Sime Darby

Sime Darby Services

SEMI-DETAILED SOIL SURVEY OF LAVANG LAND

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SEMI-DETAILED SOIL SURVEY OF LAVANG LAND

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A DIVISION OF
Sime Darby Berhad

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1. PHYSICAL ENVIRONMENT

1.1 Location and Extent

The property is a contiguous block of 6,024 ha. (14,880 acres) situated in the Lavang District in the Fourth Division, Sarawak, approximately at the bisection of 113° 30' E. and 3° 10' N. The location is shown in Figure 1.

The location is in the interior where virtually no plantation has ever been attempted. The area has been logged and logging is an ongoing activity.

Accessibility to site by surface transport is via the Batang Kemena River using fast boat. The journey to LSH Timber Contractor & Transport Sdn. Bhd. Camp lasts about 2 hrs. 45 mins. The river can accommodate towed barges of 500-tonne capacity for material transportation.

From LSH Camp, the access to the property is through logging road, the condition of which will allow all-weather light vehicle transport. No doubt, upgrading of the road will be necessary to provide greater reliability of access. The distance from the jetty at LSH Camp to the southernmost boundary is about 5 km.

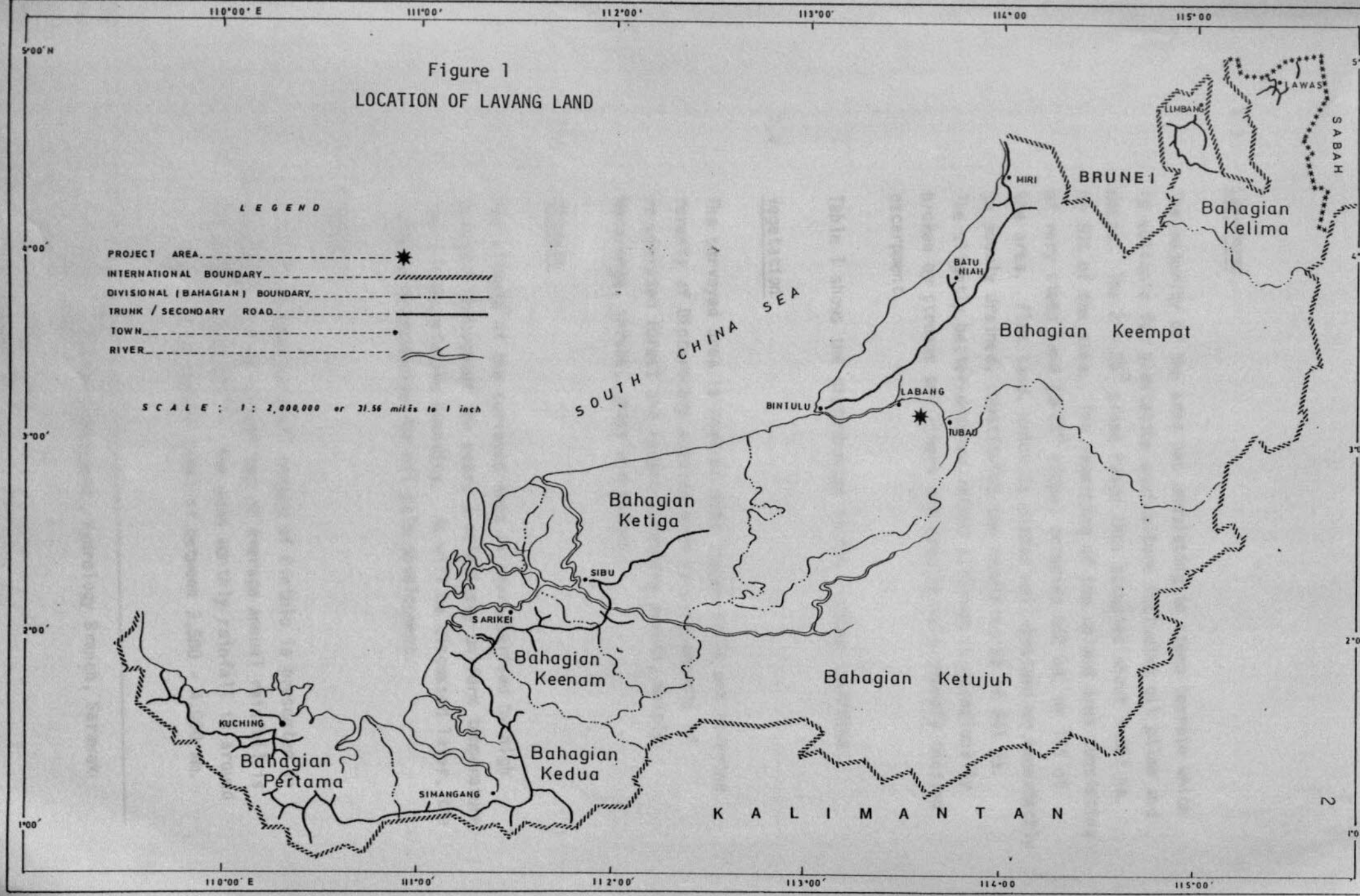
1.2 Geology

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

Alluvial materials of Pleistocene-Holocene epoch occupy the low-lying area. They consist mainly of clay and silt with minor sand. Presence of peat is rare.

Figure 1

LOCATION OF LAVANG LAND



1.3 Landform

The majority of the area has undulating to steep terrain which is suitable for plantation agriculture including oil palms and cocoa. The 2 - 25° slope range thus occupies about 4,821 ha. or 80% of the area. The remaining of the upland area consisting of very steep land (>25° slope) occupies 662 ha. or 11% of the area. Flat land, which is either well-drained or imperfectly to poorly drained, constitutes the remaining 9% or 541 ha. The slightly better-drained raised alluvium is occasionally broken by streams and rivers and results in a steeply incised escarpment.

Table 1 shows the distribution of the various landforms.

1.4 Vegetation

The surveyed area is covered with logged hills and riverine forests of Dipterocarp species with varying amounts of regenerated forest and recent secondary growth, mainly Macaranga, shrubs, grass and sedges.

1.5 Climate

The climate of the surveyed area is characterised by high rainfall throughout the year, a relatively uniform temperature and a high relative humidity. As will be discussed later, the climate is conducive for oil palm development.

1.5.1 Rainfall

A fourteen-year rainfall record of Bintulu is presented in Figure 2a and an isohyet map of average annual rainfall is shown in Figure 2b[1]. The mean monthly rainfall is around 300 mm. with an annual total of between 3,500 - 4,000 mm.

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(1) Drainage & Irrigation Department, Hydrology Branch, Sarawak

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

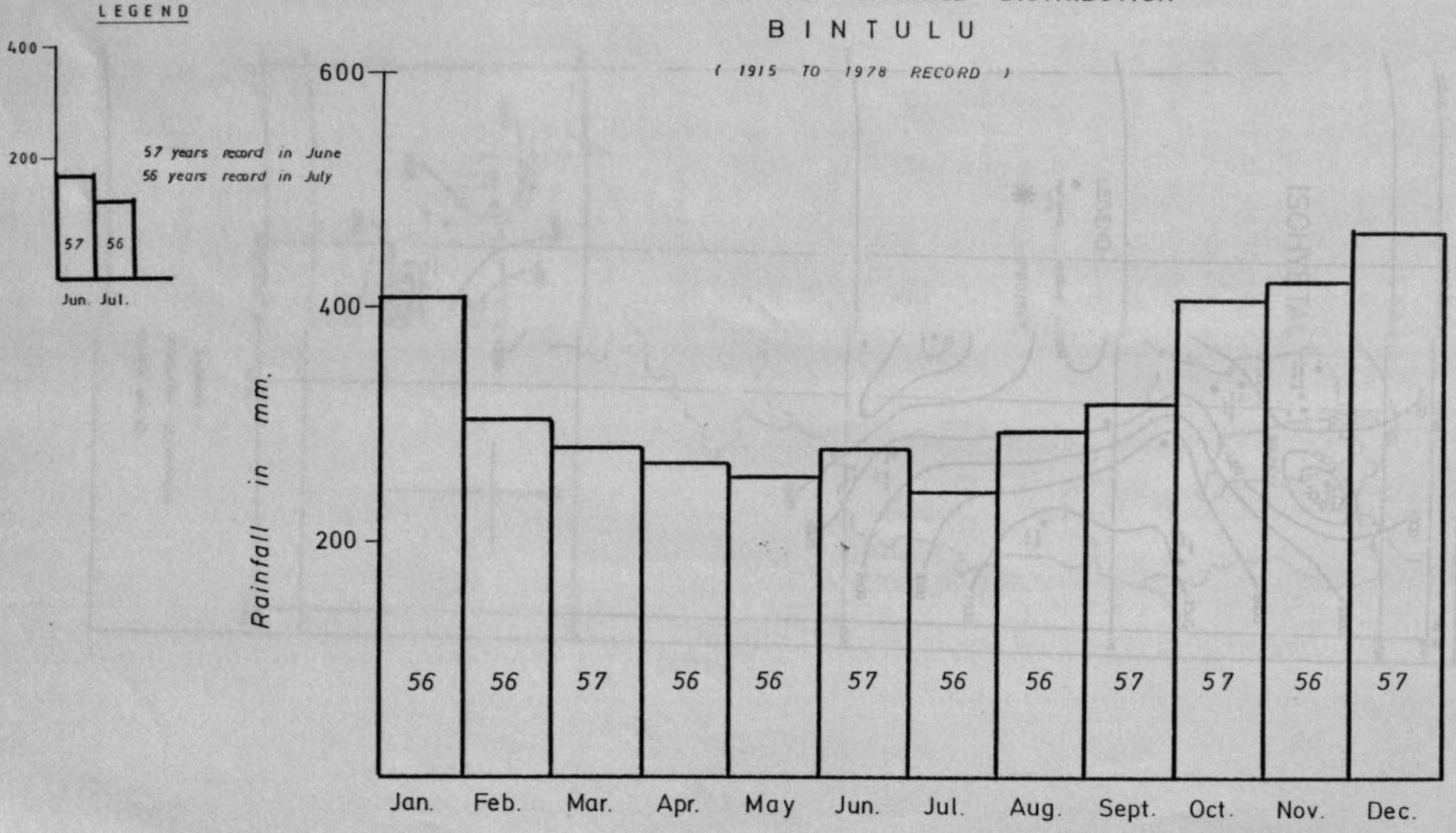
Landform	Terrain Classes	Slope (deg.)	Hectarage
Low-lying flats	Level - depressional; very poorly drained	0- 2	60
	Level to nearly level - valley floors; very poorly to poorly drained	0- 2	120
	Nearly level - recent river terrace; moderate to well-drained	0- 2	361
Low hills	Nearly level to very gently undulating - (on unfolded sediments)	0- 6	603
	Rolling	6-12	663
	Hilly to steep	12-25	2,832
	Very steep	25-33	723
	Extremely steep	> 33	662

