Depth in cm	pH (1:2.5)	Elect. cond. µmho/cm	Percentage		Fine sand	Medium sand	Coarse sand	Very coarse sand	Bulk density	Free Co ₃	CaCO ₃	Organic carbon	Organic matter	N	C/N ratio
			Clay	Silt											
Ah	5.30	190	19.7	45.0	9.0	8.6	1.2	0.3	1.20	N	0.75	2.22	3.82	0.08	27.75
B1	5.20	125	26.6	38.6	13.5	8.6	0.6	0.1	1.25	N	ND	0.90	1.55	0.15	6.00
B21	4.85	95	35.9	37.5	10.0	6.8	1.9	0.1	1.42	N	ND	0.34	0.58	0.10	3.40
B22	5.10	55	42.7	35.6	8.3	6.5	2.9	0.4	1.33	N	ND	0.25	0.43	0.08	31.25

Depth in cm	Perchloric Digestable				Total S	Av P	H ₂ O soluble B	meq CEC in NH ₄ OAC	Exchangeable Cation			IEB		
	K	Mg	Ca	ppm P					K	Ca	Na + Al			
Ah	1.50	0.24	0.36	120	100	18	1.1	10.80	0.33	0.97	15.97	0.13	0.04	17.40
B1	0.75	0.24	0.28	190	125	13	1.1	11.70	0.26	0.26	13.58	0.13	0.07	14.23
B21	0.81	0.27	0.31	160	100	11	ND	4.93	0.26	0.31	14.38	0.16	0.05	15.11
B22	0.84	0.29	0.34	145	63	11	ND	10.93	0.28	0.31	16.42	0.15	0.02	17.16

ND = Not Detected
N = Negligible

Tukau series

10.5 Tukau series

Leaf litter: 5 to 8 leaves thick

Tukau series is classified as Red-Yellow Podzolic soils that have a fine loamy or fine silty particle-size class and have developed in non-accreting alluvium. It is formed on older riverine alluvium on flat valley floors and raised river terraces with slope seldom exceeds 2°.

The physical and chemical characteristics of Tukau series are similar to those of the Bekenu series. Textures are dominated by both fine and medium sand and values for coarse sand are very low. Total cations are low at below 1.0%. This soil is also acidic with pH 4.0 to 5.0.

Tukau series is found mainly in Sungei Galasah Block. A profile description of a typical Tukau series and the analytical data is provided herewith. Plate 11 represents soils of Tukau series.

32-113 30-125 cm

Strong brown (7.5YR 5/8); sandy clay loam; moderate, coarse and very coarse subangular blocky and some angular blocky structures; friable; few very fine pores; few fine roots; presence of about 20% fine fawn yellow (10R 7/8) and yellowish red (5YR 5/8) silticles; silticles becoming more prominent and increase in amount with depth; few roots.

Typical Profile (Profile No. 20)

Tukau series

A ₀		Leaf litters; 6 to 8 leaves thick
A _h	0-8 cm	Brown (10YR 5/3); loam; moderately strong, medium and fine subangular blocky and crumb structures; friable; many very fine pores; abundant fine and coarse roots (1 to 10 mm); clear boundary
B ₁	8-30 cm	Brownish yellow (10YR 6/6); clay; moderately strong, coarse subangular blocky breaking into moderately strong, coarse and medium subangular blocky structures; friable; many fine pores; many fine and coarse roots (1 to 15 mm); weakly developed brown (10YR 5/3) organic acid coatings on ped surfaces and along pores; many krotovinas; gradual boundary
B ₂	30-80 cm	Brownish yellow (10YR 6/8); sandy clay loam; moderate; very coarse subangular blocky breaking into moderate, medium and coarse subangular blocky structures; friable; common fine pores; few fine roots; weakly developed cutans on ped surfaces; very few krotovinas; gradual boundary
B ₂ -B ₃	80-125 cm	Strong brown (7.5YR 5/8); sandy clay loam; moderate, coarse and very coarse subangular blocky and some angular blocky structures; friable; few very fine pores; few fine roots; presence of about 20% fine faint yellow (10YR 7/6) and yellowish red (5YR 5/8) mottles; mottles becoming more prominent and increase in amount with depth, few cutans.

SOIL ANALYTICAL DATA

Soil profile No: 20
Soil name: Tukau series

Depth in cm	pH (1.2.5)	Elect. cond. $\mu\text{mho/cm}$	Percentage				Bulk density	Free CaCO_3	Organic carbon	Organic matter	N	C/N ratio				
			Clay	Silt	Very fine sand	Fine sand										
Ah	4.50	260	22.6	32.0	7.4	13.2	18.8	2.5	1.7	0.99	N	ND	1.92	3.30	0.23	8.35
B1	4.00	140	44.1	27.9	9.2	6.6	7.1	1.6	2.2	1.44	N	ND	0.53	0.91	0.09	5.89
B2	4.15	65	25.5	22.7	11.9	13.9	21.8	1.1	0.1	1.53	N	0.3	0.18	0.31	0.05	3.60
B2 to B3	4.95	9	25.4	24.0	8.7	14.0	24.2	0.9	0.1	1.63	N	0.3	0.11	0.19	0.04	2.75

Horizon	Perchloric Digestible				Total S	Av P	H ₂ O soluble B	meq LEC in NH_4OAC	Exchangeable cation			TEB					
	K	Mg	Ca	p					Cu	Mn	Zn		K	Na	Al		
Ah	0.70	0.16	0.10	180	12	667	44	250	8	3.0	7.9	0.38	1.83	3.55	0.12	0.31	5.88
B1	0.60	0.13	0.02	115	8	67	40	250	7	2.4	5.1	0.10	0.61	0.17	0.12	0.41	1.00
B2	0.54	0.11	0.02	88	10	42	43	250	8	0.2	6.0	0.10	0.34	0.05	0.13	0.74	0.62
B2 to B3	0.44	0.10	0.02	70	8	26	43	ND	8	ND	9.7	0.08	0.10	0.01	0.09	1.38	0.28

ND = Not Detected
N = Negligible

10.8 Sabangan series

Sabangan series is classified as red-yellow fozzolic soils that have a coarse loamy or coarse silty particle-size class and have developed in non-accretive alluvium.



ed from sandstone
 15 and sand content
 suitable consists
 the horizon consists
 and is undurable
 structures are
 or blocky. The
 mixed with brown
 over very coarse
 is slightly firm
 ties. A granulated
 consists of weakly
 and is massive.
 the soil surface.
 face A₂ horizon and

soil pH 4.0 to 4.3.
 low. Total N₂ and Ca
 are below 0.005 and total K is less than 0.25. Exchangeable

Plate 11 - Tukau Series

10.6 Sabangan series

Sabangan series is classified as Red-Yellow Podzolic soils that have a coarse loamy or coarse silty particle-size class and have developed in non-accreting alluvium.

It is developed on riverine alluvium derived from sandstone and has a loamy soil texture with high silt and sand contents. The soil has a imperfect drainage but water-table subsides easily after the rainy period. The organic horizon consists of leaf litters about 6 to 8 leaves thick and is underlain by a dark reddish brown friable loam. Structures are moderately developed with medium subangular blocky. The sub-soil is partly gleyed, with white intermixed with brown yellow loam. Structures are weakly developed very coarse subangular and angular blocky. Consistency is slightly firm to friable with very few micro-bio activities. A variegated horizon occurs at depth below 50 cm and consists of weakly developed very coarse angular structures and is massive. Water-table fluctuates below 50 cm from the soil surface. Majority of roots are confined to the surface A_h horizon and decrease abruptly at BC horizon.

