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SOIL SUITABILITY FOR OIL PALM CULTIVATION OF AN AREA OF 2,916.8 ACRES OF SARAWAK OIL PALM SENDIRIAN BERHAD

by

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SOIL SUITABILITY FOR OIL PALM CULTIVATION OF AN AREA OF 2,916.8 ACRES OF SARAWAK OIL PALM SENDIRIAN BERHAD

INTRODUCTION

An area of 2,916.8 acres, which has already been planted with oil palm during the year 1974 and 1976, has been the subject of study as to its suitability for cultivation of oil palm. Although already planted, suitability of the area and the potential yield are now in question in view of the difficulties presented firstly by the obvious poor physical nature of the soil in certain parts and secondly by the steep terrain of the land in certain parts. It was considered necessary that a soil survey of the area should be carried out and the findings interpreted with respect to the potential yield for the various soil types that exist within this study area.

SOIL

The area was surveyed initially by auger examination to determine the different types of soils present. Subsequently, soil examination pit were sited in appropriate areas and profile description taken from the typical soil profiles. All together 11 types of soils were identified in the area. The soil types were classified on the basis of soil profile characteristics only, with due consideration on the characteristics that are regarded

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beneficial or otherwise for the growth of oil palm. The boundaries of the soil types were demarked by auger examination. The areas of each soil type was then subdivided according to their topographical or terrain classes. The attached soil map shows the areas of the different soil types together with the terrain or slope classes. The description of the soil profile and the analysis of the soil samples collected from the different horizon of the soil profile are given in Appendix A.

SOIL SUITABILITY FOR OIL PALM CULTIVATION

For considering the suitability of the soil for oil palm cultivation, 4 main factors are considered:-

A. Soil Profile Characteristics which indicate the suitability of the soil as a medium of growth of roots of oil palm. The characteristics that are important are texture and structure of the soil, absence or presence of laterites, with quantity, size and compaction, depth of water-table etc.

B. Topography of the Land. This affect water retention and erodibility of the soil and also determines the necessity and nature of contour planting, road systems and the difficulties of harvesting and transporting, in

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addition to the other field operations such as fertilizer application, ground cover maintenance etc.

C. Soil Chemical Properties. This factor indicates whether the soil is suitable with respect to the chemical properties and availability of nutrients from the soil.

D. Sunshine and Rainfall. This factor should be considered not only on annual basis but also from the point of view of distribution throughout the year.

A. Soil Profile Characteristics. On the basis of soil profile characteristics, 11 types of soil are identified in the area. These are numbered from 1 to 11. The basic features of the profiles of these soil types are summarised in Appendix B.

Based on these soil profile characteristics, the soil types are graded into 4 classes namely,

<u>CLASS 1</u>: Soils without any limiting factor for root growth of oil palm. The soil types in this class are represented by Profile Nos. 1, 6 and 7.

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<u>CLASS 2:</u> Soils which have one limiting factor of minor nature. The soil types in this class are represented by Profile Nos. 2, 5 and 9.

<u>CLASS 3:</u> Soils which have more than one minor limiting factor or one moderate limiting factor. The soil types in this class are represented by Profile Nos. 3, 8 and 10.

<u>CLASS 4:</u> Soils which have one or more serious limiting factor which are not correctable given the normal commercial conditions. The soil types in this class are represented by Profile Nos. 4 and 11.

It may be pertinent at this stage to explain the nature of limitation in this soil.

<u>CLASS 1:</u> The Profile Nos. 1, 6 and 7 are considered to have no limitation with respect to growth of oil palm. These soil are well aerated, moderate to good texture and structure upto the normal depth of soil which is explored by oil palm roots mainly upto about 3 to 4 feet from surface.

<u>CLASS 2:</u> The Profile Nos. 2, 5 and 9 have minor limitation in the sub-soil. In the case of Profile No. 2 decomposing parent materials occur at about 100cm

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from surface. In Profile No. 5 also, the decomposing parent materials occurs at about 100cm with a laterite band between 30 and 45cm depth. In Profile No. 9 also, the decomposing parent materials occur within 100cm from surface.

CLASS 3: Profile Nos. 3, 8 and 10 are all shallower than 100cm, the parent materials occurring between 75 and 100cm with or without significant amounts of laterites. Thus, the effective depth for root growth is only about 75cm or sometime less.

CLASS 4: The Profile Nos. 4 and 11 are very shallow indeed. Profile No. 4 is limited by its high water-table at about 60cm, while Profile No. 11 is limited in its depth by the very shallow top-soil, decomposing parent materials occurring between 15 and 30cm from the surface.

B. Topography of the Land. From slope or terrain point of view, the areas are classified into 6 slopes as follows:-

Gradient (%)	Degree	Acreage
a - 0-3%	$0^{\circ}-1\frac{1}{2}^{\circ}$	127.39
b - 3-8%	$1\frac{1}{2}^{\circ}-4\frac{1}{2}^{\circ}$	178.14

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1:10 GRADIENT
10% "
5.7° SLOPE

N.B. 1:4 GRADIENT
25% "

14° SLOPE

MAX ANNUAL
ARABLE CROP STANDARD

MAX PERENNIAL CROP
STANDARD.