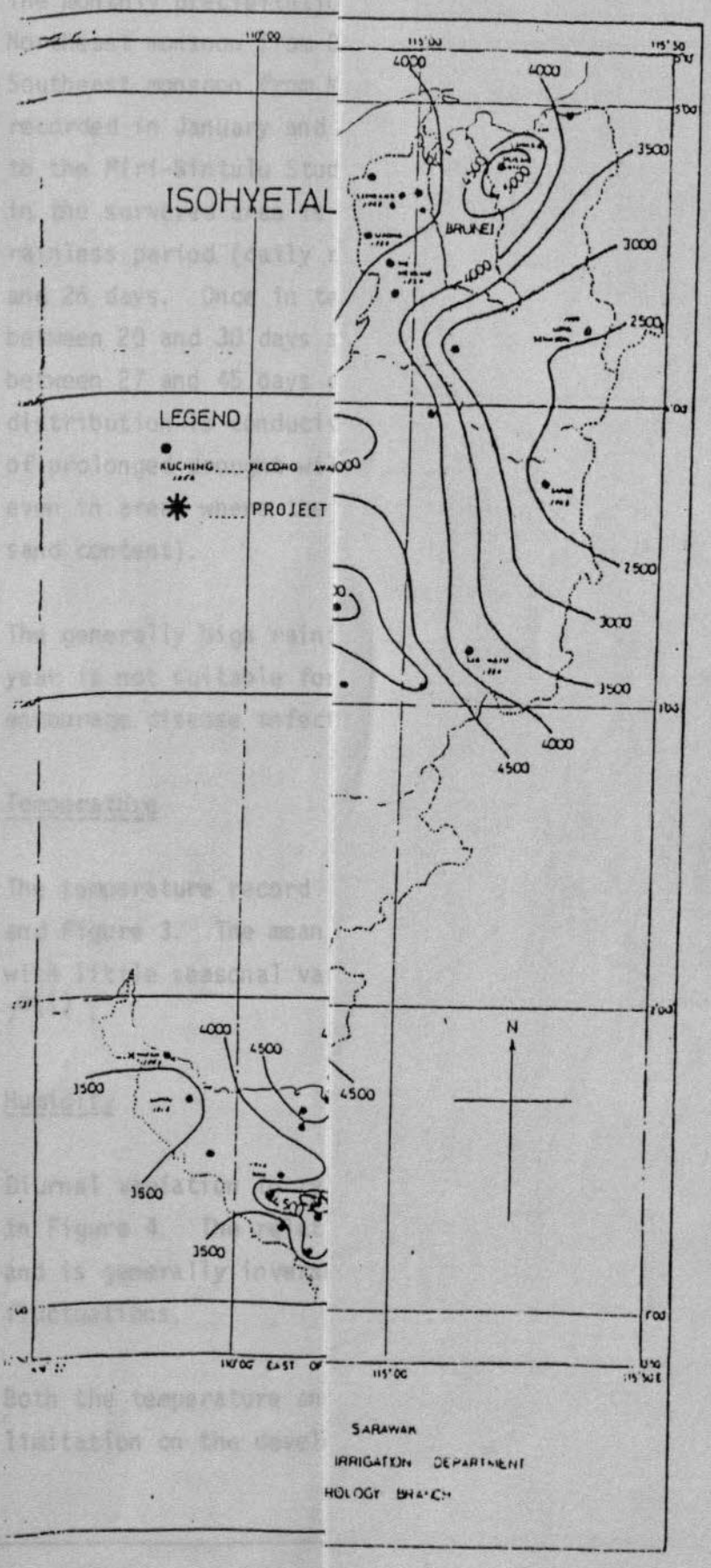
Figure 2a

AVERAGE MONTHLY RAINFALL DISTRIBUTION

B I N T U L U

(1915 TO 1978 RECORD)




ISOHYETAL
LEGEND
KUCHING
PROJECT
BRUNEI
4000
3500
3000
2500
4500
N
SARAWAK
IRRIGATION DEPARTMENT

The monthly precipitation is generally higher during the Northeast monsoon from October to January than during the Southeast monsoon from May to August. Highest rainfall is recorded in January and the lowest rainfall in March. 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. Therefore, rainfall distribution is conducive for oil palm planting and the lack of prolonged drought will ensure adequate moisture availability even in areas where the soil is of light texture (i.e. more sand content).

The generally high rainfall evenly distributed throughout the year is not suitable for rubber or cocoa planting as this will encourage disease infection particularly phytopthora.

1.5.2 Temperature

The temperature record from Bintulu is presented in Table 2 and Figure 3. The mean annual temperature is 26.5°C (79.7°F) with little seasonal variations and diurnal variation is about 7°(1).

1.5.3 Humidity

Diurnal variation in relative humidity for Bintulu is presented in Figure 4. The relative humidity ranges between 70 and 95% and is generally inversely proportional to daily temperature fluctuations.

Both the temperature and relative humidity ranges have no limitation on the development of plantation crops.

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(1) Miri-Bintulu Regional Study

Table 2: Mean Monthly Temperature (^{o}C) for Bintulu[1]

Month	Bintulu
January	25.7
February	26.0
March	26.3
April	26.9
May	27.2
June	26.9
July	26.8
August	26.8
September	26.6
October	26.6
November	26.3
December	26.1
Mean Annual	26.5

(1) Perkhidmatan Kajicuaca Malaysia (records from 1972 - 1981)