Sabangan series is acidic with soil pH 4.0 to 4.3. Both total and exchangeable cations are low. Total Mg and Ca are below 0.05% and total K is less than 0.2%. Exchangeable Mg and Ca are generally low.

Typical Profile (Profile No. 33)

Sabangan series

A ₀		Leaf litters, 6 to 8 leaves thick
A _h	0-6 cm	Dark reddish brown (5YR 3/3); loam; moderate, medium subangular blocky structures; friable; few fine pores; abundant fine to coarse roots (1 to 15 mm); clear boundary
BC	6-50 cm	White (10YR 8/1)* and brownish yellow (10YR 6/6); loam; moderately weak, very coarse subangular and angular blocky structures; friable to slightly firm; common fine pores; very few fine roots; very few yellowish brown (10YR 5/4) organic acid on ped surfaces and on few channels; clear boundary
II BC	50-130 cm	Variegated white (10YR 8/1)*, brownish yellow (10YR 6/6), reddish yellow (7.5YR 6/8) and red (2.5YR 4/8); clay; weak, very coarse angular blocky structures; slightly massive; few fine pores; very few fine to coarse roots (1-5 mm)

* White colour of the soil matrix is mainly due to the uncoated sand particles

SOIL ANALYTICAL DATA

Soil profile No: 33

Soil name: Sabangan series

Horizon	Depth in cm	pH (1:2.5)	Elect. cond. $\mu\text{mho/cm}$	Percentage			Bulk density	Free CaCO_3	Organic carbon	N	C/N ratio																																																																																
				Clay	Silt	Very fine sand																																																																																					
Ah	0-6	4.00	145	15.1	39.4	8.8	30.8	3.2	1.0	0.6	0.85	N	0.25	3.30	5.68	0.24	13.75																																																																										
BC	6-50	4.25	28	15.9	38.8	24.4	16.4	0.7	0.1	ND	1.54	N	ND	0.31	0.53	0.03	10.33																																																																										
11BC	50-130	4.90	42.5	39.7	26.6	9.4	14.5	2.5	0.1	0.1	1.61	N	ND	0.27	0.46	0.27	1.00																																																																										
<table border="1"> <thead> <tr> <th colspan="2">Perchloric Digestable</th> <th colspan="4">Perchloric Digestable</th> <th colspan="2">ppm Total</th> <th colspan="2">Av</th> <th colspan="2">H₂O soluble</th> <th colspan="2">meq CEC in NH₄OAC</th> <th colspan="3">Exchangeable Cation</th> </tr> <tr> <th>K</th> <th>Mg</th> <th>Ca</th> <th>P</th> <th>Cu</th> <th>Mn</th> <th>Zn</th> <th>S</th> <th>P</th> <th>B</th> <th>K</th> <th>Mg</th> <th>Ca</th> <th>Na</th> <th>Al</th> </tr> </thead> <tbody> <tr> <td>0.19</td> <td>0.04</td> <td>0.04</td> <td>145</td> <td>7</td> <td>11</td> <td>19</td> <td>525</td> <td>25</td> <td>2.8</td> <td>0.20</td> <td>0.63</td> <td>1.91</td> <td>0.11</td> <td>0.32</td> <td>2.85</td> </tr> <tr> <td>0.19</td> <td>0.04</td> <td>0.02</td> <td>90</td> <td>4</td> <td>9</td> <td>17</td> <td>69</td> <td>6</td> <td>ND</td> <td>0.10</td> <td>0.06</td> <td>0.01</td> <td>0.11</td> <td>1.57</td> <td>0.28</td> </tr> <tr> <td>0.79</td> <td>0.26</td> <td>0.19</td> <td>90</td> <td>12</td> <td>134</td> <td>58</td> <td>63</td> <td>11</td> <td>ND</td> <td>0.18</td> <td>1.37</td> <td>8.61</td> <td>0.13</td> <td>0.26</td> <td>10.29</td> </tr> </tbody> </table>												Perchloric Digestable		Perchloric Digestable				ppm Total		Av		H ₂ O soluble		meq CEC in NH ₄ OAC		Exchangeable Cation			K	Mg	Ca	P	Cu	Mn	Zn	S	P	B	K	Mg	Ca	Na	Al	0.19	0.04	0.04	145	7	11	19	525	25	2.8	0.20	0.63	1.91	0.11	0.32	2.85	0.19	0.04	0.02	90	4	9	17	69	6	ND	0.10	0.06	0.01	0.11	1.57	0.28	0.79	0.26	0.19	90	12	134	58	63	11	ND	0.18	1.37	8.61	0.13	0.26	10.29
Perchloric Digestable		Perchloric Digestable				ppm Total		Av		H ₂ O soluble		meq CEC in NH ₄ OAC		Exchangeable Cation																																																																													
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ND = Not Detected
N = Negligible

18.7 Seduan series

Seduan series is classified as alluvial units that have a clayey particle-size class and have formed in alluvium.



Plate 33 - Sabangan Series

Soil survey description and analytical data of Seduan series is provided herewith.

10.7 Seduau series

Seduau series is classified as Alluvial soils that have a clayey particle-size class and have formed in alluvium derived from non-calcareous sedimentary rocks. The soils have a yellowish colour class.

The soil is limited in its occurrence and is confined along the banks of Sungei Galasah. The organic A₀ horizon consists of 4 to 6 leaves thick of leaf litters and many organic debris. The A_h horizon is between 3 to 5 cm thick and consists of friable silty clay loam to silty clay with dark greyish brown to greyish brown soil colour. The underlying B₁ horizon is yellowish brown silty clay loam with friable consistency. The horizon merges gradually with depth and soil colour changes to brownish yellow with no differentiation in soil texture. Mottles are common at depth of about 20 cm from the soil surface. Towards the lower depth at about 75 cm, the soil becomes massive and gleying is more prominent due to the fluctuating water-table. This soil is moderately well-drained but is subject to flash flooding during the rainy period.

Seduau series is acidic with soil pH between 4.1 to 4.4. Total cation values are similar to those of the Merit and Bedup series but are higher than those of the Bekenu and Tukau series. Their exchangeable bases are however higher and are mainly due to the higher exchangeable Mg and Ca values.

A soil auger examination and analytical data of Seduau series is provided herewith.

