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Rainfall

Temperature

Humidity

SEMI-DETAILED SOIL SURVEY

4601 HECTARES IN SIMILAJAU

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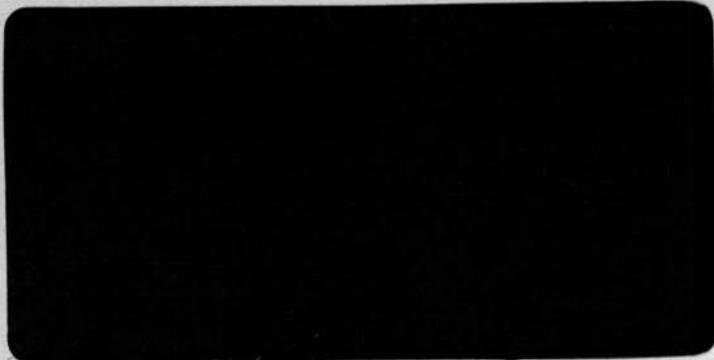
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LOCATION

SURVEYS: MALAYSIA
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Sime Darby Services

Sime Darby Plantations

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1.0	PHYSICAL ENVIRONMENT	
1.1	Location and Extent	
1.2	Geology	
1.3	Landform	
1.3.1	Alluvial Landform	
1.3.2	Hilly Landform	
1.4	Vegetation	
1.5	Climate	
1.5.1	Rainfall	
1.5.2	Temperature	
1.5.3	Humidity	
1.6	Hydrology	
2.0	SOILS	
2.1	Methods of soil survey	
2.2	Soil Classification/Units	
2.3	Soils of the Damaged Area	
2.3.1	Merit series	
2.3.2	Kepong series	
2.3.3	Prepared for :	
2.3.4	Pekan series	
2.3.5	Sibu series	
2.3.6	Kayan series	
2.3.7	Hari series	
2.3.8	Anderson series	
2.4	Summary of Soil Properties	

SEMI-DETAILED SOIL SURVEY

4601 HECTARES IN SIMILAJAU

Prepared for :
Sarawak Oil Palm Sdn. Bhd.

October 1989

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CONTENTS

	Pages
SUMMARY	(i) - (ii)
1. PHYSICAL ENVIRONMENT	1 - 21
1.1 Location and Extent	1
1.2 Geology	1
1.3 Landform	1
1.3.1 Alluvial Landform	5
1.3.2 Hilly Landform	5
1.4 Vegetation	6
1.5 Climate	6
1.5.1 Rainfall	10
1.5.2 Temperature	10
1.5.3 Humidity	10
1.6 Hydrology	20
2. SOILS	22 - 40
2.1 Method of soil Survey	22
2.2 Soil Classification Units	25
2.3 Soils of the Surveyed Area	25
2.3.1 Merit series	25
2.3.2 Bekenu series	28
2.3.3 Nyalau series	30
2.3.4 Pakan series	32
2.3.5 Similajan series	34
2.3.6 Kayan series	34
2.3.7 Miri series	36
2.3.8 Anderson series	39
2.4 Summary of Soil Properties	39

	Pages
3. LAND CAPABILITY CLASSIFICATION	41- 49
3.1 Method and Criteria	41
3.2 Landed Capability Classes	42
3.2.1 Capability classes of mineral soils	42
3.2.2 Capability classes of organic soils	46
3.3 Land Capability Sub-classes	47
3.4 Land Capability of the Surveyed Area	49
4. SUITABILITY FOR OIL PALM CULTIVATION	50
4.1 Climatic Requirement for Oil Palm Cultivation	50
4.2 Soil Requirement for Oil Palm Cultivation	50
5. SUITABILITY FOR OIL PALM CULTIVATION IN THE SURVEYED AREA	51 - 54
5.1 Climate suitability for oil palm cultivation	51
5.2 Suitability for oil palm cultivation	51
6. RECOMMENDATIONS	55
APPENDICES :	
1 - 2	Merit Series
3 - 7	Bekenu Series
8 - 9	Nyalau Series
10 - 13	Pakan Series
14	Similajau Series
15	Kayan Series
16	Miri Series
17 - 21	Merit Series
22 - 26	Bekenu Series

SUMMARY

1. The surveyed area consists of 4601 ha located about 50 km North East of Bintulu, Sarawak. It is readily accessible by road.
2. Vegetation is primarily secondary forest, which has been repeatedly logged-over. Pockets of Kerangas and peat forests were noted on very poor soils and wet peat respectively. No shifting cultivation was encountered.
3. The terrain ranges from flat to very gently undulating to rolling low hills. It is estimated that about 1518 ha (33%) of the area have slope 2 - 12 degrees and about 985 ha (21%) is flat. About 2080 ha (45%) have slope between 12 - 25 degrees and are plantable. The remaining 61 ha which have slope exceeding 25 degrees are too steep for cultivation.
4. Fine grained sandstone/sandy shale dominate the surveyed area. These are occasionally inter-bedded with argillaceous shale. Sandy riverine alluvium occupies the low lying flat.
5. The mean monthly rainfall exceeds 300 mm and are evenly distributed without a distinct dry period. Higher rainfall are recorded in November to January. Mean annual rainfall for 1981 - 1987 is 3695 mm with 218 raindays.
6. A total of eight dominant soil series have been identified and demarcated. These are classified as Merit, Bekenu, Nyalau, Similajau, Pakan, Kayan, Miri and Anderson series.
7. Soil of Merit, Bekenu and Nyalau series pose no serious limitation to oil palm cultivation, except where slope exceeds 25 or more. Soils of Pakan and Anderson series require drainage and proper water management. Soils of Miri series are very sandy and have an indurated layer occurring between 50 - 75 cm of the soil depth. No acid sulphate soil was encountered. About 30 ha of deep peat (> 2m) have been identified.

8. The hilly soils are well to excessively drained. These would require proper soil/water conservation measures to be put on as severe soil erosions are expected on steep terrain. The sandy soils are also vulnerable to moisture stress during prolonged dry period. The low lying flats are not likely to pose serious flooding problems. This is due to its sandy nature and the presence of numerous deeply-incised streams and river within the surveyed area. Water-table in the peat soil is high and flooding may occur during rainy period.
9. Most of the soils are low in plant nutrient reserves. Higher amount of fertilizer inputs, particularly K and Mg, will be required. Split application of fertilizer is also recommended.
10. The higher and evenly distributed rainfall are likely to off-set the minor limitations brought about by the sandy texture of the soils. Nevertheless, it is essential to implement soil/water conservation practices to conserve moisture and plant nutrients. These include mulching, establishment of leguminous cover, terracing on slope above 8 degree and silt pits on gentler slopes.
11. It is estimated that 4325 ha or 94% of the surveyed area are suitable for oil palm cultivation. The peat soil, if properly drained can also be planted with oil palm. The remaining 244 ha are either too steep or due to presence of unfavourable soil properties. They can only be planted with more intense management efforts and higher resource inputs.

1. INTRODUCTION

1.1 Location and Extent

The surveyed area covers an area of 1000 sq. km in the State of Karnataka, approximately 100 km from the city of Bangalore.

The area is bounded by the State of Karnataka to the north, south and west, and the State of Andhra Pradesh to the east. The area is bounded by the State of Karnataka to the north, south and west, and the State of Andhra Pradesh to the east. The area is bounded by the State of Karnataka to the north, south and west, and the State of Andhra Pradesh to the east.

1.2 Geology

The geology of the area is mainly composed of the Deccan Traps, which are of Tertiary age. The area is bounded by the State of Karnataka to the north, south and west, and the State of Andhra Pradesh to the east.

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1.3 Landforms

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1. PHYSICAL ENVIRONMENT

1.1 Location and Extent

The surveyed area consists of 4601 ha and is situated in the Bintulu Division, Sarawak, approximately at the bisection of 113 15' E and 3 25' N.

Accessibility to the area is via Miri/Bintulu main trunk road, about 50km north-east of Bintulu town. A network of well-maintained logging roads serves the area and is linked to the main trunk road about 4.8 km away. Map 1 shows the location of the area.

1.2 Geology

The dominant geology of the area is fine and medium grained sandstones, occasionally interbedded with sandy shales. They belong to the Nyalau formation of the Oligocene-Miocene epoch.

Recent riverine alluvium of the Pleistocene-Holocene epoch occupy the low lying flat. They consist mainly of sand with minor pockets of clay. A small area of peat is also present.

1.3 Landform

The surveyed area can be divided into 2 major landform units, viz; alluvial landform and hilly landform. The alluvial landform consists of alluvial plain, low terraces, river levee and recent riverine terraces. The hilly landform consists of gentle low hills with elevation below 50m and steep hills with elevation of above 50m.

Table 1 and Fig. 1 show the details of the various landforms and physiographic units. Their distribution and slope classes are shown in Maps 2 and 3 respectively.

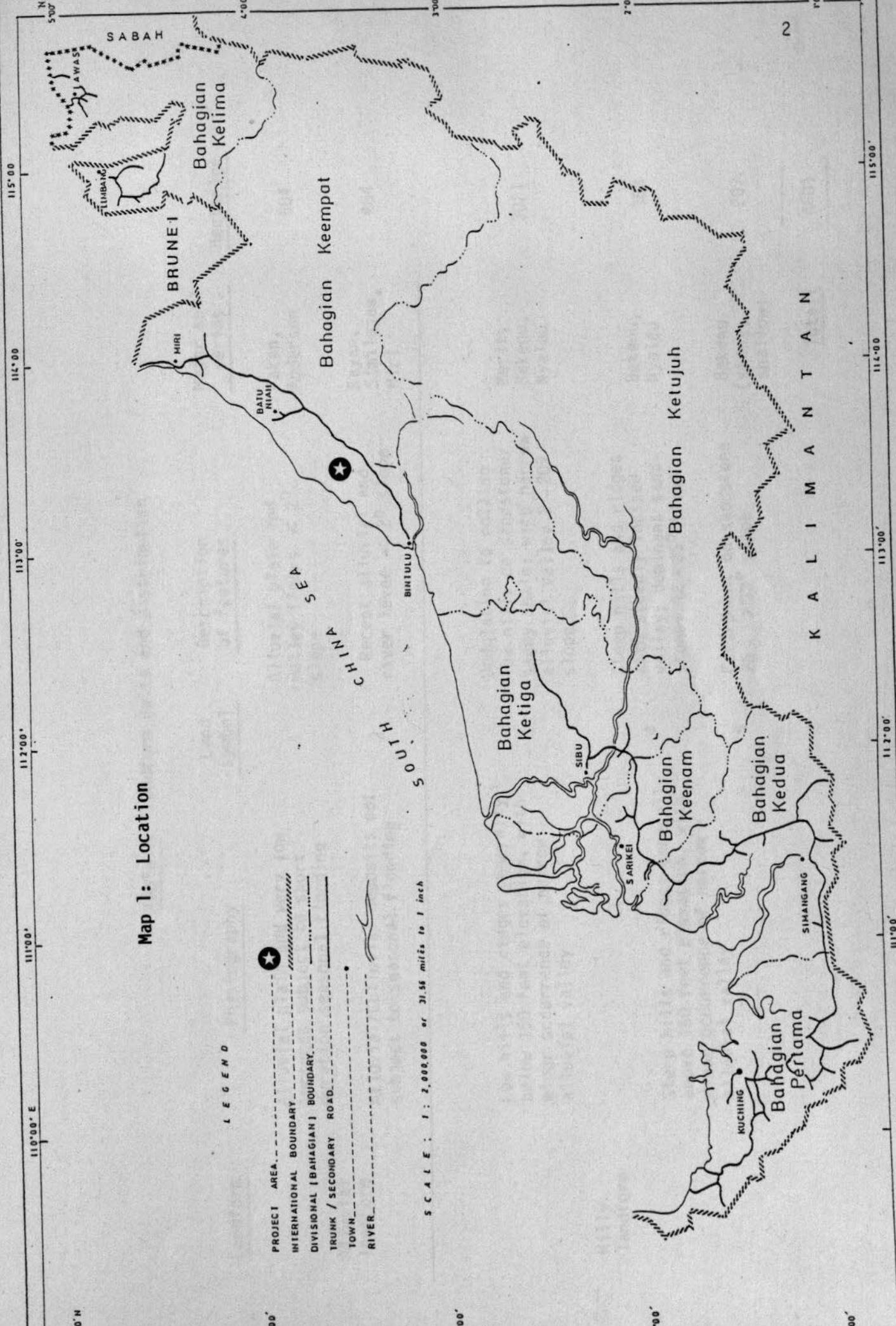
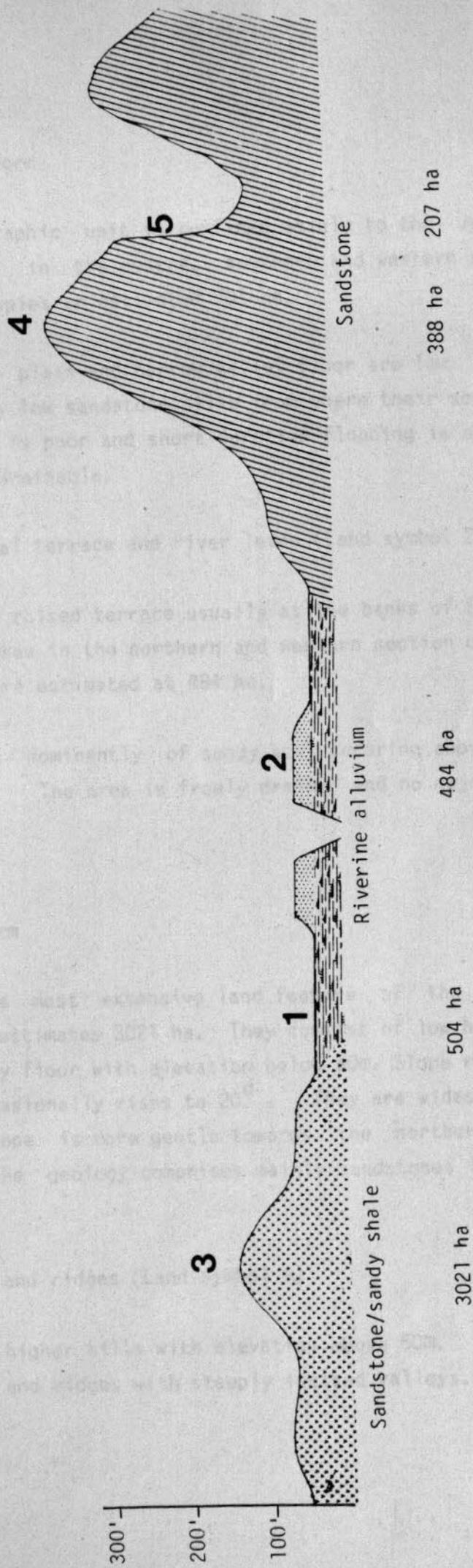