Gradient (%)	Degree	Acreage
c - 8-16%	$4\frac{1}{2}^{\circ}$ - 9°	572.96
d - 16-25%	9°-$13\frac{1}{2}^{\circ}$	634.69
e - 25-30%	$13\frac{1}{2}^{\circ}$-$15\frac{1}{2}^{\circ}$	910.05
f - 30% and above	$15\frac{1}{2}^{\circ}$ and above	493.54
	TOTAL	2916.77

	%	grade
$1\frac{1}{2}^{\circ}$	2.6	1:38
$4\frac{1}{2}$	7.8	1:12.4
9°	15.4	1:6.3
$13\frac{1}{2}^{\circ}$	24.0	1:4.2
$15\frac{1}{2}^{\circ}$	24.4	1:3.6

The slope classes a, b, and c should not impose any significant limitation, although the terrain under class c is moderately steep. With standard management practices of oil palm cultivation, this slope class is acceptable. However, the slope classes d, e and f will certainly effect the productivity as well as the normal management practices detrimentally, the extent of which will increase as the slope increases. Infact, the slope class f and class e with certain soil types are unsuitable for cultivation of oil palm. It should be pointed out that the areas under slope classes c, d and e amounting to about 2,117.70 acres will require extra expenditure in way of terracing, harvesting, transporting than is usual with slope classes a and b.

C. Soil Chemical Properties. The results of mechanical and chemical composition of soil samples from the 11 typical profiles are given in Appendix A.

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It will be seen that the texture of these soils varies from fine sandy clay, through fine sandy loom, to fine sand. The Profile Nos 1, 3, 5, 7, 8, 9 and 11 are either sandy clay loam or clay loam at different depths. On the other hand, the Profile Nos. 2, 4, 6 and 10 are fine sandy loam to fine sand at different depths. The soils of fine sand texture are expected to be low in their nutrient and moisture retention capacity.

The pH values of the soils vary from about 4.2 to upto about 5.6. The pH range from 4 to 5 is generally considered suitable for growth of oil palm. When the pH rises to 5.5 and above, there exists the possibility of imbalance of nutrition in oil palm due to inhibition of potassium uptake.

The levels of organic carbon, total nitrogen and phosphorus, both in total and available forms, are generally of normal range that are common for the inland soils derived from sedimentary parent materials from which the soils are generally derived. Generally, these values tend to be on the low side indicating the necessity of regular applications of nitrogen and phosphorus, as is usual on most soils in West Malaysia and non-volcanic soils of East Malaysia.

The values for potassium, calcium, and magnesium indicate that there are good reserves of potassium, except in Profile Nos. 4 and 6. In Profile No. 5, the top-soil upto 30cm shows

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low potassium reserve, although the sub-soil below this depth has adequate potassium reserve. The exchangeable contents of potassium however is moderate in most soils, except in Profile Nos. 4 and 6 where the contents are very low. In comparison the calcium and magnesium contents, both in total and exchangeable forms, are comparatively high. Again, Profile Nos. 4 and 6 show low magnesium contents both in total and exchangeable forms.

The above chemical characteristics indicate that except in Profile Nos 4 and 6, the chemical characteristics are acceptable, although problems relating to imbalance of nutrition particularly of potassium, calcium and magnesium will be complicated, and proper interpretation of soil analysis would be required in order to achieve the appropriate uptake of potassium and magnesium.

D. Sunshine and Rainfall. The monthly sunshine hours recorded at the Agricultural Experiment Station adjacent or near Sarawak Oil Palm Plantation for the year 1974, 1975, 1976, 1977 are given in Table 1. . Although, the records are incomplete for a few months in 1975 and in 1977, these records show that the annual sunshine hours are about 2,000 hours, the monthly variation being from about 130 to about 210. These amount of sunshine is considered to be more than adequate for satisfactory growth and yield of oil palm , not only from the annual basis but also from the point of view of the monthly distribution. Infact, the total annual sun-

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shine hours of 1,800 with a distribution of not less than 120 hours a month is adequate for oil palm growth and an yield of 25 tons FFB per hectare. It is therefore, concluded that sunshine hours as given in Table 1 is not a limiting factor for growth and yield in Sarawak Oil Palm.

The rainfall figures for the year 1976 and upto June 1977 are given in Table 2. It will be seen that the annual rainfall of about 2,500mm with a monthly distribution varying from about 50mm per month to about 500mm per month are possible. However, it is obvious that there is no consequtive 3 months with less than 100mm monthly rainfall. This signifies that there is no prolong dry period to inhibit growth and yield of oil palm.

It may be pointed out that occassionally there are perhaps not more than one month in a year which receives very high rainfall and correspondingly low sunshine. In 1976, this was in January when the sunshine hours were about 78 with a rainfall of about 300mm. In 1977, this was in February when the sunshine hours were only 68 with a corresponding rainfall of about 480mm. However, since these are occasional with not even two consequtive months, this should not prove to be a limiting factor from the physiological point of view for either growth of yield potential. However, such high rainfall and low sunshine may give rise to disease and pollination problems leading to low yield.

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YIELD POTENTIAL

Based on the four main agronomic factors determining suitability of the area for oil palm cultivation as discussed above, the following yield potentials for the different soil areas are estimated as given in Table 3.

It will be seen that of the total area of 2,916.8 acres, about 771.43 acres are considered UNSUITABLE for oil palm planting. The remaining area of 2,145.31 acres are expected to provide a yield of 15,723.24 tons FFB when the yield stabilizes after the initial period of 3 to 4 years of harvesting. This provides an average yield potential of 7.33 tons FFB per acre per annum for the planted area of 2,145.31 acres. The acreage for the different yield potentials ranging from 6 tons to 9 tons FFB per acre per annum are given below in Table 4. It will be seen that;

1) As much as 26.45% of the area under survey is not suitable for oil palm planting,

2) Approximately 59% of the area has a yield potential of about 7 to 8 tons FFB/ac/ann.,

3) Only about 5% of the area is likely to yield about 9 tons of FFB, and

4) About 10% of the area has a yield potential of 6 tons FFB per acre per annum.