Soil Auger Examination (Site No. 16)

Seduai series

A ₀		Leaf litters, 3 to 5 leaves thick with many organic debris
A _h	0-5 cm	Yellowish brown (10YR 5/4 to 5/6); silty clay; friable; (moist)
B ₁	5-18 cm	Yellowish brown (10YR 5/6); silty clay loam; friable; (moist)
B ₂	18-30 cm	Yellowish brown (10YR 5/6); silty clay loam; friable; presence of very pale brown (10YR 7/4) blotches; (moist)
B ₃	30-75 cm	Brownish yellow (10YR 6/6 to 6/8); clay loam; friable; presence of very pale brown (10YR 7/4) blotches and strong brown (7.5YR 5/6 to 5/8) streaks; (moist)
BC	75-100 cm	Light grey (10YR 7/2) and reddish yellow (7.5YR 6/8); clay loam; massive; (wet)

SOIL ANALYTICAL DATA

Soil profile No: 16

Soil name: Seduau series

Horizon	Depth in cm	pH (1:2.5)	Elect. cond. $\mu\text{mho/cm}$	Percentage		Very fine sand	Fine sand	Medium sand	Coarse sand	Very coarse sand	Bulk density	Free CO_3	CaCO_3	Organic carbon	Organic matter	N	C/N ratio
				Clay	Silt												
Ah	0-15	4.25	365	39.6	41.8	4.0	3.9	4.9	1.4	3.7	nd	N	0.5	4.80	8.26	0.46	10.43
B1	5-18	4.15	290	30.1	50.1	2.3	1.8	12.8	2.1	1.7	nd	N	ND	2.70	4.64	0.31	8.71
B2	18-30	4.05	175	35.4	44.8	0.6	16.1	2.1	0.4	0.2	nd	N	ND	0.50	0.86	0.14	3.57
B3	30-75	4.15	142	38.9	40.0	8.6	4.4	7.2	0.5	0.4	nd	N	ND	0.38	0.65	0.10	3.80
BC	75-100	4.35	107	36.3	35.8	9.4	7.3	10.5	0.5	0.2	nd	N	0.3	0.30	0.52	0.07	4.29

Horizon	Perchloric Digestable			ppm Total S	ppm Av P	H_2O soluble B	meq CEC in NH_4OAC	Exchangeable Cation			IEB		
	K	Mg	Ca					K	Ca	Na		Al	
Ah	1.10	0.19	0.13	525	23	4.5	13.6	0.51	3.88	5.68	0.15	0.40	10.22
B1	1.11	0.19	0.07	375	16	5.5	10.4	0.64	2.00	2.19	0.12	0.44	4.95
B2	1.11	0.18	0.02	125	12	1.8	7.6	0.18	0.96	0.22	0.15	0.40	1.51
B3	1.13	0.18	0.02	525	10	0.5	13.7	0.20	1.14	0.21	0.14	0.63	1.69
BC	1.03	0.17	0.02	125	10	1.6	7.9	0.18	2.11	0.68	0.20	0.18	3.17

ND = Not Detected
 nd = Not determined
 N = Negligible

10.8 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 mineral soil surface.

The organic horizon is thin with covering of peat moss - a vegetation which is closely associated with soil. This soil is very limited in occurrence in the surveyed area. They are found in some narrow valley floors in Sungei Galasah Block. It is very similar in soil characteristic as those of the Mundai series except that the soil is developed on alluvium derived from non-calcareous sedimentary rocks of the surrounding carbonaceous shale. They are associated closely with soils of Tukar and Seduan series and peat soils and are non-calcareous.

No soil samples were taken due to its minor occurrences.

Mundai series is found in closer proximity to the Subis Limestone. The chemical characteristics, like those of the Kauloh series, are therefore influenced by the calcareous rocks of the surrounding area. The soil is slightly acidic with higher pH values at 6.3 to 6.6. Although the total cation values are similar to those of non-calcareous soil, their total Ca and Mg are higher. There are distinct differences in the total exchangeable bases which have high values for exchangeable Ca and Mg.

A soil auger examination and analytical data of Mundai series is provided hereafter.

10.9 Mundai series

Mundai series is classified as Gley soils that have developed in accreting riverine alluvium from calcareous sedimentary rocks and have a clayey particle-size class.

It occurs on flat low lying broad valley floors in the upper portion of Sungei Sepupok Block and is water-logged in most part of the year.

The organic horizon is thin with debris of sedges - a vegetation which is closely associated with poorly drained gley soil. The top soil consists of dark reddish grey clay loam with moderately developed fine subangular blocky and granular structure. Underneath this A_h horizon a characteristic gley horizon occurs. This consists of weakly developed to massive light grey clay to silty clay mottled with strong brown or yellowish brown. Towards the lower depth, the mottles decrease and the soil is massive. Water-table is met within 25 cm from the soil surface and on many occasions, stagnant water on the soil surface are common. The soil is poorly to very poorly drained.

Mundai series is found in closer proximity to the Subis Limestone. The chemical characteristic, like those of the Kabuloh series, are therefore influenced by the calcareous rocks of the surrounding area. The soil is slightly acidic with higher pH values at 6.3 to 6.6. Although the total cation values are similar to those of non-calcareous soil, their total Ca and Mg are higher. There are distinct differences in the total exchangeable bases which have high values for exchangeable Ca and Mg.

A soil auger examination and analytical data of Mundai series is provided herewith.

Soil Auger Examination (Site No. 37)

Mundai series

- | | | |
|----------------|----------|--|
| A ₀ | | Organic debris - mainly decomposing sedges |
| A _h | 0-5 cm | Dark reddish grey (5YR 4); clay loam; moderately strong, fine subangular and few granular structures; friable; (moist to slightly wet) |
| C _g | 5-100 cm | Light grey (10YR 7/2); silty clay; somewhat massive becoming more massive with depth; presence of yellowish brown (10YR 5/6) mottles; mottles becoming less prominent with depth |

Water-table met at 8 cm from soil surface

SOIL ANALYTICAL DATA

Soil profile No. 37

Soil name: Mungah series

Depth in cm	pH (1:2.5) sol/100/cm	Percentages				Bulk density	Free Co ₃	CaCO ₃	Organic carbon	Organic matter	N	C/N ratio				
		Clay	Silt	Very fine sand	Medium sand								Very coarse sand			
Ah 0-5	6.60	32.2	48.4	1.9	0.2	9.3	10.7	8.2	nd	N	1.50	12.60	21.67	0.74	17.03	
Cg 5-100	6.25	43.7	41.4	4.2	4.6	0.7	0.1	0.3	nd	N	1.50	1.70	2.92	0.17	10.00	
Perchloric Digestible												Exchangeable Cation		IEB		
ppm												K	Ca	Na	Al	
Total S												meq CEC in NH ₄ OAC				
Perchloric Digestible												H ₂ O soluble				
P												Av				
Cu												P				
Mn												Zn				
Ah 0.49	0.24	1.12	500	18	182	50	1,125	42	0.7	17.47	0.44	2.11	55.20	0.18	0.04	57.93
Cg 0.65	0.33	0.55	170	14	105	68	263	15	0.7	19.60	0.28	1.14	26.42	0.18	0.03	28.02

N - Negligible
nd - Not determined

10.10 Tutoh series

Tutoh series is classified as Skeletal soils that have developed in alluvium.

Tutoh series is classified as Skeletal soils that have developed in colluvium from non-calcareous sedimentary rocks.

consists of loose leaf litters and organic debris. The

This soil is mapped in Sungei Galasah Block and occupied only about 27 hectares. It occurs on a small localised saddle with slope of less than 2°.

Consistency is friable and krotovinas are present. Root

The soil is shallow with impervious sandstone bedrock occurring between 25 to 50 cm. Soil texture is sandy and structures are weakly developed. Sub-soil colours are yellowish brown and pale brown. It is imperfectly drained and poor vegetations with buttress root system are present.

on many ped surfaces. A impervious continuous bed rock layer is met within 50 cm from the surface. This layer is not penetrable by roots.

The soil is acidic with soil pH between 4.6 to 5.3. Total cation values are similar to that of Merit and Bedug series but are higher than that of Bukew series. Exchangeable Mg and Ca are generally higher than most of the sedimentary soils but are lower than the calcareous Keviah series.

A profile description of a typical Tutoh series and the analytical data is provided herewith. Plate 13 represents soil of Tutoh series.

10.11 Binatang series

Binatang series is classified as Skeletal soils that have developed in alluvium.