Figure 3 : MEAN MONTHLY TEMPERATURE DISTRIBUTION

BINTULU

10 YEARS RECORD

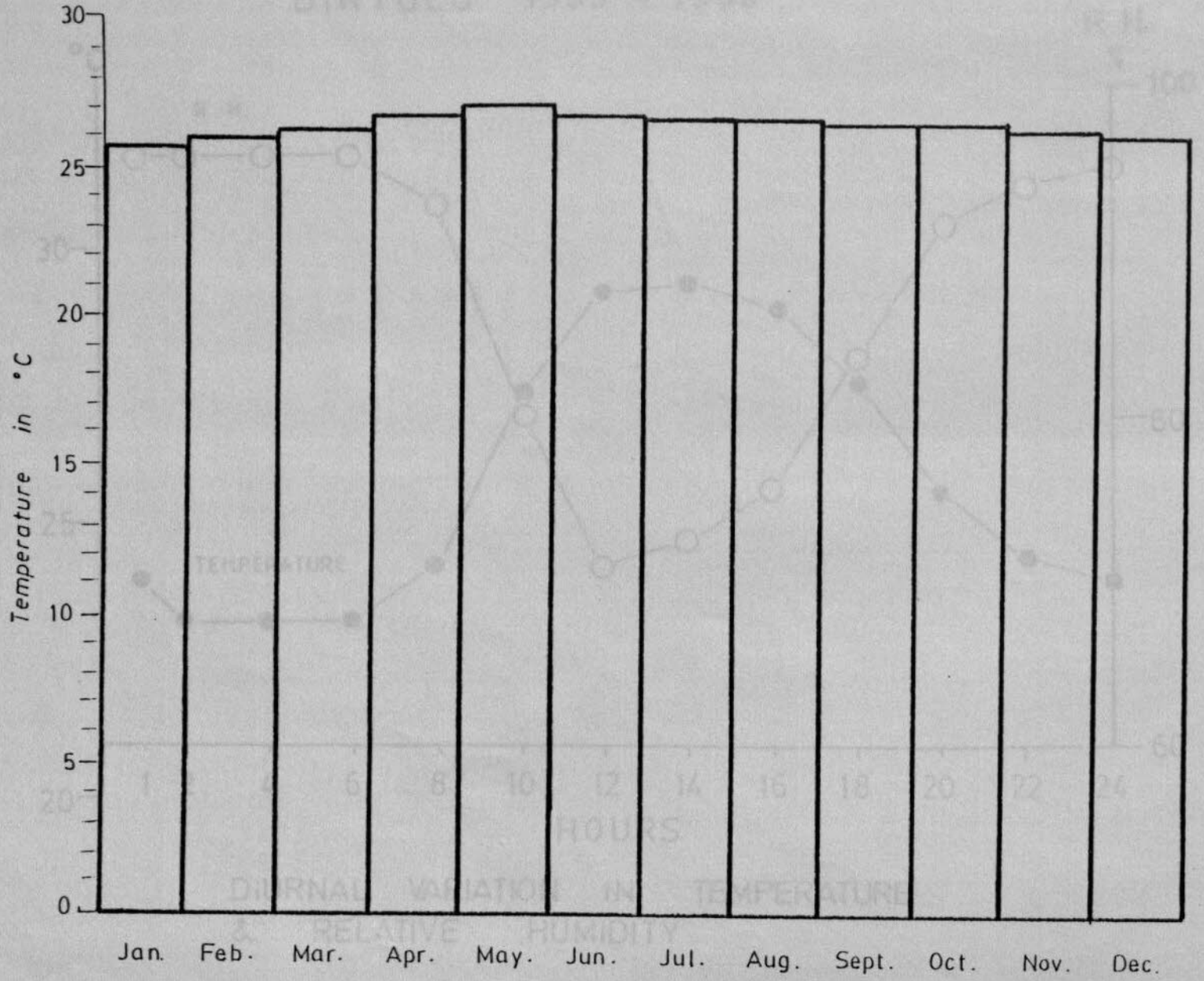
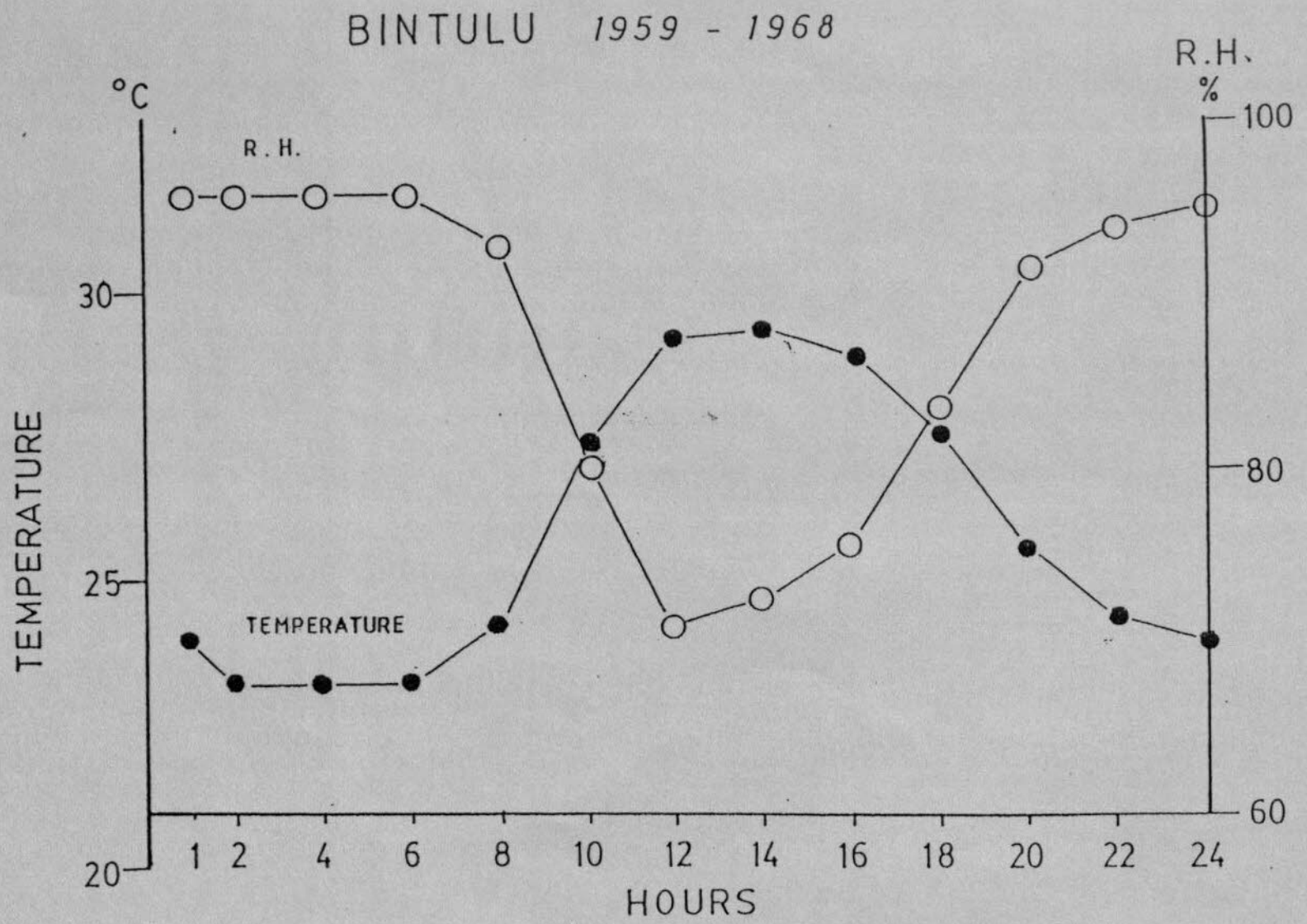


Figure 4



DIURNAL VARIATION IN TEMPERATURE & RELATIVE HUMIDITY

2. SOILS

2.1 Method of Soil Survey

The survey was carried out at a semi-detailed level. Rentices were cut at a spacing of about 1 km. apart and were aligned in north-south or east-west direction. A total of 2,700 chain or 55 km. of rentices were cut in the surveyed area. The distribution of the rentices is shown in Figure 5.

A total of 4 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. The location of the soil examination pits in the surveyed area is shown also in Figure 5. The dimensions of the soil pit are presented in Figure 6. Soil properties studied in these profiles included environmental features, soil colour, texture, structure, consistency, porosity, root distribution, etc. In addition to soil profiles, soil auger holes were made and studied at regular intervals of 200 m. or less along the rentices. The soils were described according to methods laid down in Handbook No. 18, U.S. Department of Agriculture, Soil Survey Manual (1951). Where applicable, soil auger samples were collected for analysis.

25 soil samples from the soil profiles and auger examination points were collected for soil mechanical and chemical analyses in Ebor Laboratories of Sime Darby Plantations, Klang, Selangor.

2.2 Soil Classification Units

The soils of the surveyed area are classified according to the system used in the revised "Soil Classification in Sarawak" (TIE 1982). The mapping units used are "soil series" which consist of soils with similar arrangement and characteristics of diagnostic horizons and formed on similar parent materials. Where individual soil series cannot be mapped and shown separately

