

I.L.A. YSSELMUIDEN

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THIRD MALAYSIAN
SOILS CONFERENCE
SARAWAK
1968

Programme of Papers (every paper $\frac{3}{4}$ hour)

Session 1

Morning: 16th May - Papers 1 and 2.

Afternoon: 16th May - Papers 3, 4, 5 and 6.

Teabreak at 15.00 - 15.15.

Visit to Soil Survey Office, Sarawak will be arranged at 17.00 a.m. for those interested. Please submit names to Mr. Scott as early as possible.

Session 1

Morning: 17th May - Papers 7 and 8. & 9

Coffee break at 10.00 - 10.15 a.m.

Session 2

Papers 1 and 2.

Afternoon: Papers 3, 4, 5 and 6.

Teabreak at 15.00 - 15.15.

Session 3

Morning: 18th May - Papers 1, 2, 3 and 4.

Coffee break at 10.00 - 10.15 a.m.

Afternoon: Papers 5, 6, 7 and 8.

Teabreak at 15.00 - 15.15.

If time permits report of Chemists' Meeting on Standardization of Methods.

Session 4

Morning: 19th May - Papers 1, 2, 3 and 4.

Coffee break at 10.00 - 10.15 a.m.

Afternoon: Any other business.

Third Malaysian Soils Conference

Sessions and list of papers presented

Session 1

Soil Genesis and Mapping - Chairman: Mr. R. F. Allbrook

1. ✓ Some Aspects of Soil Genesis in Sabah (East Malaysia) P. Thomas
2. ✓ Characteristics of some soils derived from Igneous Rocks of West Malaysia S. Paramanathan
3. ✓ A study of the Environment and Characteristics of Podsolis occurring in Sarawak (East Malaysia) J.P. Andriesse
4. ✓ Characteristics of a Sandy Podsol in West Malaysia K.T. Joseph & B.R. Hewitt
5. ✓ Terrace and Alluvial Soils in West Malaysia B. Gopinathan
6. ✓ A Preliminary Study on Acid-Sulphate Soils of West Malaysia Chow Weng Tai
7. ✓ Kaolinitic Clay in the Balai-Ringin-Abok Area, West Sarawak C.H. Kho
8. ✓ Padi Soils of West Malaysia Dr. Ng Siew Kee
9. ✓ Soil Survey methods in Topical Forest areas with particular reference to the use of aerial photographs B.D. Acres & C.J. Folland

Session 2

Land Capability and Land Use - Chairman: Dr. Y.T. Shao

1. ✓ Development and Land Analysis Techniques with Special Reference to Sarawak R. Gwilliam
2. ✓ Methodology of the present Land Use Survey of West Malaysia J. Donaldson
3. ✓ Land Capability Classification in Sabah (East Malaysia) P. Thomas
4. ✓ Soil Suitability Classification in Malaya - Some Critical Comments K.T. Joseph
5. ✓ Land Use in Malacca and some Agricultural Development Possibilities (West Malaysia) Siew Kam Yew

Session 3

Soil Chemistry and Fertility - Chairman: Dr. F. R. Moormann

1. ✓ FAO's Activities in the field of soil fertility research and promotion of fertilizer use Dr. H.N. Mukerjee
2. ✓ A Rapid Acid Dissolution Method for the Determination of Cations in Plant Materials Using Atomic Absorption and Emission Flame Spectrophotometry Mohinder Singh and K. Ratnasingam
3. ✓ A Study of Phosphatic Fertiliser uptake in Sarawak Soils B.J. Watson
4. ✓ A Study of the use of Cation-Exchange Resins of nutrient retention in soils B.Q.P. Corpuz & M.N.K. Hiew

Paper on Standardisation of Lab. Methods in Malaysia read by Dr. Ng Siew Kee.

- ✓ Manuring of Rubber in Relation to Soil Type:
I. Soils Derived from Acid Igneous Rocks -
Rengam Series. Dr. M.M. Guha
H.Y. Chan &
N.K. Soong
- The Soil Drainage Factor in Present Day Logging in
Sabah J.E.D. Fox
- ✓ An Ammonium Chloride Method for Determining Exchange-
able Potassium, Calcium, Magnesium and Aluminium in
Malayan Soils. Mohinder Singh
and
K. Ratnasingam
- A Thermodynamic Assessment of the Nutrient Status of
Malayan Soils: Quantity-Intensity Measurements for
Potassium Using Calcium Chloride Equilibration. Mohinder Singh,
K. T. Tan,
E. Pushparajah &
O. Talibudeen

Session 4

Soil Classification - Chairman: K. T. Joseph

- The Soil Map of Thailand Dr. F.R. Moormann
& Santhad
Rojanasoonthon
- ✓ The 1968 Reconnaissance Soil Map of Malaya Law Wei Min &
K. Selvadurai
- Malayan Soils Classified to the 7th Approximation R. F. Allbrook
- Methods of Detail Soil Classification and Mapping for
rubber growing soils of West Malaysia. Dr. M.M. Guha

Programme tour First Division

<u>3th May</u>	assembling Aurora Hotel - departure	07.45
	State Development Operations Room	
	tour ribbon development along Kuching-Serian road, <u>Kerait</u> profile	
	<u>Tarat</u> profile	
	arrival Tarat Agricultural Station	12.45
	lunch Tarat Station	
	tour Tarat Agricultural Station (Dr. Raj - Pepper Agronomist and Farm Manager in-charge)	
	departure Tarat Station	
	7th mile Kuching-Serian road - <u>Triboh</u> profile	
	departure for Kuching	
	arrival Kuching (Aurora Hotel)	estimated 17.30
<u>4th May</u>	assembling Aurora Hotel - departure	07.45
	arrival Pangkalan Batu	
	by boat to Santubong D. and I. Scheme (D. & I. Engineer in-charge)	
	to S. Trombol by boat	
	<u>Jerijeh</u> and <u>Sematan</u> profiles	
	to Sibu Laut	
	pack lunch at Sibu Laut (on beach)	13.00
	departure for Semariang	
	Semariang	
	to Matang road 9½ mile	
	<u>Buso</u> profile	
	departure for Kuching	
	arrival Kuching - Aurora Hotel	estimated 16.45
<u>5th May</u>	assembling Aurora Hotel - departure	08.00
	to Batu Kawa Peat Research Station (Mr. B. J. Watson in-charge)	
	<u>Anderson</u> profile	
	to Bau	
	<u>Abok</u> profile	
	Bukit Young' Gold Mine	
	to Semongok Research Station	
	lunch	13.00 - 13.45

Brief talk by A.D.R. on work in the Station
Tour around the Station and visit to laboratories
Tea and talk by A. D. (Education) on Farmers'
Training Centre
Visit to Farmers' Training Centre, Semongok
Departure for Kuching
Arrival Kuching (Aurora Hotel) estimated 17-45

Tour leader:	J. P. Andriesse
Transport and catering:	Ahmad Haji Ebon
Profiles:	J. P. Andriesse

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Guide First day tour, First Division - 13th May, 1968

Note: for orientation see traverse marked in blue on the map in pocket.

Land along the Kuching-Serian road is Mixed Zone land, meaning that land can be owned and held under title by all racial groups found in Sarawak.

This Mixed Zone land occupies a strip of $1\frac{1}{2}$ mile depth on each side of the road, land behind this ribbon being almost exclusively Dayak owned under Customary Rights.

The Mixed Zone land is intensively developed by the now almost exclusively Chinese population. Rubber and pepper cultivation are the main sources of income while at some points (notably between 17th and 20th mile) vegetable gardening is of local importance. These areas supply the Kuching Market daily with fresh vegetables.

From the 3rd to 4th mile the road crosses a deep peat swamp which was originally planted up by river. This area is now being developed for industrial uses! Road construction which takes place between the 4th and 7th mile (new double lane road from Kuching Airport to Kuching Town) enables the viewing of some excellent examples of Triboh and Kerait family soils (Grey-White Podsolics) developed over respectively old alluvial which in places covers the Kerait family soils developed on carbonaceous shales of probably Jurassic Age. At the Airport junction (6th mile) the white soils in which deep humus pans can be noticed concern Miri and Buso family soils (Podsolis) which have developed in Pleistocene terrace alluvium.

The Forest Department has established a Silvicultural Experiment on these soils with Casuarina (right hand side of road, Airport junction).

From this terrace (approximately 90 feet above sea level) the road dips strongly into what is considered to be an old dissected coastal plain now lying almost between 20 and 50 feet above sea level. This plain extends as far as approximately the 21st mile.

Soils in the plain vary. They range from Red-Yellow Podsollic soils on the Cretaceous sediments exposed in moderately dissected terrain to Podsolis and Grey-White Podsollic soils developed on Pleistocene deposits on slightly raised land. The lowlands are occupied with recent alluvium (Gley soils and shallow Peat soils) with in some places drowned high level alluvium. This land can be found at the 12th to 14th mile. The old alluvium is covering limestone which slowly dissolves because of acid groundwater. The overlying originally high level alluvium is subsiding slowly and occupies locations where one normally would find recent alluvial deposits.

The area between the 14th and 16 $\frac{1}{2}$ th mile is underlain by microtonalite porphyry of probably Upper Triassic Age. Huge core boulders are thrown over the generally moderately dissected terrain. Soils belong to the Lateritic Soil Group (see pepper gardens at 16th mile - red soils.)

Between the 16 $\frac{1}{2}$ th and 21st mile, a number of low lying alluvial plains are occupied by recent alluvium (Gley soils) of which the source can be found in the high hills at the right hand side of the road. The hills are built up by Basaltic and Andesitic materials. The floodplains have comparatively rich soils and yield good harvests of rice. An improvement to padi farmers scheme (A.P.P.S.) can be seen at both sides of the road at the 16 $\frac{1}{2}$ th to 17th mile.

At 17th, 20th and 21st mile three new resettlement areas can be seen along the road. In these three new villages all the Chinese population living along the 10th to 25th mile were resettled because of the threat posed by the illegal Sarawak Communist Organisation to intimidate these farmers.

At approximately the 21st mile the old coastal plain is left and the road turns into an area of strongly dissected hills of which the summits indicate a former peneplain lying between 150 feet at the boundary with the old coastal plain to approximately 350 feet in the interior.

The road follows almost the border area with the old coastal plain. The road winds along strongly dissected hills with numerous curves (the road was built before the Second World War with manual labour), the only straight stretches being occupied by small recent alluvial plains built up by a number of rivers. (25th, 27th and 29th mile).

The area is built up by Triassic sediments. From 27th mile to the 38th mile this is mainly arkose on which pepper gardens are prolific. Soils belong to the Abok family (Red-Yellow Podsolics soils).

Mountains which can be seen at the right are built up by Basic to Intermediate Igneous rocktypes on which Lateritic soil types have formed. At the 38 $\frac{1}{2}$ th milestone the road turns to the right. From here to the first stop (Kerait profile) the landscape is similar to that one found between the 27th and 38th milestone.

The hills, however, are underlain by shales of Triassic Age while where the road comes near the footslope of the above mentioned mountains Lateritic soils can be seen.

For Kerait profile - see profile description and analytical data sheet.

From the location of the Kerait profile to the site of the Tarat profile the road follows the footslope areas of the mountains and invariably Lateritic soils can be seen along the road. (Tarat profile - see profile description and analytical data sheet).

The change in land use after the turn at the 38th mile should be noted. At this point the population changes from Chinese to Dayak and the latter who practise shifting cultivation (hill rice-fallow) leave large areas uncultivated for a number of years. Note also the shifting cultivation on the steep mountain slopes which can be seen from the sites of the Kerait and Tarat profiles. The farms of this year which have recently been harvested are coloured yellow. Various stages of regrowth can be noted on the slopes.

The return trip from the Tarat profile takes the same route as the outgoing journey.

Profile KERAIT

Soil Group: Grey-White Podsollic. Parent material: Carbonaceous shale
Family: Kerait of Triassic age.
Series: Kerait External drainage: Moderate
Phase: Vegetation/Land Use: Young rubber
with dense undergrowth of ferns
mainly.
Location: Tebakang road, approx.
1½ mile - Serian District.
First Division. Altitude: ± 50 feet.
Latitude: 1° 10' N Rainfall: 139.13" (8 years' mean).
Tarat Station.
Longitude: 110° 32' E Rainfall Class (Mohr): I
Topography: Undulating, dissected, Lab. Nos: MS 1225/30
formerly peneplained terrain.
Site: Low hill with gentle slopes. Field Nos: Kerait 1/6
At site cut by road. Former
slope estimated to be approx.
10°. Date sampled: 18.8.67.

O/A1	0 - 1 inches	Rootmat with partly decomposed litter of ferns. Dark brown. Mixed with some mineral soil, sandy clay loam.
A2	1 - 7 "	10YR 6/1, grey, fs. clay loam, fine angular blocky to crumbly, friable. Dry, well rooted (mainly small rootlets). Much charcoal present. Porous. Distinct wavy boundary to
B1	7 - 29 "	2.5Y 8/4, pale yellow clay. Very firm and compact. Weak friable on pressure. Large blocky structure units break into small subangular blocky ped. Many small roots. Clay skins present on faces of larger structure units (colour 10YR 7/2, light grey). Many cracks filled in by orientated clay of light grey colour. Few small 10YR 5/6, mottles. Moist, slightly plastic, non sticky, soapy feeling. Gradual, wavy boundary to
B2	29 - 52 "	10YR 7/3, very pale brown clay with common, large light grey (2.5Y 7/N) mottles and common small brownish yellow (10YR 6/8) mottles. Slightly plastic, non-sticky, moist. Soapy feeling. Very compact and firm. Clayskins along large cracks (roots follow these cracks). Grey mottles increase gradually in size and intensity with depth. Gradual, indistinct change to
B2/C	52 - 65 "	2.5Y 7/N, light grey clay loam with common, small brownish yellow (10YR 6/8) mottles and common large pale yellow mottles. Very compact, moist. Slightly plastic and non-sticky. No roots. At approximately a depth of 20 feet this material changes into black, weathered soft shale.

Profile KERAIT

General information on the Kerait family

The Kerait family is only found on argillaceous rocks which have commonly a relatively high carbon content (2 to 2.5%) and a very low to almost nil iron content. The total alluminium content, however, may exceed 20% particularly in the B horizon.

The argillaceous materials on which the family is found are thought to have originally been deposited in estuarine or deltaic environments much the same as the present areas under Mangrove and Nipah. The high sulphate contents and low pH of the weathered shale is indicative to such conditions and the occurrence of fossil catclay in these rocks has been proved for a number of sites.

Sample 6 of this profile is an example.

Although the chemical fertility of this family is very low, the soils are used for rubber and pepper in a number of localities. The growth of rubber is retarded as compared with the growth on Red-Yellow Podsollic Soils but pepper if well fertilised grows well. The standard of maintenance must, however, be high.

The soils occur widespread in the Serian District of the First Division, mainly on Triassic shales but they have also been mapped in other Divisions, notably Third Division.

Classification

The soils are classified as Podsollic Soils because of the occurrence of a distinct argillic horizon which is easily detectable in the field and in mechanical analyses. Because of the peculiar colour range of these soils due to absence of iron oxides the group of Gray-White Podsolics was established in Sarawak. There is as yet little evidence to show that the Kerait family which, except for iron content, is very similar to the Merit family in the Red-Yellow Podsolics, is inferior or dissimilar to the latter and possibly the split on account of difference in iron oxide content was made at too high a level of classification.

According to the 7th Approximation the soils should be classified as Ultisols, suborder Udults, Paleudult group. The subgroup is difficult to assess since although the soils may qualify for Aquic Paleudults, the pale colour is not due to drainage condition but rather to type of parent material. On account of temperature range, the soils can equally well be classified as Tropudults - Typic Tropudult subgroup, but amount of weatherable minerals is too low.

The soils show similarities with the Batu Anam profile in Malaya.

KERAIT PROFILE

Lab. No.	Depth (Inches)	% silt	% clay	MECHANICAL ANALYSIS										TEXTURE
				SAND FRACTIONS (MESH)										
				% 8-16	% 16-30	% 30-72	% 72-150	% 150-300	% Total sand	Total %				
MS1225	0 - 1	19.58	26.96	0.05	0.05	0.05	1.58	19.79	42.00	68.24	Sandy clay loam			
1226	1 - 6	29.25	27.48	0.05	0.05	2.06	5.72	34.81	43.16	99.89	Sandy clay loam-clay loam			
1227	7 - 29	31.14	40.87	0.05	0.50	0.40	2.13	20.84	27.77	99.78	Clay			
1228	29 - 52	34.45	47.14	0.05	0.27	0.27	1.13	27.22	18.31	99.89	Clay			
1229	52 - 65	36.11	39.14	0.25	0.75	1.01	1.77	11.62	24.34	99.59	Clay loam			
1230	at 20'	42.80	18.44	0.05	0.05	1.23	1.39	8.76	39.11	100.35	Loam			

Lab. No.	Depth (Inches)	pH 1:2.5 H ₂ O A.2.D.	pH 1:5 KCl	CHEMICAL ANALYSIS													
				% (O.D.)				P P M (O.D.)			Exchangeable			C.E.C.	% (O.D.)	Fe ₂ O ₃ 6 N H O 1	
				Total N	Org. C	AV. P	Total P	% S04	Mg	K	Ca	Mg	K				Na
MS1225	0 - 1	4.1	3.1	0.577	14.30	13	218					2.03	3.41	1.17	0.23	39.85	0.56
1226	1 - 6	4.1	3.4	0.188	1.50	4	113					0.26	0.06	0.15	0.07	14.10	0.41
1227	7 - 29	4.9	3.9	0.075	0.21	<1	80					0.19	0.45	0.07	0.10	7.51	0.76
1228	29 - 52	4.9	3.8	0.078	0.13	<1	87					0.06	0.45	0.08	0.06	7.80	0.66
1229	52 - 65	5.1	3.9	0.075	0.41	<1	111					0.13	0.26	0.08	0.13	9.49	0.50
1230	at 20'	2.7	2.6	0.009	0.42	4	136	0.62				0.20	0.58	0.02	0.07	4.65	0.44

Profile TARAT

Soil Group: Lateritic Soils

Family: Tarat

Series: Tarat

Phase: Deep

Location: 3rd mile Serian-Tebakang road, road site.

Latitude: 1° 9' 45" N

Longitude: 110° 31' E

Topography: Moderately steep terrain with slopes of 25 degrees and over. Strongly dissected.

Site: Midslope

Slope: 10 degrees

Parent material: Altered Basalt and Andesite (Triassic).

External drainage: Rapid

Vegetation/Land Use: Young rubber with dense mixed undergrowth in which ferns are dominant.

Altitude: Approximately 150 feet

Rainfall: 139.13" (8 years' mean) Tarat Station.

Rainfall Class (Mohr): I

Lab. Nos: MS1213/18

Field Nos: Tarat 1/6

Date sampled: 18.8.67.

		Very thin layer of leave litter (1/10 of an inch).
A1	0 - 4 inches	Reddish brown (5YR 4/4) clay, fine sub-angular blocky to fine angular blocky structure (nutty). Dry. Friable. Abundant rootlets. Porous. Distinct boundary to
B1	4 - 15 "	Red (2.5YR 5/6) clay, crumbly. Moist. Friable. Many roots. Shiny surfaces of natural red surfaces possibly indicating orientated clay. Macro structure-coarse prismatic. Indistinct boundary to
B2	14 - 21 "	Red (2.5YR 5/6) clay. As above horizon but the soil is firm and does not break into crumbs on pressure. Slightly moist. (possible influence of difference in moisture content). Indistinct boundary to
B3	21 - 52 "	Red (2.5YR 5/6) clay loam which breaks into small crumbs and fine angular blocky peds if slight pressure is applied. Dry. Soft. Porous. Slight development of shiny ped surfaces. Many roots. Scattered small weathered rock pieces (possibly colluvial). Distinct wavy boundary to
C	52 - 80 "	Mixture of red (2.5YR 5/6) clay loam very friable to powdery, and brittle thoroughly weathered parent material. 50% - 50%. Slightly moist. Few rootlets. Porous.

Note:- This horizon continues to a depth of approximately 8 feet where solid rock is met.

Profile TARAT

General information on the family

The Tarat family is the only family so far mapped in the Lateritic Great Soil Group. The family is found on basic to intermediate igneous rocktypes with a high content of ferromagnesium minerals. Soils occur widespread in the First Division, and in a few localities of Second and Fourth Divisions. They may occur on some highland plateaux in the Third Division but little information on these areas is at present available.

The terrain on which these soils occur is usually steep and rugged and Skeletal soils are dominant in such terrain. Skeletal soils may be either young, not fully matured soils or eroded phases of the Tarat family. The profile shown represents a deep phase which commonly occurs on footslope areas. It is in such areas where the soils are put to agricultural use. Although chemically poor, the favourable physical characteristics appears to offset this limitation and the soils are generally regarded as superior to any other upland soil occurring in Sarawak. They are specifically sought after for pepper cultivation, good drainage being an important factor for this crop. The use of these soils for cacao is at present being investigated, trials being conducted at Tarat Station.

Classification

The family is classified in Sarawak as Lateritic soils on account of the absence of an argillic horizon and a sesquioxide content of more than 25% in horizons below the A1.

Although there is evidence in the field of orientated clay on the ped surfaces this is thought to be caused by shearing rather than illuviation of clay.

According to the amended 7th Approximation the soil should be classified as Typic Haplorthox in the Order of Oxisols. In the Malayan classification the Normacrox (Acrox - suborder) is probably the nearest equivalent.--

Nearest Malayan series is probably Segamat.

TARAT PROFILE

Lab. No.	Depth (inches)	pH 1:2.5 H ₂ O A.D.	pH KCl 1:5	Total N	Org. C	Av. P	MECHANICAL ANALYSIS							TEXTURE			
							SAND FRACTIONS (MESH)								% Total sand	Total %	
							8-16 %	16-30 %	30-72 %	72-150 %	150-300 %						
MS1213	0 - 3	4.5	3.8	0.565	8.31	4	559	221	979	386	0.57	1.55	0.42	0.31	14.76	39.45	15.57
1214	4 - 14	4.9	4.0	0.206	4.50	<1	430	111	759	167	0.28	0.49	0.08	0.08	9.12	46.99	17.82
1215	14-21	5.1	4.2	0.146	3.86	<1	391	109	913	163	0.07	0.70	0.07	0.09	10.54	50.29	17.15
1216	21-52	5.5	4.5	0.065	2.96	<1	400	194	791	216	0.35	0.62	0.05	0.10	5.66	47.79	14.63
1217	52-64	5.4	4.5	0.024	2.63	<1	414	65	1646	594	0.14	0.69	0.04	0.17	6.36	48.48	19.21
1218	65-80	5.3	4.3	0.021	2.37	<1	411	289	1211	268	0.14	0.55	0.03	0.09	5.98	45.64	21.09

CHEMICAL ANALYSIS

Lab. No.	Depth (inches)	pH 1:2.5 H ₂ O A.D.	pH KCl 1:5	Total N	Org. C	Av. P	P P M (O.D.) Reserves			M. eq. % (O.D.) Exchangeable			C.E.C	Group III Oxides	Fe ₂ O ₃ 6 N H C 1 %		
							Total P	Ca	Mg	Ca	Mg	K				Na	
MS1213	0 - 3	4.5	3.8	0.565	8.31	4	559	221	979	386	0.57	1.55	0.42	0.31	14.76	39.45	15.57
1214	4 - 14	4.9	4.0	0.206	4.50	<1	430	111	759	167	0.28	0.49	0.08	0.08	9.12	46.99	17.82
1215	14-21	5.1	4.2	0.146	3.86	<1	391	109	913	163	0.07	0.70	0.07	0.09	10.54	50.29	17.15
1216	21-52	5.5	4.5	0.065	2.96	<1	400	194	791	216	0.35	0.62	0.05	0.10	5.66	47.79	14.63
1217	52-64	5.4	4.5	0.024	2.63	<1	414	65	1646	594	0.14	0.69	0.04	0.17	6.36	48.48	19.21
1218	65-80	5.3	4.3	0.021	2.37	<1	411	289	1211	268	0.14	0.55	0.03	0.09	5.98	45.64	21.09

TARAT EXPERIMENT STATION

Latitude $1^{\circ} 12' N$ Longitude $110^{\circ} 32' E$

Rainfall: 139 inches per annum.

Topography

The topography of the area is typically that of a small alluvial fan. Near the foot of Bukit Sedong at the debouching point of the Tarat and Baeh streams colluvial material in the form of boulders and gravels were deposited and they form the base on which finer alluvial material was deposited in subsequent stages of landscape development. The low hilly terrain existing at the foot of Bukit Sedong has been levelled off and eroded away by the two rivers. At present remnants of such hills can still be found as small islands or spurs amidst the alluvial which was deposited around them.

The Tarat and Baeh streams in a recent rejuvenation stage have cut into their own deposits, especially in their bouldery cones of the alluvial fan near the foot of the mountains. It is there where steep and deep valleys occur. Thus, the area can be subdivided conveniently into three physiographic units, namely:-

- (a) The cone of the alluvial fan consisting of hilly terrain with steep slopes and made up of boulders and fine textured alluvial material overlying it.
- (b) The alluvial plain, which is very gently sloping to flat comprising alluvial soils which are in their subsoils often bouldery to gravelly, indicating former river beds.
- (c) The eroded original hills existing at the foot of the mountains and in the plain and which are at present flat topped to undulating with sometimes steep sides where the river beds have eroded away part of the hills.

Geology

The geology of the area is rather complicated and heterogenous. For the largest part parent materials are of recent alluvial origin and brought down by the streams Baeh and Tarat. These alluvials range from boulders to clays, more often than not the fine material overlying increasingly coarser textured materials. The alluvial deposits have all derived from Basic Igneous rocks ranging from basalts to andesites which form the Gunong Sedong range.

Most of the residual soil material has derived from sedimentary rocks. Most of the land comprising physiographic unit (c) is built up by these sedimentary rocks of which sandstone is the main rock type.

Again in the sandstones we distinguish between arkose, which is a sandstone in which primary rock minerals are found and the more quartzitic sandstones which are poorer in composition.

Shales occur infrequently and often as thin beds in the generally thicker sandstone beds. The occurrence of steeply folded thin beds of different types of sedimentary rocks has given rise to a complicated pattern of soils with textures ranging from sandy loam to clays, depending on the influence of shale material on the generally sandstone derived soils.

Finally in physiographic unit (a), the cone of the alluvial fan, Basic Igneous rock is found, mainly basalt. The occurrence of basalts in the cone is related to the proximity of the Sedong range and it forms part of it geologically, although topographically, this relation is no longer visible because of the erosive powers of the streams in this area.

Morphology and Soils

The station occupies part of an alluvial fan built up by a mixture of alluvium and colluvium of basic igneous rock origin. Scattered outcrops of shale, sandstone and Arkose (~~metamorphosed sandstones~~) of Triassic age occur in the northern part of the station.

Coarse textured and gravelly soils occur at the debouching points of the Tarat and Baeh streams which have their sources in the basic igneous rock massif, the Sedong mountains. The deposits become deeper and heavier in texture at increasing distances from the foothills.

The alluvials belong to the Great Soil Group of 'Recent Alluvial Soils' which are represented in the Station by two series, namely the Ramun Series which comprises the gravelly soils of basic igneous rock origin and the Terbat Series which are characterised by deep loamy to clay deposits of basic igneous rock origin.

Part of these alluvial deposits is located in hollows where high ground water tables have given rise to the formation of 'Low Humic Gley soils.' Soils in this World Soil Group are represented in the Station by the Samarahan Series and the Kakai Series, in the former the deposits are derived from shales and arkose outcrops while the latter soils have formed on deposits derived from basic igneous rocks.

The residual soils on the foot hills of the Sedong mountains in the southern part of the station, belong to the Great Soil Group of Lateritic soils, represented by the Tarat Series (deep loams to clays overlying basic igneous rocks). Soils formed on the out-crops of shale and Arkose belong to the 'Red-Yellow Podsolc soils' represented in the station by the Bedup Series on the shales and the Serin Series on the Arkose.

Some minor areas occur of residual soils found on sandstone belonging to the Tebakang series.

The following table outlines the relationship between soils:-

Great Soil Group	Family	Series	origin
Lateritic soils	Tarat	- Tarat	basic igneous rocks - residual
Red-Yellow Podsolics	Abok	- Serin	Arkose - residual
	Nyalau	- Tebakang	sandstone - residual
	Merit	- Bedup	shale - residual
Low Humic Gleys	Bijat	- (Kakai	basic igneous rocks - alluvial
		(Samarahan	shales/sandstone - alluvial
Recent alluvials	Malang	- (Ramun	basic igneous rocks - alluvial
		(Terbat	basic igneous rocks - alluvial

The soils of the station are representative for areas in the Upper Sadong District and Kuching Rural District where Basic Igneous Rocks occur in some magnitude. Basic Igneous rocks and related soils are rare in other parts of Sarawak.

The Ramun and Terbat series comprise some of the most fertile soils occurring in Sarawak.

Profile TRIBOH

Soil Group: Grey-White Podsollic.

Family: Triboh

Series: not established

Phase: not established

Location: Bau road, 7 $\frac{1}{2}$ mile,
opposite Green Spot Factory.
Kuching District, First Division.

Latitude: 1° 29' N

Longitude: 110° 19' E

Topography: Remnant of Pleistocene
terrace, strongly dissected.

Site: Top of terrace, slope
approximately 10 degrees.

Parent material: Pleistocene
terrace deposits.

External drainage: Moderately rapid.

Vegetation/Land Use: Secondary
jungle. Undergrowth mainly ferns.

Altitude: approx. 90' above sea level.

Rainfall: Kuching Airport 158.11'
71 years' mean.

Rainfall Class (Mohr): I

Lab. Nos: MS1253/58

Field Nos: Triboh 1/6

Date sampled: 24.8.67.

Thin litter layer at surface, partly decomposed
leaves and twigs.

0 - 3 inches

Grey (10YR 6/1), fine loamy sand, weak crumbly,
weak friable to loose. Dry, well rooted. Indis-
tinct boundary to

3 - 7 "

Greyish brown (10YR 5/2), fine loamy sand, weak
crumbly, weak friable, compact in profile.
Slightly moist, few roots. Few small light grey
mottles. Many charcoal pieces. Distinct but wavy
boundary to

7 - 23 "

White (10YR 8/2), sandy loam with common, small
brownish yellow mottles (mainly around root
channels). Structureless to weak crumbly. Firm
and compact. Few large roots, many fine dead roots.
Moist. Distinct wavy boundary to

23 - 38 "

Light grey (10YR 7/2), sandy loam, crumbly. Firm
and compact. Along large roots yellowish brown
mottles. Illuvial clay distinctly present in
cavities. Porous. Gradual change to

38 - 50 "

As above horizon but clay content increases with
depth, moist, gradual change to

b) 50 - 55 "

Light grey (10YR 7/2), sandy clay loam, plastic,
non-sticky. Moist. Few dark brown mottles, common
white mottles, no roots. Small grit present.