The organic A₀ horizon is about 4 to 6 leaves thick and consists of loose leaf litters and organic debris. The underlying A_h mineral horizon is brown to yellowish brown loam with moderately developed fine and medium blocky with well-developed coarse and medium structures. Consistency is friable and krotovinas are present. Most of the roots are concentrated in the A_h and B₁ horizons and consist of fine to coarse roots (1 to 15 mm in diameter). This soil has a thin B₂ sub-soil which is brownish yellow in colour and clay textured. Structures are well-developed coarse subangular blocky and well-formed cutans are found on many ped surfaces. A impervious continuous bed rock layer is met within 50 cm from the surface. This layer is not penetrable by roots.

The soil is acidic with soil pH between 4.8 to 5.3. Total cation values are similar to that of Merit and Bedup series but are higher than that of Bekenu series. Exchangeable Mg and Ca are generally higher than most of the sedimentary soils but are lower than the calcareous Kabuloh series.

A profile description of a typical Binatang series and the analytical data is provided herewith. Plate 13 represents soil of Binatang series.

Typical Profile (Profile No. 29)

Binatang series

A ₀		Leaf litters, 4 to 6 leaves thick
A _h	0-4 cm	Brown (10YR 5/3) to yellowish brown (10YR 5/4); loam; moderate, fine and medium subangular blocky and crumbs structures; friable; common very fine pores; many fine to coarse roots (1 to 15 mm); clear boundary
B ₁	4-20 cm	Brownish yellow (10YR 6/6); clay; moderate, very coarse subangular blocky structures breaking into moderately strong, coarse and medium subangular blocky structures; friable; common very fine pores; many fine to coarse roots (1 to 10 mm); few weakly developed yellowish brown (10YR 5/4) organic acid coatings; gradual boundary
B ₂	20-30 cm	Brownish yellow (10YR 6/6 to 6/8); clay; moderately strong, coarse and very coarse subangular blocky structures; friable; common micro-pores; few fine to coarse roots (1-5 mm); many well-developed light yellowish brown (10YR 6/4) cutans on ped surfaces; abrupt boundary
C _u	30-50 cm	A continuous layer of fragmented carbonaceous shale
C _R	50-90 cm	A continuous layer of consolidated carbonaceous shale
IIC _u	90-150 cm	A layer of fragmented carbonaceous shale in a 20% olive yellow (2.5Y 6/6 to 6/8) clay matrix

SOIL ANALYTICAL DATA

Soil profile No: 29

Soil name: Binatang series

Depth in cm	pH (1:2.5)	Elect. cond. $\mu\text{mho/cm}$	Percentage				Bulk density	Free CaCO_3	Organic carbon	Organic matter	N	C/N ratio				
			Clay	Silt	Very fine sand	Fine sand							Medium sand	Coarse sand	Very coarse sand	
Ah	5.30	68	18.9	40.3	7.8	0.9	22.9	3.6	2.2	1.14	N	0.25	2.70	4.64	0.30	9.00
B1	4.75	21	41.8	33.8	14.1	4.5	3.1	1.1	0.7	1.34	N	0.50	0.94	1.62	0.15	6.27
B2	4.80	21	39.3	38.9	11.2	3.8	2.9	1.1	0.9	1.43	N	0.75	0.75	1.29	0.14	5.36

Horizon	Perchloric Digestable				Perchloric Digestable				ppm				meq					
	K	Mg	Ca		P	Cu	Mn	Zn	Total S	Av P	H ₂ O soluble B	CEC in NH ₄ OAC	K	Mg	Ca	Na	Al	
Ah	0.85	0.24	0.24		180	13	502	57	525	11	ND	12.53	0.40	1.77	10.92	0.11	0.10	13.20
B1	1.14	0.31	0.08		135	16	262	68	250	8	ND	11.87	0.20	0.69	3.22	0.13	2.75	4.24
B2	1.28	0.34	0.09		130	17	292	75	84	9	ND	14.00	0.20	0.82	4.01	0.13	2.98	5.16

ND = Not Detected
N = Negligible



Shallow effective
soil depth to
bed rock

Plate 13 - Binatang Series

10.12 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 depressionnal backswamp basin along the Sungei Galasah. The organic materials consist of slightly decomposed fragments of plant tissues many of which still retain their recognisable structure 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 part of the year.

No soil samples were taken due to its minor occurrence.

11 GENERAL SOIL PROPERTIES OF THE SURVEYED AREA

- C.E.C. is generally moderate to low except on soils with high organic matter.
- Water holding capacity of most soil series is considered adequate as indicated by the relatively high clay content as most of the soils are developed on shale. Structures are mainly medium to coarse subangular blocky and are well-developed.
- Soil pH is generally above 4.0 and should not cause any serious limitation to growth of oil palm. Soil with high pH of more than 5.0 are mainly those developed over calcareous alluvium with relatively high exchangeable Ca.
- Salinity of all the soils are considered low ($<300 \mu\text{mho/cm}$) and should not give any salinity problem to oil palm cultivation

In general, as most of the soils are Ultisols and Inceptisols, their nutrient status are generally average to low especially in K and this has to be considered when formulating fertilizer programme for oil palm.

12 LAND CAPABILITY CLASSIFICATION

12.1 Method and Criteria

The method and criteria used in assessing the land capability classes of the surveyed areas 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:

- 1) Depth to impervious rock layer
- 2) Depth to massive clay
- 3) Depth to sulphidic layer (if any)
- 4) Depth of organic layer
- 5) Depth to groundwater table
- 6) Erosion hazard
- 7) Inundation hazard
- 8) Fertility status
- 9) Fertility of the organic layer
- 10) Degree of humification
- 11) Moisture holding capacity
- 12) Slope
- 13) Wetness
- 14) Texture of mineral sub-soil at 50-100 cm
- 15) 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

12.2 Land Capability Classes

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

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 (frequency & duration)	Medium	-	low fertility, low retention	acute deficiency, very low retention	-
i	Inundation hazard (frequency & duration)	none	infr-equent, 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	Imper- fectly 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 Serious	
a	Depth to sulphidic layer* ¹ (cm)	>100	75-100	50-75	-	-	
f	Fertility of the organic layer	Medium (loamy)* ² muck)	-	-	very low (peat or sandy muck)	-	
g	Depth to groundwater-table (cm)	Natural	-	-	30-60	0-30	-
		drained	60-100	-	30-60	>100	-
h	Degree of humification	hemic-sapric	-	-	fibric	-	
i	Inundation hazard (frequency & duration)	none	infrequent, short	frequent, short	infrequent, long	frequent and long, or submerged	
n	Nature (texture of mineral subsoil at 50-100 cm)	fine loamy to clayey	-	-	sandy to coarse loamy	-	
o	Depth of organic layer (cm)	-	-	50-100	>100	-	

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

*2 The clay component must be greater than 18%

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. 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°), very severe erosion hazard, frequent floods of long duration, excessive salinity, shallow soils over bedrock or extremely low nutrient and moisture-retaining capacity.

Capacity 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.

Class 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 2 or 3 moderate limitations or one serious limitation such as very 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.