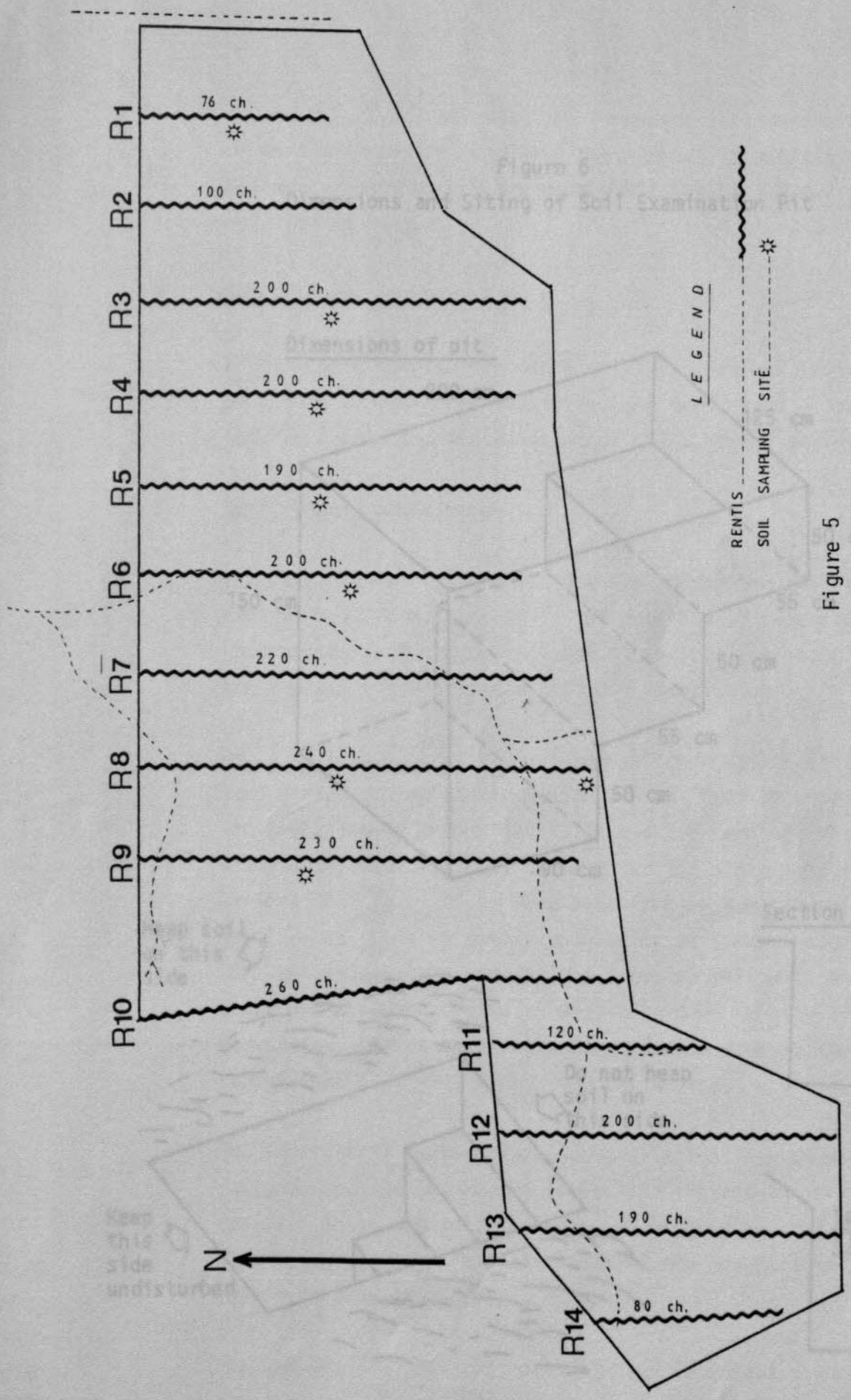
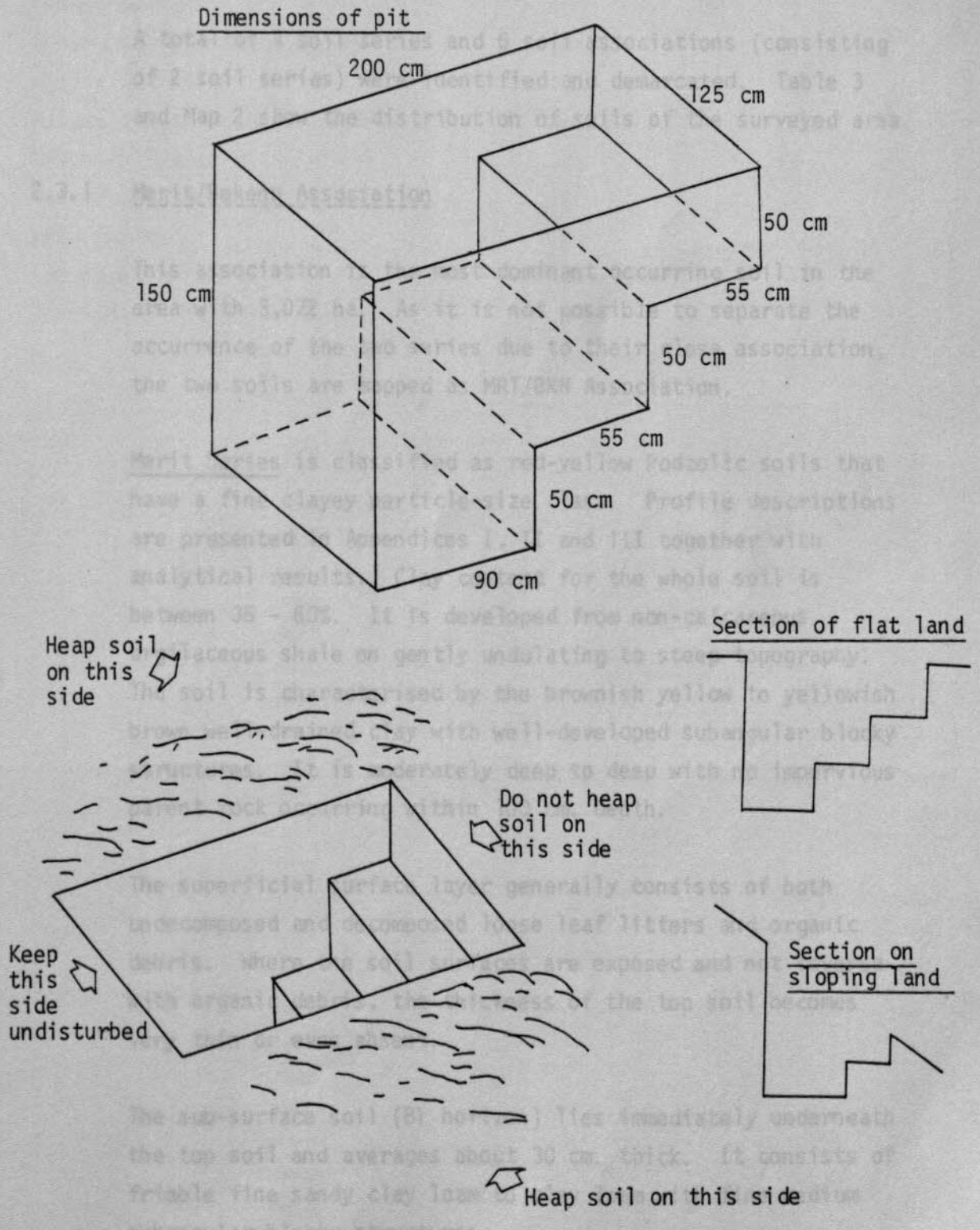


Figure 5
DISTRIBUTION OF RENTICES

Figure 6
Dimensions and Siting of Soil Examination Pit



on the map, "soil association" is used. This consists of two or more soil series regularly geographically associated in a defined proportion but are unmappable separately due to the scale of mapping.

2.3 Soils of the Surveyed Area

A total of 4 soil series and 6 soil associations (consisting of 2 soil series) were identified and demarcated. Table 3 and Map 2 show the distribution of soils of the surveyed area.

2.3.1 Merit/Bekenu Association

This association is the most dominant occurring soil in the area with 3,072 ha. As it is not possible to separate the occurrence of the two series due to their close association, the two soils are mapped as MRT/BKN Association.

Merit Series is classified as red-yellow Podzolic soils that have a fine clayey particle-size class. Profile descriptions are presented in Appendices I, II and III together with analytical results. Clay content for the whole soil is between 35 - 60%. It is developed from non-calcareous argilaceous shale on gently undulating to steep topography. The soil is characterised by the brownish yellow to yellowish brown well-drained clay with well-developed subangular blocky structures. It is moderately deep to deep with no impervious parent rock occurring within 100 cm. depth.

The superficial surface layer generally consists of both undecomposed and decomposed loose leaf litters and organic debris. 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 (B1 horizon) lies immediately underneath the top soil and averages about 30 cm. thick. It consists of friable fine sandy clay loam to clay loam with fine medium subangular blocky structures.

Table 3: Distribution of Soil Mapping Units

Soil Mapping Unit	Hectares	%
Merit/Bekenu Association	3,072	51
Bekenu Series	181	3
Bekenu/Sarieki Association	844	14
Nyalau Series	181	3
Bekenu/Nyalau Association	421	7
Silantek/Nyalau Association	784	13
Tukau/Lupar Association	361	6
Ajoh Series	60	1
Semilajau Series	60	1
Semilajau/Peat Association	60	1
Total	6,024	100

The horizon with maximum clay content occurs below the B1 horizon. Most profiles have ≥35% clay in this horizon. Structures are somewhat strongly developed medium and 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. Cutans are common on most of the ped surfaces. They are somewhat continuous, moderate to well-developed and are paler in colour than the interior of the soil peds. Although both the fine and coarse roots are present, their concentrations are generally lower.

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

They are, however, not thickly compacted and in many of the profiles studied, fine roots have been found to penetrate through this horizon. It is not likely that this concretionary layer will pose any serious limitation to root penetration.

Very common, a BC_R layer may occur, usually at the lower depth around 100 cm. of the B horizon. This consists of stony undecomposed parent rock which is generally continuous and sometimes with interstices filled with clay of the overlying horizon. Roots are present and the layer is somewhat penetrable by roots.

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 moderately developed and, in some cases, tending towards massive. Their soil colours are variegated and mottled with grey - a dominant colour of the underlying parent rock.

Micro-bio activities are practically absent and the root concentration is usually very low to nil. Underneath this variegated horizon lies the parent rock - shale, with varying degree of weathering and hardness. This impervious layer is not penetrable by roots. It is noted that in many of the profiles and soil auger examinations, the continuous impervious parent rock is not met within 100 cm. from the soil surface, even on some of the steeper slopes. Only very few auger examinations have encountered shallower soil depth on slope $> 33^{o}$.

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

Merit Series soils are acidic with pH ranges from 4.1 to 5.2. Organic carbon is low in the Ah horizons with values ranging from 0.27 to 1.1+. This is probably due to erosion of the top soil on hilly slopes. There is an abrupt decrease of organic carbon in the underlying B horizons where most values are below 0.6. The soil has low CEC but the presence of 2:1 clay mineral appears predominant due to the high CEC/100 gm. clay of around 40 meq. Total exchangeable cations are very low, indicating the soil is devoid of nutrients. High rates of balance fertilizers will be needed and in view of the high rainfall, split application of fertilizer is to be recommended. The presence of 2:1 clay, however, will improve the cation retention which otherwise may be lost through leaching.

Bekenu Series is classified as red-yellow Podzolic soils that have a fine loamy or fine silty particle-size class with 18 to 35% clay content for the whole soil. It is developed on fine sandy shale and occurs mainly on the steeper terrain in the surveyed area. It is mapped in association with soils of

the Merit Series. The physical and chemical characteristics are presented in Appendices IV and V.

The surface layer Ah horizon consists of decomposed organic matter and is usually less than 5 cm. thick. It consists of dark greyish brown friable clay loam. Structures are moderately fine and medium subangular blocky and some crumbs. The B1 horizon consists of brownish yellow loam. Structures are moderately developed with medium and some coarse subangular blocky structures and friable consistency. Coatings of organic acid are patchy on most of the ped surfaces. Both the Ah and B1 horizons have the highest concentrations of fine to coarse roots.

Sub-soil B2 horizon is usually deep, extending to below 100 cm. deep. It consists of brownish-yellow to reddish-yellow to strong brown fine sandy clay loam to fine clay loam. Structures are moderately developed with coarse subangular blocky structures and friable consistency. 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 B2 horizon. Cutans are common, and pores and roots are concentrated more towards the upper B horizon and decrease with depth.

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

The major chemical properties of Bekenu Series are quite similar to those of the Merit Series. The soils are strongly acid with pH of around 4.4. Organic carbon is highest in the Ah horizon and decreases sharply in the B horizon. Total

cations are similar to those of the Merit Series. The CEC is lower in the sub-soil compared to that of the Merit, around 6 - 9 meq/100 gm. soil. The CEC for the clay portion is more than 24 meq/100 gm. clay, indicating presence of 2:1 lattice clay. The soil is considered poor in nutrient and exchange capacity. Significant amount of balance nutrients will be needed to support a good crop of oil palms.