The attached map shows the different areas with their yield potentials.

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CONCLUSION

It would appear from the above discussion that;

1) About 74% of the area under survey is suitable for oil palm planting with an average yield potential of about 7.33 tons FFB per acre per annum after the initial 3 to 4 years of harvesting .

2) About 26% of the area under survey is not suitable for planting with oil palm.

3) In view of the differences in soil chemical properties and also the variability in the texture and in the chemical composition of the soil, discriminatory manuring will be required to achieve the balanced nutrition of the palms in the different soil areas.

4) The production cost in areas under slope classes c, d and e covering an area of about 2,117 acres will require extra expenditure for terracing, harvesting, transportation, and ground maintenance etc.

5) The heavy rainfall months with low sunshine hours may cause some loss in yield due to bunch-rot and other disease problems.

SOIL PROFILE DESCRIPTION

PROFILE NO. 1

Depth (cm)	
0-15	10YR 5/4 (Silt 25%; clay 45%; very fine sand 30%). Moderate, medium and coarse subangular blocky; very friable (moist) with 30% streaks and blotches of 7.5YR 5/6 mottles. 10% roots and 5% pores.
15-45	10YR 5/8 and in ptaches varigated. 10YR 5/8, 10YR 6/4 and streaks; blotches of 7.5YR 5/8 mottles: May at times be as high as 40% (silt 30%; clay 50%; very fine sand 20%). Clay; moderate to weak, medium and coarse sub-angular blocky; friable to firm (moist). 1% roots and no pores.
45-150	10YR 6/8 (silt 35%, clay 40%, very fine sand 25%). Moderate to weak, medium and coarse subangular blocky, friable to firm (moist). 1% roots. Water table at 150cm.

Heavy textured soil - top soil varigated with 50% mottles; friable to firm; and average drainage.

SOIL MECHANICAL AND CHEMICAL ANALYSIS

PROFILE NO. 1

Depth (cm)	0-15	15-45	45-150
Coarse Sand %	1.1	0.4	0.3
Fine Sand %	32.6	31.0	51.6
Silt %	39.0	42.1	28.4
Clay %	31.9	28.5	22.4
pH (water)	4.6	4.6	4.5
Carbon %	1.17	.55	.30
Nitrogen %	.141	.089	.053
Phosphorus $\frac{\text{Total}}{\text{Avail.}}$ p.p.m.	283 / 36	206 / 5	167 / 7
Potassium $\frac{\text{Total}}{\text{Exch.}}$ m.e.%	1.18 / .21	1.13 / .16	1.78 / .11
Calcium $\frac{\text{Total}}{\text{Exch.}}$ m.e.%	.76 / .58	.49 / .70	.34 / .40
Magnesium $\frac{\text{Total}}{\text{Exch.}}$ m.e.%	2.35 / .57	1.94 / .34	10.13 / .26

SOIL PROFILE DESCRIPTION

PROFILE NO. 2

Depth (cm)	
0-15	10YR 3/3 (very fine sand 70%; clay 10%; silt 20%). Very fine sand; strong; medium and fine crumbs; subangular blocky; very friable (moist); plenty of roots (50%) and pores.
15-20	10YR 5/8 (very fine sand 70%; clay 10%; silt 20%). Very fine sand; moderate; medium and coarse subangular blocky; friable (moist) 20% crumbs from top soil has moved down through cavities made by earth movers. Plenty of roots (30%) and pores.
20-60	10YR 6/8 (very fine sand 60%; clay 15%; silt 25%). Moderate, medium and coarse subangular blocky; very friable (moist); 10% roots.
60-90	7.5YR 6/8 (very find sand 70%; clay 10%; silt 20%). Weak, coarse subangular blocky; friable to slightly firm (moist); 2% roots and 1% laterites ¼" in size.
90-180	Matrix 7.5YR 6/8 (very find sand 85%; clay and silt 15%). Weak, coarse subangular blocky; friable; decomposing parent material, very very fine sand ½ to 2" in size and easily crushed within fingers.

SOIL MECHANICAL AND CHEMICAL ANALYSIS

PROFILE NO. 2

Depth (cm)	0-5	5-20	20-60	60-90	90-180
Coarse Sand %	1.3	0.5	0.8	6.2	0.8
Fine Sand %	67.0	69.0	52.2	55.8	78.2
Silt %	13.4	13.6	23.6	20.0	8.6
Clay %	15.3	14.6	22.8	24.0	10.9
pH (water)	4.2	4.3	4.3	4.5	4.8
Carbon %	2.61	1.13	.40	.24	.20
Nitrogen %	.191	.099	.067	.041	.26
Phosphorus Total p.p.m.	270	129	142	142	52
Phosphorus Avail. p.p.m.	58	16	7	7	7
Potassium Total m.e.%	1.94	2.00	1.76	1.52	1.31
Potassium Exch. m.e.%	.18	.11	.12	.13	.07
Calcium Total m.e.%	3.00	.86	.46	.27	.74
Calcium Exch. m.e.%	2.50	.79	.59	.40	.29
Magnesium Total m.e.%	9.92	10.33	7.69	5.87	.81
Magnesium Exch. m.e.%	.77	.12	.17	.16	.15

SOIL PROFILE DESCRIPTION

PROFILE NO. 3

Depth (cm)	
0-5	10YR 5/6 (clay 45%, silt 25%, very fine sand 25%, coarse sand 5%). Weak, medium and coarse subangular blocky; friable (moist) few pores; plenty of fine roots.
5-30	7.5YR 6/8 clay; weak, coarse subangular blocky; firm (moist); (clay 60%, silt 20%, very fine sand 15%, coarse sand 5%). 2.5YR 4/8 blotches of mottles 25%; 10% laterites - some soft and some hard. ½" to 1" in size; loosely scattered 30%.
30-150	Varigated colours 10YR 5/6 50%, 7.5YR 6/8 50% (clay 60%, silt 20%, very fine sand 15%, coarse sand 5%); weak, coarse subangular blocky; firm (moist); 30% mottles. 2.5YR 4/8 50% laterites - some hard and some soft. ½" to 6" - even the hard stones can be knocked with a parang.