Table 1: Landform Units and Distribution

<u>Landform</u>	<u>Physiography</u>	<u>Land symbol</u>	<u>Description of features</u>	<u>Major soil series</u>	<u>Hectarage</u>
Alluvial landform	Alluvial plain and very low terraces subject to short duration seasonal flooding	1	Alluvial plain and valley floors < 2° slope	Pakan, Anderson	504
	Alluvial/Colluvial deposits not subject to seasonal flooding	2	Recent alluvial and river levee < 2° slope	Kayan, Similajau, Miri	484
Hilly landform	Low hills and ridges generally below 150 feet elevation, with minor occurrence of narrow alluvial valley	3	Undulating to rolling low hills on sandstone/sandy shale; with narrow alluvial valley 2 - 20° slope	Merit, Bekenu, Nyatau	3021
	Steep hills and ridges generally above 150 feet elevation, with minor occurrence of narrow alluvial valley	4	Steep hills and ridges with steeply incised valley; dominant sandstone; 12 - 25° slope	Bekenu, Nyalau	388
		5	Escarpment on sandstone 25 - > 33° slope	Bekenu (stony; shallow)	207
				<u>Total:</u>	<u>4601</u>

Fig. 1: Landform Units



1.3.1 Alluvial Landform

- a) This physiographic unit is confined mainly to the upper reach of Sungei Takau, in the centre, southern and western section of the area. It occupies an estimated 501 ha.

The alluvial plain and narrow valley floor are low lying and are surrounded by low sandstone hills from where their soils originated. The drainage is poor and short duration flooding is expected. They are however, drainable.

- b) Recent alluvial terrace and river levee (Land symbol 2)

These are the raised terrace usually at the banks of Sungei Simalajau and Sungei Takau in the northern and western section of the surveyed area. They are estimated at 484 ha.

It consists dominantly of sandy soil occurring above the present flood level. The area is freely drained and no major flooding is expected.

1.3.2 Hilly Landform

- a) This is the most extensive land feature of the surveyed area, covering an estimated 3021 ha. They consist of low hills, ridges and narrow valley floor with elevation below 50m. Slope ranges from 2° to 12° but occasionally rises to 20° . They are widespread throughout but the slope is more gentle towards the northern and southern section. The geology comprises mainly sandstones interbedded with sandy shale.

- b) Steep hills and ridges (Land symbol 4)

These are higher hills with elevation above 50m. They consist of steep hills and ridges with steeply incised valleys.

They have slope between 12° to 25° . Sandstone rock exposures are common in the valleys/streams. Steep hills and ridges occupy an estimated 388 ha and are found in the eastern section of the area.

- c) There are very steep escarpment on sandstones. They are confined to the eastern section and have an estimated 207 ha. Their slopes frequently exceed 25° and slopes with more than 40° are not uncommon. Sandstone rocks exposure are common, especially on the valleys/streams. They have shallower soils and are often stony.

1.4 Vegetation

The surveyed area is covered with logged-over hills and riverine forest of Dipterocarp species. They are primary vegetation comprising hill forest, riverine forest, kerangas (on infertile soil) forest and peat swamp. The various vegetation types are illustrated in Plates 1 - 4.

No shifting cultivation, re-generated forest or recent secondary growth was encountered at the time of the survey. A cocoa plantation was established to the south of the area.

The distribution and extent of the various vegetation types are presented in Map 4 and Table 2 respectively.

1.5 Climate

The climate of the area is hot and wet throughout the year. It is characterised by high rainfall, a relatively uniform temperature and high relative humidity. Meteorological data of Bintulu for 1915 to 1978 and 1981 to 1987 are available and presented. The climate is conducive for oil palm cultivation.



Plate 1: Logged Hill Forest



Plate 2: Logged Riverine Forest

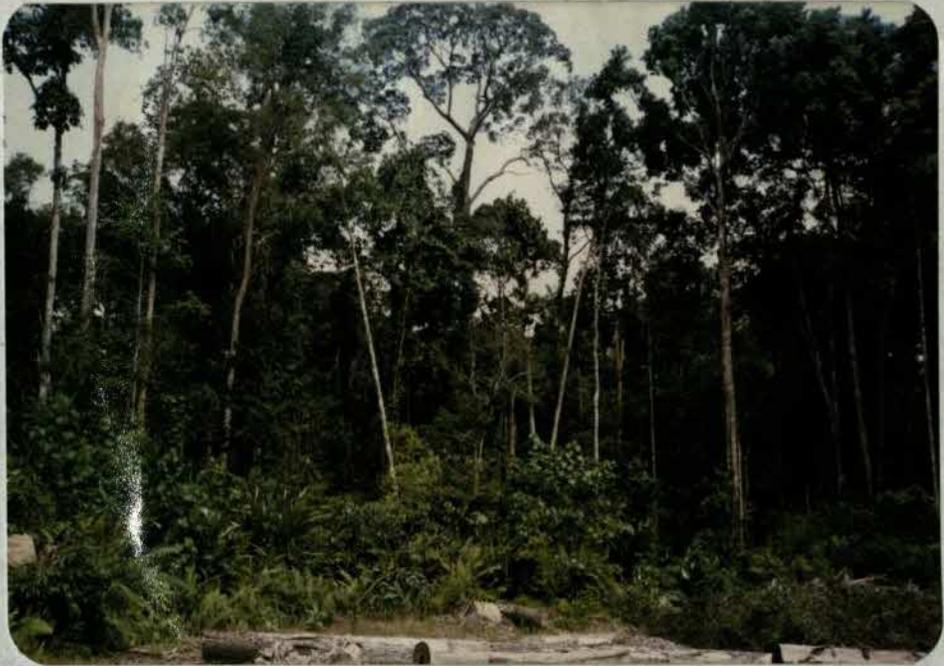


Plate 3: Kerangas Forest

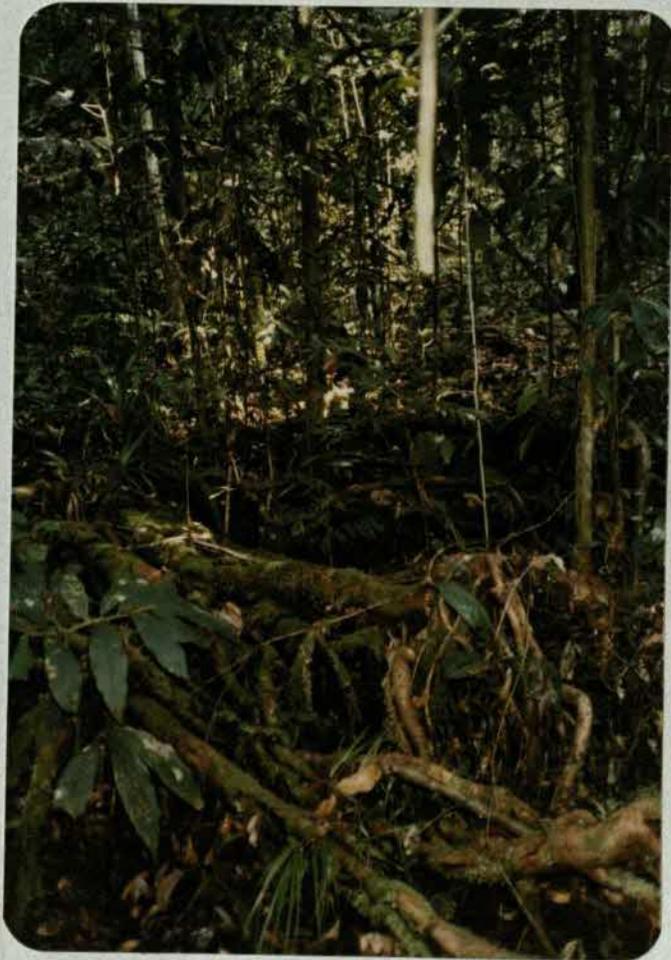


Plate 4: Peat Swamp Forest

TABLE 2: DISTRIBUTION AND EXTENT OF THE VARIOUS VEGETATION TYPES

<u>Vegetation Types</u>	<u>Distribution</u>	<u>Hectarage</u>
A. Logged-over hill-forest	Sandstone/shale hills	3616
B. Logged-over riverine forest	Poorly-drained sandy alluvium	845
C. Keranges forest	Infertile sandy podzol	110
D. Peat swamp forest	Peat Swamp	30

		4601

* Possibly with Keranges forest

1.5.1 Rainfall

Rainfall records of Bintulu are presented in Figs. 2a, 2b, 2c and Tables 3 and 4. The mean monthly rainfall is around 300mm. The isohyet map of average annual rainfall is shown in Fig. 3. The isohyet map shows the annual total rainfall of the surveyed area of between 3000 and 3500 mm.

The monthly precipitation is generally higher during the Northeast monsoon from October to January than during the Southeast monsoon from May to August. Higher rainfall are recorded in November/December. There is no distinct dry period, and lower monthly rainfall recorded generally exceeds 180 mm.

The rainfall distribution is conducive for oil palm planting and the lack of prolonged drought will ensure adequate moisture availability in the area where the soil is dominantly sandy texture.

1.5.2 Temperature

The temperature record from Bintulu is presented in Table 5 and Fig. 4. The mean annual temperature is 26.5°C (79.7° F) with little seasonal variations and diurnal variation is 7 degree celsius.

1.5.3 Humidity

Diurnal variation in relative humidity for Bintulu is presented in Fig.5. The relative humidity ranges between 70% to 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.