Remark: from 35 - 55 inches there is very little difference to notice
by visual observation. Main difference is a gradual increase
in clay content. This profile may be bisequent (due to layering
in parent material).

Profile TRIBOH

General information on the family

The Triboh family occurs widespread on terrace deposits of a medium texture range and is closely associated with the occurrence of the Buso family which develops in similar parent material. The latter, being of Podsol morphology develops on almost flat terrain while the Triboh is generally found in more undulating terrain such as dissected terrace areas.

Many soils in this family appear to be bisequent (texturally) because of the stratification in the terrace deposits. This makes it difficult to recognise argillic horizons through means of mechanical analyses. In many instances both bisequency and illimerization of clay is involved.

The soils are used for rubber cultivation mainly. Many old rubber gardens owned by the Dayaks are on this soil type. Growth is almost retarded but with adequate fertilisation moderate growth can be expected.

(ref: Rubber growth on Saratok soil in Third Division, which soil is comparable to the Triboh family).

Classification

The soils are classified as Grey-White Podsolics. Podsolic: because of the presence of an argillic horizon. Grey-White: because of the colour range.

They belong to the order of Ultisols - suborder Udults - group Paleudult - subgroup Arenic Paleudult.

Colour apparently is not considered of sufficient importance to justify a subgroup differentiation and on account of this the Grey-White Podsol Group is classified together with the Red-Yellow Podsolics in the 7th Approximation. This is probably a correct approach.

There should, however, be a provision to have within the Tropudult group a subgroup with a weatherable mineral content of less than 10% since on account of temperature the soils now classified as Paleudults should be Tropudults.

No equivalent series in Malaya is known.

TRIBOH PROFILE

MECHANICAL ANALYSIS

Lab. No.	Depth (ins.)	% silt	% clay	% (O.D.)						% Total sand	Total %	TEXTURE
				8-16	16-30	30-72	72-150	150-300				
MS1253	0-3	13.78	10.14	0	16-30	30-72	72-150	150-300		75.66	99.58	Loamy sand
1254	3-7	9.83	9.49	1.31	1.82	24.44	26.10	23.30		80.30	99.62	Loamy sand
1255	7-23	12.22	10.58	0.70	8.03	34.90	18.74	12.27		77.32	100.12	Sandy loam
1256	23-38	14.58	15.61	1.72	8.03	28.84	22.12	17.62		69.38	99.57	Sandy loam
1257	35-50	21.80	15.93	1.55	7.05	25.48	18.67	15.68		65.65	99.58	Sandy loam
1258	50-55	17.10	31.75	1.50	5.35	22.60	17.50	16.95		58.80	107.65	Sandy clay loam

CHEMICAL ANALYSIS

Lab. No.	Depth (ins.)	1:2.5 H ₂ O A.2.D.	pH 1:5 KCl	% (O.D.)			P P M (O.D.)				Exchangeable			C.E.C	Group III Oxides	Fe ₂ O ₃ 6 N H C 1	
				Total N	Org. C	AV. P	Reserves	Ca	Mg	K	Ca	Mg	K				Na
MS1253	0-3	4.4	3.6	0.126	1.53	5						0.06	0.39	0.07	0.09	4.37	0.11
1254	3-7	4.8	3.9	0.055	0.54	2						tr	0.13	0.03	0.07	2.42	0.07
1255	7-23	4.9	4.2	0.022	0.16	2						tr	0.25	0.02	0.08	1.90	0.08
1256	23-38	4.8	4.2	0.022	0.21	1						tr	0.06	0.02	0.08	3.05	0.15
1257	38-50	4.9	4.2	0.019	0.18	2						tr	tr	0.03	0.08	4.05	0.17
1258	50-55	4.8	4.1	0.023	0.16	<1						tr	tr	0.03	0.07	4.38	0.20

Guide Second day tour - First Division, 14th May, 1968

Note: for orientation see traverse marked red on the map.

The tour from Kuching to the Santubong Drainage and Irrigation Scheme leads through the delta of the Sarawak river which almost entirely is occupied by Saline-Gley soils under Mangrove and Nipah Forest.

From the river at various places remnants of old Pleistocene terraces can be seen on which dominantly Podsolis (Miri family) have formed.

Particulars on the Saline Gley soils (Rajang and Pendam families) are added.

The Santubong Drainage and Irrigation Scheme is aimed at reclaiming Rajang family soils for the growing of coconut. This involves draining to a depth of approximately 3 feet, bunding (to keep the salt water out) with the installation of floodgates and the leaching of soluble salts (rainfall between 160 and 200 inches yearly).

The costs for such reclamation is approximately 300 per acre for this scheme. At present a large Rice Scheme has been envisaged for the Sarawak river delta (over 20,000 acres) and a feasibility survey has been programmed.

Problems, apart from the saltwater infiltration, is the occurrence of catclays in these areas. Detailed investigations will be carried out to assess the magnitude of the problem before any large scheme is started.

It appears that generally catclays form after drainage but investigations so far carried out indicate that the danger is not great, (danger areas are isolated pockets and commonly the catclays occur below a depth of 2 feet). However, through the presence of 3 feet high crab mounds which in places occupy more than 50% of the land area much catclay forming material may be brought up to the surface and spread over the land after levelling. This will be investigated.

From the Drainage and Irrigation Scheme the route goes along Santubong holiday resort, a Malay fishing community situated at the foot of Bukit Santubong.

Following the coast to Kuala Sibul Laut coconut plantings can be seen on the recent coastal sands. Entering the estuary of the Sibul Laut River at the right, Casuarina Sumatrana (the natural vegetation of the coastal sands) can be seen.

From the Sibul Laut River one enters Sungei Trombol up to an old landing stage built by Japanese during the Second world War. From the landing stage a small path leads to an abandoned airstrip used during the Second World War.

For profile descriptions of the Jerijeh and Sematan family see data sheets.

Kampong Sibu Laut is a typical Malay fishing village. It is known for the large amount of crabs which are twice weekly sent to the Kuching Market.

From Sibu Laut the tour leads through a complicated network of channels and creeks which is typical for this delta area. Soils invariably belong to the Saline-Gley soil group.

Semariang is another Malay fishing settlement. The landing stage provides access to Kuching Town.

Following the road from Semariang old rubber gardens are passed through mainly established on deep peat soils (more than 10 feet deep). The hill with quarry which is passed 2 miles out of Kampong Semariang is built up by Basic Igneous Rock.

Note the subsidence of the peat after drainage and exposure of the roots of rubber trees in some localities.

Many rubber gardens are older than 40 years and are not being tapped anymore. Land is sold for dwelling purposes to mainly Malay Government servants working in Kuching.

At the 8th mile Matang road the peat swamp gives way to gentle undulating terrain built up by Pleistocene terrace deposits which have accumulated at the foot of Matang Mountain. In places these terraces are used for farming if soil conditions permit. (mainly on scarp slopes). Large areas on these terraces are, however, occupied with infertile podsols - Buso profile.

RAJANG SERIES

General Characteristics

The Rajang usually consists of clays deposited in a deltaic environment. The clays are littoral deposits characterised by a high content of soluble salts and a high content of sodium in the exchange complex. The electric conductivity is generally above 4,000 micromho/cm while the Exchangeable sodium is more than 15% of the total exchange capacity. Although the soils are generally clay throughout, a sandy loam phase was found at the mouth of the Samarahan river where the clay deposits are covered with a thin layer of sandy loam texture from Tambirat to as far north as the sea. It is suggested that the Batang Samarahan has spread this sand over this area after it cut through the coastal ridge (described under Tatau series). It is possible that this ridge was much larger in former times and that most of the material has been eroded by the Samarahan river, the material being distributed and deposited through the action of tidal water along the banks of the Samarahan river and at the sea near its mouth. Further upstream no sandy deposits of the Samarahan river were noticed along the banks and its source must therefore be sought in the coastal ridge.

Apart from being strongly saline (according to the American definition given by the Salinity Bureau Staff, the soils are classified as saline/alkali soils, ref.7) the soils are also strongly hydromorphic and display all the characteristics of the Low Humic Gleys to which they are related.

Once the salts of the Rajang Series are leached out the series is similar to the Pendam Series (probably saline phase). The profile consists of a greyish brown sticky and plastic clay (sandy loam for the sandy phase) top horizon of varying depth, depending on undulations of the surface but normally deeper than 24". There is not a normal A horizon in the sense that humus accumulates in it, but deposition of mineral matter takes place continuously thereby covering any amount of organic debris which may fall on the surface. The topsoils which may be two feet thick are therefore mixed with much organic debris, dead leaves and woody material and many roots, dead and alive, while in places whole trees can be found buried under the sediments.

The only difference between topsoil and subsoil (if one can use these terms) is that at a depth of more than two feet the colour is usually more greenish to bluish grey, while in places even a dark grey colour was observed, where the organic matter is more decomposed.

Watertables vary with the tide and location. Near streams they drop considerably during low tide, while at high tides the series is surmerged with salt water. Further away from the river the tidal change is less noticeable and watertables are more stable although most of the time not falling below a level of 2 feet.

The chemical features of the Series are dominated by its salty nature. Apart from pH and Conductivity readings no detailed chemical data was available from the area at the time of writing but analytical figures obtained from samples of the same series found in the Sarawak river delta can be used instead.

Base exchange capacity is moderately high in these samples and is over 20 meq/100 gram of soil. Base saturation is 100%, the adsorption complex being dominated by sodium. Calcium and magnesium in the adsorption complex is high for Sarawak conditions (more than 10 meq.). Magnesium may be twice as high as calcium.

The pH in the Rajang Series shows sometimes a remarkable drop after drying. All pH measurements for the Rajang Series were taken in the wet condition and give values of 7 or over indicating its saline character. After drying the pH did not drop very much but in other areas of Sarawak an acidity of as low as 3.5 has been reported for similar soils. Where this is accompanied by a high sulphate content such a fall in pH can be explained easily as sulphur compounds are most of the time present in the fresh samples of the Series. The sulphur becomes oxidised after drying and the resulting sulphates reduce the pH considerably even in the absence of cations like calcium or sodium.

The low pH of the Pendam Series reported upon in the description of that Series was contributed to the rapid leaching of bases after reclamation if the Rajang, but because of the fall in pH after drying in some Rajang samples, the occurrence of sulphates in this Series cannot be ruled out. If the Rajang is reclaimed and salts are leached out its fertility will be much the same as the related Pendam Series and if the large area of Rajang Series existing in the Nonok area could be satisfactorily reclaimed the agricultural potential of the area as a whole could be increased greatly. It would be advisable however to lime the Rajang Series if salts are leached out; this will reduce the acidifying effect of the sulphate which may form after draining and will help to revert the sodium clays into calcium clays thereby improving the structure of the soils. The lime requirement of this series should however be worked out prior to reclamation.

PENDAM SERIES

The general concept of the series is as follows:

Soils recently reclaimed from Mangrove and Nipah forest and converted into agricultural soils through leaching of salts and drainage, or soils which through natural causes have risen above normal high tide level. They are normally situated in river delta's or found at the mouth of main rivers, and occur as far inland as brackish - or saltwater can penetrate during the driest part of the year. Although topsoils and subsoils can contain soluble salts these are easily leached out by rain or freshwater flooding. Groundwater may be salty during parts of the year.

The Pendam soils have developed in a deltaic environment and traces of a former vegetation (Mangrove and Nipah) may still be found in the soils. This is indicated by mucky or peaty layers encountered at depths ranging from 1 to over 4 feet from the surface. The layers are thin and generally not more than 6" thick.

Apart from this morphological variation, chemical features are variable over a wide range because of their proximity to the sea (salt infiltration through flooding and salty ground-water) and human influence (drainage).

The general concept is therefore taken as a guidance for interpreting field and laboratory data and for mapping the series. If one characteristic of the general concept becomes significantly different from the normal soils, phases have been created to allow these soils still to be classified in the Pendam. Some of these characteristics, particularly organic matter and soluble salt contents of topsoil, appear to change quite rapidly when the soils are drained and banded - after which the soil resembles the modal concept of the series. It is therefore practical to map such differences as phases so that the soil remains in the same series if and when cultivation through draining or banding takes place.

Textures

Clay and silt fractions are dominant in the Pendam Series but more sandy textures occur in places, especially near the mouth of Batang Samarahan where topsoils can be a sandy clay loam. Normal textures of topsoils range from clay loam to clays. In the subsoil textures range from silty clays to clays.

Structure

Structure in the Pendam Series is usually absent because of the wet condition in which they are normally found. Topsoils however may display a fine angular blocky structure when dry.

Organic matter content

Typical of the Pendam Series is the high amount of organic material found in the whole profile. Loss on ignition shows an appreciable amount of old, partly decomposed and fresh organic material in all layers. Loss on ignition varies from 5 to 10% in all subsoils while in places soil layers can be found with an organic matter content of as much as 60% (muck and peaty layer of organic debris.) Where possible such soils in the Pendam series have been mapped as the 'muck and peaty layered phase' of the series, because this phase may behave differently upon drainage and subside after the organic material has oxidised.

Loss on ignition in topsoils of the whole series is usually more than 10% and is normally within a range of 10 to 20%. However where the series grades into more mucky soils the organic matter content measured as loss on ignition may be as much as 60% and over. Soils in the series with loss on ignition of more than 35% in the topsoil (0-6") have therefore been placed in the 'organic phase'.* It is very likely that with continued cultivation the organic matter in the topsoil may fall to a level of 10-20% because of oxidation and mineralization of the organic matter.

Drainage

a. internal

The soils are slowly permeable (high clay content) and only where the sand fraction is appreciable higher than the silt and clay fractions is the permeability rapid.

b. external

Most soils in the Series are located close to peat areas situated at a higher level. Water draining off the peat tends to keep the water table high in the adjacent clay soils. Watertables are in general very high (at 6" or at the surface in the wet season while in the drier season the watertable may drop to 18" depending on the presence of drains.) Near the drains the watertable may drop to 3 feet, although a daily fluctuation can be expected because the watertable is affected to a certain by the tidal movements of the water in the rivers.

All soils in the Pendam Series are therefore poorly to very poorly drained.

Gley features

Gley features are present throughout the profile. Strong brown and orange mottles commonly start in the topsoil or immediately below it. They give way to move yellow coloured mottles while the matrix colour of the soils changes from brown or greyish brown to grey. The gley horizon is normally met at a depth of 2 to 2½ feet and is coloured greenish grey or bluish grey while if much dispersed organic matter is present the gley layer is coloured dark grey. Yellow and rust-coloured mottles may persist to a considerable depth indicating that air is penetrating through root channels or that oxygen is formed by roots of certain plant species. Near drains the permanently gleyed zone is generally deeper than in the remainder of the area and may be found at a depth of 3 to 4 feet.

Salinity

Because of the location and through human interference (digging of drains) brackish water sometimes floods certain areas or the groundwater becomes slightly salty. This increase in salinity is essentially a seasonal feature in the Pendam Series and the salts are leached out by rainfall especially in the wet season. The salts in the Pendam Series are mostly soluble and the percentage of sodium in the adsorption complex should not be more than 15%. Electric conductivity may vary and depends on the time of the year, location and the depth in the profile. On the content of soluble salts the Series is subdivided into phases, namely:

- (a) Pendam Series, saline phase
- (b) Pendam Series, leached phase

* In practice soils with loss on ignition approaching 35% are also placed in the organic phase.

It should be understood that mapping of these two phases is extremely difficult because during the wet season the saline phase may revert into the leached phase while in the dry season the opposite may take place. While our studies on these soils were carried out during the transition period of wet to drier weather the boundary between these two phases shown on the map can never be accurate. The occurrence of crab mounds in the saline phase is often a useful indication to salty conditions.

The saline phase is characterised by an electric conductivity of 1,000 - 4,000 micromoh/cm in the surface horizons (0-12") while in the subsoil the E.C. is more than 4,000. E.C. of the ground-water is generally much higher than 4,000.

The leached phase has surface horizons depleted of soluble salts and the E.C. should not be more than 500. Subsoils in the dry season are permitted to have an E.C. between 1,000 - 4,000, but this is only the case if the groundwater is affected by salt infiltration through drains. The E.C. of groundwater in the leached phase is usually between 500 and 4,000.

Because the former vegetation was Mangrove and Nipah forest the Pendam Series may have high levels of sulphates, especially in the 'muck and peat layered' phase. The coarse textured organic matter in these layers (peat and muck layers) have been tested for sulphate but in all instances the sulphate content did not rise above danger level. Nevertheless Pendam subsoils in other areas of Sarawak have been found to contain high contents of sulphate and probably it is only the layers in which the organic are high and where sulphate becomes toxic after the soils are dried out. It is therefore possible that the electric conductivity values in the Pendam Series, both saline and leached phases, are partly recording the occurrence of sulphates and that high readings do not necessarily refer to sodium salts or chlorides.

Acidity

In the saline phase of the Series the pH ranges from 5 to 7 in both topsoils and subsoils. The pH in the topsoil (0-6") is frequently less than the pH in the subsoil. The pH in the leached phase is generally lower, especially in the topsoil where it varies between 4 and 5. Sometimes the pH of the topsoil may be slightly over 5. The pH in the subsoil is normally between 4 and 5 but depending on the salinity of the groundwater a pH of 6 was frequently recorded. pH may be influenced by the occurrence of 'catclay' which would cause it to be lower.

The pH of the organic topsoil in the organic phase of the Pendam Series is frequently slightly less than 4. All recorded pH values are for over dry soils.

Base Exchange Capacity

The Base Exchange Capacity of the soils reflects its organic matter content. The topsoils have T. values (Base exchange in m.e. per 100 gram soil) of more than 20, subsoils slightly less, depending on organic matter content. In the organic phase the T. value rises to above 30 in the topsoil.

Base saturation

For Sarawak conditions the soils are well supplied with exchangeable nutrients. This is due to the young stage in development of these soils, them having been recently reclaimed from sea influence.

Leaching however rapidly removes plant nutrients once the soils are drained or ingress of seawater is prevented by bunding.

The leached phase therefore has lower exchangeable bases (plant nutrients) than the saline phase.

In all Pendam soils base saturation in the subsoil is higher than in the topsoil which is an indication of the youthful state of the soils and incipient leaching.

Exchangeable bases

Exchangeable calcium ranges from 1 to 8 in the topsoil (average 5 meq.). Subsoils deeper than 3 feet have in places an exchangeable calcium content of more than 20 meq. but values are generally slightly below 10 meq. In the former case the soils are either saline Pendam soils or approaching them.

Exchangeable magnesium varies from below 1 to slightly over 6 in topsoils. Values in the deep subsoils range from 5 to 10 meq.

Exchangeable sodium is generally between 0.3 and 0.5 meq. but in the saline phase values may be between 1 and 2 meq.

Phosphate

The soils are moderately high in total phosphate. Topsoils have generally values of 400 to 1,000 ppm, while subsoils have values between 200 and 300 ppm. The lower subsoils of some profiles show a rise in total phosphate which cannot be explained. Much of the total phosphate is organic phosphate, therefore the availability of the phosphate in the Pendam Series is much better than in the Upland soils of Sarawak.

Profile JERIJEH

Soil Group: Podsol

Family: Jerijeh

Series: Stoh

Phase: not established

Location: near old airstrip at S. Trombol. Sibulaut coastal area, Kuching District, 1st Division.

Latitude: 1° 42' N

Longitude: 110° 11' E

Topography: subrecent coastal ridge, almost flat, gently undulating. At site almost highest point of ridge sloping down gently towards lagoon.

Slope: approximately 2 degrees.

Parent material: subrecent marine sand deposit of mixed origin (andesitic and sandstone material dominant).

Vegetation: Old coconut garden, stunted growth, undergrowth thick lalang. (*Imperata cylindrica*).

External drainage: moderately rapid.

Altitude: approximately 10 feet above highest tide level.

Rainfall: nearest station to remote to be reliable. Between 160 and 200 inches annual rainfall.

Rainfall Class (Mohr): I

Lab. Nos: MS1241/47

Field Nos: Jerijeh 1/7

Date sampled: 23.8.67.

- | | |
|--------------|---------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------|
| 0 - 4 inches | Light brownish grey (10YR 6/2), very fine sand, loose and structureless. Dry. Very well rooted. Distinct but wavy boundary to |
| 4 - 7 " | Light grey (10YR 7/2), very fine sand, dry, loose and structureless. Many round brown mottles (earthworm activity). Moderately well rooted. In some part of the profile this horizon is not distinctly present, where present it forms so called 'egg-cups'. Not distinct, wavy boundary to |
| 7 - 11 " | Brown (7.5YR 5/4), fine sand, slightly moist, weak crumbly and friable. Moderately well rooted. At lower boundary strong brown (7.5YR 5/8) mottles. Distinct wavy boundary to |
| 11 - 17 " | Reddish-yellow (7.5YR 6/8), fine sand with common strong brown mottles. Moist, loose, structureless. Moderately well rooted. Gradual change to |
| 17 - 29 " | Reddish yellow (7.5YR 6/8), fine sand with pale yellow streaks. Moist, loose, weak crumbly. Weakly rooted. Sporadic hard, but brittle black concretions (Fe-Mn?) Gradual but distinct change to |
| 29 - 44 " | As above horizon but the pale yellow streaks are less apparent, instead intense yellow mottling with no apparent direction. Moist, wavy but clear boundary to |
| 44 - 52 " | Yellowish brown (10YR 5/4), fine sand, with few large reddish yellow mottles. Wet. Many mica's. Few fine roots present. |

Profile JERIJEH

General information on the family

The family is found almost exclusively in some parts of the coastal area of First Division. The soils develop only on sandy marine deposits which have a high percentage of hornblende (or rather generally speaking a high content of ferro-magnesium minerals) in the heavy mineral association. This is mainly related to occurrences of igneous rocktypes of intermediate to basic character which are exclusively found near the coast in the First Division.

The soils therefore are not of any particular importance agriculturally but because of the podsol morphology they are of academic importance in that they represent a juvenile stage in the development of the extreme podsols as found on Pleistocene terrace deposits (Miri family).

The heavy mineral association is of particular interest (see paper on environment and characteristics of podsols in Sarawak by J.P. Andriess (Profile 4)) since it is the only podsol type in Sarawak with a large content of weatherable minerals in the parent material. The egg-cup morphology present in the A2 horizon may indicate that possibly vegetation may have played a role in the development of the A2 horizon. The natural vegetation on this soil is Casuarina Sumatrana.

Classification

The soils are classified as Podsols in Sarawak because of the existence of an albic and spodic horizon. The family differentiation is made on type of parent material and the weak expression of the illuvial humus horizon.

According to the 7th Approximation the soils belong probably to the group of Tropaquods (Typic tropaquod subgroup), but it would also be possible to group them into the suborder of Ferrods (probably Aquic Ferrod group). More information on free elemental iron is, however, necessary for placing this family in the proper suborder.

A very similar soil was seen in Malaya on the East Coast during the Second Malaysian Soils Conference and mapped there as part of the Bris Association (Rudua series?).

JERISEE PROFILE

Lab. No.	Depth (inches)	% silt	% clay	MECHANICAL ANALYSIS						% Total sand	Total %	TEXTURE
				SAND FRACTIONS (MESH)								
				8-16	16-30	30-72	72-150	150-300				
MS1241	0-2	3.00	3.95	0	0	0.25	26.00	66.90	93.15	100.10	Very fine sand	
1242	4-6	3.21	3.38	0	0	0.05	31.47	61.54	93.06	99.66	Very fine sand	
1243	8-11	4.21	4.16	0	0	0.10	19.48	43.10	91.90	100.27	Fine sand	
1244	11-16	4.84	3.09	0	0	0.05	46.40	45.32	91.77	99.70	Fine sand	
1245	17-29	3.64	2.47	0	0	0.29	63.05	30.46	93.80	99.91	Fine sand	
1246	29-44	4.34	2.40	0	0	0.20	39.53	53.40	93.13	99.87	Fine sand	
1247	44-52	1.22	4.19	0	0	1.29	42.08	50.99	94.35	99.76	Fine sand	

Lab. No.	Depth (ins.)	pH 1:2.5 H ₂ O A.2.D.	pH 1:5 KCl	% (O.D.)			CHEMICAL ANALYSIS						% (O.D.)	Fe ₂ O ₃ 6 N HCl			
				Total N	Org. C	AV. P	P P M (O.D.)			M. eq. % (O.D.)					Group III Oxides		
				Reserves	Ca	Mg	K	Ca	Mg	K	Na	C.E.C.					
MS1241	0-2	5.6	4.0	0.067	0.86	1	126					0.13	0.77	0.15	0.08	2.20	0.46
1242	4-6	5.2	4.0	0.025	0.35	<1	50					0.06	0.13	0.02	0.06	0.84	0.37
1243	8-11	5.2	4.2	0.048	0.77	<1	122					0.06	tr	0.03	0.09	2.22	2.40
1244	11-16	5.6	4.4	0.017	0.30	<1	157					tr	0.06	0.01	0.07	11.35	2.82
1245	17-29	5.8	4.5	0.009	0.11	<1	227					tr	tr	0.01	0.06	0.62	3.09
1246	29-44	4.9	4.5	0.006	0.07	4	270					tr	0.13	0.06	0.37	0.74	2.15
1247	44-52	5.7	4.5	0.009	0.04	3	252					tr	0.13	0.01	0.06	0.52	2.73

Profile SEMATAN

Soil Group: Recent Alluvial Soils. External drainage: Slow
Family: Sematan
Series: Sematan Vegetation/Land Use: Old coconut,
thick undergrowth of lalang
(Imperata cylindrica) and ferns.
Phase: not established
Location: Sibu Laut coastal area,
at S. Trombol. Kuching District,
First Division. Altitude: approximately 5 feet
above high tide level.
Latitude: 1° 42' N Rainfall: nearest station unreli-
able for this site. Estimated
to be 160 to 200 inches annually.
Longitude: 110° 11' E
Topography: subrecent beach
landscape, low, gently undulating. Rainfall Class (Mohr): I
Site: almost flat, near lagoon. Lab. Nos: MS1248/1252
Parent material: subrecent marine
beach deposits of mixed origin
(intermediate igneous rocks and
sandstones mainly). Field Nos: Sematan 1/5
Date sampled: 23.8.67.

At surface very thin layer of (10YR 6/2), light
brownish grey sand due to exposure to sun.

A1	0 - 5	inches	Yellowish brown (10YR 5/4), fine sand, weak crumbly, friable, dry. Very well rooted, porous. Distinct, wavy boundary to
B1	5 - 30	"	Yellowish brown (10YR 5/8), very fine sand, structureless to weak crumbly, loose, slightly moist. Very well rooted. Distinct wavy boundary to
B2	30 - 45	"	Yellowish brown (10YR 5/8), fine sand, with common large yellowish red (5YR 5/8) mottles. Structure- less, loose, very few roots. Distinct wavy boundary to
B3	45 - 51	"	Yellowish brown (10YR 5/6), fine sand with common large pale yellow mottles. Structureless. Very few roots. Distinctly overlying
B/C	51 - 60	"	Yellowish brown (10YR 5/8), fine sand with common large red and yellowish brown mottles. Slightly wet at 60 inches.

General information on the family

The family is exclusively found in the coastal area between Sematan and Santubong, First Division because of the nearness of Intermediate Igneous rocks to the coast in this area. Content of ferro-magnesium minerals is therefore high in the parent material of this soil, hence the reddish colouration. This is atypical for Sarawak coastal sands which are generally highly quartzitic and pale in colour. Mottling in the subsoil is associated with wetness. Highest ground watertable probably at 33 inches during the wet season.

Profile SEMATAN

The strong red mottles in the subsoils are caused by precipitation of iron compounds due to occurrence of brackish water at this depth. In other areas this has given rise to the occurrence of ground water laterite, but this is of a very localised nature.

The soils are used for coconut planting but without adequate fertilisation the growth is poor. Trials are carried out on this soil type but no results are yet available.

Classification

The soils are classified as Recent Alluvial soils because of the absence of diagnostic horizons. Probably this profile could be rated as an intergrade to Groundwater Lateritic soils. The latter is associated to wet conditions in the subsoil and presence of brackish water. The soils could also be regarded as intergrades to the Jerijeh family (Podsols) which develop on identical material but on slightly raised localities. The relationship between the Jerijeh and Sematan is at present not yet well understood. Are Sematan soils younger variants of the Jerijeh?

According to the 7th Approximation the soils belong to the Order of Entisols - Psamments (suborder) - they are not quartzop-samments because the content of weatherable minerals is too high (mainly hornblende) but probably Torripsamments - Typic Torripsamment (subgroup).

The soils show similarities with the Rudua series at the East Coast of Malaya.

Profile BUSO

Soil Group: Podsol

Family: Buso

Series: not established

Location: Matang road, approx.
9½ miles, First Division,
Kuching District.

Latitude: 1° 34' N

Longitude: 110° 14' E

Topography: Macro: Rim of alluvial fan of probably Pleistocene or subrecent Age. Micro: Gently undulating terrain sloping down towards river.

Slope: at site approx. 3 degrees.

Parent material: Alluvial deposits of probably Pleistocene to subrecent Age. Source: Tertiary sandstones mainly.

External drainage: moderate

Vegetation/Land Use: Mainly secondary jungle (Kerangas-Heath forest)

Altitude: approx. 50 feet.

Rainfall: 189.82 inches (21 years' mean) Sungei China records.

Rainfall Class (Mohr): I

Lab. Nos: MS1236/40

Field Nos: Buso 1/5

Date sampled: 22.8.67.

0	1 - 0	inches	Litter of partly decomposed ferns and dead leaves.
A1	0 - 5	"	Dark brown (7.5YR 4/2), loamy sand. Crumbly, weak friable to loose. Very well rooted (small roots mainly), moist. Abrupt clear boundary to
A2	5 - 8	"	Light brownish grey (10YR 6/2), loamy sand. Many dark brown coloured spots at boundary with upper horizon indicating worm activity. Structureless, loose. Slightly moist. Very few roots. Clear, wavy boundary to
Bh	8 - 10	"	Dark brown (7.5 YR 4/2), loamy sand, weak crumbly, fine to loose, common medium pale brown to yellow brown mottles increasing in intensity with depth. Moderately well rooted. Gradual regular boundary to
B2	10 - 18	"	Multi coloured yellow brown, dark brown and grey sandy loam. Dark brown coloured material mainly organic materials in old root channels. Grey mottles are more moist than the remainder. Friable, weak crumbly. Few fine roots. Gradual, indistinct boundary with
B3	18 - 35	"	Pale yellow (2.5Y 7/4), sandy loam with common large strong brown and brownish yellow mottles. Strong brown colours mainly confined to root channels. Weak fine subangular blocky, weak friable. Very moist patches which are slightly plastic and sticky, few fine roots. Abruptly overlying
IIB(h)	35-42	"	Boulders, densely packed. Mainly sandstone (brittle and soft with some hard acid igneous rock boulders.) From 35 - 39 inches boulders are weakly cemented and coated with dark brown humic materials.