SOIL MECHANICAL AND CHEMICAL ANALYSIS

PROFILE NO. 3

Depth (cm)		0-5	5-30	30-150
Coarse Sand %		3.1	6.4	7.5
Fine Sand %		45.5	28.0	33.0
Silt %		24.5	17.6	26.7
Clay %		26.9	47.9	33.2
pH (water)		4.7	4.7	4.4
Carbon %		.90	.44	1.70
Nitrogen %		.107	.060	.076
Phosphorus	Total p.p.m.	206	167	155
	Avail. p.p.m.	9	7	5
Potassium	Total m.e.%	2.62	3.52	3.71
	Exch. m.e.%	.31	.16	.25
Calcium	Total m.e.%	2.37	.62	1.51
	Exch. m.e.%	1.84	.60	.76
Magnesium	Total m.e.%	7.30	9.73	10.53
	Exch. m.e.%	.84	.13	.20

SOIL PROFILE DESCRIPTION

PROFILE NO. 4

Depth (cm)	
0-10	10YR 6/3 weak coarse to structureless (very fine sand 95%; silt 5%); friable (moist).
10-60	10YR 8/1 structureless; friable (moist) but during dry season likely to be hardened just as cement.
60	Water table and parent material.

SOIL MECHANICAL AND CHEMICAL ANALYSIS

PROFILE NO. 4

Depth (cm)	0-10	10-60	60+
Coarse Sand %	1.8	0.4	
Fine Sand %	93.0	89.8	SAMPLE
Silt %	7.3	9.5	
Clay %	2.4	0.8	MISSING
pH (water)	3.3	3.9	
Carbon %	.48	.09	ON
Nitrogen %	.032	.008	
Phosphorus $\frac{\text{Total}}{\text{Avail.}}$ p.p.m.	13 / 9	13 / 9	ARRIVAL
Potassium $\frac{\text{Total}}{\text{Exch.}}$ m.e.%	.04 / .03	.04 / .02	
Calcium $\frac{\text{Total}}{\text{Exch.}}$ m.e.%	.17 / .15	.15 / .10	
Mangesium $\frac{\text{Total}}{\text{Exch.}}$ m.e.%	.16 / .08	.15 / .02	

SOIL PROFILE DESCRIPTION

PROFILE NO. 5

Depth (cm)	
0-3	10YR 5/4 (clay 20%; silt 20%; very fine sand 50%; coarse sand 10%). Moderate to weak, medium and coarse subangular blocky; friable (moist); plenty of roots.
3-30	10YR 6/8 fine sandy clay (clay 30%; silt 20%; very fine sand 40%; coarse sand 10%). Moderate to weak, medium and coarse subangular blocky; friable to slightly firm (moist); 20% roots.
30-33	Matrix 10YR 6/8 clay (clay 50%; silt 10%; very fine sand 30%; coarse sand 10%). Moderate to weak, medium and coarse subangular blocky, friable to slightly firm (moist). This lateritic band - not always at 30cm but runs irregularly; laterite 50% - loosely packed ¼" - ¾" in size.
33-120	10YR 5/6 clay (clay 60%; silt 10%; very fine sand 25%; coarse sand 5%). Moderate to weak, medium and coarse subangular, friable to slightly firm (moist).
120-180	60% Matrix 10YR 6/8 (clay 40%; silt 30%; very fine sand 30%). Moderate to weak, medium to coarse subangular blocky; friable to slightly firm, generally on more friable side. C horizon - decomposing parent material - very very fine - easily broken with fingers.

SOIL MECHANICAL AND CHEMICAL ANALYSIS

PROFILE NO. 5

		0-3	3-30	30-33	33-120	120-180
Depth (cm)		0-3	3-30	30-33	33-120	120-180
Coarse Sand %		2.2	1.0	4.2	2.1	2.3
Fine Sand %		55.2	54.2	41.3	23.6	47.0
Silt %		22.5	21.1	27.2	41.6	21.7
Clay %		23.0	28.1	35.1	36.9	34.0
pH (water)		4.9	4.7	5.1	5.8	4.8
Carbon %		1.44	.43	.81	1.79	.31
Nitrogen %		.153	.064	.091	.224	.051
Phosphorus	Total p.p.m.	244	155	321	308	129
	Avail. p.p.m.	12	7	23	8	6
Potassium	Total m.e.%	.26	.22	3.01	4.33	6.91
	Exch. m.e.%	.21	.11	.38	.24	.23
Calcium	Total m.e.%	2.43	.84	3.74	8.40	.78
	Exch. m.e.%	2.96	.70	3.99	9.22	1.20
Magnesium	Total m.e.%	6.89	1.79	11.95	16.41	10.14
	Exch. m.e.%	.77	.15	1.10	2.62	.44

SOIL PROFILE DESCRIPTION

PROFILE NO. 6

Depth (cm)	
0-3	1OYR 5/4 (clay 10%; silt 5%; fine sand 85%). Moderate, medium and coarse subangular blocky; very friable (moist) plenty of roots.
3-15	1OYR 6/8 (clay 10%; silt 5%; fine sand 85%). Moderate to weak, medium and coarse sub-angular blocky, very friable (moist); plenty of roots.
15-30	7.5YR 6/8 (clay 15%; silt 5%; fine sand 80%). Weak, medium and coarse subangular blocky; friable (moist).
30-60	5YR 6/8 (clay 15%; silt 5%; fine sand 80%). Weak, coarse subangular blocky; friable (moist).
60-150	5YR 5/8 (clay 15%; silt 5%; fine sand 80%). Weak, coarse subangular blocky; friable (moist).