**Fig 2a: MEAN MONTHLY RAINFALL DISTRIBUTION
BINTULU - 1915 TO 1978**

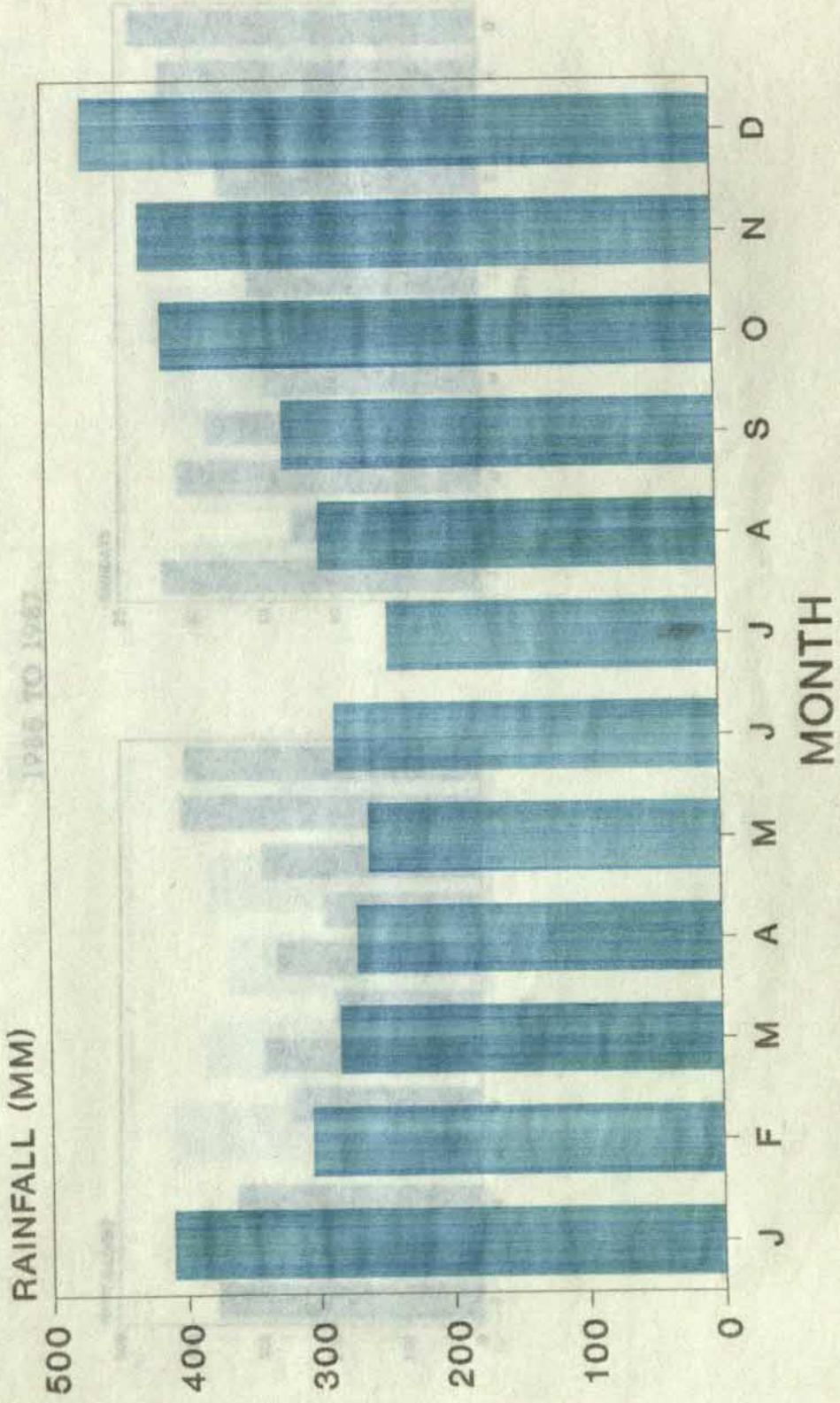


Fig 2b: MEAN MONTHLY RAINFALL AND RAINDAYS FOR BINTULU, SARAWAK

1985 TO 1987

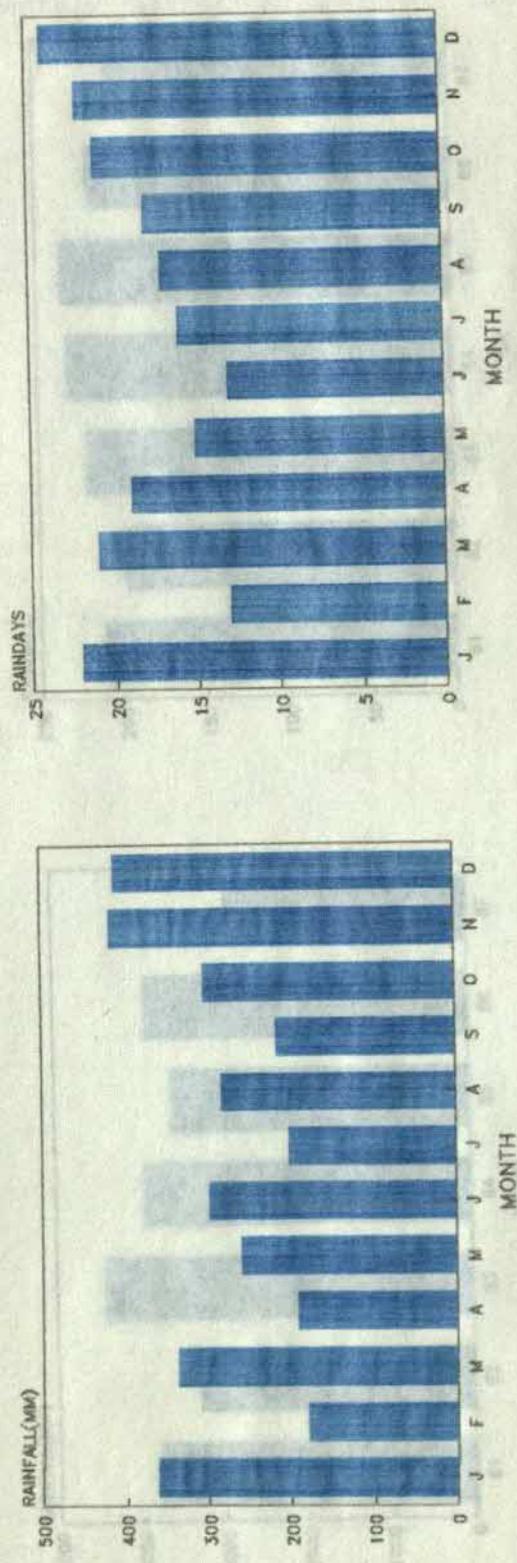


Table 3 Mean monthly rainfall and raindays for Bintulu, Sarawak (1985 - 1987)

Fig 2c: MEAN ANNUAL RAINFALL & RAINDAYS FOR BINTULU, SARAWAK 1981 TO 1987

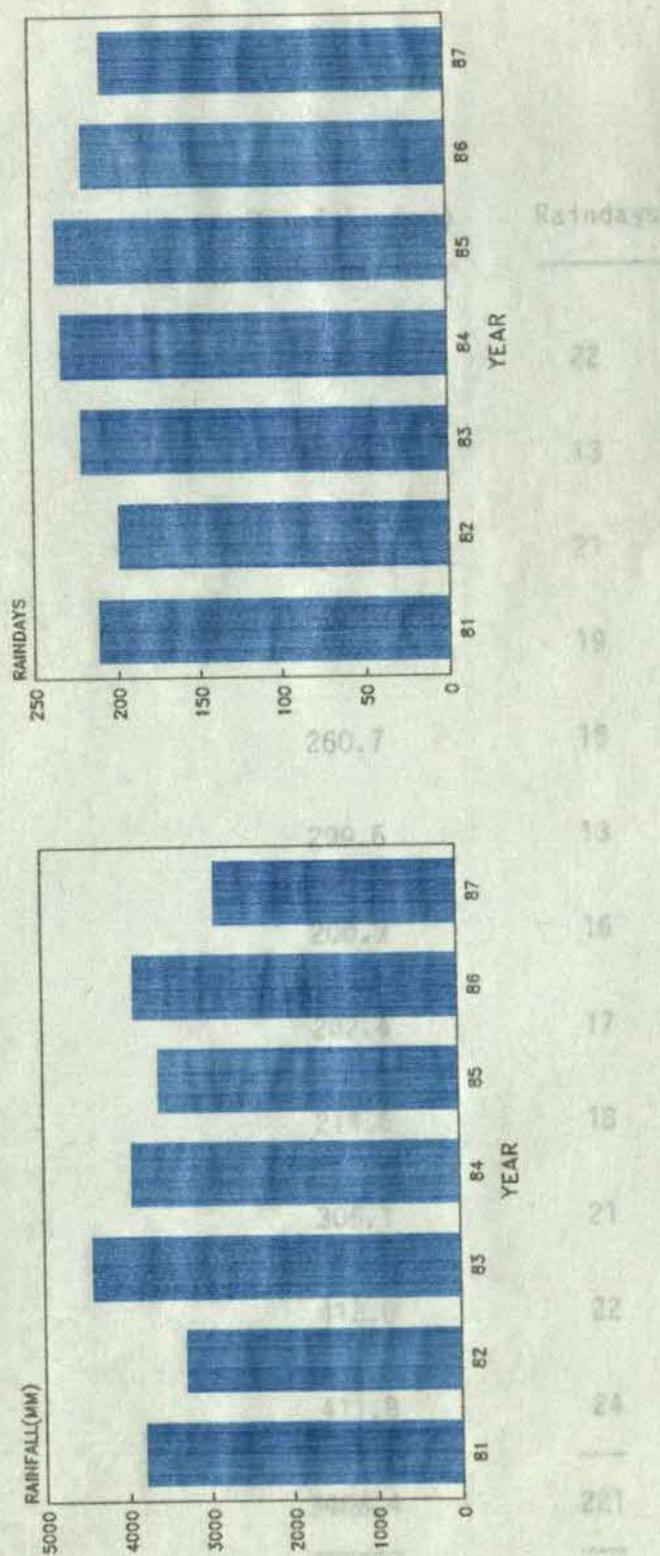


Table 3 Mean monthly rainfall and raindays for Bintulu, Sarawak
(1985 - 1987)

	Rainfall (mm)	Raindays
January	362.4	22
February	179.8	13
March	337.3	21
April	191.8	19
May	260.7	15
June	299.6	13
July	200.9	16
August	282.4	17
September	216.6	18
October	305.1	21
November	418.0	22
December	411.8	24
Total	3466.4	221

Table 4 Mean annual rainfall and raindays
for Bintulu, Sarawak (1981 - 1987)

Year	Rainfall (mm)	Raindays
-----	-----	-----
1981	3793.4	212
1982	2298.7	199
1983	4424.6	221
1984	3951.4	233
1985	3596.4	236
1986	3901.7	219
1987	2900.4	208
<hr/>		
Mean:	3695.2	218
<hr/>		

Table 5: Mean Monthly Temperature ($^{\circ}\text{C}$) for Bintulu⁽¹⁾

<u>Month</u>	<u>Bintulu</u>
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	<u>26.1</u>
Mean Annual	<u>26.5</u>

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

**Fig 4: MEAN MONTHLY TEMPERATURE FOR BINTULU
1972 TO 1981**



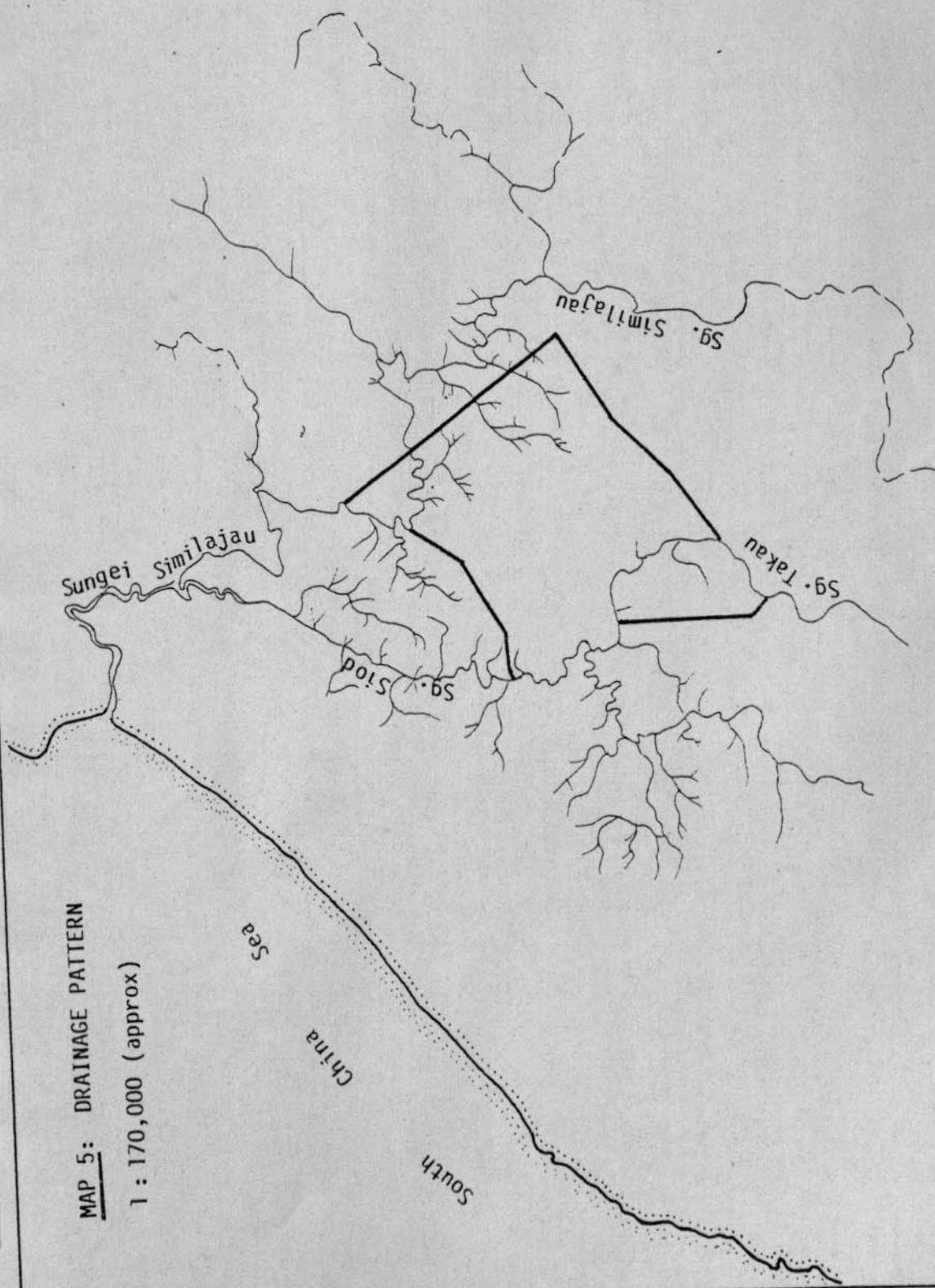
1.6 Hydrology

The surveyed area is drained by 2 main rivers. Sungei Similajau with its tributaries drain the Northern and eastern regions while Sungei Siod, which is joined to Sungei Takau, drains the Southern and Western region. Sungei Siod is joined to Sungei Similajau in the North and flows into the South China Sea about 15 km North of the surveyed area. The lower reach of Sungei Siod and Sungei Similajau are wide and deep (Plate 5) and are non-saline.

Map 5 shows the drainage systems of the surveyed area and its surrounding.



Plate 5 Sungei Similanjau



MAP 5: DRAINAGE PATTERN

1 : 170,000 (approx)

1947

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2. SOIL

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 direction. A total of 2141 chain or 55 km of rentices were cut in the surveyed area. The distribution of the rentices is shown in Map 6.

A total of 24 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 Map 6. The dimension of the soil pit are presented in Fig.6. Soil properties studied on these profiles included environmental features, soil colour, texture, consistency, structure, porosity, root distribution, etc. In addition to soil profile, soil auger hole 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).

62 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.

Ring samples were taken from 12 soil profiles of the dominant soil series for bulk density determination. From each horizon 3 ring samples were collected and the mean values are presented together with the analytical results in the Appendices.

Note : No ring samples for the top soil due to insufficient thickness.