At 60" water seeping out (watertable at time of sampling).

Profile BUSO

General information on the Buso family

The family is a typical example of a Humus Podsol with a non-indurated humus B horizon. A-typical is the secondary illuvial humus horizon at the bottom of the profile (see for further information paper on the environment and characteristics of Podsoils in Sarawak by J.P. Andriessse presented at the Conference).

The Buso family occurs widespread on terrace alluvials of a sandy texture. The total area is, however, small although in the First Division they may occur over comparatively large areas. The soils are usually not farmed but if near large markets vegetables are grown with the incorporation of much organic manures, and with intensive farming methods profitable farming is then possible.

The soils are not of economic importance.

Classification

The soils are classified as Podsoils according to the Sarawak Classification. The family is characterised by the non-indurated illuvial Humus Horizon. According to the amended 7th Approximation the soils belong to the Order of Spodosols, Aquod suborder, Tropaquods soil group. The subgroup is probably Histic Tropaquods but this depends on land use.

BUSO PROFILE

Lab. No.	Depth (inches)	% silt	% clay	MECHANICAL ANALYSIS						% Total sand	Total %	TEXTURE
				SAND FRACTION (MESH)								
		8-16	16-30	30-72	72-150	150-300						
MS1236	0 - 5	12.10	9.83	0.05	0.54	35.71	25.38	18.68	78.19	94.12	Loamy sand - sandy loam	
1237	5 - 8	11.71	3.45	0	0.92	32.74	26.52	27.08	84.92	100.08	Loamy sand	
1238	8 - 10	10.58	5.55	0	0.90	35.40	25.05	22.15	83.50	99.63	Loamy sand	
1239	10 - 18	11.31	2.44	0	0.76	34.29	23.63	21.01	79.69	100.44	Sandy loam	
1240	18 - 35	8.76	13.39	0	1.04	37.67	22.77	16.63	78.11	100.26	Sandy loam	

CHEMICAL ANALYSIS

Lab. No.	Depth (ins)	pH 1:2.5 H ₂ O A.D.	pH 1:5 KCl	% (O.D.)			P P M (O.D.)						M.eq. % (O.D.)			% (O.D.)	
				Total N	Org. C	Av. P	Reserves			Exchangeable			C.E.C.		Group III Oxides	Fe ₂ O ₃ 6 N C 1	
					P	Ca	Mg	K	Ca	Mg	K	Na	C.E.C.				
MS1236	0 - 5	4.2	3.1	0.266	6.14	1	62		3.67	1.02	0.16	0.16	16.60		0.03		
1237	5 - 8	5.1	4.0	0.016	0.22	<1	4		0.06	0.32	0.02	0.06	1.15		0.04		
1238	8 - 10	5.0	4.1	0.035	0.72	<1	15		0.13	0.25	0.03	0.06	2.95		0.05		
1239	10-18	5.1	4.2	0.025	0.56	<1	26		0.25	tr	0.02	0.08	2.64		0.41		
1240	18-35	5.1	4.2	0.009	0.20	<1	19		0.06	0.13	0.01	0.06	1.90		0.99		

Guide for third day tour - First Division - 15th May, 1968.

Note: for orientation follow the yellow traverse shown on the map.

From Kuching Town to 3rd mile the route is the same as the one followed on the first day tour.

At the 3rd mile the junction to Batu Kawa is taken and the road dips down to a riverine basin covered by deep peat. Much of the deep peat is at present planted up with pineapple to supply the Kuching Market. (Sarawak variety, unsuitable for canning). Stapok Peat Research Station is situated at approximately 5th mile. This station, formerly part of a small Peat Forest Reserve, aims at studying the growth of various crops on deep peat and the nutritional problems involved. Studies into the rate of subsidence of peat level after cutting the Primary Jungle and provision of drainage are also carried out.

Anderson profile (deep peat) - see for particulars description and analytical data sheets.

From Stapok Peat Research Station the route is known up to 6th mile bazaar which was passed on the first day tour.

From 6th mile bazaar the road to Bau is followed. The first two miles lead through a dissected terrace landscape (note gravel exposures in road cuttings.) The terrace materials rest on shales of Cretaceous Age, the latter being exposed in deeply dissected terrain where Red-Yellow Podsollic soils of the Merit family have developed. The soil is here used in places for the making of bricks (see brick factories along the road). From 8th to 10th mile the road crosses an alluvial plain covered with shallow peat and Gley soils. This is possibly an old estuary or channel of the Sarawak Kiri river. From the 10th to 11th mile, basaltic and andesitic materials underlie dissected terrain. On the steep hills deeply weathered Lateritic soils of the Tarat family can be seen. The road then crosses the Sarawak Kiri river and after having passed through an outcrop of basalt immediately across the river the road then leads through a moderately dissected shale-landscape on which mainly Red-Yellow Podsollic soils (Merit family) have formed. In places, these are rather shallow and where the road is near the Sarawak Kanan river the shales are overlain by terrace deposits.

This moderately dissected shale landscape is intersected by numerous small streams with small valleys in which wet padi cultivation is practised. Most of these valleys are liable to high back-flooding during the rainy season (January to March) when the main river overflows.

Approximately at 18th mile (Paku bazaar) a limestone hill at the right is passed. A brief stop is made here to show the Skeletal Brown Forest soil pockets which develop on the limestone and which are either formed from older material overlying the limestones or are formed from impurities in the limestone itself.

The limestone belongs to the Bau Limestone Formation (Upper Jurassic) and contains Algae. Boulders of Antimony ore (mainly stibnite) were collected from the flat land in front of the quarry during the last century, and coarse gold was also panned from streams and pockets of alluvium in, and surrounding, the limestone hill.

The Brown Forests Soils can only be studied by climbing these steep-sided Limestone hills. They are only of academic importance in Sarawak and no agriculture is carried out on them.

From the quarry the road crosses typical limestone topography, note the high domes built up by limestone which can be seen at the left when approaching Bau bazaar.

This topography is very similar to the limestone topography found at Ipoh (Karst). Surrounding the limestone hills are alluvial flats underlain by flatbedded limestone.

At the 21st mile a track to the right is followed. This track runs along the foot of Bukit Seringgok built up by Dacite.

For Abok profile see the description and analytical data sheet.

From the site of the Abok profile the back end of Bau bazaar is entered. Bau is the centre of gold mining industry which has produced more than 1,242,000 ounces of gold between 1864 and 1967 worth almost M\$ 151,000,000 at current prices. Present day output is small, averaging about 2,600 ounces per year, and is produced by several mines who use the cyanide method to treat both primary and secondary ore.

Bukit Young' Gold Mine. The opencast working at this mine exposes steeply dipping to vertical limestone and shale cut by porphyry dykes. Eluvial clayey gold ore is mined from pockets in the limestone surface and primary ore from the porphyry - limestone contact. Gold has also been recovered from tailings dumped on property from another Mine nearby and from clayey alluvium in sluice trenches which date from the last century when coarse gold was being worked in the area. Between 1955 and 1967, the mine obtained almost 15,000 ounces of gold from about 111,000 tons of ore, for an average recovery of 2.4 dwt per ton.

From Bukit Young' Goldmine the return journey follows the same route as taken for the outgoing trip.

(Geological information on the Bau area and goldmining was given by the Geological Survey Department, Borneo Region and is gratefully acknowledged).

Profile ANDERSON

Soil Group: Peat soils

Family: Anderson

Series: not established

Phase: depth phase 3 (deeper than 120 inches)

Location: Batu Kawa road near Stapok Peat Research Station, Kuching District, First Division.

Latitude: 1° 31' N

Longitude: 110° 10' E

Topography: flat riverine basin

Site: Micro-undulating because of peat shrinkage due to drainage. Excavated along drain.

Parent material: Organic deposits of a woody nature.

External drainage: impeded

Vegetation/Land Use: Secondary growth, mainly ferns.

Altitude: approx. 15 feet above sea level (estimated).

Rainfall: from nearest station (3 miles) 158.11" mean annual rainfall over 71 years.

Rainfall Class (Mohr): I

Lab. Nos: MS1231/35

Field Nos: Anderson 1/5

Date sampled: 22.8.67.

0 - 0 inches	Litter of leaves and partly decayed roots and twigs.
0 - 14 "	Dark brown (7.5YR 3/2), dry peat with abundant large to medium size roots. Large chunks of woody material which break easily into friable particles when pressed. Distinct but gradual change into
14 - 96 "	Very dark brown (10YR 2/2), woody peat. Moist to wet.

Samples:

I	0 - 7 inches
II	at 24 "
III	at 48 "
IV	at 72 "
V	at 96 "

General information on the family

This family covers approximately 13% of the State (6,240 square miles) and the development for agricultural use poses extreme drainage problems. Due to shrinkage particularly in the early years of reclamation subsidence may be more than 2 feet which aggravates the drainage problem, particularly in areas which are already low lying (along main river courses). At present research is being carried out at Stapok Peat Research Station to try out possible uses of this soil type. Coconut is growing well but anchorage is insufficiently stable for heavy bearing palms. Oilpalm has established itself well but conclusions must await final results. Pineapple is doing well on these soils but marketing is difficult. At present most peat areas are covered with Peat Forest from which valuable timber species such as Ramin are extracted for export. The bulk of Sarawak timber comes from this soil type.

Classification

The soils are classified as Peat soils in Sarawak because O horizon contains more than 35% organic matter and is more than 10 inches deep.

They are Histosols (not further differentiated) according to the 7th Approximation.

Profile ABOK

Soil Group: Red-Yellow Podsollic. Parent material: Weathered porphyritic
Family: Abok Dacite (partly colluvial boulders).
Series: Jagoi External drainage: Rapid.
Phase: Colluvial influenced,
shallow. Vegetation/Land Use: Rubber garden
with much secondary jungle
undergrowth: mainly ferns.
Location: Old road to Bau, approx.
 $\frac{1}{4}$ mile from bazaar at foot of
Bukit Sirengkok. Altitude: Approximately 50 feet.
Latitude: $1^{\circ} 25' 30''$ N Rainfall: 129.56" (17 years' mean)
Range 80.25" - 224".
Longitude: $110^{\circ} 9' 30''$ E Rainfall Class (Mohr): I
Topography: Footslope of 600'
high hill, at edge of alluvial
plain underlain by limestone. Lab. Nos: MS1219/1224(B)
Slope: at location 10 degrees. Field Nos: Abok 1/6, subsample 7.
Micro-topography: undulating
due to buried large rock
boulders of colluvial nature. Date sampled: 17.8.67.

O	0 - $\frac{1}{2}$ inches	Partly decomposed litter of fern origin mainly.
A1	$\frac{1}{2}$ - 9 "	Yellowish brown (10YR 5/8), clay, weak subangular blocky to crumb structure. Moist. Slightly plastic. Firm. Many rootlets. Weak clayskins development around larger peds. Scattered small, partly weathered rock pieces (colluvial and some hard rock fragments, mainly quartz (smaller than $\frac{1}{2}$ inch). Total volume of stones less than 5%. Distinct wavy boundary to
B1	9 - 20 "	Reddish yellow (7.5YR 6/8), clay, with sporadic quartz grit (2-3 mm in size). Weak, fine angular blocky structure, on pressure plastic and slightly sticky. Moist. Firm. Few roots and rootlets. Many partly weathered rock pieces (colluvial) about 1 inch size and some larger. Small pockets of bluish-black powdery material in weathered rock. Clayskins moderately developed on old ped faces. Illuvial clay mainly coating larger cracks evidenced by colour difference. Weathered rock approximately 20% of soil volume. Indistinct boundary to
B2	20 - 40 "	Similar to the horizon between 9 and 20 inches but clayskins are stronger developed. Weathered colluvial boulders and gravel 40-50% in volume. Indistinct boundary to
B3(b)	40 - 60 "	Reddish yellow (7.5YR 6/8), clay loam, very fine angular blocky to crumb structure. Many small, black spots (sand size). Plastic and non-sticky. Moist. Clayskins developed along large cracks. Weathered colluvial boulders and gravel about 50% volume. Distinct boundary to

Profile ABOK

- C 60 - 74 inches Red (2.5YR 5/8), soft, silty textured highly weathered bouldery material with white spots (indicating former phenocrists) mixed with reddish yellow clay similar to that found in horizons above. Slightly moist. Distinct wavy boundary to
- C 74 - 90 " Red (2.5YR 5/8), soft, silty, very friable thoroughly weathered porphyritic Dacite, many white phenocrists.

Remark: The black material found in horizon 40 - 60 inches appeared to contain a high content of Manganese. (subsample Abok 7).

General information on the Abok family soils

Abok family soils occur dominantly on acid igneous rocktypes and subordinately on metamorphosed rocks of a siliceous nature and arkose.

The profile shown is typical for an Abok soil on acid igneous rocks.

Since most Abok soils on the latter rocktype occur in rather steep terrain colluviation as shown in this profile is rather common, specifically in footslopes areas where because of the general less steep terrain the soils are put to agricultural use. On the steep slopes, soils tend to be rather shallow and rocky and most of these areas are under primary jungle. The footslopes are used for either pepper or rubber, the former where Chinese farmers are dominant, the latter where the land is native owned. Pepper is growing well on this soil type because of the good internal as well as external drainage conditions which factor appears to play an important role in the growing of pepper. Fertiliser requirements for pepper are rather high, no data is available on these requirements for the Abok soil shown but on other series a full N.P.K. dressing together with MgO + trace elements (12:12:17:2 + Tr) and with rates of 6 pound per vine per year (mature vines) is giving yields of up to 16,000 lbs of green berries per acre depending on the management.

The total acreage occurring in Sarawak is comparatively small, the majority of it being located in the First Division. Although the agricultural significance for the whole economy of Sarawak may be small, the soils are of great local importance where occurring.

Classification

Classification problems centre around the weak development of the argillic horizon. Although the occurrence of clayskins is apparent the mechanical analyses do not offer a great deal of evidence of clay migration and subsequent depositing in an argillic horizon. This problem is rather universal in most Red-Yellow Podsolics of a heavy texture. Furthermore, the colluvial nature of many of these soils may obscure the existence of the argillic horizon as revealed by mechanical analyses only. The Abok family is separated from other families in the Red-Yellow Podsollic Soil Group on the fundamental difference in parent material which in the other families within this group is essentially

Profile ABOK

sedimentary rocks. If no parent rock is found the distinction is difficult to make and the only characteristic which appears to be common in the Abok family and which is missing in the other families of the Soil Group is the rather red coloration. For practical reasons the total iron and aluminium oxide content (Group III) in most cases proved to be a reliable means on which a separation can be based. However, in rather sandy soils of the Abok family this may be lower than in the clay soils of the other families. Also high aluminium contents in other Red-Yellow Podsollic soils may yield high Group III figures of which the iron oxide content may be low to very low. Such classification and mapping problems are difficult to overcome and revision of the methods used in separating these soils from others within the Soil Group is needed or the distinction must be made at a lower level of classification. The latter idea is not appreciated, however, since the Abok soils are essentially intergrades between the true Lateritic soils and the Red-Yellow Podsollics and any subdivision at a series level may obscure this nature.

The soils can be compared with the Rengam Series established in the Malayan Peninsula. They likely belong to the Ultisols according to the U.S. 7th Approximation but the absence of a distinct argillic horizons remains a problem in classifying this soil in the latter system. The only alternative would be the Oxisols.

ABOK PROFILE

Lab. No.	Depth (Inches)	% silt	% clay	MECHANICAL ANALYSIS					% Total sand	Total %	TEXTURE
				SAND FRACTIONS (MESH)							
		8-16	16-30	30-72	72-150	150-300					
MS1219	1/2 - 9	22.45	41.87	2.65	3.71	6.89	7.10	15.79	36.15	100.47	Clay
1220	9 - 20	22.13	44.37	2.55	6.37	4.34	4.34	14.13	33.81	100.31	Clay
1221	20 - 40	28.06	43.84	3.12	4.94	5.22	3.85	10.66	27.87	99.77	Stony clay
1222	40 - 60	27.63	37.34	1.40	5.15	7.73	5.92	15.71	34.81	99.79	Stony clay loam
1223	60 - 74	36.61	33.48	5.05	1.77	3.03	5.30	19.29	29.90	99.99	Clay loam
1224	75 - 90	38.96	19.01	0.50	0.99	3.37	3.95	34.11	42.47	100.44	Loam

CHEMICAL ANALYSIS

Lab. No.	Depth (Inches)	pH 1:2.5 H ₂ O A.2.D.	pH KO1 1:5	% (O.D.) Total N	Org. C	Av. P	P P M (O.D.)			Meq. % (O.D.)			% (O.D.) Group III Oxides	% Fe ₂ O ₃ 6 N H C 1			
							Total P	Ca	Mg	K	Ca	Mg			K	Na	C.E.C.
MS1219	1/2 - 9	4.8	3.9	0.216	2.79	1	254	318	954	2094	1.01	1.24	0.03	0.16	11.18	25.22	8.44
1220	9 - 20	5.3	4.0	0.047	0.61	4.1	264	211	651	2290	0.20	0.34	0.04	0.07	8.03	31.44	10.14
1221	20 - 40	5.4	4.0	0.037	0.64	<1	240	43	1639	2694	0.27	0.27	0.04	0.06	9.28	33.60	9.41
1222	40 - 60	5.4	4.0	0.027	0.11	<1	200	22	1781	2094	0.20	0.27	0.04	0.16	10.43	33.79	10.06
1223	60 - 74	5.2	3.9	0.030	0.23	<1	164	210	751	2209	0.20	0.67	0.04	0.13	10.36	28.51	6.35
1224	75 - 90	5.2	3.9	0.017	0.07	<1	89	128	844	2211	0.26	0.53	0.04	0.07	8.94	23.83	3.45

For Mn only (Black solid tested to be Mn compound)

1224B

11/

THIRD MALAYSIAN SOIL CONFERENCE

Kuching 16-18 May 1968

Session 1/1

THE GENERAL SOIL MAP OF THAILAND

by

F. R. Moormann and Santhad Rojanasoonthon*

Introduction

The first systematic study of the soils of Thailand was made by DLETON, and published in a report, with a "provisional Map of the Land and Surface Rocks of the Kingdom of Siam". (3). This map, published first in 1959 has, with very slight alterations, been reprinted several times since, and was presented at the Fourth United Nations International Cartographic Conference for Asia and the Far East, Philippines

Collection of data for a new generalized soil map of the Kingdom was carried out between 1961 and 1967; drafting was finished in 1967. The map will be published in two forms, i.e.

1. The General Soil Map of Thailand, at a scale of 1:1,250,000, now in print.

2. The Map, showing general soil conditions, at a scale of 1:2,500,000, which is a simplified and somewhat condensed version of the General Soil Map of Thailand. The latter is presented at this meeting.

The General Soil Map is based on fieldwork by the authors, including soil surveys at various scales, generalized interpretation of airphotos, topographic maps and interpretation of related data on vegetation, climate and geology.

Elements of the Legend of the General Soil Map of Thailand, scale 1:1,250,000

The elements, used in defining the map units are threefold, i.e. dominant soil or association of soils; the broad group of parent material and the landform as expressed by the general topography of the unit area.

The level of generalization of the soil units, used in elaborating the map legend is the Great Soil Group, as defined in the US literature. The Great Soil Groups, mentioned in the legend are mostly taken from DUDAL and MCORMANN (2); additional groups, important in Thailand, are described by ROJANASOONTHON and MCORMANN (4). The criteria used in describing and classifying the Great Soil Group are set forth in the new USDA soil classification system (6). Map units, which do not show one dominant soil, but are composed of two, or even more important Great Soil Groups, are defined as associations of Great Soil Groups. Poorly defined soil areas, with complex soil conditions are indicated as miscellaneous soils and land types.

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Following Great Soil Groups form an element in the legend of the soil map.

- Regosols *- Entisols.*
- Alluvial soils *Inceptisols (aquept, some fluvent)*
- Peat and Muck soils (organic soils) *histosols.*
- Low-Humic Gley soils
- Grumusols *vertisols (sirets)?*
- Rendzinas *molisols (rendols)*
- Brown Forest soils *Inceptisols (tropesols)*
- Noncalciic Brown soils *Alvisols (ustols - octostals)*
- Red-Brown Earths *Ultisols(?) [CEC]*
- Gray Podzolic soils *Ustols x ustals; udults.*
- Red-Yellow Podzolic soils (the presence of abundant laterite gravel was indicated as a separate phase for Northeastern Thailand) *tropudults*
- Reddish-Brown Lateritic soils *Mudults, rodustults or rodustalf.*
- Reddish-Brown Latosols *Oxisols or ultisols.*
- Red-Yellow Latosols. *Oxisols (?)*

Great Soil Groups, e.g. Solodized Solonetz soils, Humic Gley Soils, groundwater Podzols, were observed in Thailand; their occurrence is so limited that they could not be indicated on the General Soil Map.

materials.

Groups of parent materials were distinguished mainly on the basis of importance in regard to the soils which formed on them. Thus, the classification of parent rocks is hardly a systematic petrographic one, since geographically very different rocks (e.g. granites and quartzite - phyllites) produce similar soils, and vice versa. The main groups of parent materials, distinguished for use in the map legend, are :

- Beach and dune sand
- Recent alluvium, subdivided in fresh water river-and lacustrine alluvium, brackish water alluvium, marine-non saline alluvium and marine - saline alluvium.
- Semirecent alluvium
- Old alluvium (non or weakly calcareous)
- Marl and limestone alluvium
- Montmorillonitic clay from alluvium, marl and basalt

- Residuum and colluvium from acid rocks (most granite, sandstones, quartzite - phyllite, etc)
- Residuum and colluvium from intermediate rocks (andesite, some granite, most gneiss, most shale, etc.),
- Residuum and colluvium from basic rocks (basalt, limestone, etc.) In the case of Reddish-Brown Latosols, the rock could be specified as basalt because in Southeast Asia this Great Soil Group is almost exclusively found on materials derived from basalt.

It should be emphasized that, under the climatic conditions in the region, the occurrence of soils formed on in-situ residuum is very rare. Most commonly the parent material of the soils has been dislocated considerably, and thus could with reason be considered as colluvium or eroded residuum.

topography.

The topography indications in the legend follow soils slope classes USDA Soil Survey Manual (5), i.e.

- Level : dominant slopes 0 to 1-3%
- Undulating : 1-3 to 5-8%
- Rolling : 5-8 to 10-16%
- Steep (including hilly and very steep) ; more than 10-16%.

The topography, as presented in the legend, is indicative for the dominant landforms, especially if interpreted in conjunction with the parent material :

Level to undulating lands are coastal beaches and dunes, alluvial plains and various sedimentary terraces.

Undulating to rolling lands are peneplained areas, foothills, plateaus in the mountainous regions, some incised terraces and a single basalt plateau.

Steep lands are mountains and hills.

management grouping.

For the benefit of the agronomist with a lack of training in soil classification, the map units have been grouped broadly in classes which give a general indication of the dominant texture, the natural drainage and general fertility status and thus are meaningful in terms of soil management.

Following broad management groupings were made.

- : Excessively drained sandy soils, low fertility
- : Poorly drained clayey soils, high to moderate fertility
- : Very poorly drained, organic soils (swamps and marshes)
- : Poorly drained and well drained soils, mostly loamy and sandy, moderate to low fertility
- : Well drained to somewhat poorly drained loamy and clayey soils, moderate to high in bases, high fertility
- : Well to excessively drained loamy and sandy soils, low weatherable minerals, and bases, low fertility.
- : Well drained clayey and loamy soils, low in bases, low fertility
- : Well drained clayey and loamy soils, high in alluvium and/or iron oxides, low in bases, moderate to low fertility.
- : Miscellaneous soils and land types on hills, mountains and plateaus.

Legend of the Simplified General Soil Map, scale 1:2,500,000

Most of the elements of the General Soil Map at scale 1:1,250,000 have been maintained on the simplified version, which is presented at the Malaysian Soils Conference.

The definition of the mapping units is based on the dominant soil types in the unit area, and on the broad type of parent material, as described in the previous paragraph. The physiographic and topographic features are also considered, with the exception of the units of steep land, not used in the definitions of the mapping units.

Physiography enters into the legend of the simplified map by of the broad grouping of the various units in :

- Soils of the alluvial plains and lower terraces
- Soils of the higher terraces and the low plateaus
- Soils of the hills and the mountains

The differentiation between lower and higher terraces is not only physiographic or topographic. Terrace areas in which hydromorphic soils (Low-Humic Gley soils) are an important element, were grouped with lower terraces, whereas such areas with predominance of well drained soils are qualified as "Higher terraces". In absolute height, thus wise, parts of the higher terraces may be lower than parts of the lower terraces, e.g. well drained marine terraces in Southeast Thailand are situated at a higher elevation than most of the river terraces in the interior of the country.

Low plateaus include peneplained areas and strath terraces, generally below an elevation of 400 meters. High plateaus and peneplains are not differentiated, but included with the hills and mountains.

Simplification applied on the present map is twofold. Small areas were dropped and boundaries were realigned. Certain units on the map at scale 1:1,250,000 were grouped together, and represented by one single map unit on the simplified version. Because of the regrouping of the original map units, the units on the simplified version are not numbered in numerical order.



THAILAND

SCALE 1:2,500,000

SHOWING

GENERAL SOIL CONDITIONS

- SOILS OF THE ALLUVIAL PLAINS AND THE LOWER TERRACES**
- 1 - Lightish on beach and dune sand
 - 2 - Alluvial soils on recent alluvium (fresh water alluvium, B - stagnate water alluvium, B to mixed alluvium)
 - 3 - Peat and Muck soils
 - 4 - Low - Heavy Gray soils on semirecent and old alluvium
 - 5 - Low - Heavy Gray soils and Homolitic Brown soils on semirecent alluvium
 - 6 - Low - Heavy Gray soils and Gray Peddic soils or Red - Heavy Peddic soils on old alluvium
- SOILS OF THE HIGHER TERRACES AND THE LOW PLATEAUS**
- 7 - Gray Peddic soils on old alluvium
 - 8 - Red - Heavy peddic soils, mostly heavy Red - Heavy Peddic soils and reddish Brown - Leucitic soils
 - 9 - Crumpled sandstone and rhyolite soils on alluvial and residual materials, associated with limestone and basalt
 - 10 - Red - Brown Lignite on alluvial and residual materials, associated with limestone
 - 11 - Peddic - gray Lignite soils on alluvium from interstrata in base rocks
- SOILS OF THE HILLS AND THE MOUNTAINS**
- 12 - Red - Heavy peddic soils, mostly heavy Red - Heavy Peddic soils and reddish Brown - Leucitic soils
 - 13 - Steep Low - Red - Heavy peddic soils, mostly heavy Red - Heavy Peddic soils
 - 14 - Steep Low - Red - Heavy peddic soils and Red - Heavy Peddic soils
 - 15 - Steep Low - Red - Heavy peddic soils and Red - Heavy Peddic soils
 - 16 - Lignite - Heavy peddic soils, mostly heavy Red - Heavy Peddic soils and reddish Brown - Leucitic soils
- Compiled from the general Soil Map of Thailand, Scale 1:2,500,000, by the Survey of Land Administration Department and with the cooperation of the Ministry of Agriculture, Department of Agriculture and Forestry, and the Ministry of Natural Resources, Department of Forests and Wildlife. The map was compiled and printed in 1967.

A STUDY OF THE USE OF

CATION EXCHANGE RESINS ON NUTRIENT RETENTION

IN SOILS

by

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Introduction

In tropical countries where rainfalls are high, plant nutrients in soils can be washed out heavily by rains. This is highly undesirable. It was considered that the introduction of additional cation exchange sites to soils would hold back part of these valuable nutrients which otherwise would have been leached out. Since it is the general property of cation exchange resins to retain as well as to exchange cations in solution, the following experiments are designed to study its effects on nutrient retention in soils.

Experimental Materials

Soil A 5705 - Cocoa Research Station, Quoin Hill Tawau.

pH	4.9
Organic C (%)	3.40
Total N (%)	0.32
C/N Ratio	11
C.E.C. (m.e.%)	12.65
Easily Soluble p (p.p.m.)	0.41 mg %

Cation Exchange Resins:- Zeo-Karb 225 resin manufactured by the Permutit Co. Ltd., was used. It is a high capacity sulphonated polystyrene bead resin supplied in Sodium form. It contains only one ion active group, viz., the $-SO_3H$ group and its total capacity of 5 milli-equivalent per (dry) gram is independent of pH. It is stable to strong oxidising and reducing agents and can be used up to 100 C°. pH of resins at 1:2.5 resin water ratio was 8.1. The resin was treated with HCl (IN) and the pH of Zeo-Karb 225-H form at 1:2.5 resin water ratio was 3.

Experimental Methods and Results

1. Introduce 10 grams of air-dried soil into a leaching column lightly packed with macerated filter paper at bottom. Leach through the soil with 100 mls of distilled water (pH 5.5). Repeat this leaching process 5 more times and determine K, Ca and Mg in these leachates. HS1,2,3,4,5 and 6 are used to designate the amount of cations in these leachates. The analytical results are shown in Table I.

Table I. Cations leached out from Soil by Distilled Water (pH 5.5)

	K	Ca (m.e.%)	Mg
HS 1	0.097	0.112	0.063
HS 2	0.054	0.028	0.022
HS 3	0.031	0.017	0.013
HS 4	0.018	0.014	0.009
HS 5	0.011	0.008	0.006
HS 6	0.008	0.008	0.005

2. Introduce 10 grams of the same soil well mixed with 2 grams of Zeo-Karb 225-H form resins into a similar leaching column. Leach through the column with 6 lots of 100 mls of distilled water and determine for K, Ca and Mg from the leachates as in Procedure I. HRS1,2,3,4,5 and 6 are used to designate the amount of cations in these leachates. The analytical results are shown in Table II.

Table II. Cations leached out from Soils and cation Exchange Resin Mixture by Distilled Water

	K	Ca (m.e.%)	Mg
HRS 1	0.036	0.101	0.036
HRS 2	0.005	0.017	0.007
HRS 3	0.005	0.008	trace
HRS 4	0.003	trace	trace
HRS 5	0.001	trace	trace
HRS 6	trace	trace	trace

3. Introduce 10 grams of air-dried soil into a leaching column and leach with 250 mls of Ammonium Acetate (IN) adjusted to pH 7 and collect the leachate in a 250 mls volumetric flask and dilute to the mark with extracting solution. Determine Exchangeable K, Na, Ca and Mg in the leachate. Analytical results are shown in Table III.