SOIL MECHANICAL AND CHEMICAL ANALYSIS

PROFILE NO. 6

		0-3	3-15	15-30	30-60	60-150
Depth (cm)		0-3	3-15	15-30	30-60	60-150
Coarse Sand %		2.7	1.4	1.9	1.9	1.4
Fine Sand %		84.5	91.6	78.1	74.3	83.0
Silt %		8.6	9.9	11.1	8.6	3.4
Clay %		8.8	1.7	4.2	14.5	16.7
pH (water)		4.8	5.4	5.5	5.2	5.0
Carbon %		2.62	.61	.39	.11	.13
Nitrogen %		.161	.038	.019	.013	.012
Phosphorus	Total p.p.m.	78	65	78	52	78
	Avail. p.p.m.	8	10	5	7	5
Potassium	Total m.e.%	.36	2.29	.27	.44	.58
	Exch. m.e.%	.17	.02	.02	.05	.06
Calcium	Total m.e.%	1.45	.22	.20	.28	.72
	Exch. m.e.%	1.60	.12	.49	.39	.39
Magnesium	Total m.e.%	1.34	7.91	.32	.16	.49
	Exch. m.e.%	.83	.04	.04	.04	.05

SOIL PROFILE DESCRIPTION

PROFILE NO. 7

Depth (cm)	
0-10	10YR 6/8 fine sandy clay to clay (clay 40%; silt 10%; fine sand 50%). Moderate to strong, medium and fine subangular blocky; friable (moist); plenty of roots, few pores.
10-30	7.5YR 6/8 clay (clay 50%; silt 10%; fine sand 35%; coarse sand 5%). Moderate, coarse subangular blocky; friable (moist), some roots.
30-120	Varigated colours - clay. 90% 7.5YR 6/8; 10% YY 6/8 (clay 60%; silt 10%; fine sand 30%). Moderate to weak, coarse subangular, blocky; friable to firm (moist) - with depth 10% roots.
120-180	C horizon - decomposing parent material and laterite. Varigated colour - 7.5YR 6/8 - 50% 5YR 6/8 - 30% 10YR 6/8 - 20% Matrix (clay 50%; silt 10%; fine sand 30%; coarse sand 10%); weak coarse subangular blocky; firm (moist). Laterite 40% in occurence - loose. 1-5" in size.

SOIL MECHANICAL AND CHEMICAL ANALYSIS

PROFILE NO. 7

Depth (cm)		10-10	10-30	30-120	120-180
Coarse Sand %		1.2	1.1	0.8	3.9
Fine Sand %		38.2	28.8	26.2	15.6
Silt %		22.0	23.4	24.7	25.7
Clay %		32.9	40.9	47.7	52.3
pH (water)		4.2	4.6	4.5	4.4
Carbon %		1.45	.93	.56	.55
Nitrogen %		.140	.093	.074	.096
Phosphorus	Total p.p.m.	129	193	206	193
	Avail. p.p.m.	12	7	3	3
Potassium	Total m.e.%	2.36	2.36	4.97	4.78
	Exch. m.e.%	.18	.20	.15	.24
Calcium	Total m.e.%	1.49	2.70	.70	.67
	Exch. m.e.%	1.10	1.10	.70	.50
Magnesium	Total m.e.%	2.76	5.47	6.89	6.07
	Exch. m.e.%	.40	.17	.10	.13

SOIL PROFILE DESCRIPTION

PROFILE NO. 8

Depth (cm)	
0-15	10YR 5/4 - fine sandy clay to clay (clay 35%; silt 10%; fine sand 35%; coarse sand 10%). Moderate to strong, medium and coarse subangular blocky; friable to slightly firm (moist); 5% pea size laterites 0.1 to 0.2"; plenty of roots and moderate pores.
15-30	10YR 6/6 - clay (clay 40%; silt 10%; fine sand 40%; coarse sand 10%). Moderate, medium and coarse subangular blocky; friable (moist). 10% fine roots, 2% fine pores. Occurence of lateritic concretions - 30% loosely packed; 1-2" in size and platy in shape; and also some peg size laterites.
30-75	10YR 6/4 - clay (clay 45%; silt 10%; fine sand 40%; coarse sand 5%). Moderate, medium and coarse subangular blocky; friable (moist). 30% loosely packed pea size laterites ½" in size and silt stones ½" in size and mixed. These moderate silt stones can be crushed within fingers.
75-130	Varigated colours 10YR 5/8 - 30% 10YR 6/3 - 70% Decomposing parent material, 'C' horizon, (clay 50%; silt 5%; fine sand 30%; coarse sand 15%). Weak coarse subangular blocky; firm (moist); 40% laterite - loosely 1-4" in rounded and platy, and soft parent material, stones platy, rounded 1-2" in size, appears to be mudstone.