Map 6: Rentis and Soil Examination Pits
Scale 1 : 100,000 (approx)

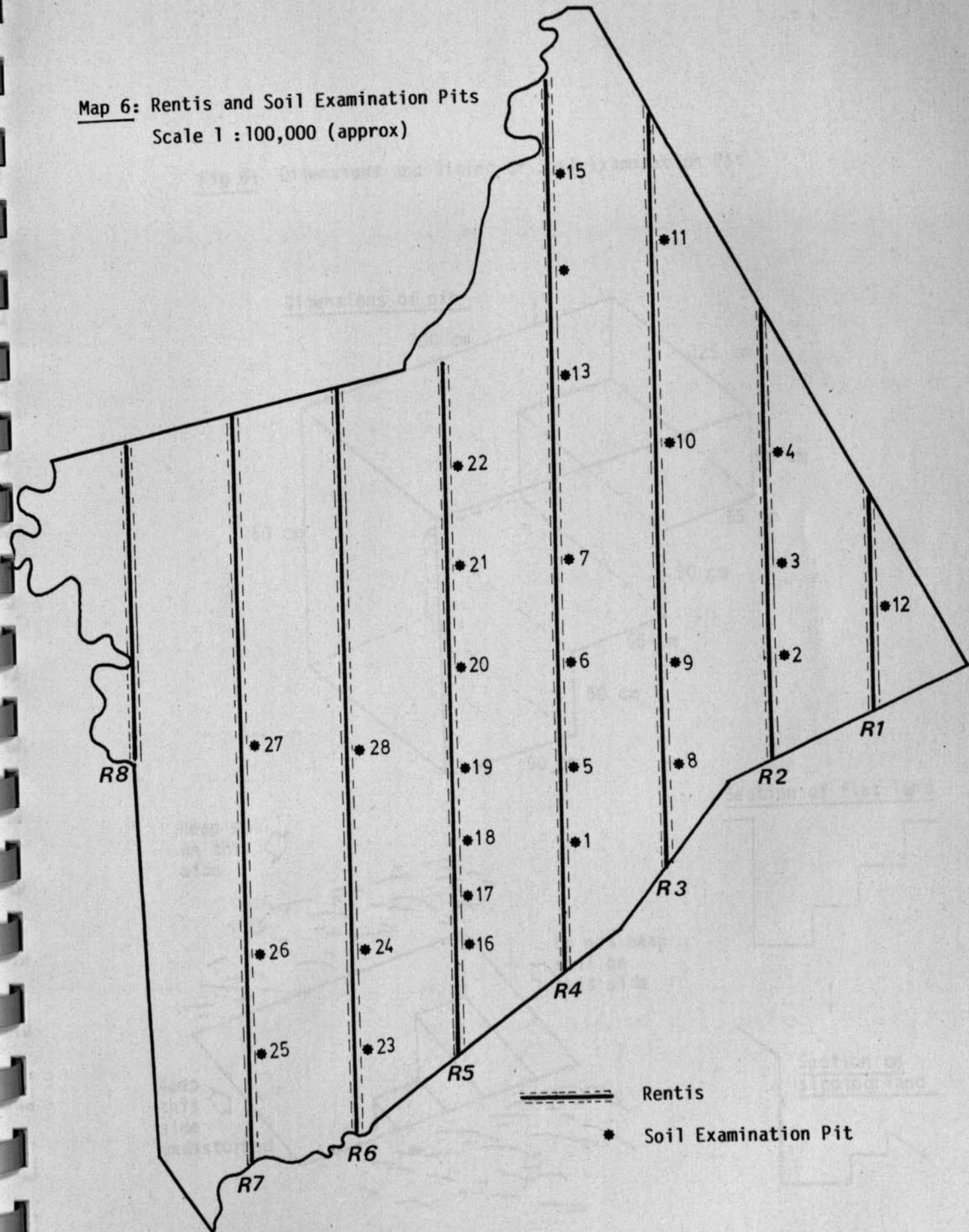
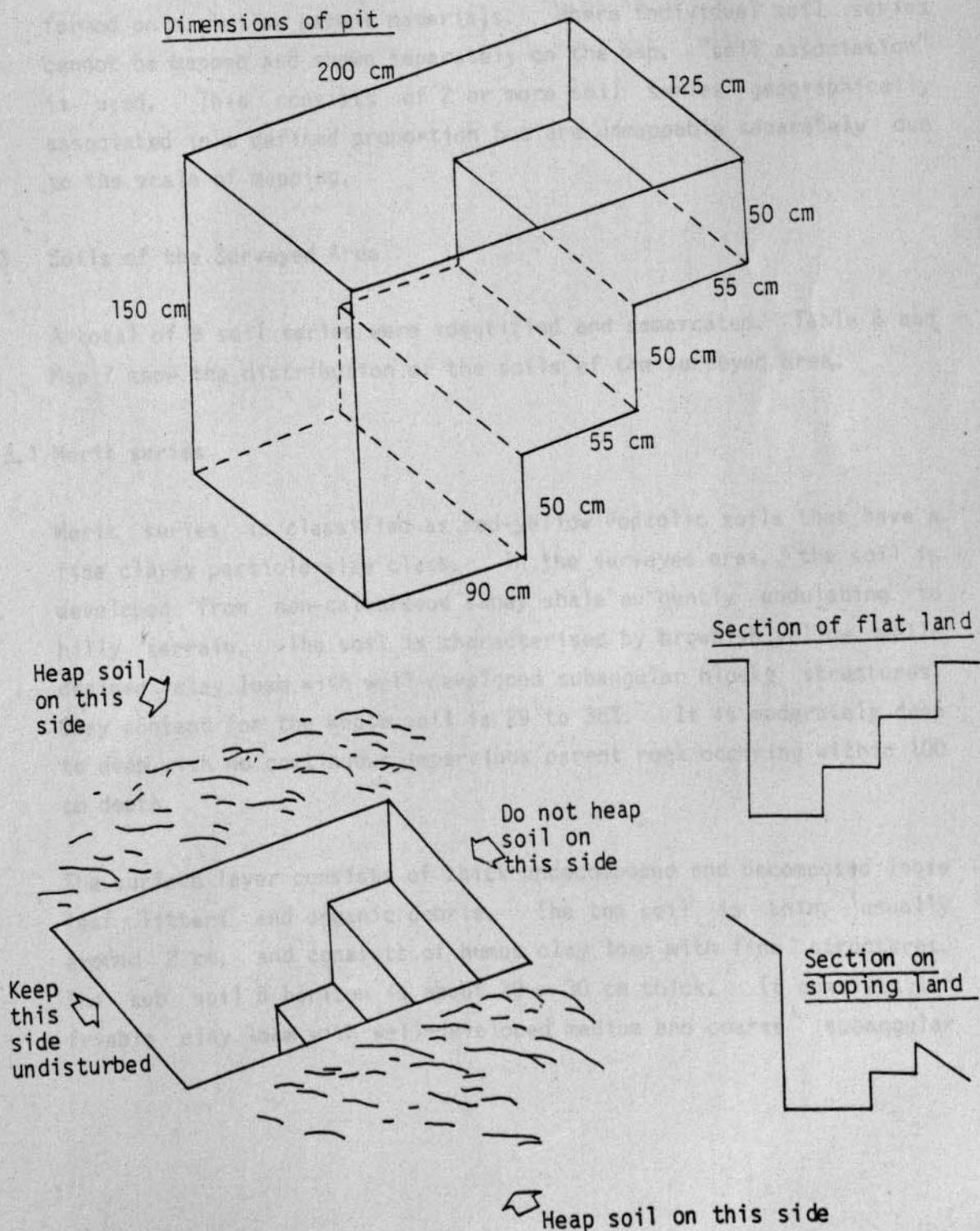


Fig 6: Dimensions and Siting of Soil Examination Pit



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 a similar parent materials. Where individual soil series cannot be mapped and shown separately on the map, "soil association" is used. This consists of 2 or more soil series 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 8 soil series were identified and demarcated. Table 6 and Map 7 show the distribution of the soils of the surveyed area.

2.3.1 Merit series

Merit series is classified as red-yellow Podzolic soils that have a fine clayey particle-size class. In the surveyed area, the soil is developed from non-calcareous sandy shale on gently undulating to hilly terrain. The soil is characterised by brownish yellow well-drained clay loam with well-developed subangular blocky structures. Clay content for the whole soil is 29 to 36%. It is moderately deep to deep with no continuous impervious parent rock occurring within 100 cm depth.

The surface layer consists of thick undecomposed and decomposed loose leaf litters and organic debris. The top soil is thin, usually around 2 cm, and consists of humus clay loam with fine structures. The sub soil B horizon is about 20 - 30 cm thick. It consists of friable clay loam with well-developed medium and coarse subangular

blocky structures. The clay content increases below the B horizon and ranges from 27 - 39%. Structures are well-developed with coarse subangular blocky and consistency is friable to slightly firm. Towards the lower depth within 100 cm, the structures are weakly developed with coarse and very coarse subangular blocky. The consistency is firm and the horizon is quite compact. Most roots are found above the compact layer. Weakly iron-coated shale gravels may be present at lower depth of the profile but these will not pose any serious limitation to root penetration.

Merit series soils are acidic with pH 3.9 - 4.1. Organic carbon for the top soils is 3.6 but decreases abruptly in the sub soil to < 1.0%. The soil has low CEC. 2:1 clay mineral appears present due to the high CEC/100 gm clay of around 40 meq. Total exchangeable cations are very low, particularly the sub soil, indicating the soil is devoid of nutrients.

High rates of balance fertilizers will be needed in view of the high rainfall of the area. Split application of fertilizer is to be recommended. The presence of 2 : 1 clay, however, will improve the nutrients retention to certain extent which otherwise may be lost through leaching.

Plate 6 shows the typical profile of a Merit Series Soil

TABLE 6: Estimated soil hectarage of various soil series/association.

<u>Soil series/Association</u>	<u>Slope (degree)</u>	<u>Estimated hectarage</u>
Anderson	< 2	30
Pakan	< 2	471
Similanjau/Kayan	< 2	374
Miri	< 2	110
Merit	2 - 6	84
	2 - 12	86
	6 - 20	123
	12 - 25	7
		<u>300</u>
Merit/Bekenu	2 - 6	382
	2 - 12	204
	6 - 20	429
	6 - 12	43
		<u>1058</u>
Bekenu	2 - 6	34
	6 - 12	25
	2 - 12	206
	6 - 20	266
	12 - 20	6
	12 - 25	226
	20 - 25	6
	25 - >33	61
		<u>830</u>
Bekenu/Nyalau	2 - 6	43
	2 - 12	22
	6 - 20	572
	12 - 20	87
	12 - 25	101
	20 - 25	42
	20 - 33	146
		<u>1013</u>
Nyalau	2 - 6	179
	2 - 12	210
	6 - 20	26
		<u>415</u>

2.3.2 Bekenu series

Bekenu series is classified as red-yellow Podzolic soils that have a fine loamy particle-size class. It is developed on sandstone/sandy shale and occurs on undulating to very steep terrain. The soil has a clay content of between 20 - 25%.

The surface A horizon consists of decomposed and undecomposed organic matter. The top soil A horizon consists of dark brown to yellowish brown fine sandy clay loam with friable fine structure. The B horizon consists of yellowish brown to brownish yellow fine sandy clay loam. Structures are moderately developed with medium and coarse subangular blocky structures and friable consistency. Organic acid coating are present on most ped surfaces. Sub soil B2 horizon is deep, usually extending to below 100 cm. It consists of predominantly brownish yellow fine sandy clay loam with clay content of 25%. Structures are developed with medium and coarse subangular blocky and consistency is friable but becoming firmer with depth. The structures are less developed but more friable as compared to the corresponding horizons in the associated Merit series. Root penetration is deep but is decreasing with depth. Some gravels of iron-coated shales and undecomposed stony parent rocks may be present, usually in the lower depth of the sub soil. They pose no serious limitation to root penetration.

Bekenu series soils are acidic with pH 3.8 - 4.2. Top soil organic carbon content is higher at 2.2% but decreases abruptly to 0.8 and 0.2 in the sub soils. The total exchangeable cations are low and are lower than those of Merit series. The CEC for the sub soil is low at 8 meq/100 gm soil.

Plate 7 shows the typical profile of a Bekenu Series Soil.



Plate 6: Merit Series

2.3.3 Nyalau series

Nyalau series is classified as Red-Yellow Podzolic soils that have a yellow coarse loamy particle-size class. It is developed on sandstones and in the surveyed area, occurs on very gently undulating to rolling terrain. It is often associated with soils of Bekenu series on a steeper terrain at higher elevation. The soil is characterised by the very sandy texture and brownish yellow sub soil colour.

The top soil consists of a thin layer of brown to yellowish brown friable fine sandy brown with moderately developed fine structure. The B1 horizon consists of brownish yellow to yellowish brown fine sandy loam. Structures are moderate to weakly developed and consistency is very friable. The underlying B2 horizon consists of brownish yellow to strong brown fine sandy loam with clay contents of 18%. It has a weakly developed coarse structures and very friable consistency. Gravels are rare and uncommon. The soil has a rapid permeability with excessive drainage.

Nyalau soils are acidic with pH 4.0 to 4.4. This sandy soils is very low in total exchangeable bases and is particularly low in the sub soil. In view of the low soil fertility and expected high leaching loss of soil nutrients, higher amounts of balance fertilizer at more frequent application is to be recommended. The expected low moisture retention capacity is however compensated by the generally



Plate 7: Bekenu Series

high and evenly distributed rainfall of the area, thus lowering the incidence of moisture stress. Nevertheless, moisture conservation measures, such as establishment of leguminous covers and mulching with empty fruit bunches (EFB) will be beneficial.

A typical profile of a Nyalau Serie Soil is shown in Plate 8.

2.3.4 Pakan series

Pakan series is classified as Clay soil that have a loamy particle-size class developed on accreting riverine alluvial. The soil is characterised by the sandy texture and greyish sub soil colour. The soil is found in the low lying flat and is subject to short duration seasonal flooding.

The top soil consists of about 3 to 5 mm thick of yellowish brown sandy loam with moderately developed fine structures. This is underlain immediately by the characteristic greyish sub soil with fine sandy loam texture. Clay content for the whole soil is around 15%. Structures are weakly developed with coarse subangular blocky breaking easily into medium and fine structures. Consistency is friable throughout the profile. Common yellowish brown mottles occurs from the upper part of the profile and extends towards the lower depth. Water-table for soils of Pakan series fluctuates according to season and short duration flooding may be expected during continuous rainy days. However, due to the sandy nature of the soils and presence of numerous deeply-incised streams/rivers, the soil can be easily drained.

Pakan soils are acidic with pH 4.1 to 4.7. Total exchangeable bases are low and CEC is very low at 5 meq %. The total exchangeable bases are however higher than soils of Merit, Bekenu and Nyalau series. This is probably due to the accreting nature of the alluvium.

Plate 9 shows the typical profile of a Pakan Series Soil.



Plate 8: Nyalau Series

2.3.5 Similajau series

Similajau series is classified as Alluvial Soils with coarse loamy particle-size class. In the surveyed area, it is developed in alluvium derived from sandstone. Its occurrence is confined mainly along the banks of Sungei Similajau and Sungei Takau. The level soil is characterised by the sandy loam texture, yellowish colour and weak structural development.