Table III. Exchangeable Cations

	m. e. %
K	0.35
Na	0.12
Ca	1.63
Mg	1.62
Total	3.72

4. Repeat Procedure 3 and collect leachate in a 500 mls Erlenmeyer flask. Add 2 grams of the Zeo-Karb 225 resin-H form into the solution. Shake the flask at frequent intervals and leave overnight. Separate the resins from the solution and collect the solution in a 250 mls volumetric flask and dilute to the mark with extracting solution. Determine K, Ca, Mg. Analytical results are shown in Table IV.

Table IV. Remaining Exchangeable Cations in Leachate after Resins' Treatment

	m. e. %
K	0.320
Ca	1.084
Mg	0.496

5. Transfer the resins from Procedure 4 to a leaching column. Leach the resins with 100 mls of distilled water. Collect leachate into 100 mls volumetric flask and dilute to mark with distilled water. Determine K, Ca and Mg in solution. Repeat the leaching process through resins nine more times. HR1,2,3 ----- represent amount of cations contained in the first, second ----- 100 mls of leachate. An interval of 5 minutes between successive leachings was adopted with an object to prevent undesirable drying up of resins. Analytical results are shown in Table V.

Table V. Cations Released From Resins by Successive Water Leachings

	Ca	Mg (m.e.%)	K
HR 1	0.103	0.032	0.03
2	0.016	0.003	-
3	0.009	trace	-
4	0.006	trace	-
5	0.009	trace	-
6	trace	trace	-
7	trace	trace	-
8	trace	trace	-
9	trace	trace	-
10	trace	trace	-

Discussion

From the experimental results contained in Tables I and II, Table VI was compiled. It could be seen that 77.2% of K, 31.5% of Ca and 66.7% of Mg. were held back by the addition of cation exchange sites to soil which otherwise would have been leached out from soil by 600 mls of distilled water (0.72 inches of rainfall).

Table VI. Percentage Retention of Soil Nutrients by The Addition of Cation Exchange Sites To Soil

	K	Ca (m.e.%)	Mg
Soil (HS 1 - 6)	0.22	0.19	0.12
Soil + Resins (HRS 1-6)	0.05	0.13	0.04
Amount Retained by resins	0.17	0.06	0.08
Retention by Resin	77.2%	31.5%	66.7%

Figures I, II and III were also plotted which are self-explanatory.

The negative sites on resins ($R-SO_3^-$) would retain cations by electrostatic force. It was expected that trivalent cations would be held more strongly onto resins than divalent cations and similarly that resins would hold divalent cations stronger than monovalent cations. This was supported by experimental results contained in Table V which showed that divalent cations (Ca and Mg) were held more strongly by resins than monovalent cation (K). Monovalent K cations were held very loosely by the ionic

Fig. I Exchangeable K. 0.35 m.e. %

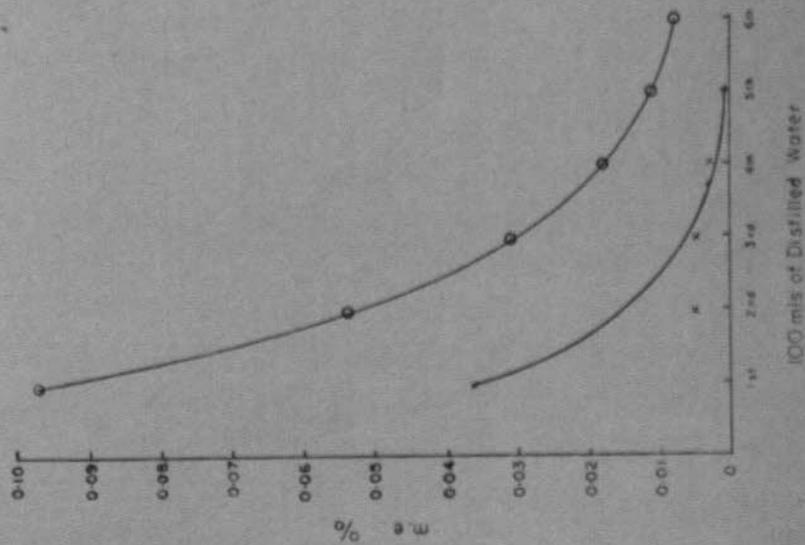


Fig. II Exchangeable Ca. 1.63 m.e. %

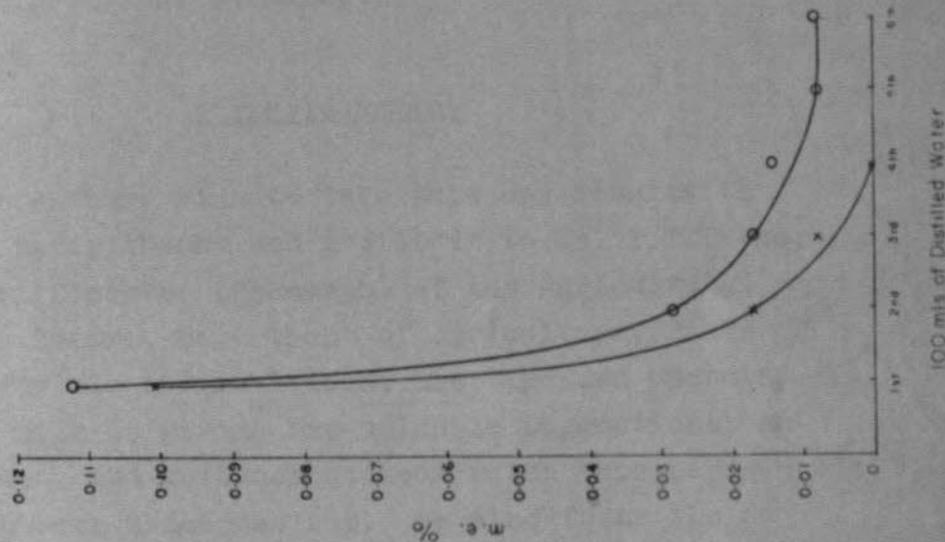
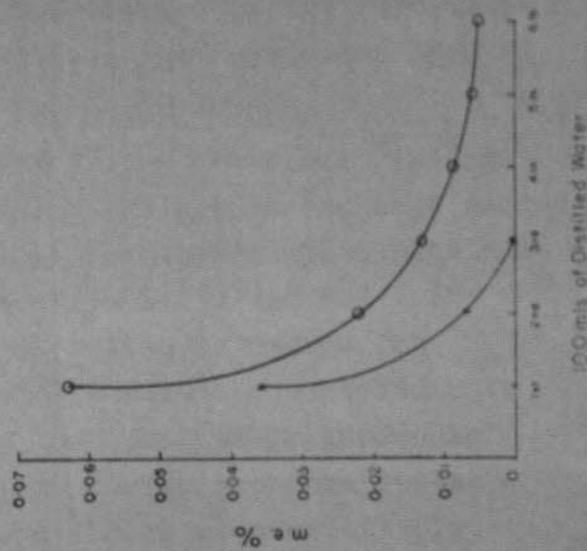


Fig. III Exchangeable Mg. 1.62 m.e. %



O for soil

x for soil + resin

resins and this was clearly illustrated by the fact that 100% of the exchangeable K held by the resins was leached out by the first 100 mls of distilled water.

It could be concluded based upon the above findings that by the addition of Zeo-Karb 225 cation exchange resins to soil, the wasteful leaching of valuable plant nutrients from soil by rainfall can be effectively reduced. The impracticability of field application of resins for economical reasons necessitated a suitable substitute to be found. It was understood that the weakly ionisable -COOH group of the Zeo-Karb 226 cation exchange resins would similarly retain cations though at a relatively slower rate. The fortuitous coincidence of the presence of -COOH functional groups in the humic acids suggests heavy mulching and application of composts to soils as a possible practical substitute.

Acknowledgement

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Session 3/5

MANURING OF RUBBER IN RELATION TO SOIL TYPE:
I. SOILS DERIVED FROM ACID IGNEOUS ROCKS -
RENGAM SERIES

by

M.M. GUHA, H.Y. CHAN and N.K. SOONG

MAY, 1968

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I. SOILS DERIVED FROM ACID IGNEOUS ROCKS - RENGAM SERIES

by

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SUMMARY

Physical and chemical properties of Rengam series soil which covers a large proportion of the area under rubber in Malaya are discussed. The relationship between responses to fertiliser application as observed in fertiliser trials and the soil properties was used to determine fertiliser requirements for the 4 to 20 years' old trees on this soil series. Based on the amounts of nutrients found required for the 99 sites of this soil series, nutrient composition of a fertiliser mixture (or compound) that is specific to Rengam series soil is worked out.

However, when a soil series is not sufficiently homogeneous, fertiliser requirement for each homogeneous unit of soil is to be separately determined by soil and leaf studies.

INTRODUCTION

Fertiliser application to rubber on almost all inland soils, excepting only the very sandy ones, is based on some general trends of growth and yield response obtained in a number of fertiliser trials. In the absence of adequate knowledge on the soils, no differential manuring according to soil type has been possible in the past. However, considerably more information on the different soils on which rubber is grown in Malaya is now available (GUHA AND YEOW, 1966). An attempt to rationalise fertiliser usage according to soil type, therefore, appears desirable.

This paper deals with the fertiliser requirement for rubber on soils derived from acid igneous rocks. The most common amongst the soils that belong to this group, is Rengam series (OWEN, 1951). Together with small areas of other soils derived from similar parent materials, Rengam series soil is

estimated to cover about 590,000 acres of rubber or almost 20 per cent of the rubber growing area in Malaya (GUHA, 1968) (a)

PHYSICAL PROPERTIES

Distribution

Rengam series soil besides being probably the most widespread well known series in Malaya is also the most common soil series amongst the latosols derived from acid-igneous parent material. It occurs in most parts of Malaya and normally stretches over about one or two thousand acres in area.

Occurrence

It can occur under a wide range of terrain conditions, ranging from gently undulating (3 to 8 percent slope), rolling (8 to 16 percent slope) hilly (16 to 30 percent slope), to steep (30 to 65 percent slope) terrain.

Profile

The description of a typical Rengam series soil profile may be given as follows:

<u>Horizon</u>	<u>Depth</u>	<u>Description</u>
A _h	0 to 4 inches	Dark brown (10YR 4/3) sandy loam; compound weak medium subangular blocky and moderately strong medium to coarse granules; friable.
A _e	4 to 27 "	Brownish yellow (10YR 6/8) coarse sandy clay; moderate medium to coarse subangular blocky; friable to firm.
B _t	27 to 37 "	Reddish yellow (7.5YR 6/8) coarse sandy clay (clay increasing with depth); moderate medium to coarse subangular blocky; firm.
C _m	37 to 48 "	Reddish yellow (5YR 6/8) to yellowish red (5YR 5/8) fine gravelly or coarse sandy clay; very weak, very coarse subangular blocky; loose and very friable.

Variation in morphological characteristics

Although the above description is considered usual, some variation in morphological characteristics occurs within the series. The colour of subsoil can vary from yellow (10YR 7/6), brownish yellow (10YR 6/8), yellowish red (5YR 5/8), reddish yellow (5YR 7/6) to red (5YR 4/6).

Figure 1 shows the textural composition, percentages of gravel, coarse sand, fine sand, silt and clay, for 71 samples of Rengam series soil collected from many rubber estates distributed throughout Malaya. Surface soil from 0 - 6" depth and sub-surface soil from 6 - 18" depth were analysed separately. Texture of subsoil is found mainly to be coarse sandy clay, although coarse sandy clay loam and clay frequently occurs. Sometimes, generally in the more clayey profiles, lateritic concretions may occur in the B₂ horizon.

Drainage

Rengam series soil is usually well drained, with medium runoff on undulating to rolling terrain and rapid runoff on hilly to steep terrain. Soil permeability is moderate, while internal soil drainage is rapid.

CHEMICAL PROPERTIES

Composite soil samples from one hundred and twelve sites of Rengam series soil spread over many estates distributed throughout Malaya were sampled from two depths, 0 - 6" and 6 - 18" and analysed for pH, organic carbon, total nitrogen and contents of concentrated acid extractable phosphorus, potassium, magnesium and manganese. The 'available' form of phosphorus and the exchangeable form of potassium and magnesium were also analysed for both soil layers. The methods of analysis used were given by MOHINDER SINGH AND RATNASINGAM (1966). The analytical results are graphically presented in Figure 2.

About 67% of the samples have a pH range of 4.4 to 5.0 indicating an acid nature. The highest and lowest pH values obtained for both soil layers are 5.7 and 4.0 respectively.

Content of organic carbon in 67 percent of the samples analysed ranges between 0.78 and 1.18% for the 0 - 6" layer of soil. The values in the subsoil layer of 6" - 18" are very much lower being mainly between 0.46 - 0.72%.

Like organic carbon, total nitrogen content is higher in the top soil than the subsoil. About two-thirds of the samples from the 0 - 6" layer of soil show values ranging from 0.08 to 0.11%, while the same for the 6" - 18" layer range from 0.05 to 0.07%.

Concentrated acid extractable phosphorus content in the top soil was between 92 and 180 ppm for two-thirds of the samples, and between 64 and 144 ppm in the subsoil. The levels of available phosphorus content in soil mainly ranged between 4 and 17 ppm, and between 1 and 7 ppm, for the two soil layers respectively.

Unlike organic carbon, total nitrogen and phosphorus, however, the concentrated acid extractable potassium and magnesium in soil were similar in both the top and subsoil layers. Two-thirds of the samples show values ranging between 0.06 and 0.97 m.eq.% and between 0.17 and 1.10 m.eq.%, for the two nutrients respectively.

The exchangeable content of potassium for two-thirds of the samples varied between 0.02 and 0.11 m.eq.% for both layers, while for exchangeable magnesium the values are between 0.02 and 0.16 m.eq.%.

NUTRIENT STATUS OF RUBBER LEAVES ON RENGAM SERIES SOIL

A total of two hundred and sixty-three leaf samples were collected from the Rengam series soil areas from which soil samples were collected and analysed. These were analysed for nitrogen, phosphorus, potassium, calcium, magnesium and manganese contents. The results of these leaf analyses are graphically presented in Figure 3.

About two-thirds of the samples show nitrogen content between 2.00 and 3.60%, while the highest and lowest values recorded were 3.26 and 2.40% respectively. A value of about 3.3% nitrogen in low shade leaves, and 3.2% in light leaves are given as the levels below which the trees are expected to respond to nitrogen application (RUBBER RESEARCH INSTITUTE, 1962).

For phosphorus, two-thirds of the leaf samples analysed show values between 0.18 and 0.26 percent. The optimum value for phosphorus in low shade and light leaves of Hevea are given as 0.21 and 0.19 percent respectively.

Potassium and magnesium contents of leaves show that two-thirds of the samples have values between 0.86 and 1.41 percent potassium, and 0.19 and 0.32 percent magnesium. Considering that a figure of 1.30% potassium in leaf is optimum, it would appear that most leaf samples from Rengam series soil area have below optimum level of potassium. The magnesium status for which the optimum value is 0.22 percent, on the other hand, is comparatively better.

For calcium and manganese the contents cover a wide range, the values for two-thirds of the samples varying from 0.53 to 1.17 percent calcium and 32 to 208 ppm manganese. This is however expected, as these two nutrients are known to increase very rapidly with aging of leaves (GUHA, 1968) Variation in age of leaves sampled, therefore, would make considerable variations in their concentration in leaves. However, since only values less than 0.4% calcium and less than 60 ppm manganese in recently matured leaves are considered as deficiency levels, such deficiencies are not commonly found on Rengam series soil and general application of these two nutrients are ^{not} recommended.

RESPONSES TO FERTILISER APPLICATION IN RELATION TO SOIL PROPERTIES

The characteristic distribution of the soil and leaf nutrient contents in samples collected from Rengam series soil areas under commercial plantations, were given in Figures 2 and 3. The results obtained for samples collected from control plots of two experiments sited on this soil series were compared with the soil nutrient content for the series as a whole (PUSHPARAJAH AND GUHA, 1968). Figure 4 shows this comparison.

The two experiments on this soil type showed marked response to potassium, the increase in yield due to potassium being about 35% in Experiment C1, where nitrogen was applied as a basal dressing, and about 63% in Experiment C2 in the presence of nitrogen treatment. However, the content of potassium in both soil and leaf samples from the control plots fall at the bottom of the main ranges for this soil type. Response to potassium, therefore, cannot be generally predicted for this soil type, even though both experiments showed marked response to potassium. The same seems to be true for magnesium where the content in both soil and leaf samples from the control plots fall at the bottom of the main ranges and it would therefore be difficult to predict response to magnesium for this soil type.

However, the soil and leaf nutrient levels from control plots in trials showed that response was obtained to application of nitrogen with 0.10% N in soil. Comparison of these values with those of Figure 4 show that response to application of N could be expected in at least half of the areas of Rengam series soil.

As for phosphorus, response was observed in Experiment C1, but not in Experiment C2 probably because this area had received sufficient phosphate application before the experiment was started. ~~However~~ Although no inference can be drawn from the soil data, the leaf phosphorus content, being mostly below that of the control lot, indicates that response to application of phosphorus is to be generally expected in this soil type.

In Experiment C1 where manganese was a treatment, it gave a 7% increase in yield.

RECOMMENDATIONS

The above relationship of soil and leaf nutrient data to fertiliser response in field experiments for different types of soils were used to provide discriminatory fertiliser recommendations to estates. The soils of the estates were first surveyed and mapped. Samples of soils and leaves were collected for analysis from representative areas. The analytical data were then interpreted for assessing fertiliser requirements, taking into account the relevant details, like age of trees, clonal characteristics, past ground cover management, past manuring of both covers and rubber trees, yield and tapping system employed, stand and other factors like disease incidence and wind damage susceptibilities. In this way, discriminatory fertiliser recommendations were offered to estates for each field. Such specific recommendations were offered to 99 sites on Rengam series soil with trees between four to twenty years of age.

From the recommendations made for these 99 sites, it is possible to calculate the amounts, in oz per tree, of the major plant nutrients that were required by the trees on each site. The mean amounts (\bar{x}) required by the trees for each nutrient element was obtained for the soil type as a whole together with the 95% confidence limits for the mean \bar{x} (Table 1).

As can be seen in Table 1 the mean amounts of N, P₂O₅, K₂O and MgO found required by rubber trees on Rengam series soil are 4.36, 4.23, 6.33 and 2.84 oz per tree respectively.

Recent manuring trials have shown that the amounts of phosphorus can be reduced if the area concerned had previously received sufficient rock phosphate application during immaturity (PUSHPARAJAH, 1966 and 1968). Further, the above recommendations for magnesium were based on slowly available magnesium from ground magnesium limestone. If magnesium is supplied in the soluble form such as Kieserite, the amount of magnesium applied should be reduced. Based on such consideration, it is considered that the amounts of the four nutrients that should be supplied on an average Rengam series soil are :-

4.25 oz N, 3.00 oz P_2O_5 , 6.33 oz K_2O
and 1.42 oz MgO (using Kieserite)

OR 2.78 lb/tree per annum of a mixture of 45.3 parts ammonium sulphate, 18.7 parts rock phosphate, 23.6 parts potassium chloride and 12.4 parts of magnesium sulphate giving 9.5 N:
6.7 P_2O_5 :14.2 K_2O :3.2 MgO.

CONCLUSIONS

The above considerations permit prescription of fertiliser formulation which is specific to a soil series. Nutrient composition of a fertiliser mixture (or compound) that is specific to a soil series can thus be evolved, provided the soil series in question is sufficiently homogeneous and large for the purpose. Where soil morphological and inherent nutrient characteristics are known, such recommendations specific to soil type is regarded as a considerable improvement over the present practice of using general fertiliser schedule irrespective of soil variability. Similar data on other commonly occurring soil on which rubber is grown in Malaya have also been collected. The results obtained from these soil areas would form the basis of papers that would follow.

Where a soil series is not sufficiently homogeneous, fertiliser requirement for each homogeneous unit of soil is to be separately determined by soil and leaf studies.

ACKNOWLEDGEMENT

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TABLE 1 AMOUNTS OF NUTRIENTS RECOMMENDED

	Amounts (in ozs per tree)			
	N	P ₂ O ₅	K ₂ O	MgO
n	99	99	99	99
\bar{x}	4.36	4.23	6.33	2.84
s	1.67	2.39	4.54	2.96
c.v.	38.4%	56.6%	71.8%	104.0%
95% confidence limits for the mean \bar{x}	4.02 to 4.69	3.75 to 4.71	5.42 to 7.23	2.25 to 3.43

n = number of samples

\bar{x} = mean

s = standard deviation

c.v. = coefficient of variance

FIGURE I: PARTICLE SIZE DISTRIBUTION IN RENGAM SERIES SOIL
(NUMBER OF SAMPLES: 71)

Particle size distribution (71 samples)

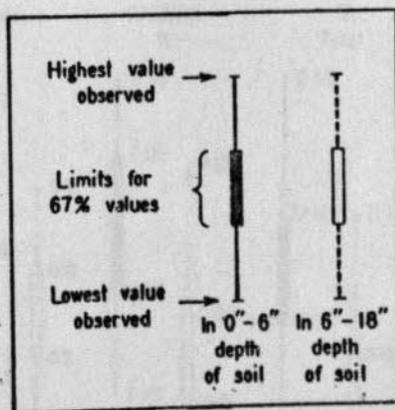
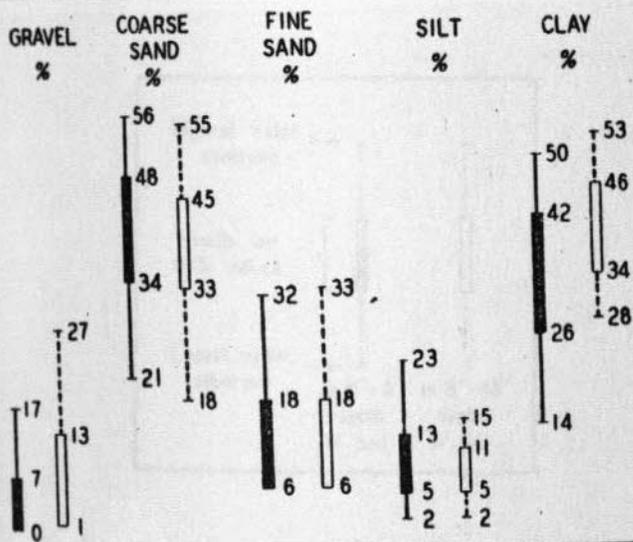
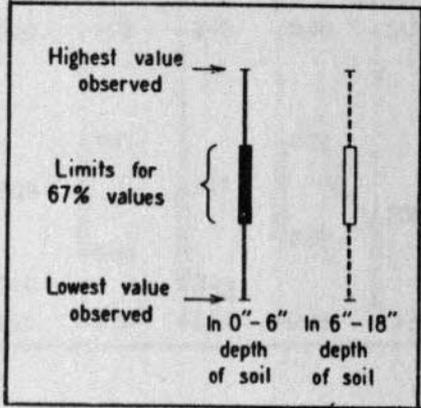
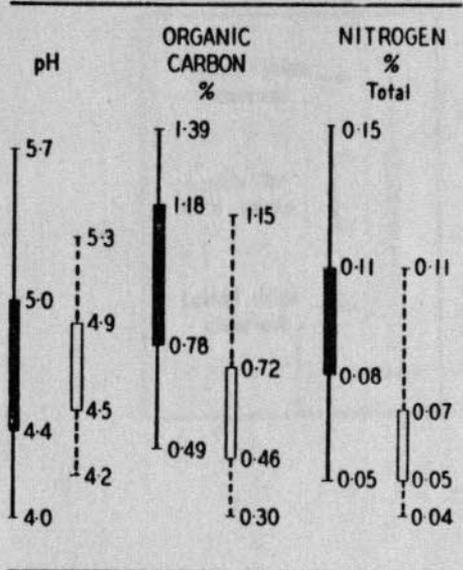


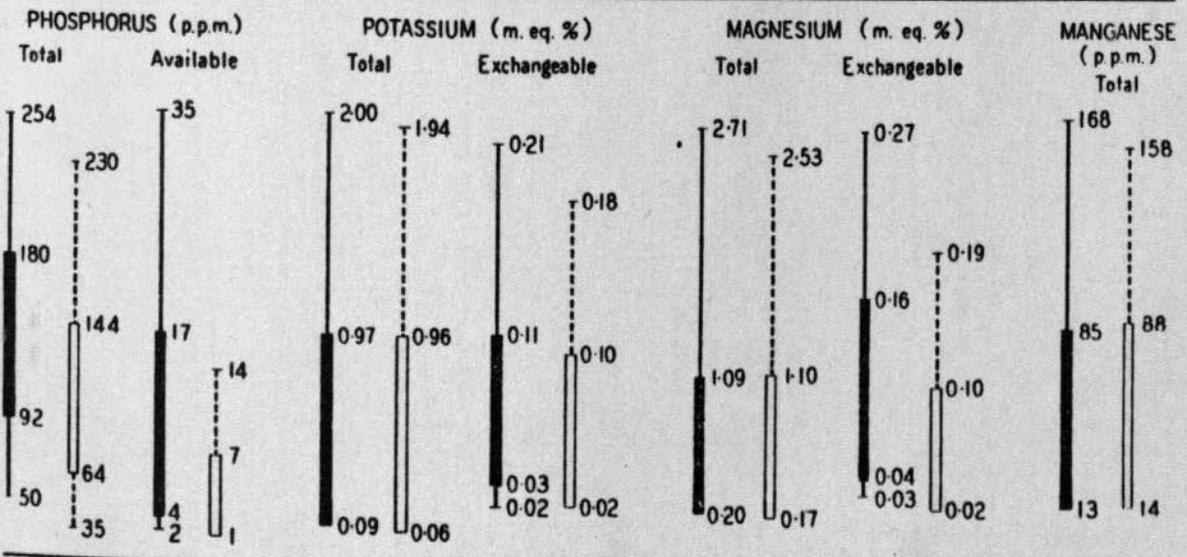
FIGURE 2: CHEMICAL ANALYSES OF RENGAM SERIES SOIL
(NUMBER OF SAMPLES: 112)



Soil analyses (112 samples)

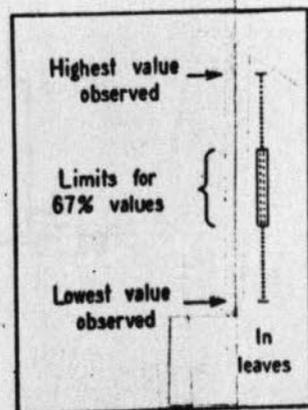
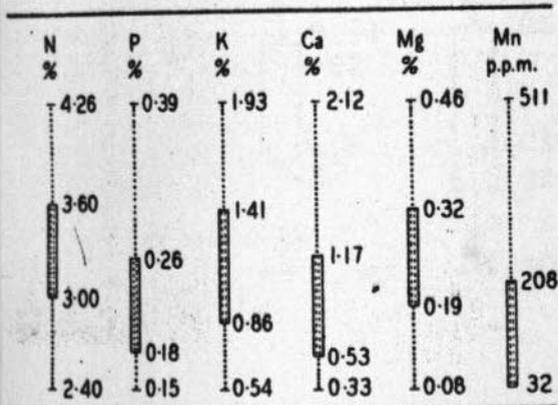


Soil analyses (112 samples) Cont.

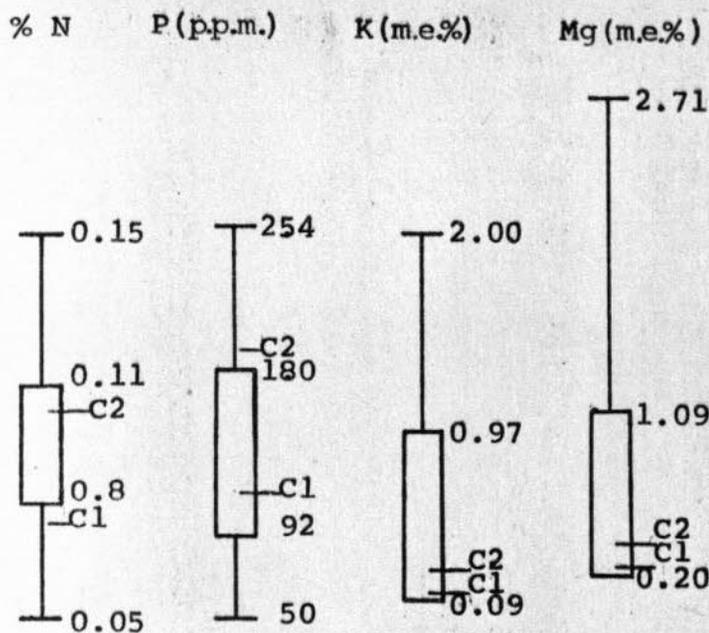


URE 3: NUTRIENT COMPOSITION OF RUBBER LEAVES ON RENGAM SERIES SOIL
(NUMBER OF SAMPLES: 263)

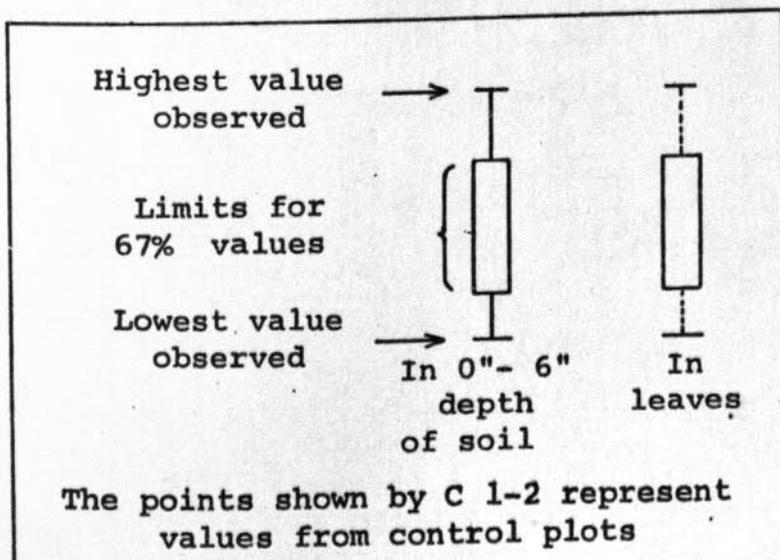
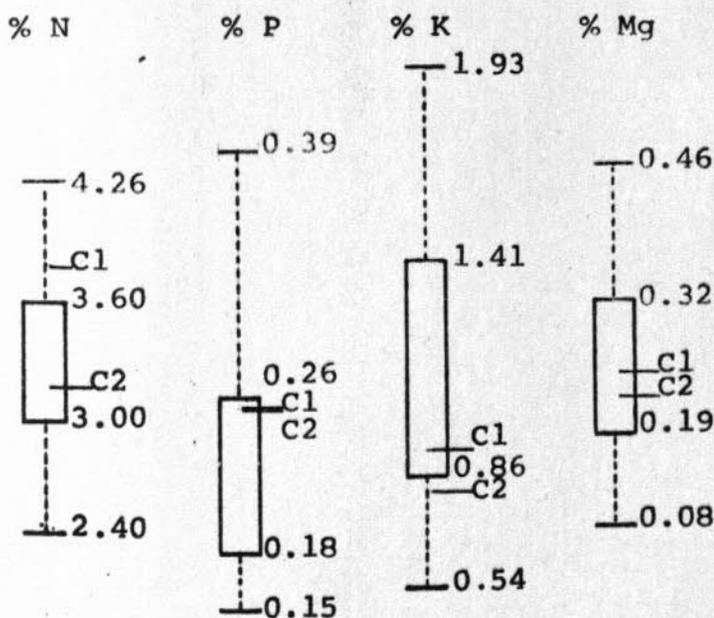
Leaf nutrient content (263 samples)



SOIL 0-6"



LEAF



The Soil Damage Factor in Present Day

Logging in Sabah

by J. E. D. Fox

Ecologist, Forest Department, Sabah.