SOIL MECHANICAL AND CHEMICAL ANALYSIS

PROFILE NO. 8

Depth (cm)		0-15	15-30	30-75	75-130
Coarse Sand %		0.1	0.9	1.9	0.9
Fine Sand %		22.5	18.8	31.8	8.9
Silt %		33.1	29.9	34.8	34.2
Clay %		47.0	55.1	37.7	60.2
pH (water)		5.6	5.0	5.1	5.7
Carbon %		2.50	1.22	.39	.49
Nitrogen %		.239	.148	.076	.120
Phosphorus	Total p.p.m.	308	257	219	219
	Avail. p.p.m.	7	4	2	3
Potassium	Total m.e.%	5.04	5.17	5.23	7.43
	Exch. m.e.%	.40	.35	.33	.46
Calcium	Total m.e.%	8.65	3.36	.58	6.64
	Exch. m.e.%	7.05	2.52	.51	5.74
Magnesium	Total m.e.%	24.31	3.01	33.23	37.28
	Exch. m.e.%	4.90	2.94	5.00	13.34

SOIL PROFILE DESCRIPTION

Appendix A

PROFILE NO. 9

Depth (cm)	
0-15	10YR 5/6 (clay 20%; silt 5%; fine sand 70%; coarse sand 5%). Moderate to weak, medium and coarse subangular blocky; slightly friable to firm (moist to dry), plenty of roots; few pores.
15-30	10YR 6/8 (clay 30%; silt 10%; fine sand 55%; coarse sand 5%). Moderate, medium and coarse subangular blocky; firm (slightly dry); 10% roots and 10% streaks and blotches not very distinct mottles. 7.5YR 6/8; few pores.
30-60	90% YR 6/8 10% 2.5Y 7/4 - blotches (clay 30%; silt 20%; fine sand 70%). Moderate coarse subangular blocky; friable (moist), 5% streaks and blotches of not very prominent mottles 7.5YR 6/8.
60-105	Varigated - 10YR 6/8 - 60% 2Y 7/4 - 40% 30% streaks and blotches of very prominent 7.5YR 6/8 mottles (clay 35%; silt 15%; fine sand 50%). Moderate to weak; medium and coarse subangular blocky; friable (moist) 10% pea size 0.1 to 0.2" laterites loose and quite easily crushed within fingers.

Cont'd 2/.......

PROFILE NO. 9 (cont'd)

105-150	Decomposing parent material; varigated colours 10YR 6/8 40%; 2.5Y 7/4 40%; 10YR 7/2 20% in streaks and blotches. Weak coarse subangular blocky; friable (moist) - (clay 40%; silt 10%; fine sand 60%); 30% occurence of lateritic concretions, which can be quite easily broken within fingers. At times as big as 5-6" in length and 2-3" in width. 40% streaks and blotches of 7.5YR 6/8 distinct mottles.

SOIL MECHANICAL AND CHEMICAL ANALYSIS

PROFILE NO. 9

Depth (cm)		0-15	15-30	30-60	60-105	105-150
Coarse Sand %		1.6	2.0	1.1	2.7	1.9
Fine Sand %		53.8	46.6	53.0	47.6	52.4
Silt %		18.3	16.0	13.9	18.0	12.8
Clay %		27.4	34.7	39.2	36.9	37.5
pH (water)		5.2	4.6	4.8	4.8	5.0
Carbon %		.99	.55	.37	.37	.38
Nitrogen %		.121	.091	.067	.054	.049
Phosphorus	Total p.p.m.	155	116	193	116	129
	Avail. p.p.m.	11	5	4	5	3
Potassium	Total m.e.%	1.97	2.42	2.81	4.52	3.46
	Exch. m.e.%	.16	.20	.21	.15	.19
Calcium	Total m.e.%	3.07	.70	.52	.46	.65
	Exch. m.e.%	2.14	.44	.78	.17	1.30
Mangesium	Total m.e.%	6.69	5.87	8.10	2.35	9.12
	Exch. m.e.%	.93	.44	.72	.55	1.25

SOIL PROFILE DESCRIPTION

PROFILE NO. 10

Depth (cm)

0-3	10YR 4/4 (clay 20%; silt 10%; fine sand 60%; coarse sand 10%). Moderate to strong, medium and fine subangular blocky; friable (moist); plenty of roots.
3-15	10YR 5/6 (clay 30%; silt 10%; fine sand 60%). Moderate, medium and coarse subangular blocky; friable (moist), with plenty of roots.
15-60	10YR 7/8 (clay 40%; silt 10%; fine sand 50%). Moderate, medium and coarse subangular blocky; friable (moist).
60-150	Varigated colours; 80% 10YR 7/8; 20% 10YR 7/3 (clay 40%; silt 10%; fine sand 50%). Moderate, medium and coarse subangular blocky; friable (moist) to firm.

SOIL MECHANICAL AND CHEMICAL ANALYSIS

PROFILE NO. 10

Depth (cm)		0-3	3-15	15-60	60-150
Coarse Sand %		2.1	2.0	1.2	1.5
Fine Sand %		59.4	69.0	67.9	57.8
Silt %		17.3	9.8	10.8	9.9
Clay %		25.4	22.7	16.8	35.2
pH (water)		5.0	4.5	4.4	4.6
Carbon %		2.06	1.63	.39	.78
Nitrogen %		.123	.103	.045	.038
Phosphorus	Total p.p.m.	142	91	52	65
	Avail. p.p.m.	11	9	3	3
Potassium	Total m.e.%	3.13	2.62	3.36	2.62
	Exch. m.e.%	.31	.16	.14	.11
Calcium	Total m.e.%	2.11	.77	.25	.35
	Exch. m.e.%	1.95	.88	.20	.19
Magnesium	Total m.e.%	5.68	3.20	5.07	7.91
	Exch. m.e.%	1.65	.57	.42	.35

SOIL PROFILE DESCRIPTION

PROFILE NO. 11

Depth (cm)	
0-120	Decomposing parent material, varigated colours - 10YR 6/1 - 40% 10YR 6/3 - 20% 10YR 4/4 - 30% 10YR 6/8 - 10% Structureless (clay 50%; silt 20%; fine sand 30%). Some 20-30% laterite formation in process. Platy structure and at 45cm parent material present in lumps but soft though.