The top soil consists of brown fine sandy clay loam with fine structures. The upper part of sub soil is yellowish brown fine sandy loam with friable consistency. The sub soil is deep, extending to below 100 cm with no pebbles or stones. It consists of brownish yellow fine sandy loam with friable consistency. Some mottles may be present at the lower depth. Soils of the Similajau series are developed on the levee of the river bank and are somewhat excessively drained. Frequent flooding is not expected except very wet period.

The soil is acidic with pH 3.9 to 4.2. The CEC is low and the total exchangeable bases are similar to soils of Pakan series and are higher than soils of Merit, Bekenu and Nyalau series.

2.3.6 Kayan series

Kayan series is classified as Arenaceous Soils that have developed in accreting riverine alluvium and have a yellowish colour class. It is also a levee soils found in association with soils of Similajau series. The physiographic properties are similar to Similajau series.

The top soil is sandy, and consist of yellowish brown fine structures. The B1 horizon is yellowish brown fine sand with moderately weak structures. The sub soil is very deep, extending to below 100 cm, and consists of yellow fine sand with weak coarse structures. Consistency for the whole soil is very friable but top soil is brittle when dried. Faint pale brown mottles may be encountered at the lower depth of the sub soil.



Plate 9: Pakan Series

Kayan series soils are acidic with pH 4.4 to 4.8. The soils have a low total exchangeable bases and the CEC is very low at 3 meq%. High amount of balance fertilizer in split applications will be required to sustain satisfactory oil palm growth.

A typical profile of Kayan Series Soil is shown in Plate 10.

2.3.7 Miri series

Miri series is classified as Podzols in which the spodic horizon is strongly indurated and is developed in non-accreting alluvium. It is characterised by white-coloured fine sand with an indurated spodic horizon within 75 cm depth.

The top soil consists of dark reddish brown fine sand with weak fine structure. The sub soil consists of white to pale brown fine sand with weakly developed coarse structures. Consistency is friable but the horizon becomes more compact with depth. At depth between 50 to 75 cm is a layer of dark yellowish brown to brown illuviated organic sand which is strongly indurated. This layer is almost impervious to water and is not penetrable by roots.

The soil has very low levels of major and minor plant nutrients and CEC is extremely low. Oil palm growth is expected to be stunted with symptoms of multiple nutrient deficiencies. High amounts of balance nutrients and trace elements will be required and more frequent applications are recommended.

A typical profile of Miri Series Soil is shown in Plate 11.



Plate 10: Kayan Series



Plate 11: Miri Series

2.3.8 Anderson series

Anderson series is classified as Organic Soils that have more than 150 cm of organic materials. The deep peat occurs in the localised depression and have water table at or near to the surface. It is very poorly drained and consists of partly decomposed organic debris intermixed with some undecomposed plant fragments. In the surveyed area the underlying clay layer is wet at below 2 m.

2.4 Summary of Soil Properties

A summary of some salient soil and physiographic properties of the surveyed area is presented in Table 7.

TABLE 7: SUMMARY OF PROPERTIES OF SOIL SERIES

SOIL SERIES	PARENT MATERIAL	TOPOGRAPHY	CLAY % FOR:		SOIL pH		BASE SATURATION %		TOTAL EXCH. BASE (MEQ %)		TEC MEQ %		EFFECTIVE SUP-SOIL	SOIL DAMAGE	REMARKS
			WHOLE SOIL	TOP SOIL	TOP SOIL	SUB-SOIL	TOP SOIL	SUB-SOIL	TOP SOIL	SUB-SOIL	TOP SOIL	SUB-SOIL			
Merit	Sandy shale	Gently undulating to rolling, occasionally hilly.	33	3.7-4.2	4.0-4.2	6-43	2-13	1.0-7.3	0.3-2.1	17	11-15	>75	Well drained	With or without stony at depth and shallow on steep slope; severely eroded on slope.	
				3.9	4.1	25	5	4.2	0.7						
Bekenu	Sandy shale/Sandstone	Gently undulating to hilly, occasionally steep to extremely steep.	23	3.4-4.5	3.9-4.5	4-10	2-6	0.6-1.0	0.2-0.4	8-22	6-13	>75	Well drained	With or without stony at depth and shallow on steep slope; severely eroded on slope.	
				3.8	4.2	6	3	0.8	0.3	14	8				
Ryalau	Sandstone	Gently undulating to hilly, occasionally steep to very steep.	18	3.9-4.2	4.3-4.4	3-9	3-6	0.4-1.2	0.2-0.3	11-13	6-8	>75	Well to excessively	With or without stony at depth and shallow on steep slope; severely eroded on slope.	
				4.0	4.3	6	4	0.8	0.3	12	6				
Pakan	Alluvium	Low lying flat	14	3.9-4.5	4.2-4.8	11-33	5-46	1.5-2.5	0.3-1.5	6-14	3-9	>100	Poorly drained	Water-table fluctuates; high water table rainy days.	
				4.1	4.4	18	14	1.8	0.6	10	5				
Siatajau	Alluvium	Slightly raised; flat	18	3.9-4.5	4.0	22	8-9	2.7	0.4-0.8	12	6-9	>100	Excessively drained	Water-table below 75 cm; very sandy soil	
				4.1	4.0		9	0.6			7				
Kayan	Alluvium	Slightly raised; flat	9	4.2-4.8	4.5	15	8-19	1.1	0.2-0.5	7	2-3	>100	Excessively drained	Water-table below 75 cm; very sandy soil	
				4.4	4.5		12	0.3			3				
Miri	Alluvium	Raised; flat	5	4.2	4.9	42	16	3.3	0.2	8	1	<75	Excessively drained	Indurated layer at 50-75 cm; perched water table at 50-75 cm during rainy days; easily drained.	

Note: Figures given are ranges on top and averages below.

LAND QUALITY CLASSIFICATION

Classification Criteria

The system was developed to evaluate the land quality classes based on the physical and chemical properties of the soil. The classification is based on the following criteria:

The system is based on the following criteria:

- Depth to water table
- Soil texture class
- Depth to surface layer (0-10 cm)
- Depth of organic layer
- Amount of groundwater table
- Groundwater quality
- Fertility status
- Fertility of surface layer
- Degree of humification
- Nutrient holding capacity
- Slope
- Aspect
- Degree of erosion (0-100%)
- Distance from top of slope (%)

The system is based on the following criteria:

The system is based on the following criteria:

3. LAND CAPABILITY CLASSIFICATION

3.1 Method and Criteria

The method and criteria used in assessing the land capability classes of the surveyed area are in accordance to the "Sarawak Land Capability Classification and Evaluation for Agricultural Crop" by E. F. Maas et al (2nd edition, 1986).

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) Moderated : 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 8 and 9 presents the limiting factors for crop growth and degree of limitations for mineral soils and organic soils respectively.

3.2 Land Capablity Classes

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

3.2.1 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 8. LIMITATIONS TO CROP SUITABILITY ON MINERAL SOILS

Symbol	Type of Limitation	Degree of Limitation				
		None	Minor	Moderate	Serious	Very Serious
a	Depth to sulphidic layer(cm)	>100	75-100	50-75	<50	-
c	Depth to massive clay(cm)	>75	50-75	25-50	<25	-
d	Soil depth to impervious layer or 50% rock fragments (cm)	>100	75-100	50-75	25-50	<25
e	Erosion hazard	none	low	medium	high	very high
f	Fertility	medium	-	low fertility, low retention	acute deficiency, V. low retention	-
i	Inundation hazard(frequency & duration)	none	infrequent, short	frequent, short	infrequent, long	frequent, long or submerged
m	Moisture-holding capacity	high(loam to clay)	-	medium(sandy loams)	low(fine and medium sands)	very low (coarse sand)
o	Depth of organic layer(cm)	<20	-	20-50	-	-
r	Stoniness(% rock fragments or stones within top 25cm)	<0.1	0.1-3	3-15	15-50	>50
s	Salinity of groundwater (uS/cm)	<1000	-	-	1000-4000	>4000
t	Slope in degree	0-6	6-12	12-25	25-33	>33
w	Wetness(drainage class)	well	moderately well	imperfectly	poorly to very poorly	-

Table 9. 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)	>150	100-150	50-100	-	-
f	Fertility of the organic layer	medium (high ash)	-	-	very low (low ash)	-
g	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, long or submerged
n	Nature(texture) of mineral subsoil at 50-150cm	fine loamy to clayey	-	-	sandy to coarse loamy	-
o	Depth to organic layer(cm)	-	-	50-150	>150	-
s	Salinity of groundwater(uS/cm)	<1000	-	-	1000-4000	>4000

*1 Depth after reclamation; allow 25cm more for subsistence of virgin organic soils.

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.

3.2.2 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: These are good soils for wet-land rice or sago and dry and 02 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 much more than 100 cm deep. These limitations restrict the range of crops or require considerable improvement before the range of crops can be extended.

3.3 Land Capability Subclasses

The land capability subclasses are subdivisions within the capability classes. They are formed on the basis of the kinds of limitations 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 :

	<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

3.4 Land Capability Of The Surveyed Area

Terrain, physiographical, soil physical and chemical properties of the surveyed area are examined. The land capability classes are presented in Map 8 and consists of the following :-

Class 1 : Land with no limitations.

Class 2 t : Land with minor limitation on slope (6-12 degree)

Class 2 w : Land with moderate soil drainage

Class 3 te : Land with 12-25 degree slope and have medium to high erosion hazard

Class 3 ef : Land with high erosion hazard, low fertility and low retention.

Class 3 iw : Land with frequent but short incensation hazard and poorly drained.

Class 3 if : Land with frequent short incensation and low fertility, low nutrient retention.

Class 4 ef : Land with high erosion hazard very low retention and fertility.

Class 4 te : Land with very steep slope (25-33 degree) and have high erosion hazard.

Class 5 te : Land with extremely steep slope and very high erosion hazard.

Class 5 md : Land with very low moisture-holding capacity and the presence of impervious layer at 50 to 70 cm depth.

Class 05 go : Land with >150 cm thick organic layer and water table within 30 cm depth.

STUDY OF THE ...

The first part of the study is devoted to the ...

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4. SUITABILITY FOR OIL PALM CULTIVATION

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

4.1 Climatic Requirement for Oil Palm Cultivation

Climate is an important factor in the assessment of environmental condition for oil palm cultivation. Ideal climate for oil palm cultivation should have an annual rainfall of at least 1800 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 degree celsius.

4.2 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 degree.

5.1 SUITABILITY FOR OIL PALM CULTIVATION IN THE SURVEYED AREA

5.1.1 Soil water availability for oil palm cultivation

The surveyed area received high and evenly distributed rainfall throughout the year. The annual rainfall is around 3000 mm. In view of the heavy rainfall in the surveyed area, the high soil water availability can be considered as one of the major factors for oil palm cultivation. However, the soil water availability is not uniform throughout the area. The soil water availability is high in the lowland areas and low in the upland areas. The soil water availability is also affected by the soil texture, soil depth, and soil organic matter content. The soil water availability is high in the soil with high organic matter content and low in the soil with low organic matter content. The soil water availability is also affected by the soil depth. The soil water availability is high in the soil with deep profile and low in the soil with shallow profile. The soil water availability is also affected by the soil texture. The soil water availability is high in the soil with fine texture and low in the soil with coarse texture.

5.1.2 Suitability for oil palm cultivation

The suitability of the surveyed area for oil palm cultivation has been evaluated and is presented in Table 10 and Map 5.

5. SUITABILITY FOR OIL PALM CULTIVATION IN THE SURVEYED AREA

5.1 Climatic suitability for oil palm cultivation

The surveyed area received high and evenly distributed rainfall with mean monthly precipitation of around 300 mm. In view of the sandy nature of the surveyed area, the high precipitation can be considered ideal in terms of soil moisture availability for satisfactory palm growth. The side effects, however, are the expected nutrient loss through leaching and erosion hazard (Plate 12) on slope. These are however, manageable and can be overcome/minimised through various soil/water conservation practices. (Plate 13).

5.2 Suitability for oil palm cultivation

The suitability of the surveyed area for oil palm cultivation has been evaluated and are presented in Table 10 and Map 9.



Plate 12: Severe Soil Erosion On Sandy Soil



Plate 13: Terracing As Soil/Water Conservation Measure

TABLE 10: SUITABILITY FOR OIL PALM CULTIVATION

SOIL SERIES/ASSOCIATION	SLOPE DEGREE	LAND CAPABILITY	OIL PALM SUITABILITY	HECTARE
Merit	2 - 6	Class 1, 2w	Suitable	84
Bekenu	2 - 6	Class 1, 2w		34
Merit/Bekenu	2 - 6	Class 1, 2w		382
Bekenu/Nyalau	2 - 6	Class 1, 2w		43
Merit	2 - 12	Class 1, 2w, 2t	Suitable	86
Bekenu	2 - 12	Class 1, 2w, 2t		206
Merit/Bekenu	2 - 12	Class 1, 2w, 2t		204
Bekenu	6 - 12	Class 2t	Suitable	25
Merit/Bekenu	6 - 12			43
Bekenu/Nyalau	2 - 12	Class 1, 2w, 2t, 3ef	Suitable	22
Merit	6 - 20	Class 2t, 3te	Suitable	123
Bekenu	6 - 20			266
Merit/Bekenu	6 - 20			429
Bekenu/Nyalau	6 - 20	Class 2t, 3te, 3ef, 4ef	Suitable	572
Merit	12 - 25	Class 3te	Suitable	7
Bekenu	12 - 25			226
Bekenu	20 - 25			6
	12 - 20			6
Nyalau	2 - 6	Class 3ef	Suitable	179
Nyalau	2 - 12			210
Nyalau	6 - 20	Class 3ef, 4ef	Suitable	26
Bekenu/Nyalau	12 - 20	Class 3ef, 4ef	Suitable	87
Bekenu/Nyalau	12 - 25			101
Bekenu/Nyalau	20 - 25			42
Bekenu/Nyalau	20 - 33	Class 3te, 4te, 4ef	Suitable - unsuitable*	146
Pakan	<2	Class 3wi	Suitable	471
Similajau/Kayan	<2	Class 3if	Suitable	374
Bekenu	25->33	Class 4te, 5te	Unsuitable	61
Miri	<2	Class 5md	Unsuitable	110
Anderson	<2	Class 05go	Unsuitable	30

* Assuming 50% unsuitable

DISCUSSION

The crop yield that with favorable climate, the available soil nutrients are available for crop production, with sufficient water in the soil to insure a good crop production.