2.3.2 Bekenu Series

This mapping unit occupies 181 hectares or 3% of the surveyed area. The characteristics are as described for Bekenu Series under Section 2.3.1.

2.3.3 Bekenu/Sarieki Association

This association occupies 844 ha. or 14% of the surveyed area. While Bekenu Series has been described in Section 2.3.1, Sarieki Series is in many respects similar to Bekenu with the exception of soil colour. Sarieki Series has a red colour profile and is mapped as a red variant of Bekenu Series.

2.3.4 Nyalau Series

Nyalau Series is classified as red-yellow Podzolic soils that have a yellow-coloured coarse loamy particle-size class. It is developed on sandstone and occurs on very gently undulating topography. In the surveyed area it occurs over 181 ha. or 3% of the area. The description, based on auger examination and chemical data, is presented in Appendix VI.

The top soil consists of a thin layer of yellowish brown friable sandy loam with moderately developed fine and medium structures. Sub-soil consists of pale brown fine sandy loam. The soil is deep but soft decomposing sandstone gravels may be encountered at depth below 75 cm. These gravels, however, pose no limitation to root penetration. The soil has high internal drainage and high leaching loss of plant nutrients can be expected.

Nyalau Series is acidic with pH around 4.7. This sandy soil is very low in available nutrients, with total exchangeable bases for sub-soil at around 0.5 meq %. Due to the low clay content, the CEC is low at less than 2 meq/100 gm. soil. The soil is moderately suitable for oil palms due to low fertilizer and cation retention capacity. The expected low moisture-retention capacity is however compensated by the generally high and evenly distributed rainfall thus lowering the incidence of moisture stress.

2.3.5 Bekenu/Nyalau Association

This association occurs over 421 ha. or 7% of the surveyed area. The occurrence of these two series in a heterogenous manner does not permit clear delineation though their properties are significantly different.

The properties of these two series have been described in Sections 2.3.1 and 2.3.4. This association is moderately suitable to suitable for oil palms.

2.3.6 Silantek/Nyalau Association

The characteristics of Silantek Series are presented in Appendix VII. Together with Nyalau Series, the STK/NLU Association accounts for 784 ha. or 13% of the surveyed area.

Silantek Series is classified as podzol with non-cemented or weakly-cemented spodic horizon. The soil is developed on sandstone over rolling topography. It is characterised by the very sandy pale-coloured sub-soil with a spodic horizon below 75 cm. depth.

The top soil consists of dark reddish grey to brownish fine loamy sand with very friable to loose consistency. It is underlain by an eluvial sub-soil with light grey to white loamy sand to sand exceeding 100 cm. It has a weakly-developed structure with very friable to loose consistency. At depth below 100 cm. is a layer of dark yellowish brown to brown illuviated sand which is weakly cemented.

Chemical properties for Silantek Series is expected to be poor for plantation especially oil palm. The soil has very low levels of major plant nutrients and CEC is extremely low. Oil palms on Silantek Series are usually stunted in growth with symptoms of multiple nutrient deficiencies. Above normal doses of balance nutrients composing of N, P, K, Mg and trace element at split application and carefully scheduled with cropping cycle and rainfall pattern will help to maximise plant uptake. The soil is considered marginally suitable for oil palms.

2.3.7 Tukau/Lupar Association

This association occupies 361 ha. or 6% of the surveyed area. Tukau Series is an alluvial soil which is deep and well-drained. The soil is fine loamy in texture with about 18 - 35% clay throughout.

The top soil consists of dark greyish brown to very dark greyish brown friable silty loam to clay loam with moderately-developed fine and medium blocks and crumbs. Sub-soil is deep to very deep and consists of yellowish brown silty clay loam to silty loam with 15 - 35% clay content. It has well-developed medium and coarse blocky structures and is friable. No stones or pebbles are encountered within 150 cm. soil depth. Grey mottles may be present at lower depth of the sub-soil.

Top soil is acidic with pH between 5.4 to 5.9 and sub-soil is strongly acidic with pH 4.3 to 4.9. Organic carbon is highest in top soil with values between 2.0 to 2.5% while sub-soil organic carbon is less than 1%. Exchangeable cations are medium to high in the top soil and very low to low in the sub-soil.

The above characteristics are extracted from our previous experience on detailed soil survey of Sarawak Oil Palm Estate.

The association is suitable for oil palm development and exceptional performance is expected due to the good moisture status of the soil.

2.3.8 Ajoh Series/Semilajau Series/Semilajau/Peat Association

These are miscellaneous series and association and together occupy 180 ha. or 3% of the surveyed area.

Ajoh Series is classified as grey-white Podzolic soils with clayey particle-size class and has abundant (> 20%) mottles with 100 cm. soil depth. The soil is imperfectly drained and occurs on flat valley floors. The characteristics are presented in Appendix VIII.

The top soil consists of light greyish friable clay loam to silty clay loam with many reddish yellow mottles. Sub-soil colour is light grey to grey with prominent reddish yellow mottles of about 5 to 15 mm. diameter with clay loam texture. Consistency is friable to slightly firm, becoming more massive and plastic with depth. Structures are moderately developed, coarse and very coarse subangular blocky, becoming weakly developed and prismatic with depth. Soft manganese mottles may be present at the lower depth of thw sub-soil.

Ajoh Series has an acidic top soil with pH around 4.0 while the sub-soil is less acidic with pH around 4.5. Exchangeable cations for the top soil are medium through the profile while CEC is low.

Semilajau Series is alluvial soil that has a coarse loamy particle-size class with less thatn 18% clay content for the whole soil. It is formed in alluvium derived from non-calcareous sandstones. Its occurrence is confined mainly along the banks of some tributaries.

The top soil is about 5 cm. thick and consists of dark yellowish brown loose sand with weakly-developed structures. Sub-soil is deep with pale brown to yellow loose sand and structures are weakly developed. Mottles may be present at lower depth. The soil is well-drained to somewhat excessively drained but may be subject to short duration of flooding during the rainy days.

Peat is undecomposed organic material and in the surveyed area is shallow to about 1.5 m. deep. The soil is suitable to moderately suitable for oil palms due to slight drainage/ nutrition problem.

2.3.9 A summary of some salient soil properties is presented in Table 4.

Table 4: Summary of Some Salient Soil Properties

Soil Series/ Association	Soil Characteristics
Merit/Bekenu Association	On shale; clay loam to clay with 18 to 60% clay; brownish yellow to strong brown; moderately deep to deep (100 cm.); well-drained; undulating to steep; low nutrient with moderate cation exchange capacity.
Bekenu Series	On shale; undulating to steep; brownish yellow to strong brown; clay loam to clay; moderately deep to deep (100 cm.); stony and non-stony; well-drained.
Bekenu/Sarieki Association	As above with exception of Sarieki Series which has a red colour profile.
Nyalau Series	On sandstones; well-drained; on very gently undulating topography; fine sandy loam; soft gravels at 75 cm; low nutrient and cation exchange capacity.
Silantek/Nyalau Association	On sandstones; Silantek with a bleached horizon; loamy sand; very low nutrient and cation exchange capacity.
Tukau/Lupar Association	On alluvium; deep and well-drained; fine loamy with 18 - 35% clay; low nutrient and cation exchange capacity.
Miscellaneous	On alluvium or low lying with poor drainage; loam to clay loam texture or peaty; low nutrient and cation exchange capacity.

3. LAND CAPABILITY CLASSIFICATION

3.1 Method and Criteria

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

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

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

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

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

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

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

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

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

Table 5 presents the limiting factors for crop growth and the degree of limitation for mineral soils.

3.2 Land Capability Classes

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

Capability classes of Mineral Soils

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

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

Table 5 : Limitations to Crop Suitability on Mineral Soils

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

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

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

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

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

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

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

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

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

3.3 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.

3.3.1 Climatic Requirement for Oil Palm Cultivation

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

3.3.2 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 exceeding 25^{o}.

3.3.3 Suitability for Oil Palm Cultivation in the Surveyed Area

a) Climatic Suitability for Oil Palm Cultivation

The surveyed area has high rainfall with mean monthly precipitation of around 300 mm. Mean annual temperature is about $26.5^{o}C$. These are considered suitable for oil palm cultivation.

b) Suitability for Oil Palm Cultivation

The suitability for oil palm cultivation has been evaluated and classified according to suitability classes. This is presented in Table t together with the hectarage. An oil palm suitability map is presente in Map 3.

Table 6: Soil Suitability Class for Oil Palm

	Soil Mapping Unit	Hectares	%
Suitable	Merit/Bekenu Association Bekenu Series Bekenu/Sarieki Association Tukau/Lupar Association Ajoh Series Semilajau Series Semilajau/Peat Association	4,098	68
Moderately suitable	Nyalau Series Bekenu/Nyalau Association	602	10
Marginally suitable	Silantek/Nyalau Association Merit/Bekenu 45ef Bekenu/Nyalau 45ef	1,324	22
		6,024	100

4. RECOMMENDATIONS

The area is predominantly suitable for oil palm development with about 78% of the area able to sustain a good or reasonable production.

The remaining 22%, however, has severe limitation of either very low fertility/moisture-retention capacity or very steep topography. Both limitations, however, can be corrected through more intense management effort and require higher resource inputs.