SOIL MECHANICAL AND CHEMICAL ANALYSIS

PROFILE NO. 11

Depth (cm)		0-120
Coarse Sand %		8.2
Fine Sand %		14.8
Silt %		36.4
Clay %		46.5
pH (water)		5.5
Carbon %		1.37
Nitrogen %		.106
Phosphorus	Total / Avail. p.p.m.	334 / 1
Potassium	Total / Exch. m.e.%	7.27 / .37
Calcium	Total / Exch. m.e.%	3.51 / 1.99
Magnesium	Total / Exch. m.e.%	11.95 / 9.66

BASIC FEATURES OF THE PROFILES OF THE SOIL TYPES

Profile No.	Slope at Site		Soil Description
1	0-1%	T.S.	Yellowish brown (10YR 5/4) silty clay loam; moderate medium & coarse subangular blocky; very friable; 30% streaks & blotches of strong brown (7.5YR 5/6) mottles; 10% roots; 5% pores.
		S.S	Yellowish brown (10YR 5/8) to brownish yellow (10YR 6/8) silty clay loam, moderate to weak medium & coarse subangular blocky; friable to firm with depth; 40% streaks and blotches of strong brown (7.5YR 5/8) mottles; 1% roots; water table at 150cm.
2	20%	T.S.	Yellowish brown (10YR 5/8) fine sandy clay loam; moderate medium & coarse subangular blocky; friable; 50% roots and pores.
		S.S.	Brownish yellow (10YR 6/8) to reddish yellow (7.5YR 6/8) fine sandy clay loam; friable to slightly firm; moderate medium & coarse to weak medium & coarse with depth, subangular blocky; 10% roots; 1% laterites-¼" in size; soil depth 90cm; 90cm and below decomposing parent material.
3	30%	T.S.	Yellowish brown (10YR 5/6) to reddish yellow (7.5YR 6/8) clay loam to clay weak medium & coarse subangular blocky; friable to slightly firm; 25% blotches of reddish yellow (7.5YR 6/8) mottles; 10% laterites-some soft and some hard and ranging from ½"-1" in size.
		S.S.	Varigated colours yellowish brown (10YR 5/6) 50% and reddish yellow (7.5YR 6/8) 50% clay loam weak coarse subangular blocky firm with depth; 30% blotches of red (2.5YR 4/8) mottles; 50% laterites-some soft and some hard and ranging from ½-6" in size-(even the sandstones can be knocked with a parang).
4	0-3%	T.S.	Pale brown (10YR 6/3) to white (10YR 8/1) fine sand; structureless friable when moist and very hard (like a cement wall) when dry.

cont'd

Profile No.	Slope at Site		Soil Description
4	0-3%	S.S.	White (1OYR 8/1) fine sand; structureless very firm; water table at 60cm.
5	6%	T.S.	Brownish yellow (1OYR 6/8) fine sandy clay loam; moderate to weak medium and coarse subangular blocky; friable to slightly firm; 20% roots.
		S.S.	[a thin laterite band of 3cm thickness and running irregularly at 30cm and 45cm depth; laterites 50%-loosely packed ¼-¾" in size and matrix brownish yellow (1OYR 6/8) fine sandy clay loam; moderate to weak medium and coarse subangular blocky; friable to slightly firm] Yellowish brown (1OYR 5/6) silty clay loam; moderate to weak medium and coarse; subangular blocky; friable to slightly firm. 120cm + decomposing P.M. (N.B. roots can penetrate).
6	20%	T.S.	Brownish yellow (1OYR 6/8) fine sand; moderate to weak medium and coarse subangular blocky; very friable; 40% roots.
		S.S.	Reddish yellow (7.5YR 6/8) to reddish yellow (5YR 6/8) fine sand to loamy fine sand with depth; weak medium and coarse to weak coarse subangular blocky; friable.
7	16%	T.S.	Brownish yellow (1OYR 6/8) fine sandy clay loam, moderate to strong medium and fine subangular blocky friable; plenty of roots and few pores.
		S.S.	Reddish yellow (7.5YR 6/8) clay, % of clay increasing with depth; moderate to weak coarse subangular blocky; friable to slightly firm; 120cm + p.m.- Matrix 60%; laterites 40% (N.B. roots can penetrate) (good soil).
8	8%	T.S.	Yellowish brown (1OYR 5/4) clay; moderate to strong; medium and coarse subangular blocky; friable to slightly firm; 5% .1 to .2" pea sized laterites; plenty of roots and pores.

cont'd

Profile No.	Slope at Site		Soil Description
8	8%	S.S.	Brownish yellow (10YR 6/6) clay; moderate medium and coarse subangular blocky; friable to slightly firm; 30% loosely packed ½-2" size laterites at 75cm + decomposing p.m. though roots can penetrate but not as good as in Profiles 5 and 7.
9	30%	T.S.	Yellowish brown (10YR 5/6) loam; moderate medium and coarse subangular blocky; friable to slightly firm; 10% streaks and blotches of reddish yellow (7.5YR 6/8) mottles; 10% roots
		S.S.	Brownish yellow (10YR 6/8) to varigated colours brownish yellow (10YR 6/8) 60% and pale yellow (2.5Y 7/4) 40%; fine sandy clay loam to clay; moderate coarse subangular blocky; friable to slightly firm; 30% streaks and blotches of very prominent reddish yellow (7.5YR 6/8) mottles; 20% .1 to 2" pea sized laterites -loose and quite easily crushed within fingers. 105cm + decomposing P.M. (roots can penetrate).
10	30%	T.S.	Yellowish brown (10YR 5/6) fine sandy clay loam; moderate medium and coarse subangular blocky; friable with plenty of roots;
		S.S.	Yellow (10YR 7/8) to varigated colours; Yellow (10YR 7/8) 80% and very pale brown (10YR 7/3) 20%; fine sandy clay loam ; moderate medium and coarse subangular blocky; friable to slightly firm around 100cm + appear to be decomposing P.M. and in the lower horizon bigger sandstones 1-10" size appears.
11	30%		Decomposing P.M. - Structureless varigated colours - 10YR 6/1 40% 10YR 6/3 20% 10YR 6/8 10% 10YR 4/4 30%

soil consistency always under moist conditions, unless otherwise mentioned.