Introduction

Logging changes the physical landscape and on the level of the small site exploitation ecotypes are formed. Where logging is light the Dipterocarp forest can regenerate itself readily. When top soil is moved and exposed layers compacted as on tractor paths little of any value can grow (Figure 7). In between the extremes a range of vegetation spectra is created. The soil being subjected to a more changeable environment it in its turn affects the rates of growth and the range of species which can grow.

The soil damage factor is believed to be of considerable importance in present day logging in Sabah especially with the widespread use in recent years of heavy machinery (Figure 4). Some attempts will be made to describe the effects of logging on the soil with particular reference to the growth of the following crop and some recent data on the extent of soil damage in logging operations will be discussed.

Other forms of damage appear to be more important in the peat swamp forests (Brunig, 1964; Anderson, 1964) where climatic factors are more significant in regeneration than is exploitation. Techniques developed to assess such damage may be of some relevance to the Lowland Dipterocarp Forest. It is elementary that if a Sabah soil is to be developed agriculturally the timber must first be removed - indeed the capital value of the timber usually provides both a development incentive and capital for development. Managers must take into account the effect of heavy machinery on the soil.

Natural Regeneration

Dipterocarp forest in Sabah is characterised by the presence of shade tolerant seedlings on the forest floor. These seedlings may persist in dense shade retaining a potential for rapid growth when light conditions are favourable. Exploitation provides these favourable conditions and seedlings will grow rapidly following logging. This phenomenon forms the rationale of the system of silviculture - the "Malayan Uniform System" used in W. Malaysia and Malaysian Borneo to regenerate the forest. Poison-girdling of non-commercial species and of relict Dipterocarp trees is used to augment the light quantity and to refine the stock.

If for some reason the seedlings either do not exist in a particular place or are destroyed during the period of establishment of the new crop a problem arises. This problem is intensified by the lack of seed bearers of the desirable species - they will have been cut out if of merchantable size, poisoned if over mature or defective and are in small quantities and not usually of seed bearing ability in the size classes below the merchantable limit.

In normal commercial lowland Dipterocarp forest there is rarely a shortage of seedlings - some very moist forests may be patchy and some forests on undulating ground may have bamboo thickets where seedlings are scarce. The main source of concern is the process of logging, particularly in so far as logging alters the soil surface.

Falling & Yarding of Timber

When a large tree falls the seedlings which are in the path of the log are smashed - either bent, broken off or uprooted. The fallen crowns obscure patches of the forest floor and, especially in wet weather, the foliage may smother seedlings and promote mildews.

There is a fair indication that destruction by the log is not of much significance (Wyatt Smith and Foenander, 1962) - bent or broken seedlings grow again, either with a bend near the ground which probably affects the timber very little or they may produce a viable coppice shoot (Strugnell 1947) which will grow into a tree. Tree marking, however, is not practised and the fallers have complete freedom over the direction and method of fall (Nicholson 1958(b)). These forms of damage are relatively insignificant compared to that incurred in moving logs.

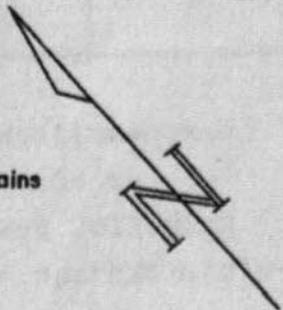
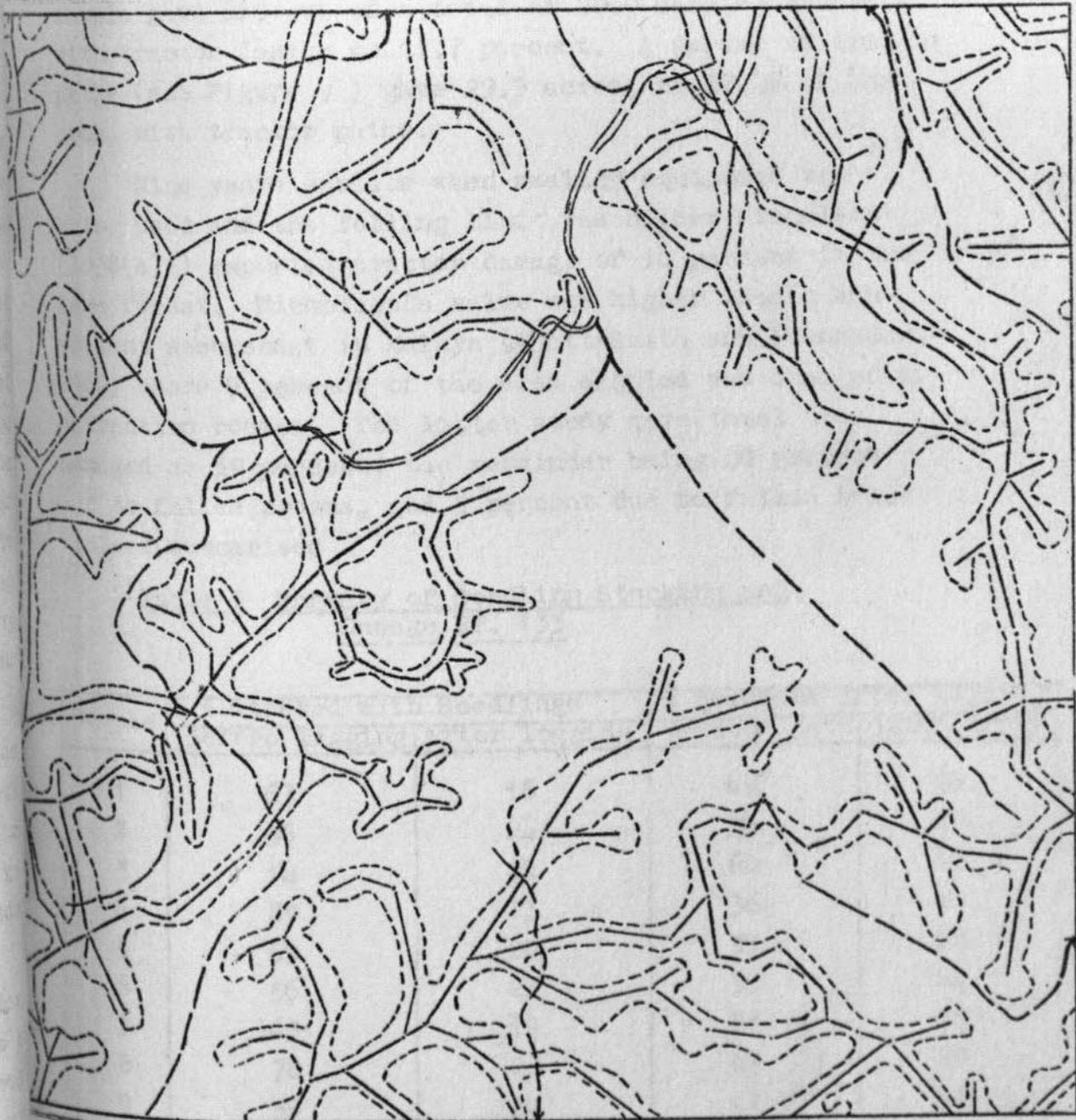
When the log is hitched to a bulldozer the machine will have moved into the forest from its unloading point on a roadside along a track which has been made by the use of the blade. Occassionally it will not be necessary to use the blade and the weight of the tracks plus the log will cause the only noticeable soil disturbance. Even this is sufficient to effectively eliminate regeneration in the skid mark and to snap off seedlings in the tractor paths. In wet weather and on undulating ground compaction and more frequent blade work respectively render even the minor tracks devoid of topsoil and consequently of the seedlings and of their roots. The major tractor paths are either compacted so much that very little will grow on them again or effectively lose their topsoil and thus their capacity for carrying useful regeneration.

Each block of worked forest has one or more large collection points - the landings. These are grouping areas for the onward movement of logs whether by rail or lorry. Such areas incur a great deal of movement by heavy machines resulting in more effective soil change than the major tractor paths (see Figs. 2-3).

With high lead yarding the only contact with the soil is the butt end of the log. Principal radii from a spar tree setting may have a number of butt ends dragged along them - particularly so when hidden ground is involved. Generally the soil damage is less restricted and less in intensity since the heavy machinery stays at the road head.

Figure 1.

R.P. 203 LUNGMANIS—SEGALUID LOKAN FOREST RESERVE
TRACTOR PATHS SURVEYED AFTER LOGGING 1966 FELLING AREA



Extent of Tractor Path Damage

The standard method of assessing regeneration is to run a narrow line across the area at intervals. Seedlings are then counted in quadrats, each of which is 0.001 of an acre in size. Full stocking by this method is thus 1000 per acre. In 1966 an area of 108.9 acres of recently cut forest in Segaliud-Lokan F.R. was assessed for the presence of tractor damage in this way. A 2 percent sample gave 860 out of a total of 2060 sampled quadrats with tractor damage or 41.7 percent. A survey of tractor paths (see Figure /) gave 29.9 acres, or 27.4% of the area, with tractor paths.

Nine years earlier when smaller equipment was being used and the felling limit was higher Nicholson (1958(a)) reported tractor damage of 14 percent in the same forest. Nicholson's value was higher than a subsequent assessment in Malaya (Wyatt-Smith and Foennander, 1962) where 9 percent of the area sampled was damaged by extraction routes. The latter study gave total area damaged as 39 percent, the remainder being 28 percent due to fallen crowns, and 2 percent due to fallen boles. Table I summarises

Table I Summary of Seedling Stocking and Damage RP. 135

Sample	% Stocked with Seedlings		% quadrats after logging	
	Before logging	After logging	Tractor path	Other empty
1	67	18	49	26
2	56	24	38	26
3	14	24	60	17
4	85	23	36	41
5	49	20	39	44
6	56	23	33	44
7	85	19	58	25
8	78	20	49	29
9	59	34	17	43
10	81	19	53	25

the results of another study (RP.135) in the Segaliud-Lokan F.R. In this example there were 600 stocked quadrats (60%) prior to logging and of the plots unstocked following logging well over half had tractor movement and approximately 43% of the sampled quadrats were damaged by machinery.

Fig. 2 A large landing and associated tractor workings.
Segaliud—lokan Forest Reserve

Mound of bark debris

Standing water in
tractor tracks

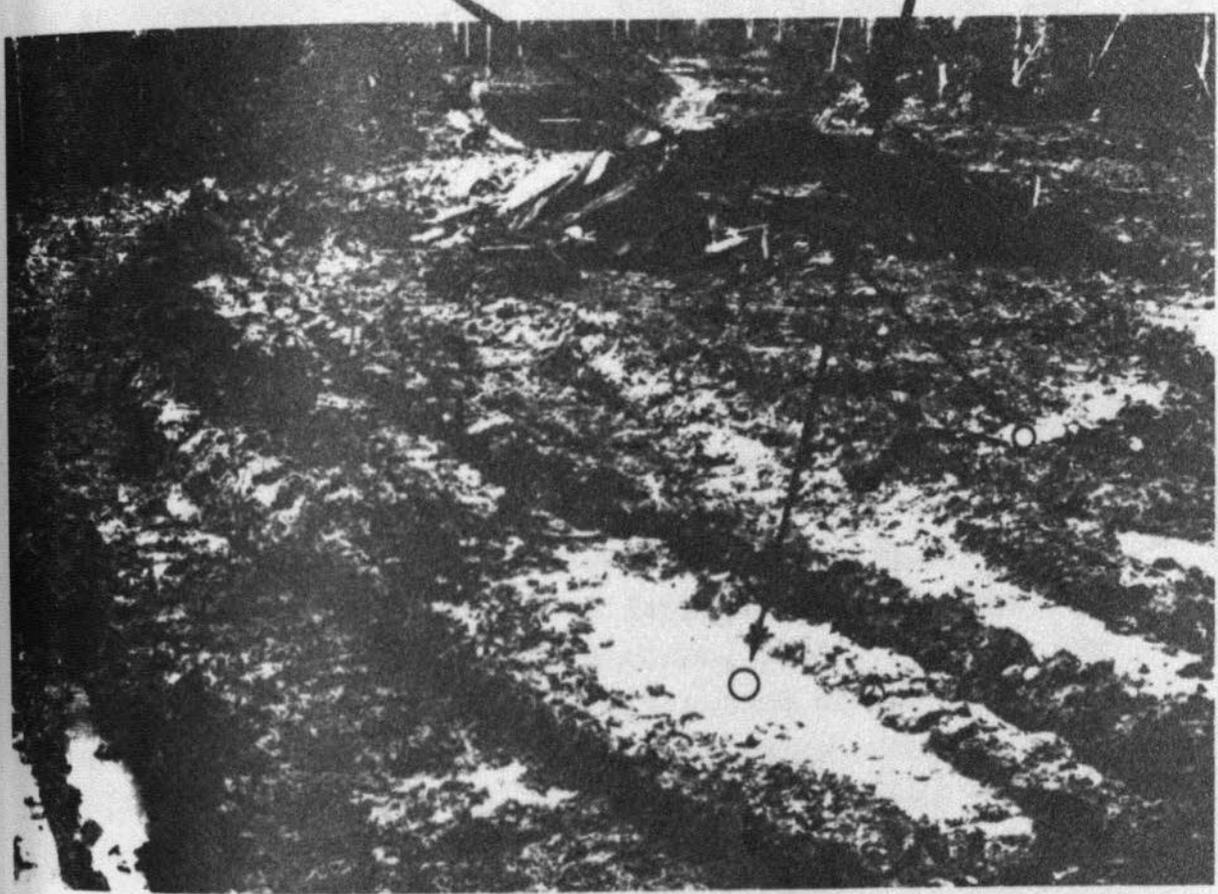


Fig. 3 A far view of the detail presented in figure 2.

Bulldozer TD 25



A proportion of the cases of tractor damage obviously fall on quadrats originally unstocked - nevertheless considerable reduction in stocking is due to tractor paths. A more extensive survey of the entire area cut over in 1967 in the Segaliud-Lokan F.R. showed that the average stocking following logging was 30.8% and of the unstocked quadrats 35% fell on tractor paths. This survey consisted of 36 separate reports in 26 of which the percentage stocking following logging was lower than the percentage damaged which for three quarters of the reports was between 21 and 50 percent of the sampled areas.

The examples given above were on areas subjected to normal commercial operations using tractor yarding. High lead yarding, though visually appalling and sometimes described as eliminating Dipterocarp forest (Egerton, 1953 re. N. Mindanao in the Philippines), results in a smaller loss of seedlings (Nicholson, 1963). Perhaps the most common pre-requisite to cultivation in Sabah today is a too stage exploitation. Initially large commercial trees are removed for export by major licencees. Subsequently on alienation the remaining trees are removed by smaller contractors. This means that heavy machinery enters the area on two occasions - this is most undesirable if forest regeneration is required, especially if a considerable time lapse ensues between the visits as the seedlings will have commenced rapid growth and will be vulnerable to damage. An assessment of a re-logging operation (RP.233) in 1967 showed that tractor damage increased by 13% even though the routes largely followed the first logging. Seedling stocking was reduced by 15%.

A recent survey of tractor paths etc. by the Soils Section of the Agriculture Department (Report No.67/3 - D.W.McCredie) gave a value of only 3% or so for damaged soil by area survey. The area concerned is near a river and has been tractor logged - several almost parallel main tractor paths of a mile or so are recorded. The details of the method of sampling and the characterisation of what is disturbed may well differ for agronomists, however the figure of three percent is surprisingly low.

It is important to minimise the number of tracks made in removing timber, whether the land is to be regenerated with forest or to be planted with an agricultural crop. Much of the extent of damage in any one unit depends on the individual bulldozer driver. In wet weather more tracks tend to be made as a track in use quickly develops a muddy surface which is hard going. Most drivers are paid on production or receive productivity bonuses and aim naturally, at moving the maximum number of logs possible. At the limits of the extraction net work this often implies that a dozer will move in to each log rather than spend time on winching in. Similarly the emphasis on efficiency has resulted in recent years in the use of ever more powerful - and weighty - machines which cause considerably more disturbance than the less powerful ones. A recent development of some promise has been the pioneering of a wheeled skidding machine by Messrs River Estates at Lumerau F.R.

Nicholson (1965) has said that the most pressing need is to curtail logging damage (in securing maximum regeneration) and logging agreements now carry clauses specifying heavy penalties for avoidable damage to seedlings or poles. These forms of damage are difficult to assess and since agricultural development is not concerned the more logical approach would seem to be to aim at specifying the density of tractor paths. Blocks of land to be developed as plantation estates should certainly have a plan of operations which takes into account future road needs and the overall topography and drainage pattern.

A further effect of tractor yarding is the blockage of natural drainage channels (Figure 6). This is particularly important in low-lying moist areas. Tractor paths may cross a minor water course, effected by filling it in at the point of traverse. Water then builds up behind the dam and forms a pond covering a much larger area of land than the original water course. All woody vegetation is killed, sometimes over several acres, and no seedling regeneration is left on such an area even if it subsequently dries out.



Fig. 4
TD 25 Bulldozer
preparing major
traction route.



Fig. 5
Soil surface in
Dipterocarp
forest.

Cicada
exit hole.

Changes Following Logging

The average annual litter production for forest in the equatorial zone is about 11 tons per hectare compared with 5.5 for warm temperate and 3.5 for cool temperate forests (Bray and Gorham, 1964). Fresh surface litter is seen in Figure 5. Most rain forest soils however are characterised by a low content of plant nutrients (Richards, 1952). When the jungle is felled the cycle of organic matter is broken (Coulter, 1950) and exposure to the sun and higher temperatures accelerate oxidation. Ovington (1962) reported numerous instances of change in the chemical and physical properties of woodland soils, mainly concerned with the uptake of nutrients as varying between species on similar soils or the same species on differing soils. The upset to the virgin - more or less stable - environment of Dipterocarp forest is of sudden change and extensive loss due to extraction.

Soil physical characters in the tropics generally have more effect on the type of forest than do variations in most of the chemical properties (Richards 1952). The effect of compaction and loss of topsoil (plus litter), besides the physical removal of such seedlings as were present originally, is the creation of conditions which are unfavourable to any new Dipterocarp seedling establishment even if seed trees are available to produce fruit. Dipterocarp fruit is produced irregularly but when it does fall on a bare exposed area a large proportion is eaten by rodents. That which germinates is desiccated by the hot sun or develops fungal infection causing the death of the root and shoot tips. If the seedling can withstand these the radicle finds difficulty in penetrating the surface layer which is easily baked in dry weather and often has standing surface water in wet weather. On areas where fertility is still present climbers such as Mezoneuron sumatrana and Merremia borneensis may become established. On wet areas sedges and Melastoma spp. shrubs can grow, and on the margins of tractor paths the nomadic belukars may germinate (seed from bat droppings) and form rapidly growing stands e.g. Macaranga spp., Anthocephalus cadamba and Pterospermum stapfianum. These tend to colonize the edges of landings and paths and where the area is small their crowns will meet over the disturbed soil.

The extreme of complete topsoil loss may never regain normal fertility, without assistance from man, and can only support low stature colonizing species of no economic value (Mitchell 1959). Coulter (1950) mentions a general rule that soils of secondary plant associations are more or less impoverished especially so in relation to organic matter. However nitrogen values and crumb structure are better indicators than organic matter of the relative stability of forest. He (Coulter) found nitrogen to be higher and the crumb structure better in virgin forest than in plantations and higher in plantations than in belukar and lalang (Imperata). Litter production from belukar is high, often as high as virgin forest but ash content is low for such pioneer species (Bray and Gorham, 1964).

On narrow tractor paths, and other damaged areas, which can receive litter and shade from edge effects preliminary observations show that the soil structure may improve with time. Earthworms appear to be present in fair numbers under stands of Macaranga gigantifolia for example. While this improvement may be adequate to support cycles of shifting cultivation, for commercial forest regeneration the problem of absence of seedlings remains and will only be alleviated by a slow process of successional change involving seeding in from outside and the maturation and death of belukar species. Improvement may be speeded up for agricultural tree crops by fertilising, soil working and cover crops to obtain shade for the soil as rapidly as possible. It may be postulated that a higher proportion of planting sites falling on tractor damaged soil may increase costs of establishment.

Grubbing effects of trees have been described by Holland (1967). He postulated that at the sites of old trees there was a shortage of nitrifying bacteria. This kind of hidden effect can only be allowed for in carefully controlled trials which would involve considerable assessment prior to plantation establishment.



Fig. 6
Litter pattern
created by road-
cutting.



Fig. 7
An old extraction
site, abandoned
several months before.
The seedling has been
planted in a pot.

Management Alternatives

Where high stands of commercial timber are to be removed some logging damage to the soil is unavoidable and must be accepted by management. Ideally the planning of exploitation should precede its execution to account for subsequent access requirements on alienated or alienable land.

For forest regeneration the principal requirements would seem to be :

1. Minimise the width of the track.
2. Avoid excessive wet weather yarding.
3. Make use of winching in to avoid crawling over small hills.
4. Re-open any blocked drainage routes as soon as possible.
5. Restrict the radius of landings.

In yield calculations for future production areas damaged will contribute less commercial timber than areas not damaged. Therefore such areas need to be quantified for management units and their relative productivity should be known. The forest can tolerate a fairly high percentage of land surface scraped bare (Nicholson, 1965) provided it is scattered in narrow strips running between otherwise productive forest. Roads per se are essential and unavoidable losses of productive area whether for agricultural estates or forests. Provided the crowns of trees cover these little space is lost, if the roads need sun to dry out more is lost. With forest the original pattern of roads must suffice since very few access journeys and none using machinery, are likely during the crop rotation. With plantations it may be necessary to re-make roads especially where the land was pre-logged prior to planning though the tendency is for acceptance of original tractor paths (cf. Ag. Dept. Rep.No.67/3 - D.W. McCredie).

Fields of Investigation

The preceding remarks suggest that there are several lines of investigation which could be considered. From the Soil Scientist's interest the subjects may be grouped as physical and chemical effects. The forester is concerned with species which may be fostered and the agronomist with techniques to avoid damaged soil or to ameliorate it. Administrators and planners must concentrate on efforts to minimise the soil damage factor.

Brunig (1964) has used aerial photographs on a time scale to measure the incidence of lightning damage. This approach may be useful in assessing the future yield of large blocks of forest provided realistic yield data from ground plots can be incorporated.

A biological problem of some interest arises on consideration of the demands on the soil. The climax vegetation is a high forest of large trees with several canopies. Agricultural crops, even the tree crops, are essentially simpler in structure and are likely to have a lower overall amount of nutrients as organic matter standing above ground. Similarly the regeneration phase, especially the first few years, often dominated by belukar and climbers may be seen as "recovering" towards the original state. Demands on the soil would appear to be greater under both conditions - the original vegetation was more or less stable and in equilibrium. The problem then is this : if the belukar species do have large demands on the soil how do they manage when they grow more abundantly on disturbed soil ? If factors could be isolated to deal with this there is then the question of a dividing line between successful belukar and the sedge/Melastoma exploitation ecotype.

Effects of logging on the soil's physical structure may vary with soil types. It is likely that any physical changes wrought by logging will change with time but that with a certain maximum change little progress is made (cf. Mitchell, 1959).

A range of physical changes similar to the vegetation changes may be found. Would this then necessitate sub divisions of soil types ?

The nutritional status of the soil which is there - whether exposed subsoil, original soil with surface compacted or removed, or semi-virgin soil - and supporting obviously different regeneration types could usefully be examined. In all these examples, where dynamic change is at least a possibility, ideally, studies should begin prior to exploitation and continue for some years.

Since it is inevitable that large bare areas will be found in most logged areas it is necessary to consider experiments to find the best means of restoring them to forest production (Nicholson, 1965). The most logical approach is to use species for which a ready seed supply is available and which are hardy. Dipterocarps satisfy neither condition but nevertheless some trials are being made using wildings. It would be of interest to foresters if fertiliser studies relating to agricultural tree species on damaged soils were available.

A more strictly forestry problem is to consider the sizes of gaps, widths of tractor paths etc. which can be expected to shade over naturally. Certain maximum sizes could then be determined to advise management. A similar problem for the agronomist is the desirable density and layout of estate roads for different crops.

Other related fields which have not been touched on include the effect of logging on erosion, run off and catchment effects generally and the general problem of what precisely is removed in the way of nutrients when the big trees are felled and taken away.

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AN AMMONIUM CHLORIDE METHOD FOR DETERMINING EXCHANGEABLE POTASSIUM,
CALCIUM, MAGNESIUM AND ALUMINIUM IN MALAYAN SOILS

by

Mohinder Singh & K. Ratnasingam

MAY, 1968

SOILS DIVISION
THE RUBBER RESEARCH INSTITUTE OF MALAYA
KUALA LUMPUR

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SUMMARY

An equilibrium extraction method of determining exchangeable cations, including exchangeable aluminium, with normal ammonium chloride, at the pH of the soil, is given. Four successive extractions with fresh lots of normal ammonium chloride, of at least 6 hours extraction time, were found necessary to extract all the exchangeable cations.

Values of potassium and magnesium obtained by this ammonium chloride equilibrium extraction procedure were similar to those obtained by the commonly used neutral ammonium acetate method. Much more calcium was generally extracted by the ammonium chloride method than by the ammonium acetate method. This difference may be due to solubility of the calcium compounds in soil.

Exchange capacity values determined on the ammonium saturated soil, after repeated ammonium chloride extraction, showed that in the case of two soils (Kuantan and Segamat Series), the C.E.C. values were greater than the sum of the exchangeable cations K, Ca, Mg and Al. This possibly indicates that an appreciable amount of exchangeable H was present in these soils. With Chemor, Ulu Tiram, Malacca and Batu Anam Series soils, C.E.C. values were similar to the sum of the exchangeable cations. For Serdang and Selangor Series soils, on the other hand, C.E.C. values were appreciably lower. This may be due to dissolution of calcium and aluminium compounds by acidified ammonium chloride solution.

An examination of the exchangeable values indicates that Malayan soils are predominantly aluminium saturated, 6 out of the 8 soils under study having more than 50% of their exchange capacity (as determined by summing K, Ca, Mg and Al) saturated with aluminium. In the case of Serdang Series soil, Al saturation was as high as 86%.

INTRODUCTION

In an investigation on thermodynamic assessment of nutrient status of Malayan soils, it became important to study the cation exchange complex of the soils. Although normal ammonium acetate extraction method at a buffered pH of 7.0 has commonly been used to study exchangeable cations in soils, this cannot be used to determine exchangeable aluminium which is the main constituent of soil acidity (SCHOFIELD, 1949; COLEMAN et.al, 1959; YUAN, 1960, 1963; McLEAN et.al, 1958, 1959, 1964; AYRES et.al 1965). MIDDLETON (1964) showed that the amount of aluminium extracted from Malayan soils depended on the pH of the extracting solution. His method of determining exchangeable aluminium was developed for determination of aluminium only and was considered time-consuming. Further, the barium ion is a hydrolysable ion which can form basic salts and was thus not preferred. A simpler method to determine exchangeable potassium, calcium and magnesium as well as aluminium by a single extraction procedure was therefore considered necessary.

EXPERIMENTAL

Normal ammonium chloride solution was used. This was preferred to acidified ammonium acetate solution as used by McLEAN and workers (1958, 1959) as the smaller ionic size of Cl^- compared to that of CH_3COO^- is likely to facilitate exchange of cations and also as the acetate ion is likely to form complexes with transitional group elements, such as Fe and Al. A pH value of 4.0 was selected for the extracting solution, most Malayan soils for the present study have pH range of 3.5 to 4.5.

Preliminary studies on time of extraction showed early equilibration with respect to potassium and magnesium while for calcium and aluminium a minimum of 6 hours was necessary. For convenience, a period of 16 hours extraction time was selected as there was no difference in extracting between 6 to 24 hours (Figures 1a and 1b). To determine the number of equilibrations necessary for complete extraction of exchangeable cations another preliminary study on successive extractions was carried out. Two equilibrium extractions were sufficient for potassium and magnesium. For calcium and aluminium, extraction of exchangeable amounts appeared to be complete by four extractions, the amounts released by subsequent extraction were considered to be due to dissolution of calcium and aluminium compounds (Figures 2a and 2b).

Based on these results, a procedure of four successive equilibrium extractions of 10g soil with 50 ml of \underline{N} NH_4Cl solution at pH 4.0 and 16 hours shaking was adopted.

The extracts were analysed for potassium and calcium by flame emission, for magnesium by atomic absorption and for aluminium by "Aluminon" method (CHENERY, 1948). To overcome interference in these determinations, it was found necessary to add 250 ppm of LaCl_2 for potassium and calcium determinations and 500 ppm SrCl_2 for determination of magnesium. In addition, appropriate amounts of NH_4Cl was incorporated in the solutions used for preparing standard curves, to compensate presence of NH_4Cl in the extracting solution.

The residual soil was washed free of excess NH_4Cl ; and adsorbed ammonium determined both by steam-distillation and CONWAY micro-diffusion (BREMINER and SHAW, 1955) for estimating cation-exchange capacity.