Soil Profile No.: 4
Location: Rentice No. 3; 80th chain
Soil Series: Merit
Parent Material: Shale
Landform: Rolling
Slope: 6 - 12°
Drainage: Well-drained

Profile Description

B_{1t} 0 - 35 cm — Brownish yellow 10YR 6/8; fine sandy clay loam; moderately strong, fine and medium subangular blocky structures; friable; many fine roots; diffuse boundary.

B_{2t} 35 - 55 cm — Brownish yellow 10YR 6/6; fine sandy clay loam; few reddish yellow 7.5YR 6/6 mottles; moderately strong, medium subangular blocky structures; friable; few fine roots; diffuse boundary.

BC 55 - 100 cm — Light yellowish brown 10YR 6/4; clay loam; many reddish yellow 5YR 6/8 mottles; moderately strong, coarse subangular blocky structures; friable to firm; few pockets of decomposing shale; wavy boundary.

R 100 cm+ — A continuous layer of decomposing shale.

SOIL ANALYTICAL DATA

Depth in cm	Particle Size Distribution (%)				pH	%	
	Clay	Silt	Coarse Sand	Fine Sand		OC	N
0-35	25.3	26.8	3.6	41.8	4.5	0.55	0.07
35-55	27.5	25.4	3.0	40.8	4.3	0.17	0.00
55-100	38.4	27.3	2.3	29.3	4.3	0.22	0.00

Depth in cm	ppm		CEC in IN NH_4 OAC (Meq %)	Exchangeable Cations (Meq %)		
	Available P	Boron		K	Mg	Ca
0-35	13.0	2.6	9.47	0.10	0.07	0.01
35-55	13.0	2.0	10.27	0.09	0.03	0.01
55-100	12.2	1.6	14.40	0.14	0.03	0.01

Soil Profile No.: 7
Location: Rentice No. 5; 80th chain
Soil Series: Merit
Parent Material: Shale
Landform: Undulating
Slope: 2 - 6°
Drainage: Well-drained

Profile Description (Soil auger examination)

0 - 20 cm Brownish yellow 10YR 6/8; clay loam.

20 - 40 cm Brownish yellow 10YR 6/8; clay loam.

40 - 100 cm Brownish yellow 10YR 6/8 with few reddish yellow 7.5YR 6/8 mottles; clay loam.

SOIL ANALYTICAL DATA

Depth in cm	Particle Size Distribution (%)				pH	%	
	Clay	Silt	Coarse Sand	Fine Sand		OC	N
0-20	34.0	38.8	0.50	24.9	4.1	1.14	0.17
20-40	35.9	40.5	0.30	20.9	4.1	0.55	0.09
40-60	34.4	37.8	0.23	25.2	4.1	0.32	0.07
60-100	37.0	39.4	0.21	21.6	4.1	0.33	0.06

Depth in cm	ppm		CEC in IN NH_4 OAC (Meq %)	Exchangeable Cations (Meq %)		
	Available P	Boron		K	Mg	Ca
0-20	12.0	4.4	15.60	0.17	0.37	0.01
20-40	13.0	3.0	17.87	0.15	0.27	0.01
40-60	12.0	4.0	13.47	0.15	0.25	0.01
60-100	12.0	3.4	16.93	0.14	0.24	0.01

Soil Profile No.:	11
Location:	Rentice No. 8; 22lst chain
Soil Series:	Merit
Parent Material:	Shale
Landform:	Hilly
Slope:	12 - 20^{o}
Drainage:	Well-drained

Profile Description

Bt_1	0 - 30 cm	Brownish yellow 10YR 6/6; clay loam; many reddish yellow 5YR 6/8 mottles; moderate, coarse subangular blocky; friable to slighty firm; many fine and few medium roots; diffuse boundary.
Bt_2	30 - 60 cm	Brownish yellow 10YR 6/6; clay; many reddish yellow 5YR 6/8 mottles; moderate, coarse subangular blocky; firm; many fine roots; diffuse boundary.
BC	60 cm+	Saprolite; clay.

SOIL ANALYTICAL DATA

Depth in cm	Particle Size Distribution (%)				pH	%	
	Clay	Silt	Coarse Sand	Fine Sand		OC	N
0-30	32.4	24.7	2.9	37.0	4.6	0.27	0.04
30-60	40.8	26.8	2.3	26.6	5.2	0.23	0.05
60+	47.1	34.9	3.1	12.5	4.7	0.26	0.06

Depth in cm	ppm		CEC in IN NH_4 OAC (Meq %)	Exchangeable Cations (Meq %)		
	Available P	Boron		K	Mg	Ca
0-30	11.5	2.0	16.67	0.15	0.09	0.04
30-60	13.1	1.6	14.53	0.15	0.04	0.00
60+	10.9	2.6	12.93	0.23	0.06	0.01

Soil Profile No.:	1
Location:	Rentice No. 1; 50th chain
Soil Series:	Bekenu
Parent Material:	Shale
Landform:	Rolling
Slope:	10^{o}
Drainage:	Well-drained

Profile Description

Ah	0 - 2 cm	Dark greyish brown 10YR 4/2; clay loam; moderate, fine subangular blocky; friable; many medium and coarse roots; clear boundary.
B1	2 - 30 cm	Brownish yellow 10YR 6/8; loam; moderate, coarse and medium subangular blocky; friable; many coarse and medium roots; many fine pores; patchy organic acid coatings; clear boundary.
Bt	30 - 90 cm	Strong brown 7.5YR 5/8; clay loam; moderate, very coarse subangular blocky; slightly firm; few medium roots; few coarse pores; few pale brown 10YR 6/3 mottles.

SOIL ANALYTICAL DATA

Depth in cm	Particle Size Distribution (%)				pH	%	
	Clay	Silt	Coarse Sand	Fine Sand		OC	N
0-2	29.8	33.3	5.9	25.7	4.0	2.89	0.27
2-30	23.9	31.7	5.1	35.2	4.3	0.60	0.06
30-90	30.6	27.3	4.0	33.6	4.4	0.19	0.03

Depth in cm	ppm		CEC in IN NH_4 OAC (Meq %)	Exchangeable Cations (Meq %)		
	Available P	Boron		K	Mg	Ca
0-2	23.5	2.4	16.53	0.21	0.71	0.22
2-30	10.0	3.4	7.60	0.07	0.06	0.01
30-90	12.1	1.6	9.07	0.06	0.02	0.01

Soil Profile No.:	6
Location:	Rentice No. 4; 75th chain
Soil Series:	Bekenu
Parent Material:	Shale/sandstone
Landform:	Hilly
Slope:	12 - 20°
Drainage:	Well-drained

Profile Description (Soil auger examination)

0 - 30 cm	Brownish yellow 10YR 6/6; fine sandy loam.
30 - 70 cm	Brownish yellow 10YR 6/6; fine sandy loam.
70 cm+	Brownish yellow 10YR 6/6; fine sandy loam.

SOIL ANALYTICAL DATA

Depth in cm	Particle Size Distribution (%)				pH	%	
	Clay	Silt	Coarse Sand	Fine Sand		OC	N
0-30	18.6	19.7	7.4	52.0	4.4	0.48	0.06
30-70	19.0	17.8	6.5	54.6	4.3	0.24	0.04
70-100	19.1	17.9	5.7	57.2	4.4	0.25	0.04

Depth in cm	ppm		CEC in IN NH_4 OAC (Meq %)	Exchangeable Cations (Meq %)		
	Available P	Boron		K	Mg	Ca
0-30	11.8	1.6	5.87	0.08	0.04	0.02
30-70	13.5	1.6	6.93	0.06	0.04	0.03
70-100	13.0	2.6	6.27	0.07	0.05	0.04

Soil Profile No.:	10
Location:	Rentice No. 8; 95th chain
Soil Series:	Nyalau
Parent Material:	Sandstone
Landform:	Undulating
Slope:	2 - 6°
Drainage:	Somewhat excessively drained

Profile Description (Soil auger examination)

20 - 60 cm	Pale brown 10YR 6/3; fine sandy loam.
60 - 100 cm	Pale brown 10YR 6/3; fine sandy loam; with few reddish yellow 7.5YR 6/6 mottles.

SOIL ANALYTICAL DATA

Depth in cm	Particle Size Distribution (%)				pH	%	
	Clay	Silt	Coarse Sand	Fine Sand		OC	N
20-60	9.9	15.2	5.5	64.6	5.0	0.40	0.02
60-100	9.7	14.4	6.2	65.4	4.2	0.86	0.06

Depth in cm	ppm		CEC in IN NH_4 OAC (Meq %)	Exchangeable Cations (Meq %)		
	Available P	Boron		K	Mg	Ca
20-60	13.0	3.4	2.93	0.06	0.05	0.05
60-100	14.5	3.8	3.60	0.12	0.08	0.04

Soil Profile No.:	3
Location:	Rentice No. 6; 100th chain
Soil Series:	Silantek
Parent Material:	Sandstone
Landform:	Gently undulating
Slope:	2
Drainage:	Excessively drained

Profile Description (Soil auger examination)

Ah_1	0 - 10 cm	Dark reddish grey 5YR 4/2; fine loamy sand; slightly brittle.
Ah_2	10 - 25 cm	Brown to dark brown 7.5YR 4/2; fine loam sand; very friable to loose.
Ae	25 - 100 cm	White 10YR 8/1; fine loamy sand; loose; structureless; with few patchy organic acid coatings.