12.3 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:

13. LAND CAPABILITY OF THE SURVEYED AREA

	<u>Limitation</u>	<u>Symbol</u>
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
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 groundwater	s
c) Organic soils	Depth to groundwater table	g
	Degree of humification	h
	Nature (texture) of mineral sub-soil	n

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

- Class 1 (a) Land with no limitations
- Class 2 (b) Land with minor limitations (5-12%)
- Class 3 (c) Land with moderate limitations due to slope (12-25%) and have high erosion hazard
- Class 4 (d) Land with serious limitations due to slope (25-33%) and erosion hazard

13 LAND CAPABILITY OF THE SURVEYED AREA

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

Soils of the Merit, Bedup and Bekenu and Tukai series

These are deep to moderately deep well-drained soils. Textures range from clay loam to clay in the Merit and Bedup 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 $> 25^{\circ}$ are likely to have serious soil erosion hazard. It also affects the movement in the field for land preparation, planting, field maintaining etc and lower efficiency in harvesting and crop removal.

The land capability class for this group of soils are as follow:

- | | |
|------------|--|
| Class 1 | Land with no limitations |
| Class 2t | Land with minor limitation on slope (6-12 $^{\circ}$) |
| Class 3 te | Land with moderate limitations due to slope (12-25 $^{\circ}$) and have high erosion hazard |
| Class 4 te | Land with serious limitations due to slope (25-33 $^{\circ}$) and erosion hazard |

Soils of the Kabuloh series

These are soils that have developed on older alluvium derived from calcareous sedimentary rocks. They have loam to clay loam textures and well-developed structures. These soils are moderately deep to deep and are moderately well-drained.

The land capability class for the soils of the Kabuloh series is as follow:

Class 2w Land with minor limitation due to moderately-well soil drainage

Soils of the Binatang series

These soils occur in association with soils of the Kabuloh series. They have a shallow effective soil depth (< 50 cm) and is underlain by rounded boulders. The soils are well-drained with well-developed structures and clay textures.

The land capability class for soils of the Binatang series is as follow:

Class 3-4d Land with serious to very serious limitation due to shallow effective soil depth to bedrock.

Soils of the Mundai and Bijat series

These soils are found in the low lying valley floors. They are characterised by the poor to very poor soil drainage and massive gley sub-soil. The massive clay horizon is encountered within 25 cm from the soil surface. They are water-logged in most part of the year.

The land capability class for soils of the Mundai and Bijat series is as follow:

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 the Mukah series

These are shallow organic soils with 50 to 150 cm of peat overlying clayey, non-sulphidic substratum. They are very poorly drained and are water-logged almost throughout the year

The land capability class for the soils of the Mukah series is as follow:

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

Soils of the Seduau series

Soils of the Seduau series occurs on raised river bank. The soil is moderately deep with silty clay loam to clay loam textures. 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 Seduau series is as follow:

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

14. SUITABILITY FOR OIL PALM CULTIVATION

In formulating the suitability for oil palm cultivation, Soils of the Sabangan series of the crop and the land capability have to be taken into consideration.

These are the sandy alluvium with imperfect soil drainage. The effective soil depth is somewhat shallow and water-table fluctuates below 50 cm from the soil surface. These soils, however can be easily drained.

The land capability class for the soils of the Sabangan series is as follow:

Class 3 fm Land with moderate limitations due to low soil fertility and low moisture holding capacity

14.2 Soil requirement for oil palm cultivation

Soils of the Tutoh series

Oil palm requires > 30 cm effective soil depth with sandy These are sandy colluvial soils resting on top of an impervious layer of bedrock and are imperfectly drained. They have very low soil fertility and moisture holding capacity

The land capability class for soils of the Tutoh series is as follow:

Class 3 dw Land with serious limitation due to shallow effective soil depth to bedrock (25-50 cm) and moderate limitations due to low fertility and imperfect soil drainage

14 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.

14.1 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 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°C.

14.2 Soil requirement for oil palm cultivation

Oil palm requires > 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 exceeds 25°.

15 SUITABILITY FOR OIL PALM CULTIVATION IN THE SURVEYED AREAS

15.1 Climatic suitability for oil palm cultivation

The surveyed areas have high rainfall with mean monthly precipitation of around 200 mm. Mean annual temperature is about 26.50 C. These are considered suitable for oil palm cultivation.

15.2 Suitability for oil palm cultivation

The suitability for oil palm cultivation has been evaluated and is presented in Tables 6a and 6b. A summary of their hectareage statistic is presented in Table 7.

Table 6a: Suitability for Oil Palm Cultivation in Sungei Sepupok Block

Mapping Unit	Soil Series	Effective soil depth (cm)	Slope class	Soil drainage	Land Capability Class	Suitability for Oil Palm	Hectarage (%)
MR-5b	Merit Bedup	> 100	2-6°	Well-drained	Class 1	Suitable	625 (17)
MR-5c	Merit Bedup	> 100	6-12°	Well-drained	Class 2t	Suitable	545 (14)
MR-4b	Merit Bedup	75-100	2-6°	Well-drained	Class 1	Suitable	35 (1)
MR-3b	Merit Bedup	50-75	2-6°	Well-drained	Class 2d	Suitable	51 (1)
MR/Bk-5C	Merit Bedup Bekenu	> 100	6-12°	Well-drained	Class 2t	Suitable	66 (2)
MR/Bk-5d	Merit Bedup Bekenu	> 100	12-20°	Well-drained	Class 3te	Suitable	290 (8)
MR/Bk-5e	Merit Bedup Bekenu	> 100	20-25°	Well-drained	Class 3te	Suitable	58 (1)

Mapping Unit	Soil Series	Effective Soil depth (cm)	Slope class	Soil drainage	Land Capability Class	Suitability for Oil Palm	Hectareage (%)
MR/Bk-45d	Merit	75- >100	12-20°	Well-drained	Class 3te	Suitable	19
	Bedup						(<1)
	Bekenu						
MR/Bk-45de	Merit	75- >100	12-25°	Well-drained	Class 3te	Suitable	143
	Bedup						(4)
	Bekenu						
MR/Bk-45f	Merit	75- >100	25-33°	Well-drained	Class 4te	Unsuitable	21
	Bedup						(<1)
	Bekenu						
MR/Bk-45g	Merit	75- >100	> 33°	Well-drained	Class 5te	Unsuitable	307
	Bedup						(8)
	Bekenu						
MR/Bk-45fg	Merit	75- >100	25- >33°	Well-drained	Class 4te-5te	Unsuitable	410
	Bedup						(11)
	Bekenu						
Kb-45a/Bg-12a	Kabuloh	75- >100	0-2°	Moderately well-drained	Class 2w	Suitable to	691
	Binatang	< 50	0-2°	Well-drained	Class 3-4d	Unsuitable	(19)
							173* (5)

*Figure based on estimated 20% of the mapping unit

Cont ...3

Mapping Unit	Soil Series	Effective soil depth (cm)	Slope class	Soil drainage	Land Capability Class	Suitability for Oil Palm	Hectarage (%)
Md-1a	Mundai	<25	0-2°	Poorly to very poorly drained	Class 4 cw	Unsuitable	249 (7)
Sb-3a	Sabangan	50-75	0-2°	Imperfectly drained	Class 3fm	Suitable	37 (1)