The weathering of the soil, however, has very little effect on the soil fertility and productivity and the crop yield. The crop yield is determined by the amount of water available in the soil and the amount of fertilizer applied. The crop yield is determined by the amount of water available in the soil and the amount of fertilizer applied.

Summary - Field Forecast

Following our ongoing conversation, we are pleased to provide you with a forecast of the yields for the various soil types occurring in the area.

Harvesting Year	Yield (tonnes/ha) in Soil Groups		
	Perlitobekere	Fekir & Sibiragan	Nyalai & Kiri & Kaye
1	7.5	6	5
2	12.0	10	8
3 - 4	17.5	16	14
5 - 6	21.0	20	17
7 - 12	25.0	22	20
13 - 18	28.0	26	23
19 - 22	29.0	28	25

In general, the soils are coarse textured. The high rainfall experienced by the area could compensate for the low moisture retention capacity of the soils to a certain extent. Higher rates of fertilizers in soil application are recommended. Mulching could bring about significant improvement especially on the Nyalai, Kiri and Kaye soils.

Please contact us if you require further clarification.

[Signature]
 [Name]
 [Title]

cc: Mr. [Name]

12	13	14	15	16	17	18	19	20
21	22	23	24	25	26	27	28	29
30	31	32	33	34	35	36	37	38
39	40	41	42	43	44	45	46	47
48	49	50	51	52	53	54	55	56
57	58	59	60	61	62	63	64	65
66	67	68	69	70	71	72	73	74
75	76	77	78	79	80	81	82	83
84	85	86	87	88	89	90	91	92
93	94	95	96	97	98	99	100	

6

6. RECOMMENDATIONS

The study shows that with favourable climate, the surveyed area is predominantly suitable for oil palm cultivation, with 4327 ha (94%) of the area able to sustain a good or reasonable production.

The remaining 274 ha (6%), however, have very serious limitation of either very steep topography, low fertility and moisture-retention capacity, or thick organic layer with very poor drainage. Experience has shown that these limitations, however, can be corrected through more intense management efforts and require higher resource inputs.

Similajau - Yield Forecast

Following our morning conversation, we are pleased to append our estimates of ffb yields for the various soil types occurring in the area.

Harvesting Year	FFB (tonnes/ha) in Soil Groups		
	Merit/Bekenu	Pakan & Similajau	Nyalau & Miri & Kayan
1	7.5	6	5
2	12.0	10	8
3 - 4	17.5	16	14
5 - 6	21.0	20	17
7 - 12	25.0	22	20
13 - 18	22.0	20	19
19 - 22	20.0	18	17

In general, the soils are coarse texture. The high rainfall experienced by the area could compensate for the low moisture retention capacity of the soils to a certain extent. Higher rates of fertilisers in split application are recommended. Mulching could bring about significant improvement especially on the Nyalau, Miri and Kayan soils.

Please contact us if you require further clarification.

Lai Ah Lam
LAI AH LAM

c.c. Mr. Chuah Joo Hor

	Act	Inf
FS		
FSS		
FSS (Fin)		
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FIR (i)		
FIR (ii)		
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4 DEC 1989

tm

NOTE: ALL PERCHLORIC DIGEST

POTASSIUM AND MAGNESIUM VALUES

SHOULD NOT HAVE THE DECIMAL
POINT INCLUDED.

EG.

SOIL PROFILE 10

K

Mg

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1913

APPENDICES

APPENDIX 1a

Soil Profile No. : 10
 Soil Name : Merit Series
 Landform : Undulating
 Physiography at Site : Gentle lower slope
 Slope at Site : 3°
 Effective Soil Depth : 80 cm
 Vegetation : Logged forest; dense vegetation

<u>Horizon</u>	<u>Depth (cm)</u>	<u>Profile Description</u>
Ah	0-2	Dark yellowish brown (10 YR 4/4); clay loam; moderate, medium and fine subangular blocky structures; friable; few medium pores; abundant, fine, medium and coarse roots; clear boundary.
B1	2-25	Yellowish brown (10 YR 5/6) to brownish yellow (10 YR 6/6); clay loam; moderately strong, medium and coarse subangular blocky structure; friable; few coarse pores; many medium and coarse roots; weak organic acid; gradual boundary.
B2	25-50	Brownish yellow (10 YR 6/6) to brownish yellow (10 YR 6/8); clay loam; moderately strong, coarse subangular blocky structures; friable; few fine and medium pores; many medium roots; clear boundary.
BC	50-80	Brownish yellow (10 YR 6/8), very pale brown (10 YR 7/4), reddish yellow (7.6 YR 6/8); sandy clay loam; moderately weak, coarse subangular block structures; slightly firm; rare pores; few decomposing sandstone; few fine roots; gradual boundary.
C	80-130	Sandy clay loam; weak, coarse and very coarse subangular blocky and angular blocky structure; slightly firm slightly compact; rare pores; very few, fine roots.

APPENDIX 2a

Soil Profile No. : 14
 Soil Name : Merit Series
 Landform : Rolling
 Physiography at Site : Mid-gentle slope
 Slope at Site : 9°
 Effective Soil Depth : > 130 cm
 Vegetation : Logged hill forest

<u>Horizon</u>	<u>Depth (cm)</u>	<u>Profile Description</u>
Ah	0-2	Yellowish brown (10 YR 5/4); clay loam; moderate, fine and medium subangular blocky structures; friable; few medium and coarse pores; many fine, medium and coarse roots; clear boundary.
B1	2-35	Brownish yellow (10 YR 6/6) to brownish yellow (10 YR 6/8); clay loam; moderate, medium and coarse SBK; friable; common fine and medium pores; many fine and medium roots; weak organic acid; gradual boundary.
B21	35-70	Brownish yellow (10 YR 6/6) to brownish yellow (10 YR 6/8); clay loam; moderately strong, coarse SBK; slightly firm; few coarse pores; many medium roots; gradual boundary.
B22	70-130	Reddish yellow (7.5 YR 6/8); many very pale brown (10 YR 7/4) and yellowish red (5 YR 5/8); clay; moderately weak, coarse and very coarse subangular blocky structures; slightly firm, compact; rare pores; rare roots.

SOIL ANALYTICAL DATA

Soil Profile Number :14.....
 Soil Series :Merit.....

Horizon	Depth in cm	Percentage				Bulk Density	pH 1:2.5	Electro Conductivity umho / cm (1 : 2.5 H2O)	CEC in IN NH4OAc	Meq %			
		Clay	Silt	Coarse Sand	Fine Sand					Exchangeable Cations			
										K	Mg	Ca	Na
Ah	0-2	28.8	41.1	1.1	22.0	-	3.65	257.0	16.53	0.16	0.44	0.24	0.19
B1	2-35	31.3	37.4	0.7	25.5	1.28	3.95	89.8	13.373	0.18	0.09	0.01	0.11
B21	35-70	35.5	34.9	0.7	22.8	1.54	4.10	51.7	14.00	0.13	0.05	<0.01	0.08
B22	70-130	39.3	34.4	0.8	22.8	1.37	4.10	54.9	14.00	0.16	0.05	<0.01	0.11

Meq %	Percentage	Base Saturation	PPM		C/N ratio	Perchloric Digestible (PPM)							
			Exchangeable B (Hot water soluble)	Avail. P		Organic Carbon	N	P	K	Mg	Cu	Mn	Zn
1.03	6	6	1.6	12.0	3.40	0.30	11	135.0	35.20	12.13	5.5	51.5	30.5
0.39	3	3	1.0	7.0	0.70	0.09	8	95.0	44.10	17.13	6.5	41.5	39.5
0.27	2	2	0.9	8.0	0.13	0.06	2	85.0	48.80	19.00	8.0	34.0	58.5
0.33	3	3	0.9	9.0	0.17	0.05	3	85.0	52.40	19.25	9.0	25.5	80.5

Soil Profile No. : 1
 Soil Name : Bekenu Series
 Landform : Gentle low hill
 Physiography at Site : Mid to lower slope
 Slope at Site : 12°
 Effective Soil Depth : > 130 cm
 Vegetation : Logged hill forest

<u>Horizon</u>	<u>Depth (cm)</u>	<u>Profile Description</u>
Ah	0-3	Dark yellowish brown (10 YR 4/4); fine sandy clay loam; crumbs attached to roots; very friable; a thick mat of mainly fine with few medium and coarse roots.
AB	3-15	Yellowish brown (10 YR 5/6) with dark yellowish brown (10 YR 4/4); fine sandy clay loam; moderate, fine and medium subangular blocky and few crumbs structures; very friable; many fine and medium pores; many organic acid; abundant, medium, coarse and very coarse roots; gradual boundary.
B21	15-35	Brownish yellow (10YR 6/6); fine sandy clay loam; moderate, medium and some coarse subangular blocky structures; very friable; many fine and medium pores; few organic acid; many coarse and very coarse roots; gradual boundary.
B22	35-70	Fine sandy clay loam; moderate, coarse and medium subangular blocky structures, slightly firm; few medium and fine pores; few medium and coarse roots; gradual boundary.
B23	70-95	Brownish yellow (10 YR 6/8), fine sandy clay loam; moderately strong, coarse subangular blocky structures; slightly firm, slightly compact; very few, fine pores, very few, medium roots; gradual boundary.
B3-BC	95-130	Brownish yellow (10 YR 6/8); with few medium very pale brown (10 YR 7/4) and reddish yellow (5 YR 6/6) mottles; fine sandy clay; moderate, weak and very coarse subangular blocky structures; firm, compact; no roots.

SOIL ANALYTICAL DATA

APPENDIX 3b

Soil Profile Number :
 Soil Series : Bekenu

Horizon	Depth in cm	Percentage				Bulk Density	pH 1:2.5	Electro Conductivity umho / cm (1 : 2.5 H2O)	CEC in IN NH4OAc	Meq %			
		Clay	Silt	Coarse Sand	Fine Sand					K	Mg	Ca	Na
Ah	0-3	26.2	10.8	1.6	56.3	-	3.40	234.0	16.40	0.13	0.34	0.01	0.12
AB	3-15	26.7	17.4	0.9	54.2	1.14	3.85	112.0	13.33	0.10	0.12	<0.01	0.09
B21	15-35	27.4	15.0	1.0	53.9	1.31	3.95	69.3	11.20	0.07	0.05	0.01	0.11
B22	35-70	30.3	15.2	1.0	53.2	1.44	4.10	51.8	10.13	0.06	0.03	<0.01	0.12
B3-BC	70-95	32.0	14.0	0.7	48.8	1.68	4.10	48.5	10.00	0.06	0.02	<0.01	0.08

Meq %	Percentage	Base Saturation	PPM		C/N ratio	Perchloric Digestible (PPM)							
			Exchangeable B (Hot water soluble)	Avail. P		Organic Carbon	N	P	K	Mg	Cu	Mn	Zn
0.60	4		1.0	10.0	2.78	0.18	15	75.0	13.59	8.75	5.5	20.0	18.0
0.32	2		1.0	7.0	1.00	0.10	10	70.0	22.85	11.63	4.0	18.5	17.5
0.24	2		0.6	6.0	0.33	0.05	7	70.0	22.80	13.75	5.5	22.0	23.0
0.22	2		0.9	10.0	0.13	0.04	3	75.0	25.15	14.38	5.5	22.5	22.5
0.17	2		ND	10.0	0.15	0.03	5	75.0	29.55	15.50	6.5	22.5	21.5

Soil Profile No. : 6
 Soil Name : Bekenu Series
 Landform : Gentle low hill
 Physiography at Site : Mid-gentle slope
 Slope at Site : 15°
 Effective Soil Depth : >160 cm
 Vegetation : Logged forest; dense undergrowth

<u>Horizon</u>	<u>Depth (cm)</u>	<u>Profile Description</u>
Ah	0-2	Brown to dark brown (10 YR 4/3); sandy clay loam; moderate, fine and medium subangular blocky and crumbs structure; very friable; common medium pores; abundant fine, medium and coarse roots; clear boundary.
B1	2-35	Brownish yellow (10 YR 6/6); sandy loam; moderate; medium and coarse subangular blocky structures; very friable; many fine, medium and coarse pores; many fine and medium roots; weak organic acid; gradual boundary.
B2	35-115	Brownish yellow (10 YR 6/8); fine sandy clay loam; moderate to coarse subangular blocky structures; very friable; common fine and medium pores; many fine and medium roots; clear boundary.
B3	115-160	Brownish yellow (10 YR 6/8); many reddish yellow (7.5 YR 6/8) and white (10 YR 8/2) mottles; fine sandy clay loam; moderate, weak, coarse and very coarse subangular blocky and angular blocky structure; slightly firm; few coarse pores; very few fine roots.

Soil Profile No. : 9
 Soil Name : Bekenu Series
 Landform : Steep hills
 Physiography at Site : Mid-steep slope
 Slope at Site : 25°
 Effective Soil Depth : > 180 cm
 Vegetation : Logged hill-forest

<u>Horizon</u>	<u>Depth (cm)</u>	<u>Profile Description</u>
Ah	0-2	Brown to dark brown (10 YR 4/3) to dark yellowish brown (10 YR 4/4); fine sandy loam; moderate, fine subangular blocky and crumbs structure; very friable; few medium pores; many, fine, medium and coarse roots; clear boundary.
B1	2-45	Yellowish brown (10 YR 5/6) to brownish yellow (10 YR 6/6); fine sandy clay loam; moderate, medium and coarse subangular blocky structures; very friable; many fine and medium pores; many medium and coarse roots; many organic acid; clear boundary.
B21	45-90	Brownish yellow (10 YR 6/8); fine sandy clay loam; moderate, strong, medium and coarse subangular blocky structures; friable; common fine and medium pores; many fine and medium roots; gradual boundary.
B22	90-180	Brownish yellow (10 YR 6/8) to strong brown (7.5 YR 5/8); fine sandy clay loam; moderate, strong, medium and coarse subangular blocky structures; friable; few fine and medium pores; many fine and medium roots.