RESULTS AND DISCUSSION

Exchangeable K, Ca and Mg values of 8 Malayan soils which are known to have widely different K, Ca and Mg nutrient status, are given in Table 1, together with values for exchangeable cations obtained with the neutral \underline{N} NH_4OAc method. Exchangeable aluminium values obtained with the NH_4Cl method are also included. Cation-exchange capacity values by determining adsorbed ammonium ion using CONWAY micro-diffusion and steam-distillation methods are given in Table 2.

The K and Mg values obtained by \underline{N} neutral NH_4OAc and \underline{N} NH_4Cl for the soils were generally similar although in a few soils the Mg value tended to be slightly higher with the NH_4Cl method. Much more Ca was however removed by \underline{N} NH_4Cl by extracting at the pH of the soil than by \underline{N} NH_4OAc at pH 7.0. Some of this Ca probably comes from the dissolution of Ca compounds in soil as was apparent from successive extractions (see Figure 2b). The amount of Ca removed from the soils was still appreciable even after 6 extractions, in contrast to K and Mg which were nearly completely removed by two successive extractions.

Cation-exchange capacity measurements by both the CONWAY and the

steam-distillation procedure on soils saturated with NH_4^+ by successive extractions with NH_4Cl gave similar values. If the sum of the cations K, Ca, Mg and Al is compared with the C.E.C. values thus obtained, it is seen that only in the case of Kuantan and Segamat Series soils are the C.E.C. values higher than the sum of the cations. This suggests that in these soils exchangeable H may be appreciable. Exchangeable hydrogen was however not measured in the extracts. With Chemor, Ulu Tiram, Malacca and Batu Anam Series soils, the C.E.C. values were in close agreement with the sum of the cations. This may indicate that exchangeable H in these very acid soils is low, in line with the findings of several workers (COLEMAN et.al, 1959; THOMAS, 1960; MEHLICH, 1960; YUAN, 1960) that exchangeable acidity in soils is mainly accounted for by Al. The absence of exchangeable H in the soils under study however needs confirmation. Only in the case of Serdang and Selangor Series soils was the sum of the exchangeable cations found to appreciably exceed C.E.C. values. This may suggest that calcium and aluminium were also extracted from non-exchangeable positions as for example by dissolution of calcium and aluminium compounds. Further studies are required to confirm the validity of the above interpretations. Irrespective of the differences between the C.E.C. and summation of cations, it is evident from the amounts of aluminium extracted that the exchange complex of Malayan soils is predominantly saturated with Al ions. If all the aluminium extracted is considered as exchangeable, exchangeable Al content accounts for over 50% of the exchange capacity in 6 of the 8 soils examined. In the case of Serdang Series soil aluminium saturation was as high as 86%.

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TABLE 1 EXCHANGEABLE CATIONS DETERMINED USING AMMONIUM CHLORIDE AND AMMONIUM ACETATE AS EXTRACTANTS

S o i l	pH ^(a)	Silt+Clay	me/100g						
			NH ₄ Cl Method			NH ₄ OAc Method ^(b)			
			K	Ca	Mg	Al	K	Ca	Mg
Serdang	3.8	36	0.09	0.63	0.08	5.08	0.10	0.12	0.08
Selangor	3.6	83	0.33	1.39	1.80	12.40	0.37	0.63	1.58
Kuantan	4.3	79	0.09	1.23	0.40	0.90	0.10	0.58	0.28
Malacca	4.0	34	0.09	1.00	0.13	1.40	0.09	0.26	0.07
Segamat	4.3	82	0.13	0.84	0.35	0.70	0.16	0.38	0.26
Batu Anam	3.8	85	0.17	1.20	0.33	3.10	0.12	0.45	0.24
Chemor	4.2	18	0.04	0.80	0.06	1.33	0.06	0.12	0.07
Ulu Tiram	4.2	27	0.05	0.78	0.07	1.60	0.06	0.16	0.07

(a) in 10⁻² M CaCl₂

(b) MOHINDER SINGH and RATNASINGAM (1966)

TABLE 2 CATION-EXCHANGE CAPACITY AND PERCENTAGE ALUMINIUM SATURATION OF SOILS

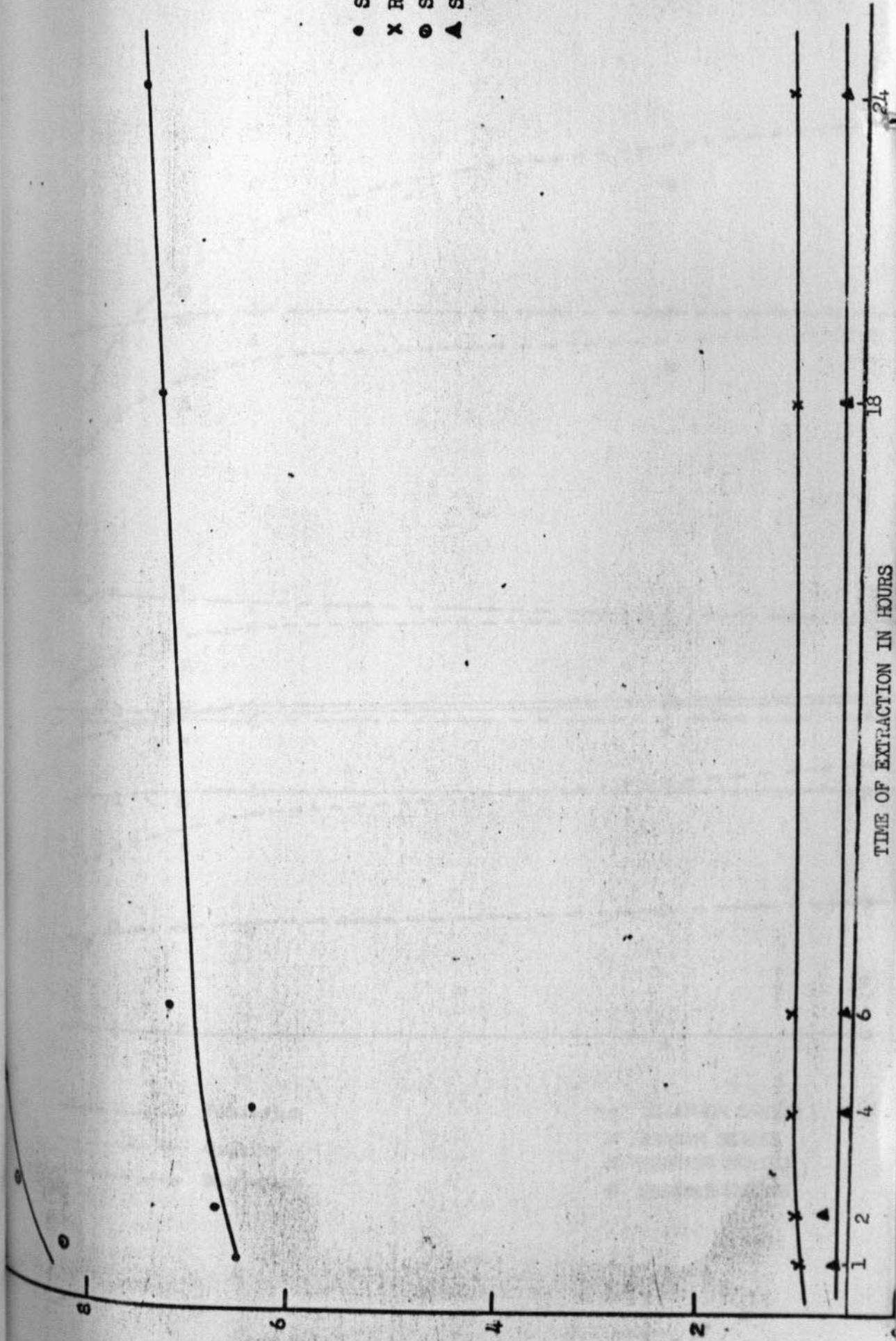
Soil	C.E.C. (CONWAY) me/100g	C.E.C. (Distillation) me/100g	Sum of Exch. Cations me/100g	Percentage Al Saturation (b)
Serdang	4.02	4.49	5.88	86
Selangor	13.84	12.40	15.92	78
Kuantan	3.15	3.90	2.62	34
Malacca	1.98	2.25	2.62	54
Segamat	3.28	3.88	2.02	35
Batu Anam	4.07	4.15	4.80	65
Chemor	1.81	2.03	2.23	60
Ulu Tiram	2.16	2.32	2.50	64

(a) Sum of Exch. cations = K + Ca + Mg + Al.

(b) Percentage Aluminium Saturation = $\frac{\text{Al}}{\text{K} + \text{Ca} + \text{Mg} + \text{Al}} \times 100$

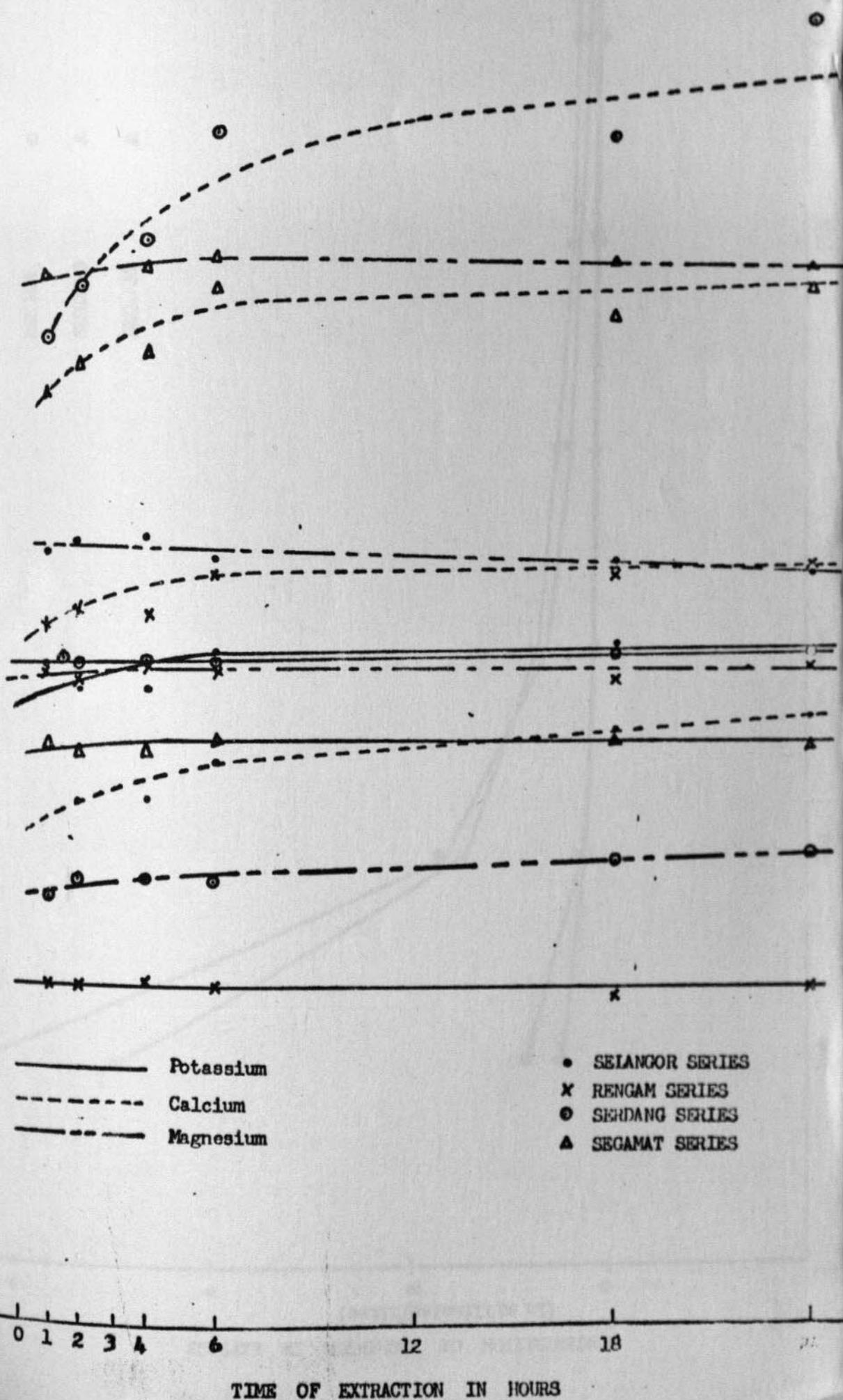
AMOUNT OF ALUMINIUM EXTRACTED FROM SOIL
(milliequivalents/100g soil)

- SELANGOR SOIL
- x RENGAM SOIL
- o SERDANG SOIL
- ▲ SEGAMAT SOIL



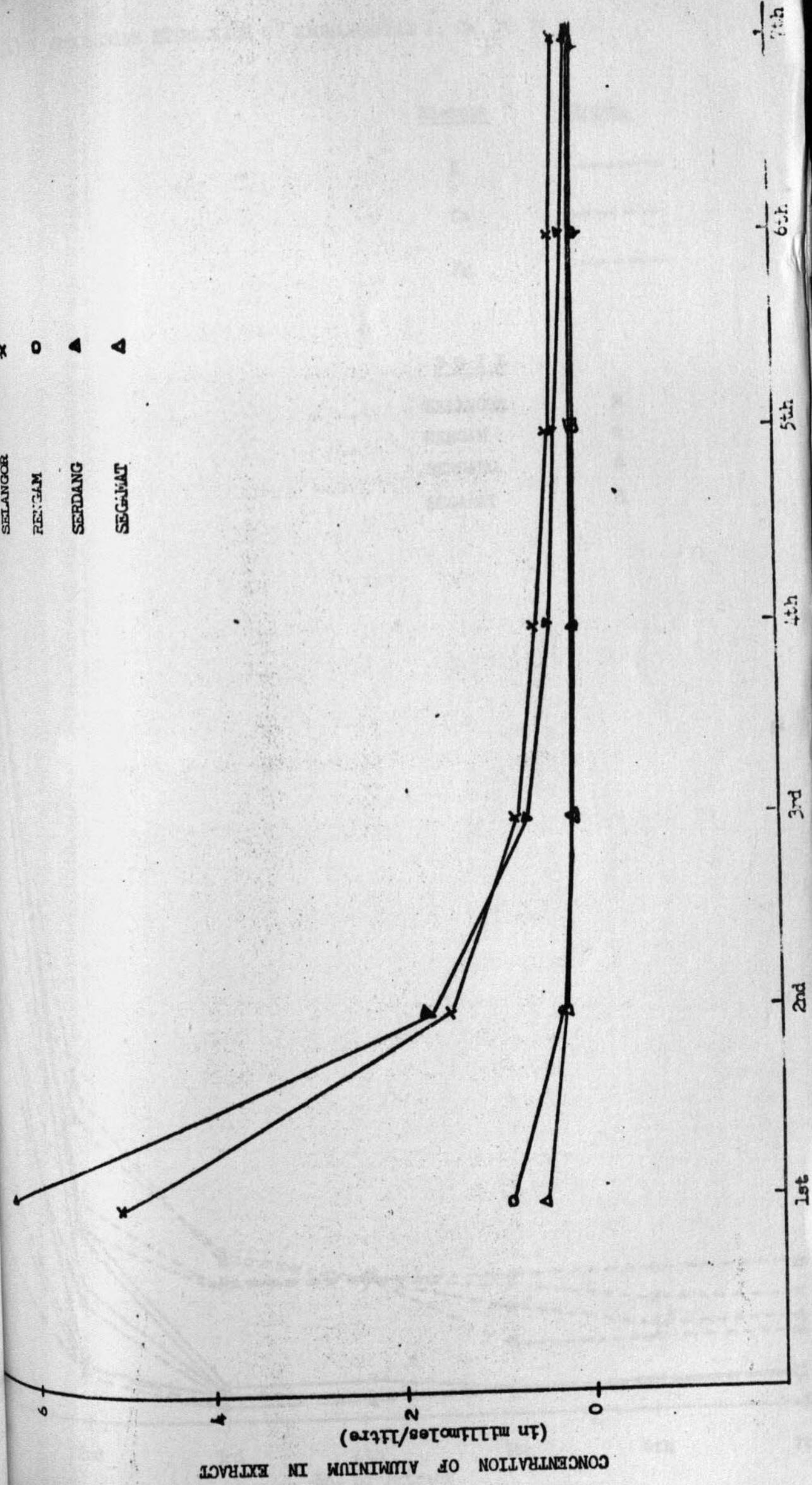
TIME OF EXTRACTION IN HOURS

FIGURE 1(b) EFFECT OF TIME OF EXTRACTION ON THE EXTRACTION OF SOIL POTASSIUM, CALCIUM AND MAGNESIUM BY N AMMONIUM CHLORIDE SOLUTION



SOIL SYMBOL

SELANGOR X
 REJANG O
 SERDANG ▲
 SEGAMAT △



CONCENTRATION OF ALUMINUM IN EXTRACT (in millimoles/litre)

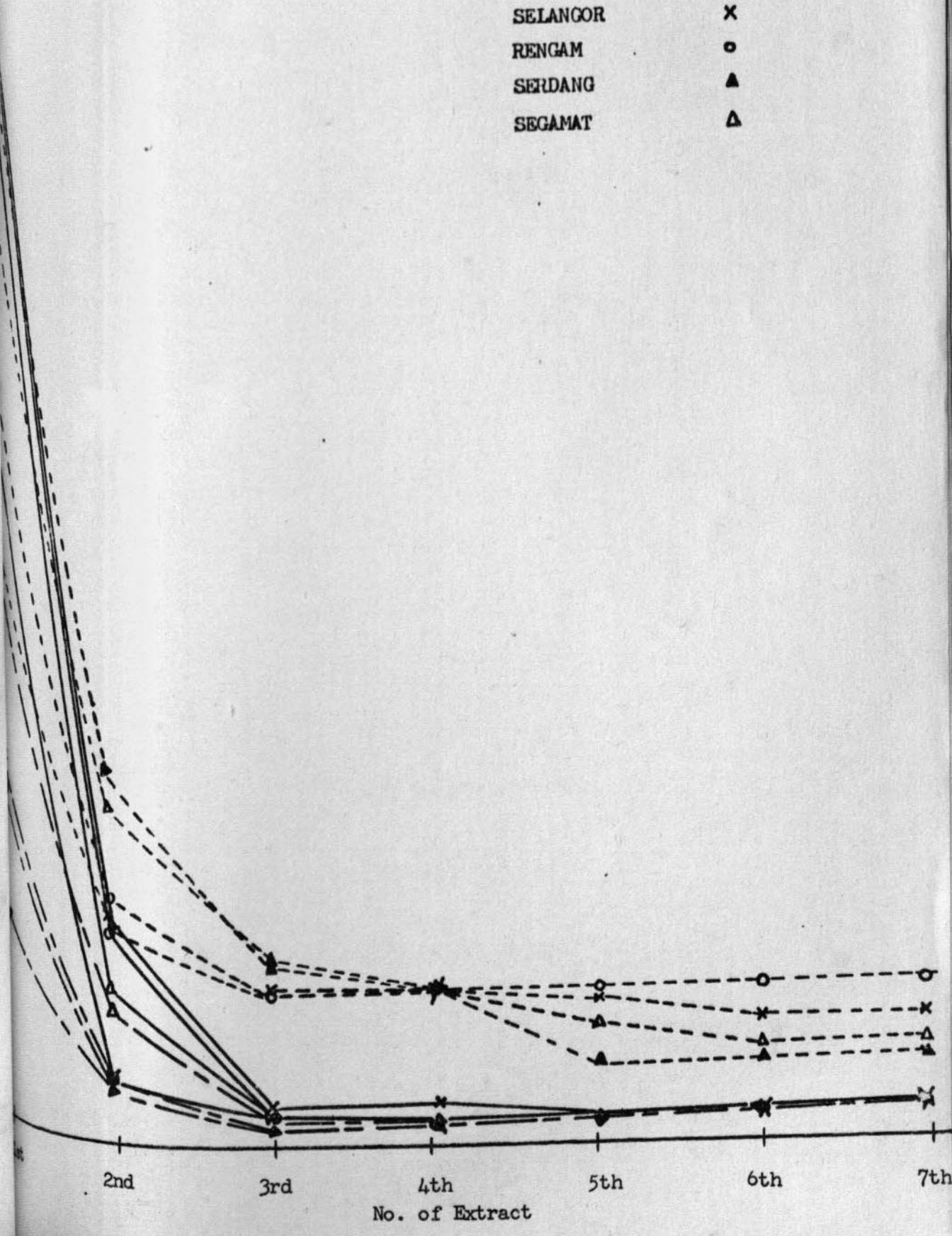
1st 2nd 3rd 4th 5th 6th

FIGURE 2(b)

SUCCESSIVE EXTRACTION OF EXCHANGEABLE K, Ca, Mg IN SOIL

<u>Element</u>	<u>Symbol</u>
K	—————
Ca	- - - - -
Mg	- - - - -

<u>S O I L</u>	
SELANGOR	X
RENGAM	o
SERDANG	▲
SEGAMAT	△



A THERMODYNAMIC ASSESSMENT OF THE NUTRIENT STATUS OF
MALAYAN SOILS: QUANTITY-INTENSITY MEASUREMENTS FOR
POTASSIUM USING CALCIUM CHLORIDE EQUILIBRIATION

by

Mohinder Singh, K.T. Tan, E. Pushparajah
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MAY, 1968

SOILS DIVISION
THE RUBBER RESEARCH INSTITUTE OF MALAYA
KUALA LUMPUR

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SUMMARY

Quantity/Intensity (Q/I) relationships for potassium status of soils

were determined in nine acid soils of Malaya which are known to have widely differing K-status and on which rubber is commonly grown, by the calcium chloride equilibration procedure of BECKETT. Quantity, Intensity and Buffer Capacity values derived from these Q/I relationships did not ^{give} relate better ^{with} relation the status of soil, as indicated by greenhouse cropping by Pueraria than the conventional acid-extractable value. The best assessment parameter appeared to be a Buffer Capacity value (B.C. cropping), obtained from greenhouse cropping data and the laboratory measured intensity, although intensity when taken alone is the poorest indicator of soil K status as assessed by greenhouse cropping by Pueraria.

INTRODUCTION

Methods of assessing nutrient availability in soils for uptake by plants are generally based on extraction procedures mostly using acids of different strengths or salt solutions. These methods, calibrated by laborious field trials, have met with some success. Since SCHOFIELD introduced his Ratio Law (1947), applicable to the equilibrium between the exchangeable cations and those in the soil solution, attempts have been made to place nutrient assessment in soils on a thermodynamic basis. SCHOFIELD's Ratio Law states that "when cations in solution are in equilibrium with a larger number of exchangeable cations, a change in the activity of the solution will not disturb the equilibrium if the activities of all monovalent ions are changed in one ratio, those of all the divalent ions in the square of that ratio and those of all trivalent ions in the cube of that ratio". This Law holds as long as the outside solution concentration is low enough for a diffuse double layer to form. K and Ca, for example, will therefore be in

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a fixed ratio on the soil for a given K/\sqrt{Ca} activity ratio in solution. This activity ratio is called the Intensity (I) of the soil potassium and is a measure of the strength with which an ion is attached to the electro-chemical system of the soil. The concept of intensity led to the concepts of Quantity (Q) and Buffer-Capacity (B.C.). Quantity is the amount of the ion which is present at a definite potential or held at a definite strength in the soil at a particular time. The relationship between the quantity and intensity is termed the Q/I relationship for a nutrient ion in a soil and is therefore an inherent property of the soil which shows the variation of the quantity of the nutrient held at a particular strength, as well as in the strength itself with which the nutrient is held. Buffer Capacity is the rate of change of quantity with intensity (dQ/dI) and is a measure of the capacity of the soil to maintain the intensity against depletion.

Several methods of measuring the thermodynamic parameters of Q, I and B.C. have been proposed using notations as free energies of exchange (WOODRUFF, 1955), the expression $pK - \frac{1}{2}p(Ca + Mg)$ (TAYLOR, 1958; MOSS and HODNETT, 1963) and cation activity ratios $K/\sqrt{(Ca+Mg)}$ (MATTHEWS and BECKETT, 1964a). Attempts have been made to relate these laboratory measurements to greenhouse cropping or field responses to manuring (WOODRUFF, 1955; ARNOLD, 1962; TINKER, 1964; MOSS and COULTER, 1964; MCCONAGHY and SMILLIE, 1965; ACQUAYE et. al., 1967). Nearly all of these measurements have however been with soils whose exchange complex is dominantly saturated with Ca ions. Since Mg behaves similar to Ca in ion-exchange, Ca and Mg are often considered together for convenience. The intensity index for potassium has therefore been expressed with reference to the Ca and Mg ions and expressions as $K/\sqrt{(Ca+Mg)}$ and $RT \ln K/\sqrt{(Ca+Mg)}$ have been widely used. TINKER (1964) showed that with acid soils of Nigeria, an index such as $K/\sqrt{(Ca+Mg)}$ based on calcium and magnesium only, was not related to potassium yield response of oil palm in field experiments and suggested that an activity ratio including aluminium ions also, of the type $K/\{\sqrt{(Ca+Mg)} + P \sqrt[3]{Al}\}$, P being an arbitrary constant, is more appropriate. The purpose of this work was to examine whether Q/I relationships using the activity ratio $K/\sqrt{(Ca+Mg)}$ were applicable to the ^{acid} rubber growing soils of Malaya.

EXPERIMENTAL

Materials

Nine soils were sampled from 0-6" depth in unmanured plots of or adjacent to, current manurial trials, air-dried and sieved (<2 mm). Mechanical analysis, pH, exchangeable cations and "total"(concentrated acid-extractable) cations are given in Table 1.

Methods

10 g samples were brought to a moisture content of 50% of soil and left overnight. 25 ml of .012M CaCl_2 solutions containing varying amounts of potassium from 0 to 3 m.moles/litre, were added to the samples and shaken for 24 hours. After centrifuging at 9000 rpm for 30 minutes (in a refrigerated centrifuge), the supernatant solution was filtered and analysed for potassium, calcium and magnesium on a Unicam SP900A atomic absorption/emission flame spectrophotometer, potassium and calcium being determined by flame emission and magnesium by atomic absorption methods. The amount of soil potassium adsorbed (ΔK positive) or desorped (ΔK negative) by the equilibration was plotted against the intensity (I) given by $K/\sqrt{\text{Ca}+\text{Mg}}$, where K, Ca and Mg are concentrations in the equilibrium solution. Concentrations are used instead of "activities" as the solutions are considered dilute enough to permit this approximation.

I_0 , the "true" intensity of K in the soil was obtained from the no potassium exchange position ($\Delta K = 0$) of the Q/I curve; Q_0 , the quantity in equilibrium with this intensity was obtained by interpolation of the linear part of the Q/I curve. "B.C.(laboratory)" was determined as the slope of the linear portion of the Q/I curve.

Exchangeable cations were determined on a NH_4Cl extract (MOHINDER and RATNASINGAM SINGH, 1968). Potassium, calcium and magnesium were determined by atomic absorption/emission spectrophotometry, and Al by the "aluminon" method (CHENERY 1948).

RESULTS AND DISCUSSION

Q/I curves are given in Figure 1. The shapes of the curves are similar to those reported by BECKETT (1964a) although the exchange complex of these soils is not dominantly saturated with Ca ions. Exchangeable Ca plus Mg of these soils are below 30% of the cation-exchange capacity for Rengam, Serdang and Selangor^{series} soils, 32 to 38% for Batu Anam, Ulu Tiram and Chemor, 43% for Malacca and above 50%, only for Segamat (58%) and Kuantan (62%)^{series} soils. The concentration of calcium in the equilibrium solution was between $0.63 \times 10^{-2} \text{M}$ (Selangor soil) to $0.93 \times 10^{-2} \text{M}$ (Chemor) while Ca plus Mg, which are normally considered together because of their similar exchange behaviour, was between $0.81 \times 10^{-2} \text{M}$ (Selangor) to $0.94 \times 10^{-2} \text{M}$ (Chemor). These figures represent a nett increase of 0.36 and 1.14 me/100g in the initial exchangeable Ca + Mg contents of the Chemor and Selangor soils respectively due to adsorption of calcium and desorption of magnesium from the equilibrating solutions. The initial exchangeable Ca + Mg status of the 9 soils studied were increased by 35 to 40% in the case of Selangor and Batu Anam soils, 40 to 50% with Kuantan, Malacca and Chemor, 60-70% with Ulu Tiram and Segamat, and 85-90% with Serdang and Rengam, that is, appreciable and variable quantities of calcium was absorbed by soils from the equilibrating solutions. For comparison, the "Lower Greensand" soil used by BECKETT (1964a) in his Q/I studies, had 6.88 me/100g exchangeable calcium and 0.70 me/100g exchangeable magnesium, which together accounted for 93% of the exchange capacity. With 0.02M calcium chloride equilibrating solution, the equilibrium solution had a Ca + Mg concentration of 0.0194M . This represents a nett change (increase) of only 1.6% in the initial Ca + Mg status of the soil.

Q_0 values for all the nine soils (see Table 2) are lower than conventionally measured exchangeable K values. This is in line with BECKETT's information (BECKETT 1964b) that the exchangeable K may be considered as being composed of (a) a "immediate" labile pool which equilibrates rapidly and is the one measured here as Q_0 , and (b) a "slow" or "less readily" exchangeable pool which represents K held on "specific" sites. This potassium held on "specific" adsorption sites accounts for the lower curvilinear part of the Q/I curve.

Several indices of soil potassium status were correlated with the potassium uptake by Pueraria in greenhouse. These indices were the thermodynamic values of Q_0 , I_0 and B.C. (laboratory), obtained from the Q/I relationships, and the conventional indices of exchangeable K and acid-extractable K, obtained by common empirical extraction methods. Two other thermodynamic indices of buffer capacity, namely, "buffer capacity (cropping)" and "buffer capacity (exchangeable)", have also been calculated using the formula $B.C. = dQ/dI$. Buffer capacity (cropping) was calculated with dQ as the total uptake by Pueraria during greenhouse cropping and buffer capacity (exchangeable) was with dQ as the exchangeable value measured by a conventional laboratory method. In both cases $I_0 = 0.5 \times 10^{-3}$, where I_0 is the initial intensity of the soil for potassium obtained from the Q/I relationship curve, was used for dI . The value 0.5×10^{-3} is the lower limit of the intensity of soil depleted by ryegrass cropping in Rothamsted greenhouse experiments (TALIBUDEEN and DEY 1967). Ideally, this value at which cropping ceases or is terminated should have been measured on the depleted soils after cropping with Pueraria; in the absence of such a figure, the value of 0.5×10^{-3} obtained at Rothamsted, was taken as the intensity of the depleted soils for calculating B.C.(cropping) and B.C. (exchangeable). Further, a linear relationship between Q and I values is assumed in the cropping.