SOIL ANALYTICAL DATA

Depth in cm	Particle Size Distribution (%)				pH	%	
	Clay	Silt	Coarse Sand	Fine Sand		OC	N
0-10	7.5	12.8	17.9	59.1	4.7	1.65	0.10
10-25	4.9	10.8	21.0	58.8	4.6	0.82	0.06
25-100	4.3	13.9	20.0	59.4	4.8	0.19	0.01

Depth in cm	ppm		CEC in IN NH_4 OAC (Meq %)	Exchangeable Cations (Meq %)		
	Available P	Boron		K	Mg	Ca
0-10	25.0	3.4	4.53	0.10	0.28	0.17
10-25	20.0	3.4	1.73	0.04	0.09	0.07
25-100	16.0	1.2	1.33	0.01	0.01	0.05

Soil Profile No.:	12
Location:	Rentice No. 9; 75th chain
Soil Series:	Ajoh
Parent Material:	Alluvial
Landform:	Valley floor
Slope	$<1^{o}$
Drainage:	Somewhat poorly drained

Profile Description

0 - 20 cm	Light grey 10YR 7/1; clay loam; many reddish yellow 7.5YR 6/8 and brownish yellow 10YR 6/8 mottles.
20 - 40 cm	Light grey 10YR 7/1; clay loam; many reddish yellow 7.5YR 6/8 mottles.
40 - 60 cm	Light grey 10YR 7/1; clay; many yellowish red 5YR 4/6 mottles.
60 - 100 cm	As above; fine sandy clay loam.

SOIL ANALYTICAL DATA

Depth in cm	Particle Size Distribution (%)				pH	%	
	Clay	Silt	Coarse Sand	Fine Sand		OC	N
0-20	26.6	47.5	0.7	21.9	4.0	1.95	0.23
20-40	38.1	37.4	0.5	20.8	4.2	0.66	0.08
40-60	39.8	36.7	5.1	15.2	4.6	0.50	0.06
60-100	19.9	20.5	0.7	56.0	4.7	0.53	0.07

Depth in cm	ppm		CEC in IN NH_4 OAC (Meq %)	Exchangeable Cations (Meq %)		
	Available P	Boron		K	Mg	Ca
0-20	21	3.0	14.67	0.22	0.32	0.13
20-40	14	2.6	9.47	0.16	0.16	0.04
40-60	12	1.2	12.00	0.16	0.15	0.03
60-100	11	2.6	8.27	0.13	0.12	0.05

MAP 1

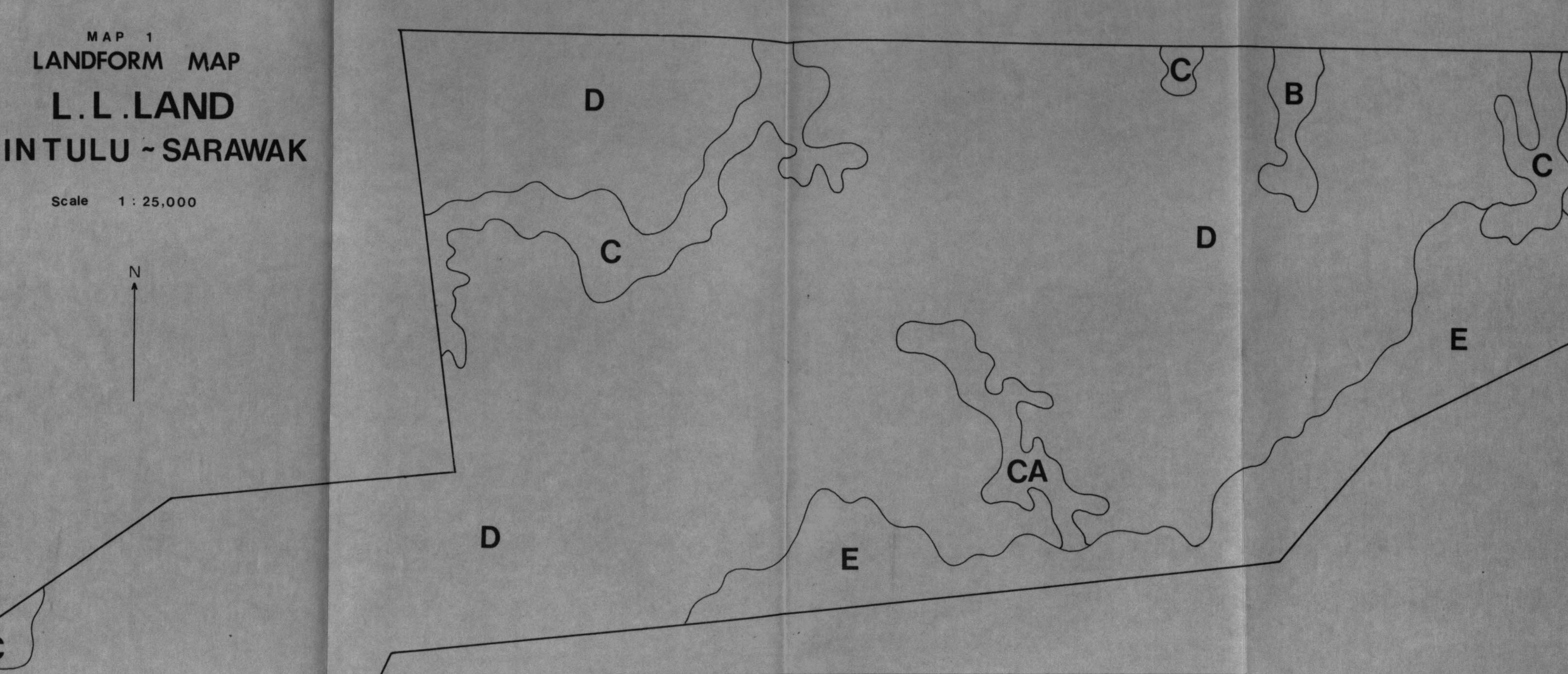
LANDFORM MAP

L.L.LAND

INTULU ~ SARAWAK

Scale 1 : 25,000

N



	LANDFORM	TERRAIN CLASS	SLOPE (degree)	REMARKS
A	LOW LYING FLAT	flat ; depressional ; very poorly - drained	0 - 2	backswamp ; water-logged
B		flat ; valley floor ; poorly to imperfectly drained	0 - 2	frequent flooding
C		river terrace ; levee ; moderate to well drained	0 - 2	short duration flooding ; with deeply incised streams
D	LOW HILLS	undulating to low hilly	2 - 20	slight to moderately dissected ; occassional steep escarpments
E		steep	> 20	moderate to strongly dissected with steep slope ; occassional steep escarpments

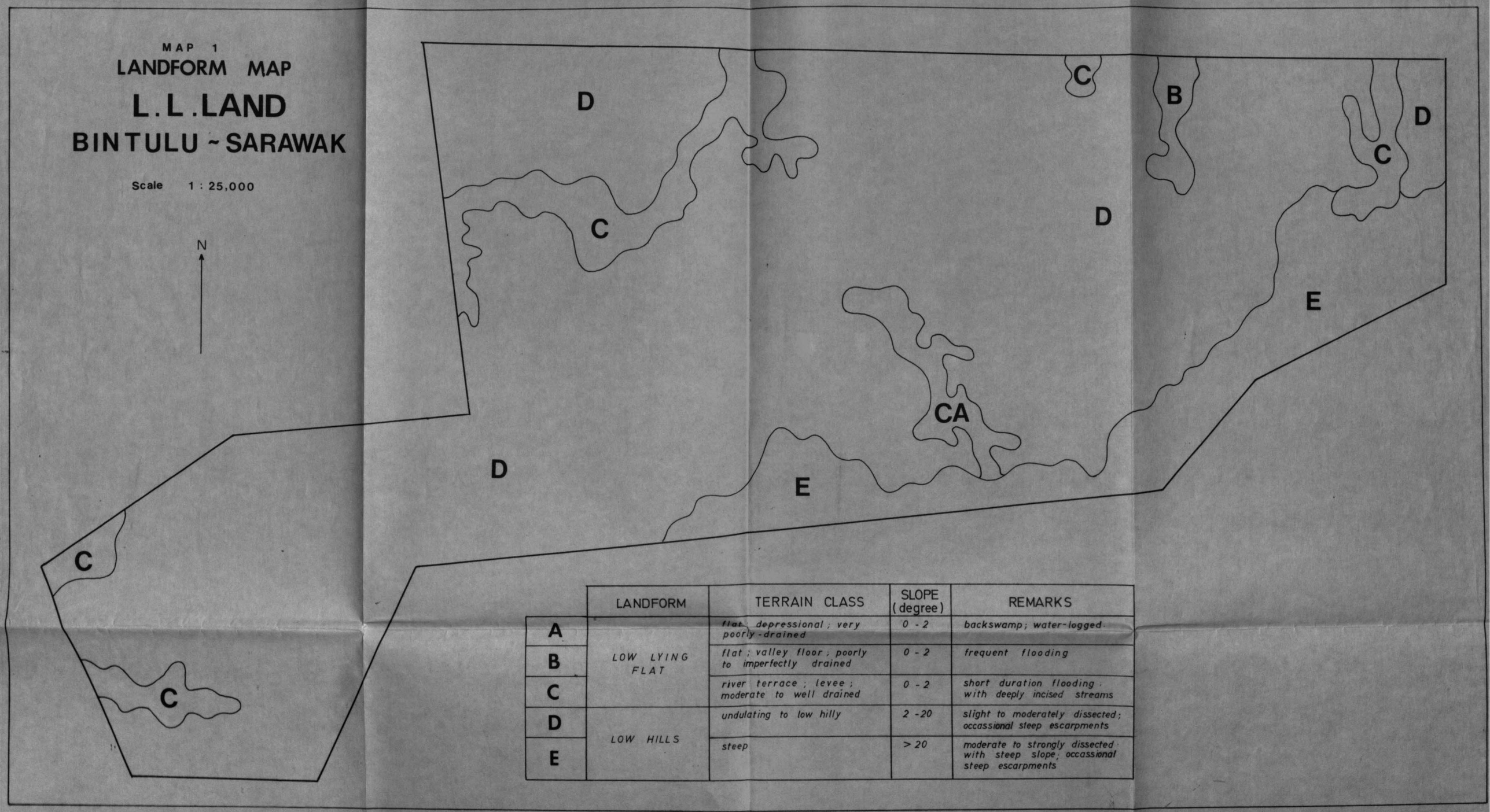
MAP 1

LANDFORM MAP

L.L.LAND

BINTULU ~ SARAWAK

Scale 1 : 25,000



	LANDFORM	TERRAIN CLASS	SLOPE (degree)	REMARKS
A	LOW LYING FLAT	flat ; depressional ; very poorly-drained	0 - 2	backswamp; water-logged
B		flat ; valley floor ; poorly to imperfectly drained	0 - 2	frequent flooding
C		river terrace ; levee ; moderate to well drained	0 - 2	short duration flooding ; with deeply incised streams
D	LOW HILLS	undulating to low hilly	2 -20	slight to moderately dissected; occassional steep escarpments
E		steep	> 20	moderate to strongly dissected with steep slope; occassional steep escarpments