Soil Profile No. : 18
 Soil Name : Bekenu Series
 Landform : Gentle rolling
 Physiography at Site : Mid to lower slope
 Slope at Site : 12°
 Effective Soil Depth : >140 cm
 Vegetation : Logged forest

<u>Horizon</u>	<u>Depth (cm)</u>	<u>Profile Description</u>
Ah	0-2	Yellowish brown (10 YR 5/4) to light yellowish brown (10 YR 6/4); fine sandy loam; moderate, fine subangular blocky structures; slightly hard; few coarse pores; abundant medium and coarse roots; clear boundary.
B1	2-10	Yellowish brown (10 YR 5/6) to brownish yellow (10 YR 6/6); fine sandy clay loam; moderate, medium and coarse subangular blocky structures; friable; common coarse pores; many coarse roots; weak organic acid; gradual boundary.
B21	10-60	Brownish yellow (10 YR 6/8); fine sandy clay loam; moderate, coarse and medium subangular blocky structures; friable; few medium and fine pores; many medium and coarse roots; gradual boundary.
B22	60-110	Brownish yellow (10 YR 6/8); fine sandy clay loam; moderately, strong, medium and coarse structures; friable; few, medium and fine pores; few, medium and fine roots.
B3	110-140	Brownish yellow (10 YR 6/8) to reddish yellow (7.5 YR 6/8); common, faint very pale brown (10 YR 7/4) and yellowish red (5 YR 5/8); fine sandy clay loam moderate, medium and coarse structures; rare pores; very few fine roots.

Soil Profile No. : 25
 Soil Name : Bekenu Series
 Landform : Hilly
 Physiography at Site : Lower slope
 Slope at Site : 18°
 Effective Soil Depth : 120 cm
 Vegetation : Logged hill forest

<u>Horizon</u>	<u>Depth (cm)</u>	<u>Profile Description</u>
Ah	0-3	Yellowish brown (10 YR 5/4) to dark yellowish brown (10 YR 4/4); fine sandy loam; moderately strong, fine and medium subangular blocky structures; friable; abundant fine, medium, and coarse roots; clear boundary.
B1	3-15	Brownish yellow (10 YR 6/6) and light yellowish brown (10 YR 6/4); fine sandy loam; moderate, medium subangular blocky structures; friable; many medium and coarse roots; gradual boundary.
B21	15-50	Brownish yellow (10 YR 6/8); few very pale brown (10 YR 7/4); fine sandy clay loam; moderate, coarse subangular blocky structures; friable; many medium roots; gradual boundary.
B22	50-85	Brownish yellow (10 YR 6/8); common very pale brown (10 YR 7/4) mottles; fine sandy clay loam; medium, coarse and very coarse subangular blocky structures; slightly firm, slightly compact; few fine roots; abrupt boundary.
Bcn	85-120	Brownish yellow (10 YR 6/8); fine sandy clay loam; compact; very frequent gravelly laterites; rare roots.

Soil Profile No. : 4
 Soil Name : Nyalau Series
 Landform : Undulating
 Physiography at Site : Steep ravine shoulder
 Slope at Site : 30°
 Effective Soil Depth : 110 cm
 Vegetation : Logged hill forest; dense undergrowth

<u>Horizon</u>	<u>Depth (cm)</u>	<u>Profile Description</u>
Ao	0-5	A thick mat of roots and litters; clear boundary.
Ah	5-20	Dark yellowish brown (10 YR 4/4) and yellowish brown (10 YR 5/4); fine sandy loam; moderate, weak and medium subangular blocky structures; friable; few medium and coarse pores; many fine and medium roots; clear boundary.
B1	20-60	Yellowish brown (10 YR 5/8) to strong brown (7.5 YR 5/8); fine sandy loam; moderate, weak, medium and coarse subangular blocky structures, friable; common medium and coarse pores; very few sandstone; many medium roots; weak organic acid; diffuse boundary.
BCR	60-110	Strong brown (7.5 YR 5/8) to yellowish red (5 YR 5/8); fine sandy loam; moderate, weak, coarse subangular blocky structures; friable; few coarse pores; frequent strong sandstone; few medium roots; diffuse boundary.
CR	110-160	Dominant boundary sandstone; very few medium roots.

Soil Profile No. : 23
 Soil Name : Nyalau Series
 Landform : Gently undulating
 Physiography at Site : Mid-gentle slope
 Slope at Site : 7°
 Effective Soil Depth : 130 cm
 Vegetation : Logged hill forest

<u>Horizon</u>	<u>Depth (cm)</u>	<u>Profile Description</u>
AB	0-3	Brown to dark brown (7.5 YR 4/4); fine sandy loam; moderately strong, fine and medium SBK; friable; many fine, medium, and coarse roots; clear boundary.
B1	3-20	Light yellowish brown (10 YR 6/4) and brownish yellow (10 YR 6/6); fine sandy loam; moderately strong, medium SBK; friable; common, coarse pores; many medium and coarse roots; gradual boundary.
B21	20-80	Brownish yellow (10 YR 6/8); fine sandy loam; moderate, medium and coarse SBK; friable; common, coarse and medium pores; few fine and medium roots; gradual boundary.
B22	80-110	Brownish yellow (10 YR 6/8); fine sandy loam; common very pale brown (10 YR 7/4) mottles; moderate, coarse and very coarse SBK; friable; few fine and medium pores; very few fine and medium roots; gradual boundary.
Bc	110-130	Brownish yellow (10 YR 6/8); many very pale brown (10 YR 7/4-7/2); fine sandy loam; moderately weak, very coarse and coarse SBK; abrupt boundary.
CR	130+	Sandstone rocks.

Soil Profile No. : 13 (Soil auger examination)
Soil Name : Pakan Series
Landform : Alluvial flat
Physiography at Site : Flat
Slope at Site : $< 2^\circ$
Effective Soil Depth : > 100 cm
Vegetation : Riverine forest

<u>Horizon</u>	<u>Depth (cm)</u>	<u>Profile Description</u>
Ah	0-3	Yellowish brown (10 YR 5/4) to dark yellowish brown (10 YR 4/4); clay loam.
Bg1	3-25	Light gray (10 YR 7/1) to light gray (10 YR 7/2) and yellowish brown (10 YR 5/6); common yellowish brown (10 YR 5/8) mottles; fine sandy clay loam.
Bg2	25-60	Light gray (10 YR 7/1) to light gray (10 YR 7/2); light gray (10 YR 7/1) to light gray (10 YR 7/2) mottles; sandy loam.
Bg3	60-100	Light gray (10 YR 7/1); loamy sand.

Soil Profile No. : 17 (Soil auger examination)
Soil Name : Pakan Series
Landform : Alluvial plain
Physiography at Site : Flat
Slope at Site : $< 2^\circ$
Effective Soil Depth : > 160 cm
Vegetation : Riverine forest

<u>Horizon</u>	<u>Depth (cm)</u>	<u>Profile Description</u>
Ah	0-3	Dark yellowish brown (10 YR 4/4); fine sandy loam.
B1	3-20	Yellowish brown (10 YR 5/6) and very pale brown (10 YR 7/4); fine sandy loam.
Bg1	20-80	Light gray (10 YR 7/2); many very pale brown (10 YR 7/4) mottles.
Bcg	80-100	Grayish brown (10 YR 5/2); sandy loam.

Soil Profile No. : 24 (Soil auger examination)
 Soil Name : Pakan Series
 Landform : Alluvial plain
 Physiography at Site : Nearly flat
 Slope at Site : $<1^\circ$
 Effective Soil Depth : 100 cm
 Vegetation : Riverine forest

<u>Horizon</u>	<u>Depth (cm)</u>	<u>Profile Description</u>
Ah	0-5	Dark yellowish brown (10 YR 4/4); fine sandy loam.
AB	5-15	Dark yellowish brown (10 YR 4/4) to yellowish brown (10 YR 5/6); fine sand loam.
Bg	15-40	Very pale brown (10 YR 7/3); many dark yellowish brown (10 YR 4/6); fine sandy loam.
Cg	40+	White (10 YR 8/1); common dark yellowish brown (10 YR 4/6); fine sandy loam.

Soil Profile No. : 26
 Soil Name : Pakan Series
 Landform : Alluvial plain
 Physiography at Site : Nearly flat
 Slope at Site : $<1^\circ$
 Effective Soil Depth : >100 cm
 Vegetation : Riverine forest

<u>Horizon</u>	<u>Depth</u> (cm)	<u>Profile Description</u>
Ah	0-4	Brown (10 YR 5/3) to pale brown (10 YR 6/3); fine sandy loam; moderately weak, medium SBK; friable many fine and coarse roots; diffuse boundary.
AB	4-15	Brown (10 YR 5/3) to pale brown (10 YR 6/3) and very pale brown (10 YR 8/3); fine sandy loam; moderately weak, medium and coarse SBK; friable many medium and fine roots; gradual boundary.
Bg1	15-40	Very pale brown (10 YR 8/3); few faint yellow (10 YR 7/6) mottles; fine sandy loam; moderately weak coarse SBK; friable; few coarse gravels; few medium and fine roots; gradual boundary.
Bg2	40-80	Very pale brown (10 YR 8/3); many distinct yellow (10 YR 7/8) mottles; fine sandy loam; moderately weak, coarse and very coarse SBK; slightly firm; few medium and fine roots; gradual boundary.
Bg3	80-135	Very pale brown (10 YR 8/3) to white (10 YR 8/2); fine sandy loam; weak, coarse and very coarse SBK; slightly compact; nil roots.

SOIL ANALYTICAL DATA

APPENDIX 13b

Soil Profile Number :
 Soil Series :
 26
 Pakan

Horizon	Depth in cm	Percentage				Bulk Density	pH 1:2.5	Electro Conductivity umho / cm (1 : 2.5 H2O)	CEC in IN NH4OAc	Meq %			
		Clay	Silt	Coarse Sand	Fine Sand					Exchangeable Cations			
										K	Mg	Ca	Na
Ah	0-4	8.7	18.3	0.8	66.1	-	4.10	105.0	6.40	0.15	0.38	0.90	0.09
AB	4-15	7.8	20.6	0.9	68.0	1.39	4.50	31.5	2.67	0.11	0.06	0.05	0.07
Bg1	15-40	8.6	19.8	1.0	66.7	1.70	4.30	68.8	2.53	0.45	0.05	0.07	0.18
Bg2	40-80	16.7	16.4	1.0	61.9	1.60	4.55	38.3	4.27	0.12	0.03	<0.01	0.10
Bg3	80-135	17.5	17.8	0.6	60.1	1.39	4.75	26.9	6.00	0.16	0.03	<0.01	0.11

Meq %	Total Exchangeable Bases	Percentage	Base Saturation	PPM		C/N ratio	Perchloric Digestible (PPM)							
				Exchangeable B (Hot water soluble)	Avail. P		Organic Carbon	N	P	K	Mg	Cu	Mn	Zn
1.52	24	11.0	1.0	11.0	1.14	11	60.0	11.70	4.50	4.0	21.5	13.0		
0.29	11	8.0	ND	8.0	0.44	11	45.0	12.40	3.63	2.5	11.5	11.0		
0.75	30	4.0	1.2	4.0	0.09	5	40.0	16.95	5.13	3.5	13.0	15.0		
0.26	6	7.0	0.1	7.0	0.09	5	45.0	29.10	13.50	4.0	20.0	24.5		
0.31	5	6.0	ND	6.0	0.09	5	50.0	45.50	17.62	6.0	24.5	35.0		

Soil Profile No. : 11 (Soil auger examination)
Soil Name : Similajau Series
Landform : Alluvial flat
Physiography at Site : Flat
Slope at Site : $< 2^\circ$
Effective Soil Depth : > 100 cm
Vegetation : Riverine forest

<u>Horizon</u>	<u>Depth (cm)</u>	<u>Profile Description</u>
Ah	0-2	Dark yellowish brown (10 YR 4/4); fine sandy; clay loam, friable.
B1	2-20	Yellowish brown (10 YR 5/6); fine sandy loam, friable.
B2	20-100	Brownish yellow (10 YR 6/6); fine sandy loam; friable.

Soil Profile No. : 19
 Soil Name : Kayan Series
 Landform : Raised terrace
 Physiography at Site : flat
 Slope at Site : $< 2^\circ$
 Effective Soil Depth : > 120 cm
 Vegetation : Riverine forest

<u>Horizon</u>	<u>Depth</u> (cm)	<u>Profile Description</u>
Ah	0-3	Yellowish brown (10 YR 5/4); moderate, medium and fine subangular blocky structures; slightly brittle; many fine and medium pores; sandy (9.8) clear boundary.
B1	3-20	Light yellowish brown (10 YR 6/4); moderately weak, medium and coarse SBK; very friable; few fine and medium pores; many medium roots; weak organic acid; gradual boundary.
B21	20-90	Yellow (10 YR 7/6); sand; coarse and medium subangular blocky structures; very friable; few fine and medium pores; many medium roots; gradual boundary.
B22	90-120	Yellow (10 YR 7/6); medium faint very pale brown (10 YR 7/4); loamy sand; weak coarse angular blocky structures; very friable; rare pores; very few fine roots.