All the above-mentioned indices have been examined with respect to Pueraria K-cropping values, correlation coefficients of which are given in Table 3. The correlations are also shown graphically in Figure 2.

TABLE 3 RELATIONSHIP OF SOIL K INDICES WITH GREENHOUSE CROPPING BY PUERARIA

Soil Index	Correlation coefficient	
	All soils	Excl. Selangor Series soil.
Q_0	0.719*	0.026 NS
Exchangeable	0.832**	0.228 NS
Acid Extractable	0.951***	0.959***
B.C.(laboratory)	0.807**	0.363 NS
B.C.(cropping)	0.959***	0.957***
B.C.(exchangeable)	0.895**	0.568 NS
I_0	-0.215 NS	-0.314 NS

** : $P < 0.01$

* $P < 0.05$

NS : Not Significant

As one soil (Selangor Series) gave an exceptionally high cropping value, correlation coefficients were also calculated without this value (see Table 3). Taking all the 9 values (9 soils) into consideration, I_0 is found not to relate at all ($r = -0.215$) to soil K status by Pueraria cropping. Acid-extractable and B.C. (cropping) values give correlations significant at the 0.1% level, r being 0.951 and 0.959 respectively. B.C. (exch.), B.C. (lab.) and exch. K values give correlations significant at the 1% level ($r = 0.807 - 0.895$) while Q_0 only gives at the 5% level ($r = 0.719$). When the extreme value for the Selangor soil is excluded from the correlations, significant correlations are obtained only with B.C. (cropping) and acid-extractable indices, both still retaining their significance at the 0.1% level. A visual examination of the graphical plots of K-uptake by Pueraria against soil indices (see Figure 2) reveals that though the acid-extractable index gives a good fit, the soils are divided mainly into two distinct categories - soils with high and low potassium status. The index B.C. (cropping), on the other hand, gives a better spread of the index with Pueraria cropping status of soils, and therefore proves to be a more sensitive index.

CONCLUSIONS

In comparing a number of analytical indices based on both thermodynamic principles and conventional extraction procedures for measuring availability of potassium in soil for plant uptake, Buffer Capacity (cropping) and acid-extractable K values were found to relate well to greenhouse cropping by Pueraria. The former appeared more sensitive in the sense that it gave a better spread of results compared to the latter. The "immediate" labile pool (Q_0) and Buffer Capacity derived from the Q/I curve using calcium ion for equilibration were found to be less sensitive. The poorer relations of the thermodynamic parameters derived from the Q/I curve may be a consequence of using calcium as the equilibrating ion with soils where aluminium appears to be the dominant ion occupying exchange sites. Improved relationships may be expected if aluminium (Al^{+++}) were used for equilibration. Results of Q/I relationship studies using Al^{+++} as the reference ion are underway and will be the subject of a subsequent paper under preparation (MOHINDER SINGH AND TALIBUDEEN, 1968).

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TABLE 1. MECHANICAL AND CHEMICAL COMPOSITION OF TOP SOILS (0-6") USED IN EXHAUSTIVE CROPPING FOR POTASSIUM BY FUERARIA IN GREENHOUSE

Soil Series	Mechanical Analysis (a)		pH (b)		Exchangeable cations (c)				Acid extractable cations (e)						
	(% oven dry soil)		CaCl ₂	H ₂ O	K ⁺	Ca ⁺⁺	Mg ⁺⁺	Al ⁺⁺⁺	% K in C.E.C.	Ca+Mg (d) % C.E.C.	K ⁺	Ca ⁺⁺	Mg ⁺⁺		
	C.S.	F.S.	Silt	Clay							me/100g	me/100g	me/100g		
1. Rengam	38	6	8	41	4.0	4.6	0.14	0.78	0.09	1.92	4.8	29.7	0.32	0.30	0.66
2. Serdang	29	30	10	26	3.8	4.6	0.10	0.63	0.08	5.08	1.7	12.1	2.95	0.23	4.50
3. Selangor	1	9	43	40	3.6	4.5	0.37	1.39	1.80	12.40	2.3	20.0	3.99	0.67	14.16
4. Kuantan	3	8	33	46	4.3	5.0	0.10	1.23	0.40	0.90	3.8	62.0	0.37	1.54	8.26
5. Malacca	48	12	5	29	4.0	4.6	0.09	1.00	0.13	1.43	3.4	43.0	0.20	0.34	0.42
6. Segamat	6	4	25	57	4.3	5.2	0.16	0.84	0.35	0.70	7.8	58.0	0.42	0.76	0.63
7. Batu Anam	1	8	34	51	3.8	5.0	0.12	1.20	0.33	3.10	2.5	32.2	2.76	0.77	1.44
8. Chemor	58	20	3	15	4.2	5.1	0.06	0.80	0.06	1.33	2.7	38.2	0.26	0.24	1.36
9. Ulu Tiram	62	10	7	20	4.2	5.2	0.06	0.78	0.07	1.60	2.4	33.9	0.40	0.24	0.77

(a) International scale

(b) 1:5 soil: solution, 30 min. shaking; strength of CaCl₂ used is 0.01 M

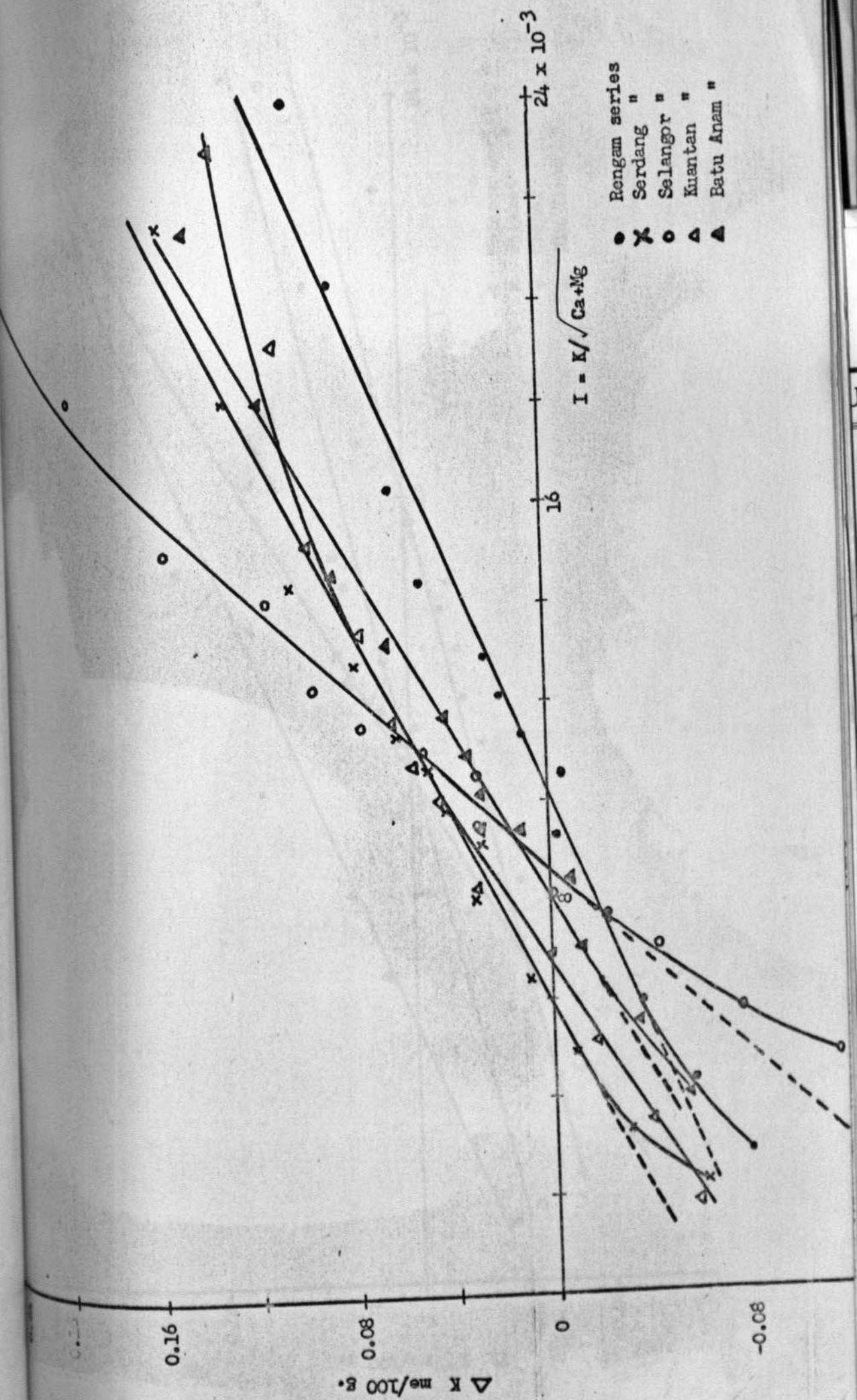
(c) to N - NH₄Cl, adjusted to pH 4.0

(d) C.E.C. is taken as K + Ca + Mg + Al

(e) 1 hr. boiling, 6N HCl (MOHINDER SINGH AND K. RATNASINGAM 1966)

TABLE 2
SOIL INDICES FOR POTASSIUM AND VALUES OF TOTAL UPTAKE BY
PUERARIA IN GREENHOUSE CROPPING FROM TOP SOILS (0 - 6")

No.	Soil Series	Exch. K	Acid Extr. K	Q ₀	I ₀ x 10 ⁻³ (moles/l) ^{1/2}	Buffer Capacity			Uptake by Pueraria me/100 g
						B.C. "laboratory"	B.C. "cropping"	B.C. "Exch."	
1	Rengam	0.14	0.32	0.085	10.2	8.3	16.5	14.4	0.16
2	Serdang	0.10	2.95	0.060	5.9	10.2	77.8	18.5	0.42
3	Selangor	0.37	3.99	0.184	8.6	21.4	92.6	45.7	0.75
4	Kuantan	0.10	0.37	0.084	6.7	12.5	16.1	16.1	0.10
5	Malacca	0.09	0.20	0.076	16.0	4.8	7.7	5.8	0.12
6	Segamat	0.16	0.42	0.120	10.4	11.5	10.1	16.2	0.10
7	Batu Anam	0.12	2.76	0.092	8.1	11.4	43.4	15.8	0.33
8	Chemor	0.06	0.26	0.050	10.6	4.7	5.9	5.9	0.06
9	Ulu Tiram	0.06	0.40	0.044	5.2	8.5	14.9	12.8	0.07



$\Delta K \text{ me}/100 \text{ S}$

0.16

0.08

0

-0.08

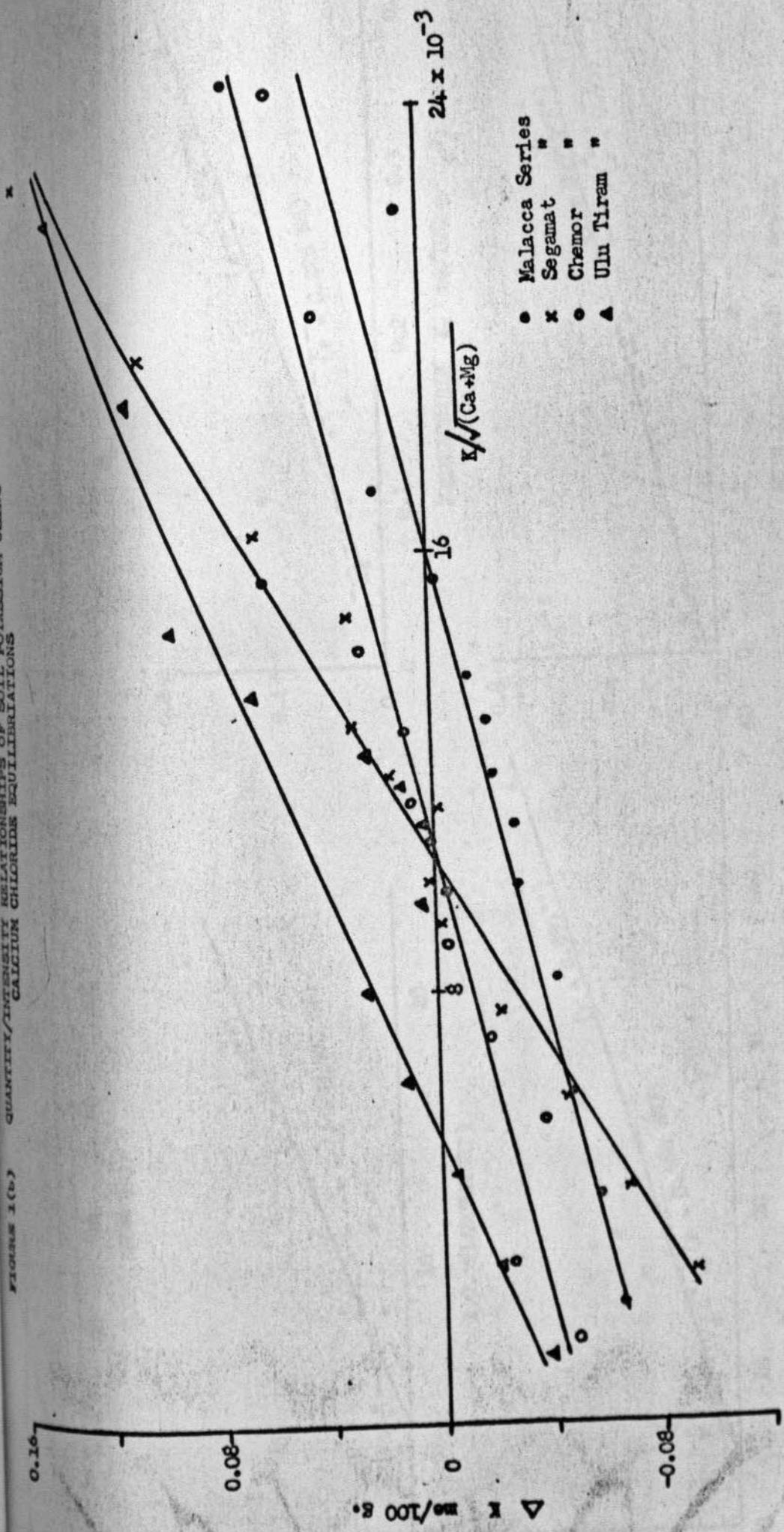
$I = K/\sqrt{\text{Ca}+\text{Mg}}$

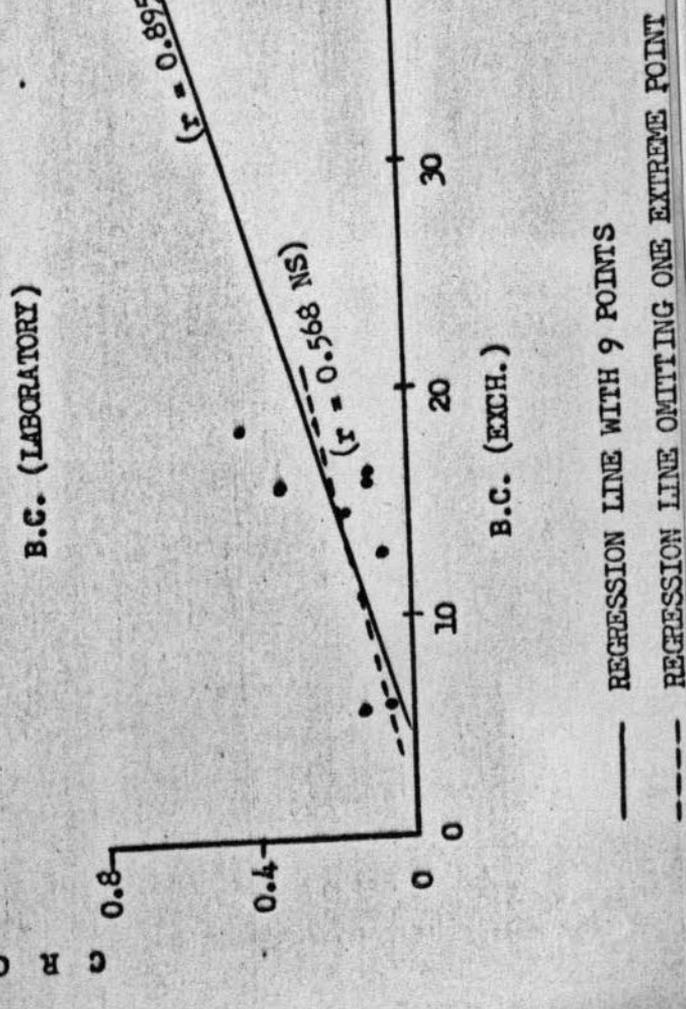
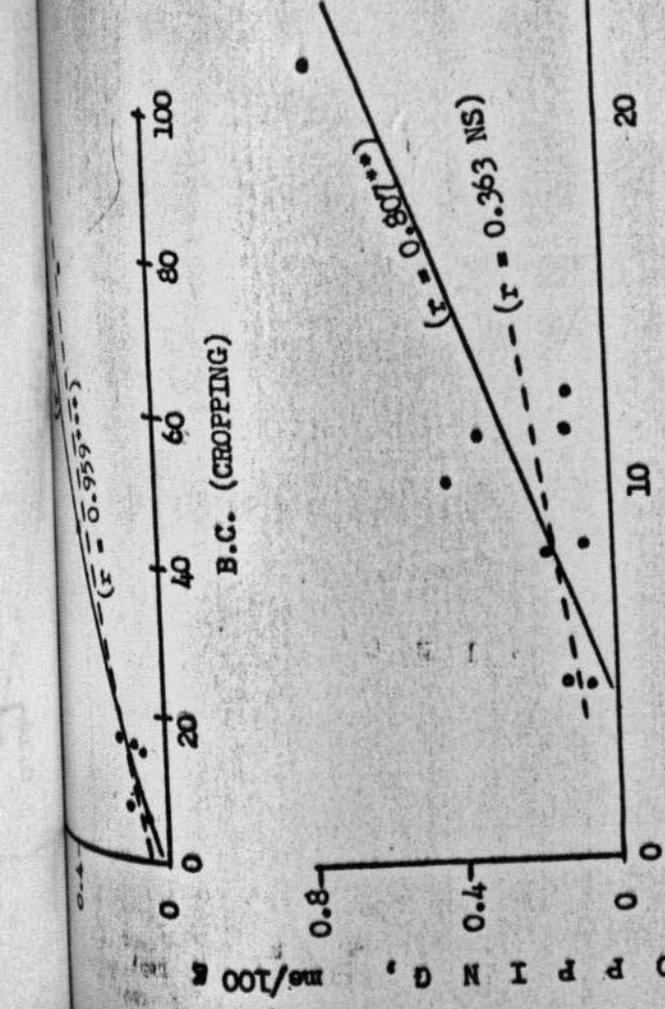
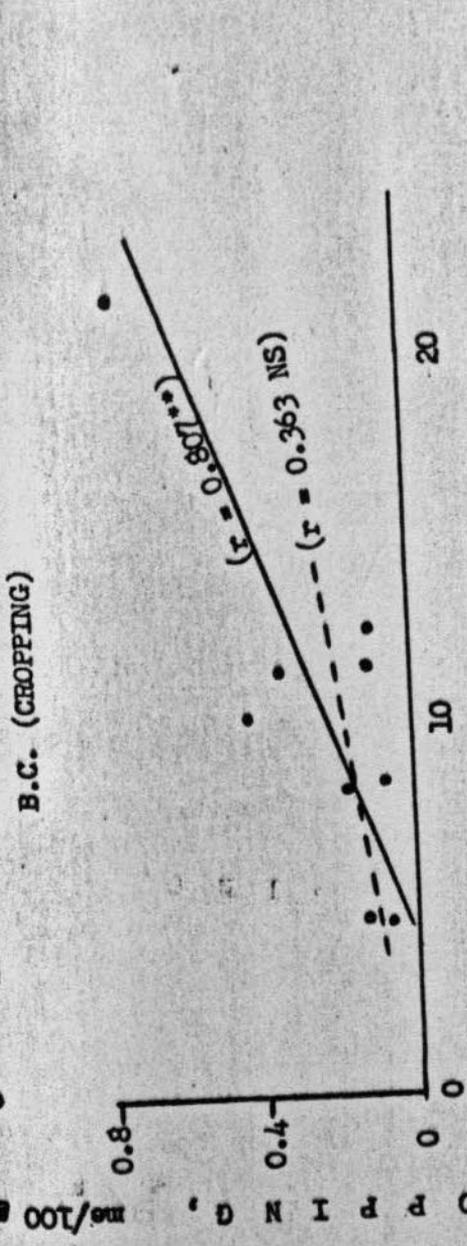
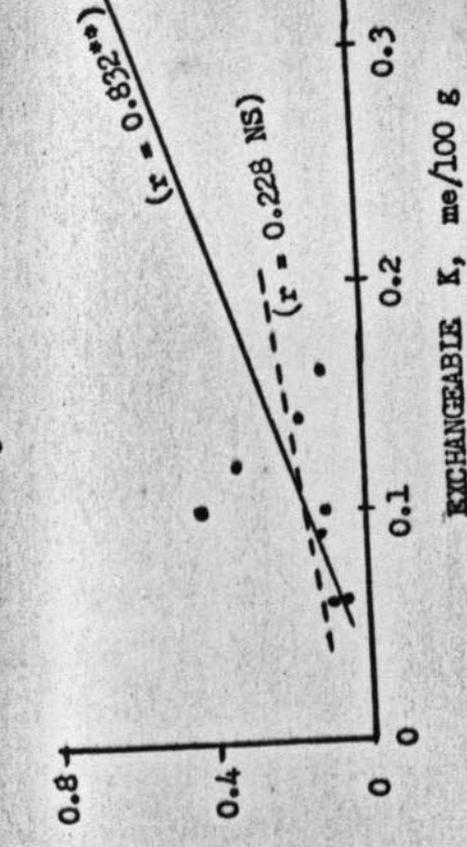
16

24×10^{-3}

- Rengam series
- × Serdang "
- Selangor "
- △ Kuantan "
- ▲ Batu Anam "

FIGURE 1(b) QUANTITY/INTENSITY RELATIONSHIPS OF SOIL POTASSIUM USING CALCIUM CHLORIDE EQUILIBRIATIONS





— REGRESSION LINE WITH 9 POINTS
 - - - REGRESSION LINE OMITTING ONE EXTREME POINT

*** : $P < 0.001$ ** : $P < 0.01$ * : $P < 0.05$ NS: NOT SIGNIFICANT

3rd MALAYSIAN SOIL CONFERENCE

RECOMMENDATIONS OF SUB-COMMITTEE ON STANDARDISATION
OF SOIL ANALYTICAL METHODS.

STAGE I.

The Sub-Committee on Analytical Methods comprising Drs. Shao, I.T., Guha, M.M. Ng Siew Kee and Mr. Sim, E.S., met on 12th May, 1968 in the Soils Laboratory, Kuching, to consider the results of laboratory investigations on routine analysis carried out in Stage I. Also present were interested soil chemists from various organizations participating in the 3rd Malaysian Soil Conference. As a result of the deliberations, certain recommendations were made in respect of Stage I analysis. These are as follows:-

1. pH

Measurements are to be made both in water and potassium chloride solution, using a 1:2.5 soil/solution ratio. In the case of water, measurement is to be made after 16 hours.

2. Organic carbon

The commonly used Walkley and Black Method gives satisfactory results and its use is to be continued.

3. Nitrogen

The present micro-Kjeldhal method used by the four laboratories is satisfactory and will continue to be used.

4. Cation Exchange Capacity

The ammonium acetate method is to be the common procedure for determining C.E.C. The time of leaching is to be regulated at 5 - 6 hours.

5. Exchangeable Cations

Potassium is to be determined by flame photometry.

The EDTA method for determining calcium and magnesium is unsatisfactory and where used, should be abandoned as quickly as possible. It should be substituted by atomic absorption.

The cations in the extract are to be determined directly, without destruction of the ammonium acetate.

6. Easily Soluble P

The acidified ammonium fluoride extraction (Bray's No. 2.) is to be the standard method. Hand shaking is to be regulated at 30 gentle inversions/min. The suitability of the 0.1 N NaOH method as a routine method is to be investigated.

7. Total P

As the results were not entirely conclusive, further investigations are to be carried out to test:-

a) HF/HNO₃ digest, and

b) Na₂CO₃ fusion,

and determination of P in solution by:-

- i) Method of Fogg & Wilkinson and
- ii) The Vanado-molybdate Method.

8. Laboratory Staff

To achieve and sustain reliability of laboratory results, it is strongly recommended that laboratory staff actually performing analyses should possess a Grade II qualification in the Malaysian Certificate of Education or the Cambridge Overseas School Certificate.

9. Future Programme

In order to monitor the accuracy of each laboratory, a set of 6 check samples should be distributed to the laboratories from one rotating source once every three months. The results of such checks are to be compiled and circulated to the laboratories by whoever is responsible for distributing the check samples.

The Sub-Committee should meet in Kuala Lumpur in mid 1969 to deliberate upon:-

- a) results of remaining studies in Stage I and
- b) analyses to be studied in Stage II off the Standardisation Programme.

Sub-Committee
on Analytical Methods.

Session 1/1

SOME ASPECTS OF SOIL GENESIS IN SABAH

by
P. THOMAS
Department of Agriculture, Sabah

Introduction. Sabah provides a wide variation in the main soil determining factors. Geological studies have revealed that an extremely wide range of rock types is present as parent material for soil formation. The range of altitude from sea-level to nearly 13,500 ft., at the summit of Mount Kinabalu is responsible, in addition to the various monsoonal patterns occurring, for wide differences in climate (Table 1) and in types of natural vegetation. Great differences in relief are found between the level areas of the sea-board and interior plains and the strong-sloping areas of the mountain ranges, and the expression of age as a time factor is found to be closely related to these effects. Variations in vegetation appear to be more related to the effects of climate as influenced by the elevation of the land.

These wide variations in the pedogenic factors result in a great diversity of soil conditions and an extremely complex soil distribution pattern. It is not within the scope of this paper to explore in detail the inter-relationships of these factors, and what is meant to be achieved is a general account of their influence in the genesis of the soils of the State with emphasis given to their particular bearing on soil classification.

The Pedogenic Agencies. The most important pedogenic factor influencing the ultimate nature of the soils is the mineral characteristics of the parent material. This is of particular importance because of the geological youthfulness of the country, and, therefore, soil characteristics are found to be closely related to lithology. Of secondary, but of profound, importance follows the nature of the water relationships within, and the intensity of the gravitational processes on, the solum. The period of time for the latter two factors to act on the soil has also a very profound effect on the ultimate soil characteristics. Thus the age of the soil is largely reflected in the stage of the weathering of its mineral fraction and the degree of accumulation of the organic material.

Table 1. The range of climate as induced by differences in altitude.

Station	Altitude ft.	Average Rainfall ins.	Temperature °F	
			Mean. Max.	Mean Min.
Sandakan Airport	39	123	87	73
Kundasang	4,500	85	72	62
Tanbarangan	7,040	160	62	52

The Effects of Climate. With the prevailing high soil temperatures and water availability these processes are relatively rapid, associated with a high rate of chemical action, biological activity and energy released by water moving through the soil and rock. The high rainfall in particular has brought about a degree of uniformity in that almost all soils, to greater or lesser extent, tend to be deficient in bases and acid in reaction. Variation in this leaching regime as induced by changes in climate is well illustrated by the altitudinal sequence of the soils on Mount Kinabalu. (Askew, 1964). Up to an altitudinal line of 4,000 ft., Red-Yellow Podzolic Soils occur which are thoroughly leached and acid. A marked difference is found above this altitude in that micropodzols are developed on less sloping sites marking a mor type of humus formation. It is instructive to note that this corresponds reasonably with the altitude of 1,250 ft., described in Java (Mohr and Van Baren, 1954), above which as the result of the influence of temperatures less than 25°C (77°F) predominating, organic decomposition is slower than organic accumulation. Above this the effects of decreasing temperature below an average of about 70°F and increasing rainfall is manifest in well developed podzols occurring as a continuous mantle up to 5,500 ft. where extremely moist soil conditions induced by prevalent mist gives rise to a peaty gley soil. In the cooler and probably drier zone above 9,500 ft., there is a .../3.

change to alpine humus soils.

In the low-land zone temperatures are high and equable, and although great variations in rainfall occur they are considered generally of similar pattern and high order to mark any soil differences likely to be induced by the effects of climate; although schematic soil surveys in the wetter low-land zones might in future disprove this.

The pedogenic processes can be conveniently categorised as follows.

Mechanical Action which is concerned with the removal and accumulation of soil and soil parent material by the various abiotic agencies. This is frequently found to be a dominant soil forming factor because of the young age of the land surface and its general sloping nature.

It is found on its largest scale as a factor influencing the soil geography. For example, coastal platforms usually coincide with land overlies country rock which is poorly resistant to marine erosion and their increasing incidence seems to be related to decreasing resistance to weathering and erosion (Paton, 1963). Thus most of the peneplanation is found in the eastern half of the country mainly coinciding with the occurrence of the clastic suite of rocks more common to that area. Conversely, massive sandstones, limestones and igneous rocks normally give rise to the more mountainous areas because of their greater resistance to weathering and erosion.

Soil movement is frequently found to be the dominant feature in soil formation because of the relative youthfulness of the land mass, with the oldest of the land surfaces being Pliocene in age and most of the lower lying uplands having emerged during the Quaternary or later. Hence the time factor for pedological processes can be considered to be brief. Thus the major impression on soil genesis, is found simply as the formation of soil in the upper slope locations with a corresponding accumulation of soil in the lower slopes due to colluviation, and in the valley bottoms as alluvial infillings. Considerable accumulations of

marine alluvium are frequently found along the coastline, but
colluvial deposition is restricted to a narrow tract between the
sea and the limits of the zone of vegetation. Catastrophic
movements of soil and rock debris as land-slides are rare, and
are restricted to the more mountainous areas.

Similarly, the physical shattering of rock is not
a commonly occurring phenomenon. Where rock outcrops are exposed
to the effects of insolation rock exfoliation becomes manifest;
but because of the almost continuous forest mantle this is rarely
seen.

Biological Action which although important in rock shattering is
of more profound importance as a process whereby kinetic energy
is stored within the soil. It is invariably intense but never
spectacular. This is because the climax forest occupies an
almost continuous cover which varies little with differing soil
conditions. Away from this forest the role of *Agathis* sps.,
(Askev, 1964) and similar plants with an extreme acid litter as
possible strong podzolising agents must be borne in mind.
Invariably, however, mature trees are found firmly established
on very shallow soil mantles and thereby act as important soil
forming agents under the former conditions whereby the first
stage of rock disintegration and mineralogical decay are initiated.