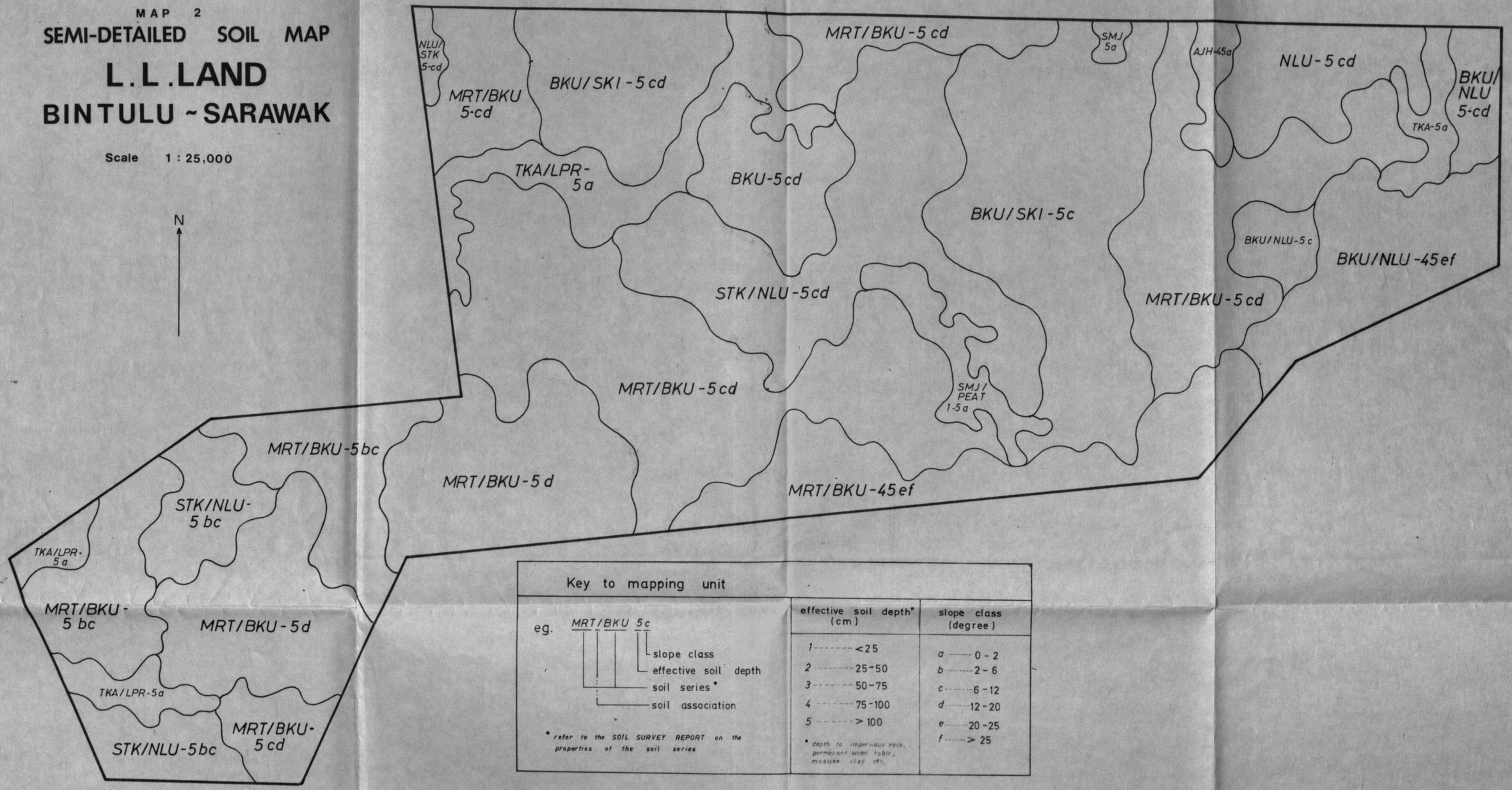
MAP 2

SEMI-DETAILED SOIL MAP

L.L.LAND

BINTULU ~ SARAWAK

Scale 1 : 25,000



Key to mapping unit

eg. MRT/BKU 5c

- 5c: slope class, effective soil depth
- MRT/BKU: soil series*
- MRT/BKU 5c: soil association

* refer to the SOIL SURVEY REPORT on the properties of the soil series

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

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

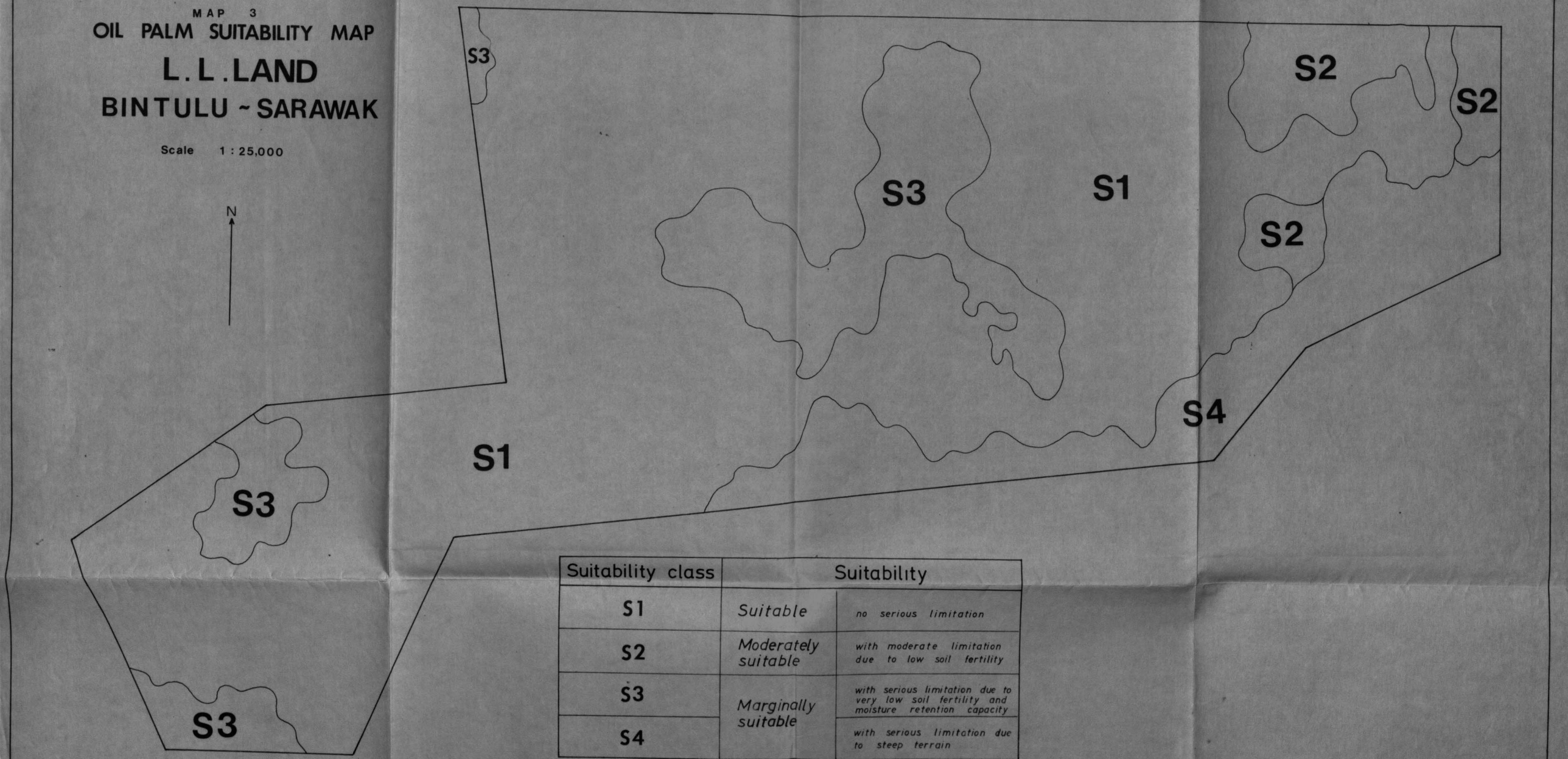
MAP 3

OIL PALM SUITABILITY MAP

L.L.LAND

BINTULU ~ SARAWAK

Scale 1 : 25,000



Suitability class	Suitability	
S1	Suitable	no serious limitation
S2	Moderately suitable	with moderate limitation due to low soil fertility
S3	Marginally suitable	with serious limitation due to very low soil fertility and moisture retention capacity
S4		with serious limitation due to steep terrain