T.S. - Top Soil
S.S. - Sub Soil

TABLE 1: MONTHLY SUNSHINE HOURS IN SARAWAK OIL PALM SDN BHD

	1974	1975	1976	1977
January	148.90	191.8	77.7	118.40
February	132.40	168.5	189.4	68.40
March	174.53	138.0	168.6	152.60
April	236.95	191.7	192.8	196.60
May	181.45	-	187.4	215.50
June	208.45	-	201.1	204.50
July	196.35	-	168.40	163.60
August	185.50	-	209.00	167.50
September	192.15	-	181.60	158.10
October	120.25	-	171.00	-
November	163.45	166.9	153.90	-
December	152.13	145.6	188.80	-
TOTAL	2,093.13	-	2,089.7	-

TABLE 2 : YEARLY RAINFALL IN SARAWAK OIL PALM SDN BHD

	Days Rain	Inches	MM
1976			
January	19	21.99	558.55
February	9	15.11	129.79
March	15	3.33	84.58
April	15	3.55	90.17
May	10	10.44	265.18
June	6	4.91	124.71
July	4	1.98	50.29
August	13	13.55	344.17
September	7	5.35	135.89
October	13	10.21	259.33
November	9	8.99	228.35
December	18	10.60	269.24
TOTAL	118	100.01	2,540.25
1977			
January	20	13.18	334.77
February	21	18.89	479.81
March	12	4.80	121.92
April	3	1.08	27.43
May	6	3.86	98.04
June	12	8.68	220.47
TOTAL	74	50.49	1,282.44

TABLE 3: YIELD POTENTIALS FOR THE DIFFERENT SOIL TYPES

Area No.	Acreage	Yield Potential (FFB ton/ac/ann)	Total Yield
1a	96.66	9	869.94
2c	46.17	8	369.36
2d	59.44	8	475.52
2e? 2e	156.79	7	1097.53 ?
2f	25.66	Not Suitable	-
3a	13.61	7	95.27
3b	4.82	7	33.74
3c	131.98	7	923.86
3d	19.81	6	118.86
3e	50.83	6	304.98 ?
3f	101.83	Not Suitable	-
4b	38.08	Not Suitable	-
4f	18.78	Not Suitable	-
5b	85.11	8	680.88
5c	44.28	8	354.24
5d	75.81	7	530.67
5f	4.82	Not Suitable	-
6a	17.12	9	154.08
6c	14.81	8	118.48
6d	40.83	8	326.64
6e	41.17	7	288.19
7c	30.14	9	271.26
7d	164.02	8	1312.16
7e	303.05	7	2121.35
8c	98.72	7	691.04
8d	96.66	6	579.96
8e	83.39	6	500.34 ?
9b	50.13	8	401.04
9c	199.11	8	1592.88

cont'd

Area No.	Acreage	Yield Potential (FFB ton/ac/ann)	Total Yield
9d	168.47	7	1179.29
9f	15.95	Not Suitable	-
10c	7.75	7	54.25
10d	9.65	7	67.55
10e	34.98	6	209.88 ?
10f	39.97	Not Suitable	-
11e	239.84	Not Suitable	-
11f	286.53	Not Suitable	-

Suitable	2145.31
Not Suitable	771.43
TOTAL	2916.74ac.

$$\text{Average Yield} = \frac{\text{Total Yield}}{\text{Total Suitable Acreage}}$$

$$\text{i.e.} = \frac{15,723.24}{2,145.31}$$

$$= 7.33 \text{ tons/ac/ann.}$$

$$\text{Average overall yield} = \frac{\text{Total Yield}}{\text{Total Acreage}}$$

$$\text{i.e} = \frac{15,723.24}{2,916.74}$$

$$= 5.39 \text{ tons/ac/ann.}$$

TABLE 4: AREAS WITH DIFFERENT YIELD POTENTIALS

Expected Yield	Total Acreage	Total Tonnage	% Total Area
9	143.92	1295.28	4.94
8	703.90	5631.20	24.13
7	1011.82	7082.74	34.69
6	285.67	1714.02	9.79
Not Suitable	771.46	-	26.45
TOTAL	2916.74	15723.24	99.98

S.O.P SDN. BHD.
SOIL MAP (1974&'76 PLANTINGS)

Scale 1 : 10,000

LEGEND

1	Friable to firm silty clay W.T. at 150 cm
2	" " " very fine sand P.M. at 90 cm
3	Firm clay laterites from 30-150 cm
4	Friable (moist) firm (dry) very fine sand W.T. at 60 cm
5	Friable to firm fine sandy clay P.M. at 120 cm
6	Friable " " " up to 150 cm
7	Friable to firm clay P.M. at 120 cm
8	" " " " " " 75 cm
9	" " " fine sandy clay P.M. at 105 cm
10	Friable " " " P.M. at 60 cm
11	0-120 cm decomposing P.M.