Table 6b: Suitability For Oil Palm Cultivation In Sg.Galrasah Block

Mapping Unit	Soil Series	Effective Soil depth (cm)	Slope Class	Soil drainage	Land capability class	Suitability for oil palm	Hectareage (%)
MR-5b	Merit	>100	2-6°	Well-drained	Class 1	Suitable	143 (7)
	Bedup						
MR-5c	Merit	>100	6-12°	Well-drained	Class 2t	Suitable	687 (35)
	Bedup						
MR-5d	Merit	>100	12-20°	Well-drained	Class 3te	Suitable	277 (14)
	Bedup						
MR-5cd	Merit	>100	6-20°	Well-drained	Class 2t-3te	Suitable	140 (7)
	Bedup						
MR/Bk-5d	Merit	>100	12-20°	Well-drained	Class 3te	Suitable	177 (9)
	Bedup						
	Bekenu						
MR/Bk-5e	Merit	>100	20-25°	Well-drained	Class 3te	Suitable	37 (2)
	Bedup						
	Bekenu						
MR/Bk-5de	Merit	>100	12-25°	Well-drained	Class 3te	Suitable	96 (5)
	Bedup						
	Bekenu						

Cont ...2

Mapping Unit	Soil Series	Effective Soil depth (cm)	Slope Class	Soil drainage	Land capability class	Suitability for oil palm	Hectarage (%)
MR/Bk-45f	Merit	75- >100	25-33°	Well-drained	Class 4te	Unsuitable	41 (2)
	Bedup						
	Bekenu						
MR/Bk-45ef	Merit	75- >100	20->35°	Well-drained	Class 3te-4te	Suitable	20 (1)
	Bedup						
	Bekenu					Unsuitable*	19* (1)
Tk-5a	Tukau	> 100	0-2°	Well-drained	Class 1	Suitable	148 (8)
Sd-4a	Seduau	75-100	0-2°	Moderately well-drained	Class 2i	Suitable	66 (3)
Tt-2a	Tutoh	25-50	0-2°	Imperfectly drained	Class 3dw	Unsuitable	27 (1)
Mk/Bj-1a	Mukah	<25	0-2°	Very poorly drained	Class 04gf	Unsuitable	105 (5)
	Bijat	<25	0-2°	Very poorly drained	Class 4cw		

*Figure based on estimated 50% of the mapping unit

Table 7 : Hectarage Statistic Of Land Suitability For Oil Palm Cultivation
In The Surveyed Areas

	Suitable	Unsuitable	Total
Sg. Sepupok Block	2560 (69%)	1160 (31%)	3720
Sg. Galasah Block	1791 (90%)	192 (10%)	1983
	4351 (76%)	1352 (24%)	5703

CONCLUSION

A total of 12 main soil series are identified and demarcated in the surveyed area. About 76% of the area have moderate to good soil properties occurring on slope below 25°. About 14% of the area have spongy excluding 23% of very poorly drained low water table and shallow effective soil depth.

CONCLUSION

A total of 12 main soil series are identified and demarcated in the surveyed area. About 76% of the area have moderate to good soil properties occurring on slope below 25°. About 14% of the area have slope exceeding 25°, 6% on very poorly drained low lying and 4% have shallow effective soil depth.

It is estimated that 76% of the area is suitable for oil palm cultivation. Major limitations likely to affect oil palm performance are steep topography, very poor soil drainage, shallow effective soil depth and very low soil fertility. These properties are difficult and costly to rectify and constitute about 24% of the area.

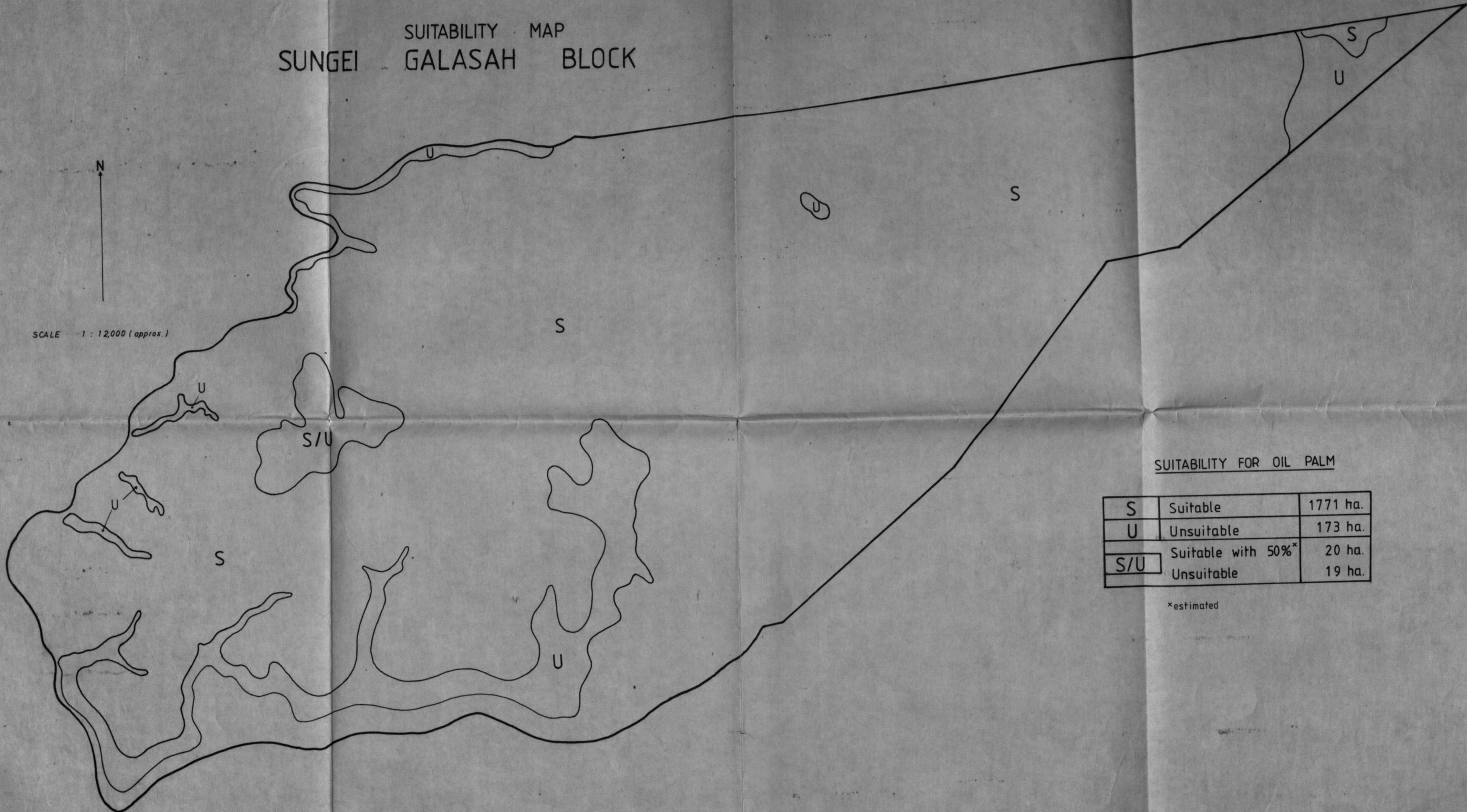
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SUITABILITY MAP
 SUNGEI GALASAH BLOCK



SCALE 1 : 12,000 (approx.)



SUITABILITY FOR OIL PALM

S	Suitable	1771 ha.
U	Unsuitable	173 ha.
S/U	Suitable with 50%*	20 ha.
	Unsuitable	19 ha.