Soil Profile No. : 22
 Soil Name : Miri Series
 Landform : Nearly flat; raised
 Physiography at Site : Nearly flat
 Slope at Site : 2°
 Effective Soil Depth : 65 cm
 Vegetation : Kerangas

<u>Horizon</u>	<u>Depth</u> (cm)	<u>Profile Description</u>
Ah	0-10	Dark reddish brown (5 YR 3/3) to dark reddish brown (5YR 3/4); loamy fine sand; moderately weak, fine crumbs; friable; abundant fine, medium and coarse roots; clear boundary.
Ae	10-35	White (10 YR 8/2) to pale brown (10 YR 6/3); many pale brown (10YR 6/3) mottles; loamy fine sand; weak coarse subangular blocky and angular blocky structures; friable; very few fine pores; rare roots; gradual boundary.
B	35-65	White (10 YR 8/1); patchy pale brown (10 YR 6/3); loamy fine sand; weak, coarse and very coarse angular blocky structures; compact; no pores; rare roots; abrupt boundary.
Bir	65+	Indurated iron-humus horizon.

Soil Profile No. : 3
 Soil Name : Merit Series
 Landform : Low hill
 Physiography at Site : Top gentle slope
 Slope at Site : 6°
 Effective Soil Depth : >130 cm
 Vegetation : Logged hill forest; dense undergrowth

<u>Horizon</u>	<u>Depth</u> (cm)	<u>Profile Description</u>
Ah	0-2	Dark yellowish brown (10 YR 4/4); fine sandy loam; moderate, fine and medium subangular blocky structures; friable; many fine and medium roots; clear boundary.
B1	2-30	Brownish yellow (10 YR 6/6); fine sandy clay loam; moderate, medium and coarse subangular blocky structure; common fine and medium pores; many fine and medium roots; weak organic acid; gradual boundary.
B+	30-85	Brownish yellow (10YR 6/6) to reddish yellow (7.5 YR 6/8); fine sandy clay; moderate, strong, coarse subangular blocky structures; slightly firm; few fine and medium pores; few medium roots; clear boundary.
Bc	85-130	Reddish yellow (7.5 YR 6/8); clay; many very pale brown (10 YR 7/4) and reddish yellow (5 YR 6/6) mottles; moderate, weak, coarse subangular blocky and angular blocky structures; firm, compact; rare porosity; rare roots.

Soil Profile No. : 5
 Soil Name : Merit Series
 Landform : Gently rolling hills
 Physiography at Site : Mid slope
 Slope at Site : 12°
 Effective Soil Depth : > 130 cm
 Vegetation : Logged hill forest; dense undergrowth

<u>Horizon</u>	<u>Depth</u> (cm)	<u>Profile Description</u>
Ah	0-2	Dark yellowish brown (10 YR 4/4); clay loam; moderate, fine subangular blocky and crumbs structure; friable; few medium pores; abundant fine and medium roots; clear boundary.
B1	2-15	Yellowish brown (10 YR 5/4) to yellowish brown (10 YR 5/6); clay loam; moderate, fine and medium subangular blocky structures; friable; common, fine and medium pores; many medium roots; many organic acid; clear boundary.
B21	15-50	Brownish yellow (10 YR 6/6) to brownish yellow (10 YR 6/8); clay loam; moderate, medium and coarse subangular blocky structures; friable; common medium pores; many, fine, medium and coarse roots; gradual boundary.
B22	50-85	Brownish yellow (10 YR 6/8); clay loam; moderate, strong and coarse subangular blocky structures; friable; few medium pores; few medium roots; clear boundary.
B3	85-130	Reddish yellow (7.5 YR 6/8); common very pale brown (10 YR 7/4) and very pale brown clay loam; moderate, weak, very coarse subangular blocky and angular blocky structures; slightly firm, slightly compact; rare pores; rare roots.

Soil Profile No. : 15
 Soil Name : Merit series
 Landform : Gently rolling
 Physiography at Site : Mid-gentle slope
 Slope at Site : 5°
 Effective Soil Depth : >135 cm
 Vegetation : Logged hill forest; dense

<u>Horizon</u>	<u>Depth</u> (cm)	<u>Profile Description</u>
Ah	0-3	Yellowish brown (10 YR 5/4) to dark yellowish brown (10 YR 4/4); clay loam; moderate, fine and medium subangular blocky structures; friable; few medium and coarse pores; many fine, medium and coarse roots; clear boundary.
B1	3-25	Brownish yellow (10 YR 6/6); clay loam; moderate, medium and coarse subangular blocky structures; friable; common fine and medium pores, many, fine and medium roots; weak organic acid; gradual boundary.
B2	25-55	Brownish yellow (10 YR 6/8); clay loam; moderate, strong, medium and coarse subangular blocky structures; friable; few coarse pores; many medium roots; gradual boundary.
B3	55-85	Strong brown (7.5 YR 5/8); many very pale brown (10 YR 7/4) and yellowish red (5 YR 5/8); clay loam; moderate weak, coarse and very coarse subangular blocky structure; slightly firm, compact; rare pores; rare roots; gradual boundary.
B3 cn	85-135	Strong brown (7.5 YR 5/8); strong brown (7.5 YR 5/8) mottles; clay loam; weak, coarse and very coarse subangular blocky and angular blocky structures; firm, compact; rare pores; frequent laterised-shale, gravelly; rare roots.

Soil Profile No. : 21
 Soil Name : Merit Series - stony
 Landform : Rolling
 Physiography at Site : Lower slope adjacent to small gully
 Slope at Site : 15°
 Effective Soil Depth : 60 cm
 Vegetation : Logged hill forest

<u>Horizon</u>	<u>Depth (cm)</u>	<u>Profile Description</u>
Ah	0-2	Brown (10 YR 5/3); clay loam; moderately strong, fine subangular blocky structures; friable; many fine, medium and coarse roots; clear boundary.
B1	2-10	Light yellowish brown (10 YR 6/4); clay loam; moderate, medium SBK; friable; few coarse pores; many fine and medium roots; gradual boundary.
B2	10-45	Brownish yellow (10 YR 6/6) to brownish yellow (10 YR 6/8); clay loam; moderately strong, medium and coarse SBK; friable; few coarse pores; many fine roots; clear boundary.
BCR	46-60	Brownish yellow (10 YR 6/6-6/8); clay loam; weak, very coarse SBK; with about 60% stony sandstone; few medium roots; clear boundary.
CR	60+	Impervious sandstone.

Soil Profile No. : 28
 Soil Name : Merit Series
 Landform : Rolling
 Physiography at Site : Upper slope
 Slope at Site : 6°
 Effective Soil Depth : >120 cm
 Vegetation : Logged hill forest

<u>Horizon</u>	<u>Depth</u> (cm)	<u>Profile Description</u>
Ah	0-2	Yellowish brown (10 YR 5/4); clay loam; friable; few coarse pores; abundant fine, medium and coarse roots; clear boundary.
B1	2-30	Disturbed layer.
B2	30-120	Brownish yellow (10 YR 6/8); clay loam; friable; few coarse pores; few fine roots.

Soil Profile No. : 2
 Soil Name : Bekenu Series
 Landform : Hilly
 Physiography at Site : Lower slope
 Slope at Site : 20°
 Effective Soil Depth : > 160 cm
 Vegetation : Logged hill forest; dense undergrowth

<u>Horizon</u>	<u>Depth (cm)</u>	<u>Profile Description</u>
Ah	0-5	Dark yellowish brown (10 YR 4/4) and yellowish brown (10 YR 5/4); fine loamy sand; moderate, fine subangular blocky structures; very friable; few medium porosity; abundant, fine, medium and coarse roots; clear boundary.
B1	5-20	Yellowish brown (10 YR 5/6) to brownish yellow (10 YR 6/6); fine sandy clay loam; moderate, medium, subangular blocky structures; very friable; common, medium porosity; many medium roots; weak organic acid; gradual boundary.
B2	20-65	Brownish yellow (10 YR 6/6); fine sandy clay loam; moderate, weak, medium and coarse subangular blocky structures; very friable; common, fine, medium and coarse porosity; many medium and fine roots; gradual boundary.
II B2	65-110	Brownish yellow (10 YR 6/6); fine sandy clay loam; moderate, strong and coarse subangular blocky structures; friable to slightly firm; few coarse porosity; many medium roots; clear boundary.
II B3	110-160	Brownish yellow (10 YR 6/6); many very pale brown (10 YR 7/4) and reddish yellow (5 YR 6/6) mottles; fine sandy clay; moderate, weak and coarse subangular blocky structures; firm; rare porosity; rare roots.

Soil Profile No. : 8
 Soil Name : Bekenu Series
 Landform : Gently rolling
 Physiography at Site : Mid-slope
 Slope at Site : 9°
 Effective Soil Depth : >150 cm
 Vegetation : Logged hill forest

<u>Horizon</u>	<u>Depth (cm)</u>	<u>Profile Description</u>
Ah	0-2	Brown to dark brown (10 YR 4/3); loamy fine sand; moderate, fine subangular blocky structure; friable; few coarse pores; abundant, fine medium and coarse roots; clear boundary.
B1	2-15	Yellowish brown (10 YR 5/6) to brownish yellow (10 YR 6/6); fine sandy loam; moderate, medium and coarse subangular blocky structures; very friable; common, medium and coarse pores; many medium roots; many organic acid; gradual boundary.
B21	15-30	Brownish yellow (10 YR 6/8); fine sandy clay loam; moderate, medium and some coarse subangular blocky structures; very friable; common medium and coarse pores; many fine and medium roots; gradual boundary.
B22	30-70	Brownish yellow (10 YR 6/8); fine sandy clay loam; moderate, coarse subangular blocky structures; very friable; few coarse pores; many few medium and coarse roots; clear boundary.
B3	70-150	Brownish yellow (10 YR 6/8), light gray (10 YR 7/2), yellowish red (5 YR 5/8); fine sandy clay loam; moderate, weak, coarse and very coarse subangular blocky and angular blocky structures; friable, rare pores; few, fine and medium roots.

Soil Profile No. : 16
 Soil Name : Bekenu Series
 Landform : Rolling
 Physiography at Site : Rolling
 Slope at Site : 7°
 Effective Soil Depth : 100 cm
 Vegetation : Logged hill forest

<u>Horizon</u>	<u>Depth (cm)</u>	<u>Profile Description</u>
Ah	0-2	Yellowish brown (10 YR 5/4), loamy sandy; moderate, fine and medium subangular blocky and single grain structure; friable; few medium pores; abundant medium and coarse roots; clear boundary.
B1	2-15	Yellowish brown (10 YR 5/6) to brownish yellow (10 YR 6/6); loamy sand; moderate, medium and coarse subangular blocky structures; friable; few medium and coarse pores; many medium roots; many organic acid; gradual boundary.
B21	15-40	Brownish yellow (10 YR 6/6) brownish yellow (10 YR 6/8); sandy clay loam; moderate, coarse subangular blocky structures; friable; few medium pores; few, fine and medium roots; gradual boundary.
B22	40-60	Brownish yellow (10 YR 6/6) to brownish yellow (10 YR 6/8); few very pale brown (10 YR 7/4) and very pale brown (10 YR 7/3) mottles; sandy clay loam; moderate, weak, coarse subangular blocky structures; slightly firm, slightly compact; few medium pores; very few fine roots.
B3	60-100	Brownish yellow (10 YR 6/8) to reddish yellow (7.5 YR 6/8); common very pale brown (10 YR 7/4) and very pale brown (10 YR 7/3) mottles; fine sandy loam, weak, coarse subangular blocky structures; slightly firm, slightly compact; rare pores; nil roots; diffuse tongue boundary.
CR	100-150	Decomposing parent rock - sandstone.

Soil Profile No. : 20
 Soil Name : Bekenu Series - stony
 Landform : Gently rolling
 Physiography at Site : Mid-gentle slope
 Slope at Site : 6°
 Effective Soil Depth : 100 cm
 Vegetation : Logged hill forest

<u>Horizon</u>	<u>Depth (cm)</u>	<u>Profile Description</u>
Ah	0-2	Brown (10YR 5/3) to yellowish brown (10 YR 5/4); fine sandy clay loam; moderate, fine subangular blocky structures; friable; many fine and coarse roots; clear boundary.
B1	2-20	Light yellowish brown (10 YR 6/4); fine sandy clay loam; moderately weak, medium and coarse subangular blocky structures; friable; few coarse pores; many medium roots; clear boundary.
B2	20-45	Brownish yellow (10 YR 6/8); fine sandy clay loam; moderate, medium and coarse subangular blocky structures; friable; few fine and medium pores; few fine roots; clear boundary.
Bcn	45-100	Brownish yellow (10 YR 6/8) to reddish yellow (7.5 YR 6/8); fine sandy clay loam; moderately weak, very coarse subangular blocky structures; friable; few coarse pores; frequent gravelly and stony laterised parent material; very few fine roots.

Soil Profile No. : 27
 Soil Name : Bekenu Series
 Landform : Hilly
 Physiography at Site : Top slope
 Slope at Site : 25°
 Effective Soil Depth : >120 cm
 Vegetation : Logged hill forest

<u>Horizon</u>	<u>Depth (cm)</u>	<u>Profile Description</u>
Ah	0-2	Dark yellowish brown (10 YR 4/4); fine sandy clay loam; moderate, fine and medium SBK; friable; abundant roots; few coarse pores; clear boundary.
B1 ₁	2-15	Dark yellowish brown (10 YR 4/6); fine sandy clay loam; moderate, medium and coarse SBK, friable, many roots; few coarse pores; gradual boundary
B1 ₂	15-40	Yellowish brown (10 YR 5/6); fine sandy clay loam; moderately strong, coarse SBK; friable; few roots; few pores; gradual boundary.
B2 + 1	40-70	Yellow (10 YR 7/8); fine sandy clay loam; moderately strong, coarse and very coarse SBK; friable; few roots; few fine pores, gradual boundary.
B2 + 2	70-120	Yellow (10 YR 7/8); fine sandy clay loam - strong, very coarse SBK; slightly firm; few roots; few pores; gradual boundary.
B3	120+	Strong brown (7.5 YR 5/8); fine sandy clay loam; very pale brown (10 YR 8/4) common mottles; fine sandy clay loam; moderately weak, very coarse SBK; slightly compact; very few roots.

MAPS : 2

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