*estimated

SUNGEI

SUITABILITY
SEPUPOK

MAP
BLOCK

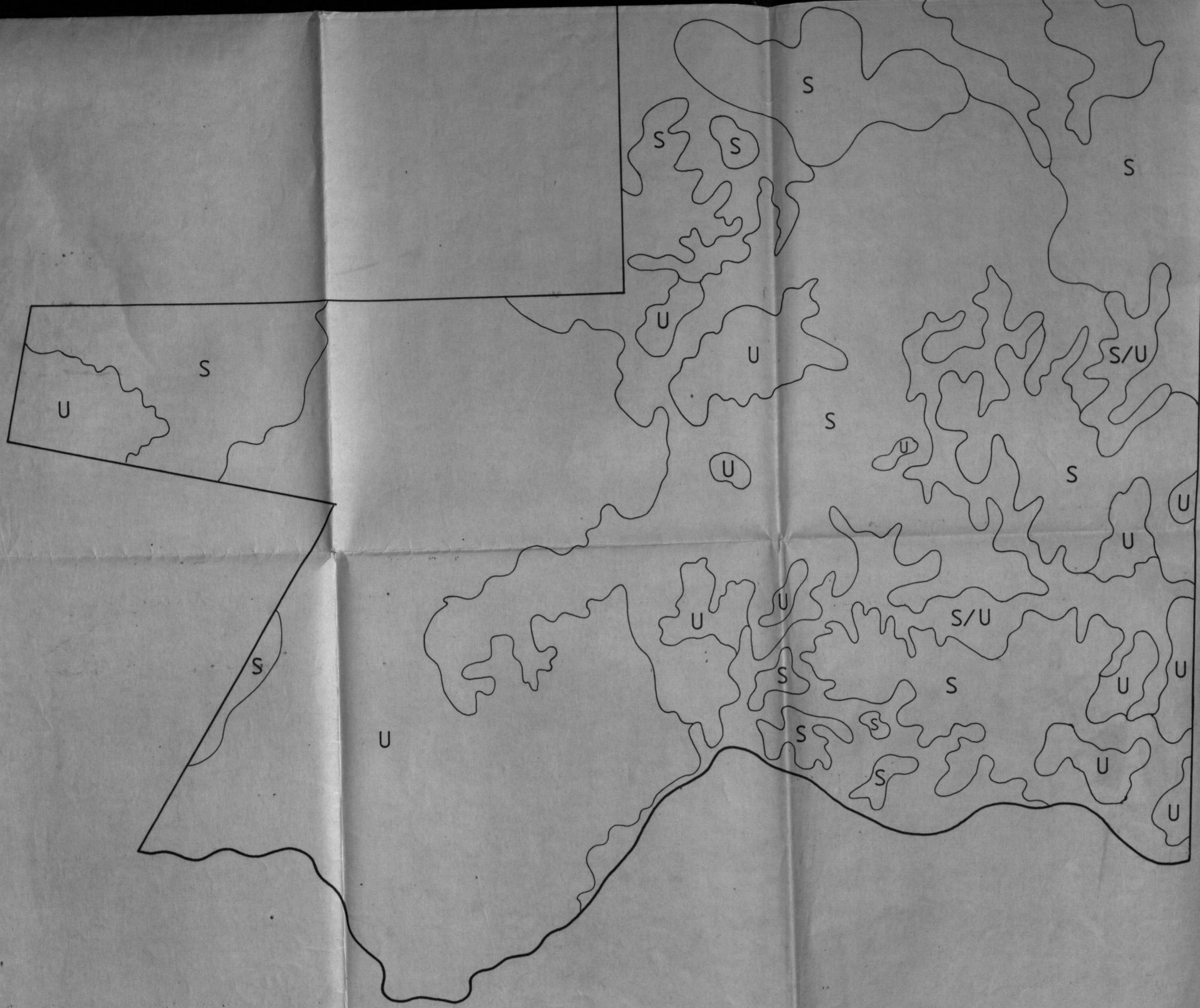


SCALE 1 : 12,000 (approx.)

SUITABILITY FOR OIL PALM

S	Suitable	1869 ha.
U	Unsuitable	987 ha.
S/U	Suitable with 20% [*] unsuitable	691 ha. 173 ha.

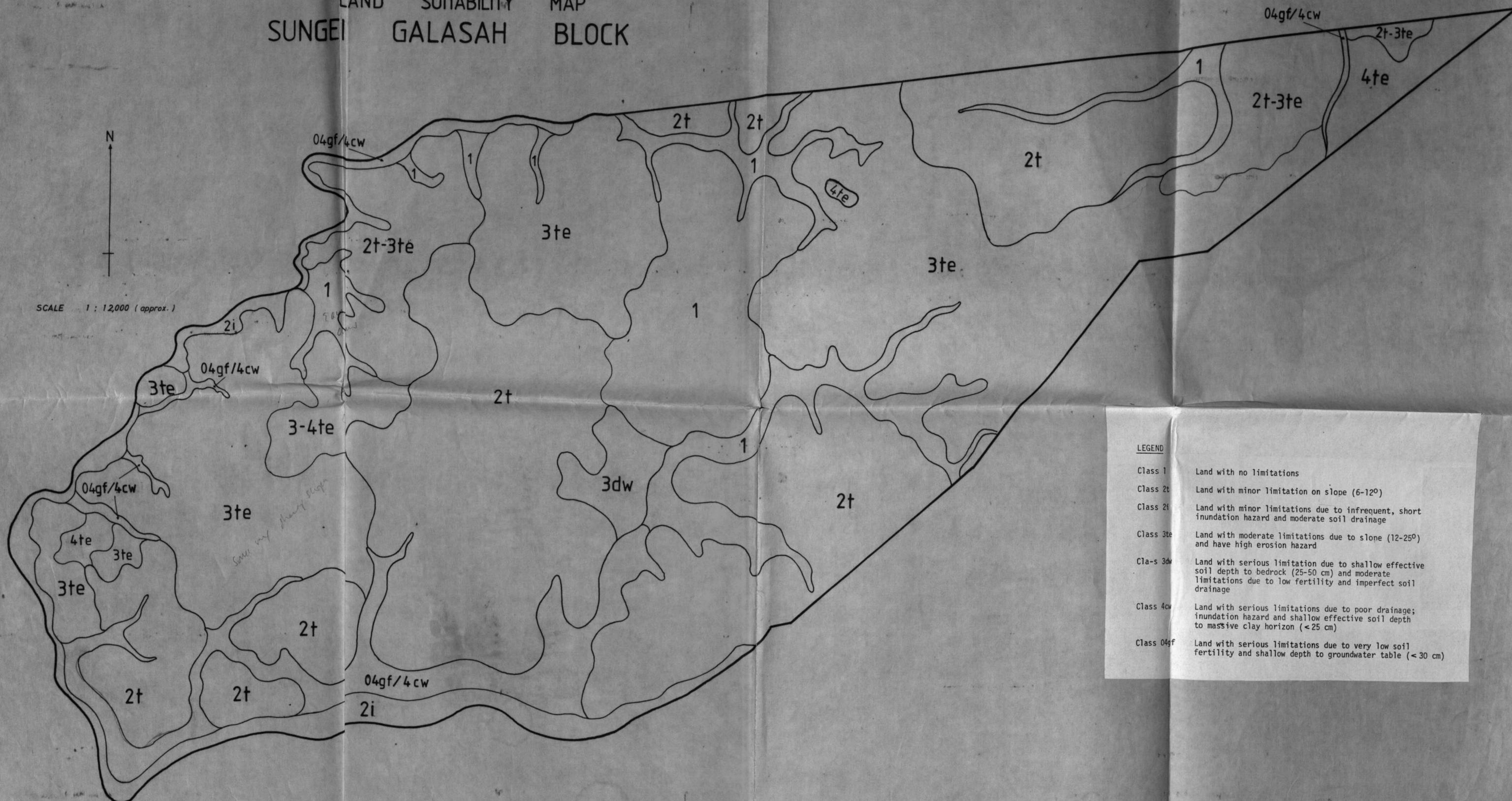
^{*} estimated



LAND SUITABILITY MAP
SUNGEI GALASAH BLOCK



SCALE 1 : 12,000 (approx.)



LEGEND

Class 1	Land with no limitations
Class 2t	Land with minor limitation on slope (6-12°)
Class 2i	Land with minor limitations due to infrequent, short inundation hazard and moderate soil drainage
Class 3te	Land with moderate limitations due to slope (12-25°) and have high erosion hazard
Class 3dw	Land with serious limitation due to shallow effective soil depth to bedrock (25-50 cm) and moderate limitations due to low fertility and imperfect soil drainage
Class 4cw	Land with serious limitations due to poor drainage; inundation hazard and shallow effective soil depth to massive clay horizon (<25 cm)
Class 04gf	Land with serious limitations due to very low soil fertility and shallow depth to groundwater table (<30 cm)

SEMI - DETAILED SOIL MAP SUNGEI SEPUPOK BLOCK

Mapping Unit	Soil Series	Effective soil depth (cm)	Slope class	Soil drainage
MR-5b	Merit Bedup	> 100	2-6°	Well-drained
MR-5c	Merit Bedup	> 100	6-12°	Well-drained
MR-4b	Merit Bedup	75-100	2-6°	Well-drained
MR-3b	Merit Bedup	50-75	2-6°	Well-drained
MR/Bk-5C	Merit Bedup Bekenu	>100	6-12°	Well-drained
MR/Bk-5d	Merit Bedup Bekenu	>100	12-20°	Well-drained
MR/Bk-5e	Merit Bedup Bekenu	>100	20-25°	Well-drained
MR/Bk-45d	Merit Bedup Bekenu	75- >100	12-20°	Well-drained
MR/Bk-45de	Merit Bedup Bekenu	75- >100	12-25°	Well-drained
MR/Bk-45f	Merit Bedup Bekenu	75- >100	25-33°	Well-drained
MR/Bk-45g	Merit Bedup Bekenu	75- >100	> 33°	Well-drained
MR/Bk-45fg	Merit Bedup Bekenu	75- >100	25- >33°	Well-drained
Kb-45a/Bg-12a	Kabuloh	75- >100	0-2°	Moderately well-drained
	Binatang	< 50	0-2°	Well-drained
Md-1a	Mundai	<25	0-2°	Poorly to very poorly drained
Sb-3a	Sabangan	50-75	0-2°	Imperfectly drained



SCALE 1 : 12,000 (approx.)

MR-5c
Md-1a
MR/Bk-5e

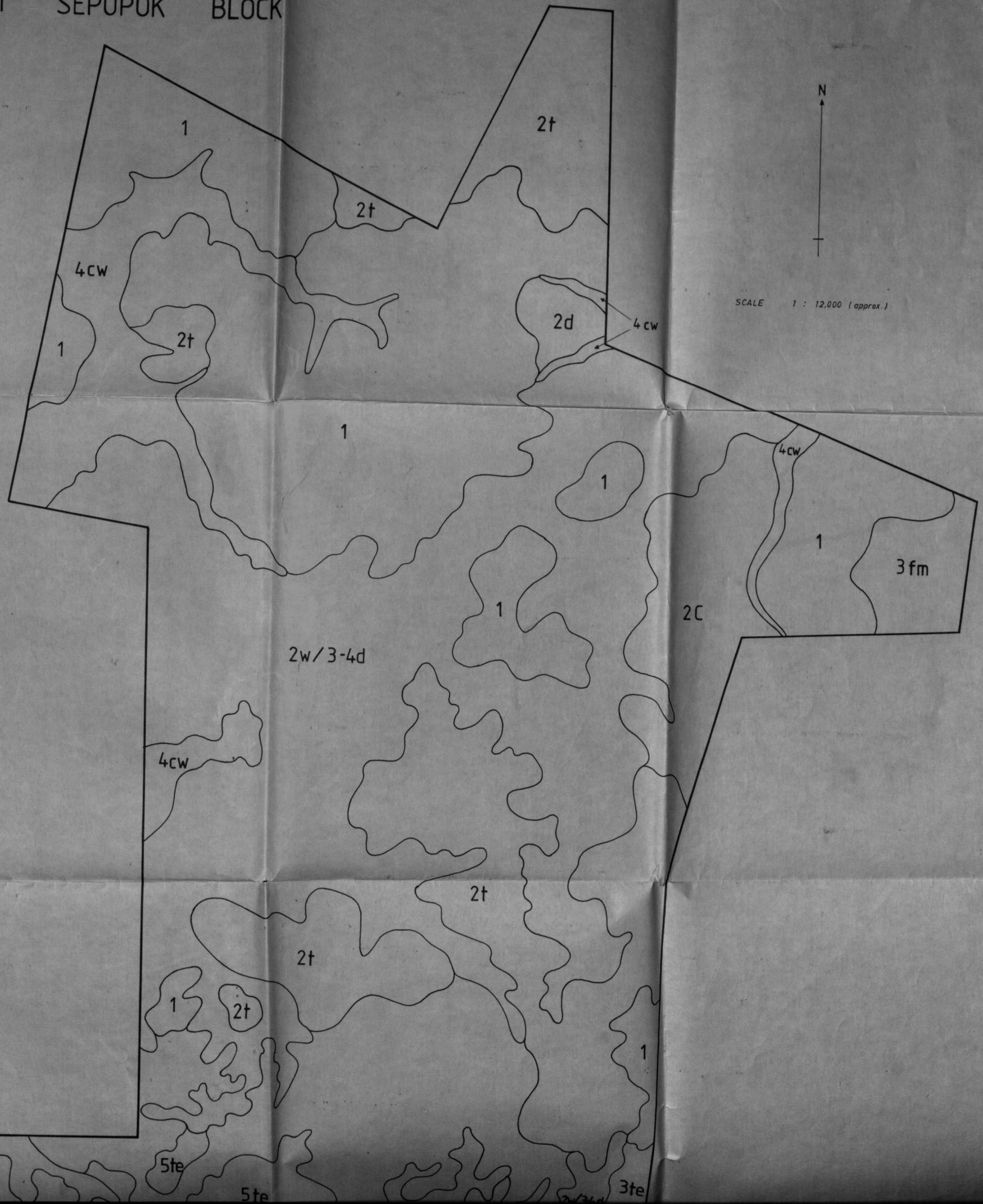
MR/Bk-45de

MR/Bk-5d

LAND SUITEI
SUNGEI

SUITABILITY
SEPUPOK

MAP
BLOCK



LEGEND

- Class 1 Land with no limitations
- Class 2t Land with minor limitation on slope (6-12°)
- Class 2d Land with moderate limitations due to somewhat shallow effective soil depth
- Class 2w Land with minor limitation due to moderately-well soil drainage
- Class 3te Land with moderate limitations due to slope (12-25°) and have high erosion hazard
- Class 3-4d Land with serious to very serious limitations due to shallow effective soil depth
- Class 4te Land with moderate limitations due to slope (25-33°) and have high erosion hazard
- Class 5te Land with very serious limitation due to extremely steep slope (> 33°)