Under forest conditions the soil is overlain by a continuous
layer of decomposing plant litter which in low altitudes and
under normal freely draining conditions is rarely more than an
inch or two in thickness; but with waterlogging in association
with excessive acidic or alkaline conditions peat formations
occur. Thus organic soils tend to be formed in backwater swamps
related to water-catchments with acidic rock suited, and also in
some estuarine areas.

Mineral Metamorphism which involves the decay of the inorganic
skeleton of the soil as the result of a series of binary
weathering reactions followed by the movement of the mineral
particles within the solum. This involves essentially two
processes in the soil.

Table 2. The relationship between the mineralogy of the sand fraction, and soil genesis and soil classification.

Great Soil Group	Soil Family	Parent Material	Horizon Designation	Sample Number	% MINERAL CONTENT 2mm-50//																
					Feldspar	Quartz	Zircon	Garnet	Rutile	Kyanite	Siliminite	Epidote	Saussurite	Hornblende	Actinolite	Augite	Enstatite	Hypersthene	Rock	Ore	
Litho-sol	Tumun-ong	Basic igneous intrusive rock	A1	9351	12	45	-	-	-	-	-	7	tr	1	-	-	tr	-	35		
			AC	9352	10	52	-	-	-	-	-	8	2	1	tr	-	-	-	-	27	tr
			C	9353	12	18	-	-	-	-	-	9	31	-	-	-	-	-	-	-	30
Active Riverine Alluvial Soil	Diwata	Basic Alluvium	A1	9347	2	41	-	-	-	-	-	11	1	5	1	5	2	2	30		
			AB	9348	3	28	-	-	-	-	-	15	-	7	2	6	1	1	37	tr	
Red-Yellow Latosol	Beruang	Basic igneous intrusive rock	A2	9753	-	77	1	-	-	-	-	2	-	-	-	-	-	-	17	3	
			B2	9754	-	94	-	tr	-	-	-	-	-	-	-	-	-	-	-	6	tr
			C	9755	-	49	1	1	2	5	21	-	2	-	-	-	-	-	-	18	1
Red-Yellow Lypsollic	Tengah Nipah	Sandstone	A2	9329	-	83	-	-	-	-	-	-	-	-	-	-	-	-	17		
			B2	9330	-	80	-	-	-	-	-	-	-	-	-	-	-	-	tr	19	1
Litho-sol	Ambun	Ultra-basic rock	A2	6410	-	93	-	tr	-	-	-	-	-	-	-	-	-	-	tr	7	
			B2	6411	tr	86	tr	-	-	-	-	-	-	-	-	-	-	-	-	1	13
Litho-sol	Serai	Raised marine alluvium	A2	3968	-	99	tr	-	-	-	-	-	-	-	-	-	-	-	-	1	
			B2	3969	-	99	tr	-	tr	-	-	-	-	-	-	-	-	-	-	tr	1

1. tr= traces.

2. The mineralogical determinations were undertaken at the Royal Tropical Institute, Amsterdam.

Mineral Change. The chemical change involved is an universal and continuous process. Its intensity largely depends on the nature of the parent material of the soil. Thus with hard compact rocks containing resistant minerals of approximately the same dimensions chemical breakdown can be expected to be slow, whilst, conversely, in porous rocks containing a variable assemblage of weatherable minerals of differing dimensions the breakdown can be expected to be rapid.

The first stage in the decay of the mineral skeleton is for the primary silicate minerals to be broken down. Table 2. shows

that the breakdown of the primary silicate minerals forming the coarser part of the fine earth fraction is extremely rapid in all well aerated soils but tends to be inhibited with inferior drainage conditions e.g. Diwata Soils (sample Nos. 9347 and 9348). Thus it can be seen that almost from the onset of weathering only the more resistant minerals remain, the occurrence of reasonably weatherable minerals being associated with the petrological fabric of rock fragments which themselves become less common with increasing weathering. Quartz invariably dominates the sand fraction of soils developed on slopes below 15° , but above this slope limit rock fragments generally increase in content, whilst below this limit the reverse relationship is found with quartz forming almost all of this fraction. This is well seen in the Podzol representative shown (sample Nos. 3968 and 3969). Between the two extremes illustrated by a Lithosol and Podzol are shown important intermediate stages, which have a bearing on mineral plant nutrient status of the main Great Soil Groups.

The breakdown of the primary silicate minerals gives rise in part to the formation of clay size particles of minerals which are found to be increasingly more resistant to weathering, and the study of which can be rewarding in soil genetic studies. This can be best seen when the weathering sequence of the clay size minerals is followed (Jackson, et al, 1948). This is shown on Table 3. Stages I to V are considered to involve largely primary minerals and Stages VI to IX secondary minerals formed as the result of a number of pedologically induced binary transformations. Stage I involves soluble salts very transient in nature in the soil under normal weathering conditions, whilst Stages II and III would be very easily weathered. Stages IV to VII slowly weathered, and Stages VIII and IX very slowly weathered.

The first stage in clay mineral formation is to be seen in the Lithosols, typically developed on slopes of about 25° or more and where weathering can not proceed far before soil material is removed by erosion. This effect is marked by the

.../7..

Table 3. The relationship between the weathering of the clay minerals and soil genesis and soil classification (After Jackson, et al, 1948)

Soil Group	Soil Family	Parent Material	Sample Number	Horizon Designation	CLAY MINERAL SEQUENCE								
					Calcite	Biotite	Albite	Quartz	Illite	Montmorillonite	Kaolinite	Gibbsite	Haematite
					I	II	III	IV	V	VI	VII	VIII	IX
Lithosol	Cook	Sandstone and shale	1185	A	-	-	-	pr	-	dom	pr	-	tr
Lithosol	Tanjong	Andesitic ash	1969	A	-	pr	pr	pr	-	mod	pr	-	tr
Lithosol	Bombalai	Basalt	1972	R	-	pr	pr	pr	-	mod	pr	-	tr
Lithosol	Bombalai	Basalt	1087	A	-	-	-	pr	-	-	dom	tr	pr
Active Ferrine Alluvial Soil	Diwata	Basic alluvium	9929	G	-	-	-	-	tr	dom	tr	-	-
			9930	G	-	-	-	-	tr	dom	tr	-	-
			9931	C	-	-	-	-	tr	dom	tr	-	-
Vertisol	Tamang-gong	Bentonitic mudstone	9948	A2	-	-	-	-	pr	dom	tr	-	-
			8950	B2	-	-	-	-	pr	dom	tr	-	-
			8952	C	-	-	-	-	pr	dom	tr	-	-
Andisina	Semporna	Coralline limestone	1714	A	-	-	-	pr	-	dom	pr	-	-
			1716	C	tr	-	-	pr	-	dom	mod	tr	-
Yellow Lithosol	Beruang	Basic igneous intrusive rock	9753	A2	-	-	-	-	-	-	dom	-	-
Yellow Solonchalc	Tengah Nipah	Sandstone	9329	A2	-	-	-	tr	-	dom	pr	-	-
			9330	B2	-	-	-	tr	-	dom	pr	-	-
			9332	C	-	-	-	tr	-	dom	pr	-	-
Yellow Solonchalc	Edam	Basic colluvium	8722	A2	-	-	-	tr	dom	-	pr	-	-
			8723	B2	-	-	-	-	dom	-	pr	-	-
			8724	C	-	-	-	-	dom	-	tr	-	-
Brown Lithosol	Table	Basalt	1667	AB	-	-	-	pr	-	-	dom	-	tr
Brown Lithosol	Bakapit	Basalt	1668	AB	-	-	-	pr	-	-	dom	-	tr
		Basic ash	6711	AB	-	-	-	-	-	-	dom	-	-
			6712	AB	-	-	-	-	-	-	dom	-	-
			6713	AB	-	-	-	-	-	-	dom	-	-
	Serai	Raised marine alluvium	3968	A2	-	-	-	dom	-	-	dom	-	-
			3969	B2	-	-	-	dom	-	-	dom	-	-
			3970	C	-	-	-	dom	-	-	dom	-	-

- Group II Can also include glauconite and chorite.
- Group III Anorthite, microcline and stiblite.
- Group IV Cristobalite.
- Group V Muscovite, sericite, etc.
- Group VI Beidellite.
- Group VII Halloysite.
- Group VIII Boehmite, and
- Group IX Goethite and limonite.

dom = dominant, mod = moderate, pr = present, tr = traces.

The determinations were carried out by X-Ray analysis. An asterisk indicates that the analyses were undertaken at Rothamstead Experimental Station, the others at the Royal Tropical Institute, Amsterdam.

presence of rapidly weathered clay minerals such as bitite and albite, (samples 1969 and 1972) and also by the presence of quartz (samples 1189, 1969 and 1972, and 1087), and in addition by the dominance of montmorillonite. The Bombalai Soil (sample 1087) may be dominantly kaolinitic due to hydrothermal alteration during the formation of the basalt (Eaton, 1963). The presence of gibbsite and haematite in the lithosolic soils at first sets an anomaly. The traces of gibbsite found in the Bombalai soil might mark the latter part of a transient phase in weathering in which a premature development of this mineral is found with the occurrence of primary quartz in the colloidal fraction of the soil giving rise to the later formation of kaolinite (Watson, 1965., Jackson et al, 1948., Mohr and Van Baren, 1954). The presence of iron-oxides in the clay fraction again might mark a transient phase in this process prior to formation of montmorillonitic and kaolinitic clays.

With the high rainfall, alkalies and alkaline earths are usually completely washed out of the soil and when found invariably occur in the weathering mantle immediately adjacent to highly calcareous rock material, e.g. Rendzinas (sample No. 1716).

In the majority of cases however, quartz is the most easily weathered clay mineral to be found and hence it is generally seen that the breakdown of primary silicate minerals is relatively rapid. With the decrease in particles size found during this process there occurs a corresponding increase in the rate of mineral change, but the normal end point is reached in the Ferralsols with the dominance of kaolinite in the clay fraction. Usually, however, more than one clay mineral in the sequence between quartz and kaolinite is found indicating intermediate weathering stages between these minerals. These can reflect either an arrest in the process of weathering or a transient phase in the process (Jackson et, al, 1948). Thus, for example, poor drainage tends to minimise soil leaching and can cause the predominance of montmorillonite, e.g. Diwata soils (sample Nos. 9929, 9930 and 9931). In relatively impervious .. /9.

soils containing an abundance of bentonite the inefficiency of the leaching regime is reflected in the predominance of montmorillonite and the occurrence of illite, e.g. Vertisols (sample Nos. 8948, 8950 and 8952). A reversal to normal weathering occurs with profound changes in the leaching processes of the soil. Thus for example kaolinite is converted to illite, e.g. Edam soils (sample Nos. 8722, 8723, and 8724); or montmorillonite, due to an influx in the ground waters of bases. In addition, the rate of weathering appears to increase with the proximity of the soil surface and there is a tendency in most freely draining soils for the lower horizons to be dominated by quartz or cristobalite with an increase in less weatherable minerals at shallower depths. This is illustrated in Table 4., and in addition it can be seen that the rate of change generally increases inversely with the size of the soil particles.

Table 4. The relationship between the weathering of the clay minerals, soil depth and soil texture in the Timbac Family. (derived from basalt).

Depth, ins.	Sample No.	CLAY MINERAL SEQUENCE					% PARTICLE SIZE DISTRIBUTION				
		Chlorite II	Cristobalite IV	Illite V	Montmorillonite VI	Kaolinite VII	2mm-200μ	200μ-50μ	50μ-2μ	20μ-20μ	<2μ
0-2	9343	tr	-	-	pres	dom	2	4	48	41	5
2-10	9344	-	-	dom	-	dom	2	4	33	43	18
10-26	9345	-	dom	pres	-	dom	2	2	34	46	16
26-40	9346	-	dom	pres	-	dom	24	5	42	18	11

C.F. Notes as for Table 3.

Mineral Movement. The movement of mineral particles and colloids within the solum as the result of leaching thereby giving expression to the processes of podzolisation and laterisation (Trayford and Wright, 1966).., is important in Sabah generally on slopes less than 15° . Normally above this slope limit the effects of colluviation result increasingly in an almost continuous mineral enrichment of the soil and the degree of horizonation becomes increasingly dependant on surface soil movement except at high altitudes where the effect of climate has a very strong podzolising effect e.g. at altitudes between 4,000 ft. and 5,500 ft. on Mount Kinabalu, or when the soil parent material is very highly siliceous and deficient in bases.

The processes of podzolisation and laterisation frequently occur simultaneously within the solum and morphologically are easily recognisable at both ends of a continuum which these processes make up during the leaching of the soils, but with the majority of the soils in Sabah transient stages in both these soil forming process are represented. This is illustrated in the series of graphs shown in Figure 1. The tendency for clay-sized particles to accumulate in the lower horizons appears to be common to all such soils developed on gently inclined slopes, and invalidates the use of the latosol concept as defined by Kellog (1949) in the exhibition of essential horizons of clay accumulation, thereby showing podzolic tendencies.

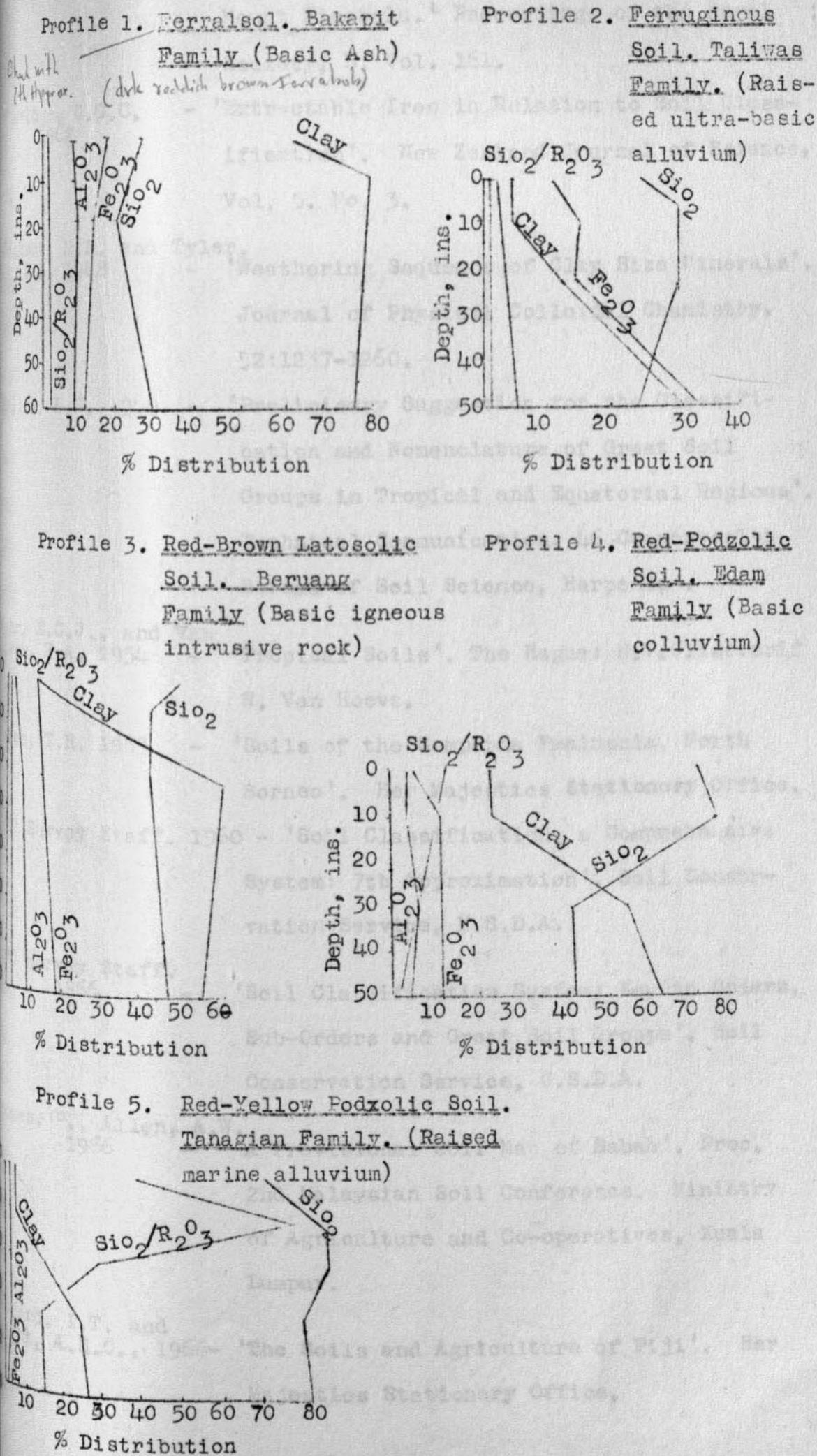
It would appear that the best key for the elucidation of these relationships would be the use of criteria on silica, iron oxides and aluminium oxides. Thus in soils subject to extreme weathering, laterisation is best expressed when the parent rock material is composed of a basic to ultrabasic mineral assemblage rich in iron and aluminium with the result that oxides of these elements occur as surface enrichments in the solum which coincide with a zone of silica depletion; and podzolisation has its greatest expression in soils developed from an acidic suite of minerals rich in silica and poor in iron and aluminium giving rise in this case to a marked upper

..//11..

of silica accumulation with little range and with very low levels of iron and aluminium oxides. The two extreme ends of this continuum is shown in Fig. 1 by the Ferralsol and Red-Yellow Podzolic profiles. Three important intermediate stages are also demonstrated. The Ferruginous Soils are developed on ultra-basic parent material unusually rich in iron, and top soil enrichment of iron oxide occurs coinciding with an accumulation of silica. This is the result of a low degree of soil weathering induced by poor drainage conditions. With a moderate degree of weathering and a parent material well supplied with iron and aluminium a distinct zone of silica impoverishment is seen in the upper part of the solum coinciding with a gradual increase of the iron oxide and aluminium oxide content in depth marking the Red-Yellow Latosol stage in this process; whilst the stage shown in the Red Podzolic Soil differs in that a horizon of silica enrichment occurs and the levels of iron and aluminium oxides tend to be less.

Conclusion. An attempt has been made to sketch in broad detail the course of the main soil forming processes in the genesis of the soils of Sabah, during which emphasis has been given to the role of mineralogical change as a key to the various stages of soil evolution. This is a relatively new approach in Sabah and it has so far indicated that some important variances do occur with the previously established genetic classification of its soils (Thomas and Allen, 1966), which was based mainly on morphological and environmental data. It is considered as the first step in the process of evaluating the relationships of the soils of the State with the advanced soil classifications developed in other countries, particularly with the system being developed by the United States Department of Agriculture (Soil Survey 1960, and 1966). It is hoped that the ultimate result of this line of research will in particular give rise to a sound basis with which to make a local appreciation of this latter approach.

Figure 1. The relationships between clay, SiO_2 , Fe_2O_3 and Al_2O_3 distribution in the profile and soil classification.



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K.T. Joseph and B.R. Hewitt

Podsols have been reported in the tropics since 1935 when Joachim described what he called the cinnamon soils on the West Coast of Ceylon. Hardon (1937) described some lowland podsols from the Island of Bangka. The profile descriptions of Joachim (1935) and Hardon (1937) differ significantly in that Joachim's 'podsol' did not contain an A_2 horizon which is characteristic of the classical podsol whereas Hardon's description showed the sequence of an A_0 over an A_1 over an A_2 over both a B_1 and B_2 horizon. In both cases, however the soils were developed on a pervious quartz sandy soil poor in bases and a low base content of the vegetation.

Pendleton and Sharasuvana (1942) state that a true podsol profile to be typical must include the organic matter of an iron illuvial horizon. Zakharov (1910) cited by Muir (1961) discussed podsolisation in the following stages. In the youngest (or cryptopodsolic) there is a slight development of an accumulation horizon as shown by a graying and browning of the upper layer of the parent material. As organic matter accumulates the conditions become suitable for the appearance of podsolisation which shows as whitish spots and patches that merge to form a layer - the eluvial horizon, with the concurrent formation of the brownish ortstein horizon. As this develops there appears a subdivision of the ortstein horizon into an upper layer darker red brown when wet, and a low layer lighter in colour. Zakharov considered the upper darker layer to be due to humus leached down after the loss of iron from the iluvial horizon. Muir considers that this subdivision indicates stages of podsolisation and should be used as follows :

Slightly podsollic where $A_1 > 2 \times A_2$; medium podsollic where $A_1 \triangleq A_2$;

true podsol where $A_1 < \frac{1}{2} \times A_2$

Joseph (1966) described a profile on the East Coast of Malaya (approximately 5 miles from Dungun) close to a stream, the characteristics of which are reproduced below :

- 0" - 6" A_1 very dark grey sand (2.5Y 3/3)
- 6" - 12" A_2 grey sand (5Y 5/1)
- 12" - 18" A_3 light brownish grey sand (2.5Y 6/2)
- 18 1/2" - 20" B_1 black sand with organic matter and iron (2.5Y 2/0) co-impregnated.
- 20" - 20" B_2 dark red sand (10R 3/3)
- 30" - 40" B_3 light yellowish brown sand with some white mottles (2.5Y 6/4)

The A_3 horizon in the Dungun series is unique as the sandy podsols previously described by Joachim (1935), Hardon (1936, 1937) Van der Merwe (1940) do not appear to have an A_3 horizon. The iron content in the A_3 horizon of the Dungun series is much lower than in

the A₂ horizon (see table 1). When the A₂ and A₃ horizons are combined the condition as laid down by Zakharov where $A_1 < \frac{1}{2}A_2$ for true podsol is approximated. The Dungun series can be regarded as a true podsol since in addition to the above it contains the classical coffee rock in the illuvial horizon.

The Chemical characteristics of the above profile is given below in Table 1.

Table 1

Horizon	pH measured* in 1:5.02MKCl	Mixed Se- squioxides	Iron con- tent % Fe	P in mg/ 100 gm soil	Organic Carbon %	Nitrogen %
A ₁	3.3	0.91	0.057	4.2	4.4	0.18
A ₂	4.0	0.69	0.055	0.9	0.6	0.03
A ₃	4.7	0.55	0.032	0.6	0.1	0.01
B ₁	4.1	5.4	0.226	6.1	4.0	0.13
B ₂	4.4	3.7	0.184	4.5	4.4	0.13
B ₃	4.8	4.4	0.188	3.1	4.5	0.01

*pH measurements in 0.2MKCl were about 0.7 unit lower than in distilled water.

The pH values are lowest in the A₁ horizon, rising to a maximum in the A₃, falling in the B₁ and rising again in the B₃ horizon. The rise in the pH in the B₂ and B₃ horizons may be ascribed to the influence of the water table (note mottles in B₃ horizon) which is invariably characteristic of podsol which have an organic matter/iron illuvial horizon. The mixed sesquioxides drop steadily from the A₁ to the A₃ horizon and rise (tenfold increase) in the B₁ horizon. The iron content follows a similar trend and the increase of iron from the A₃ horizon to the B₁ is also approximately a tenfold increase. The iron content data confirms the field description of a truly differentiated eluvial and illuvial zone with the downward movement of iron. The phosphorus figures are also tied up with the iron illuvial zone, since iron hydroxides and oxides have a high capacity to adsorb the dihydrogen phosphate anion. In the A₁ horizon the phosphorus can be ascribed to be tied up in the organic matter.

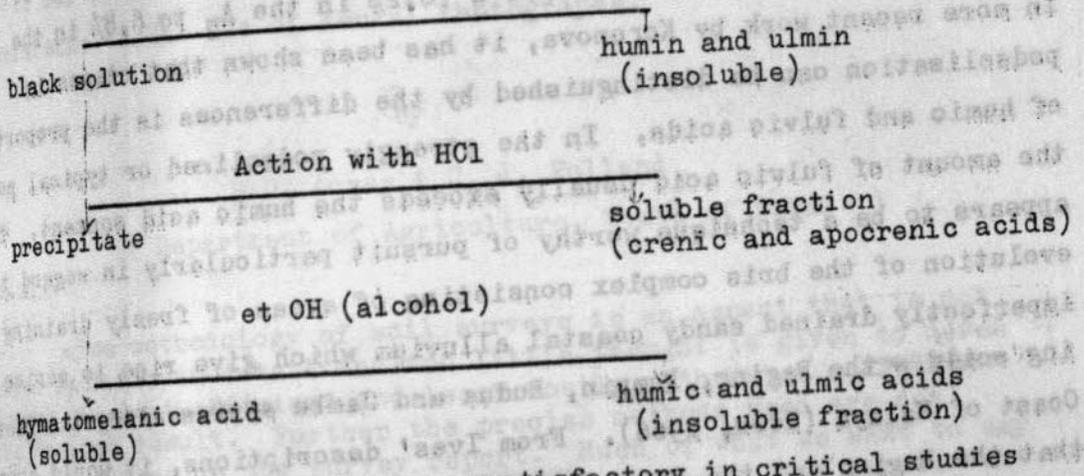
Table 2 is a summary of the organic matter fractionation which was carried out according to the scheme of Kononova (1961).

Table 2

Horizon	Sand Humus		HUMUS FRACTIONS			
	%	%	(1) Humic & Ulmin	(2) Crenic and Apocrenic Acid	(3) Hymetomelanic Acid	Humic and Ulmic Acid
A ₁	87	10.7	2.4	6.3	0.3	1.2
A ₂	97	2.6	2.1	0.2	0.3	0.1
B ₁	85	13.3	3.8	6.8	0.4	4.8

fractions were carried out according to the scheme shown below.

Soil (extracted with 0.1N Na OH)



Although this scheme is regarded as unsatisfactory in critical studies on the nature of organic matter, it nevertheless is useful in ascertaining the broad groups associated with ^{various} the horizon in the podsol profile. The 4 main groups of soil humus are (1) humin and ulmin (2) crenic and apocrenic acids (3) hymatomelanic acid and (4) humic and ulmic acids. Table 2 summaries the distribution of these various humus fractions in the 3 horizons examined. As expected the total humus content is lowest in the A₂ where almost 90% of the low total humus value consists of Humin and Ulmin. This fraction was found to be fairly consistent in the horizons A₁, A₂, and B₁ and represents humus substances not extracted during treatment with alkali solutions. According to Kononova (1961) the humins of soil humus are humic acids which have lost the capacity for dissolving ⁱⁿ the alkali, due to the ^{firmness} dirmness of the combination with the mineral part of the soil and not presumably due to any alteration in their nature.

The fraction crenic and apocrenic acid (fulvic acid) drops by a factor of 30 from the A₁ to the A₂ horizon and rises in the B₁ to an amount approximately equal to that in the A₁ horizon. Tiurin (1940) cited by Kononova (1961) showed that fulvic acids of soil humus represent hydroxycarboxylic acids of high molecular weight containing nitrogen. Bremner (1954) found that when fulvic acids were hydrolysed with 6N HCl 20% to 30% of their nitrogen was solubilised, producing a large number of α-amino acids.

The hymatomelanic acid group (alcohol soluble fraction of humic acids) is constantly low in all the 3 horizons examined. The humic and ulmic acid fraction differs in all three horizons being highest in the B₁ (4 times as much as in the A₁) and lowest in the A₂ where the level is exceedingly low. The humic acid molesule has a complex structure consisting of aromatic ring with nitrogen containing compounds in cyclic forms and in the form of peripheral chains, the nitrogen content varying within 3% - 5% (Hobson and Page 1932).

In the podsol a striking mobility of the fulvic acid has been demonstrated (Kononova 1951 cited by Muir 1961). In the Dungun profile this is well exemplified in table 2 (0.2% in the A₂ to 6.8% in the B₁). In more recent work by Koronova, it has been shown that stages in podsolisation can be distinguished by the differences in the proportions of humic and fulvic acids. In the strongly podsolised or typical podsol the amount of fulvic acid usually exceeds the humic acid content. This appears to be a technique worthy of pursuit particularly in regard to the evolution of the bris complex consisting of areas of freely draining and imperfectly drained sandy coastal alluvium which give rise to a series of soils - the Baging, Rompin, Rudua and Jambu series along the East Coast of Malaya (Ives, 1966). From Ives' descriptions, it would appear that the Baging and the Rompin series are cryptopodsolic whilst the Rudua and Jambu appear to represent more advanced stages in the podsolisation process. Some chemical work on these soils should prove interesting.

The Dungun series can be regarded as a true podsol in view of the characteristic horizon differentiation and the sharp change in the B horizon. The organic matter content in the B horizon was shown to be higher than in the A₂ horizon. In view of the sandy nature of the soil, translocation of clay could not be measured but the sesquioxide and iron distribution figures substantiates a translocation from the eluvial to the illuvial horizons. The profile was shown to be acid, the maximum pH being in the A₁ as is typical of sandy podsol.

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KTJ/EC

Soil Survey Methods in Tropical Forest Areas with Particular
Reference to The Use of Aerial Photographs.

by

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The methodology of soil surveys is an aspect that is not often analysed in detail and too little thought is given to developing the most efficient and least costly methods of achieving the desired result. Further the precise methods used are not always outlined in the survey report. Much of what we want to say on the subject will not be new to any present who have carried out soil surveys and the object of the paper is to outline the approach we have been trying in Sabah, to stimulate some discussion on methods in the forest environment and, in particular, the value of air photographs.

Opinions seem to vary as to the usefulness of photos in reconnaissance surveys in forest regions. As long ago as 1949 van der Eyck working in N. Surinam, based his reconnaissance survey on air photo interpretation with the aim of developing a method to cover large areas in a relatively short time, at low cost, and gave a detailed outline of the approach adopted. Much has been written on the subject since but in most former British territories surveys have been apparently reluctant to try to use air photographs. It appears that in Malaysia there has been little use of photos in any systematic way and as recently as 1963 doubts have been expressed as to their value. Panton, in his paper on soil survey methods in Malayan forest states that aerial photographs .. "are of little value during the period of fieldwork at least in most types of forested terrain" and goes on to say that the topographic maps available normally reflect the relevant details on the aerial photographs themselves. He limits their usefulness to the different vegetation patterns that may be visible and which may be correlated with soil differences, to preliminary inspection prior to fieldwork and after to clarify obscure details.

On the other hand, Wall working in Sarawak, stresses the advantages of using air photo analysis in order to delineate what he terms 'topo-soil associations' and as an aid to covering large areas in a shorter time and presumably that is the method used in Sarawak. In Sabah photos have been used in much the same way as in Malaya, mainly as a supplement to extensive ground surveys.

It must be well-known that all major organisations concerned with natural resource surveys at the reconnaissance level employ systematic airphoto interpretation. CSIRO have been applying this method mainly in areas where vegetation and soils have been little influenced by man. In New Guinea, for example, emphasis was placed on the delineation of landforms and drainage patterns on photographs to show the recurring patterns of landscape within which 'key sites' were selected for field examination. It is based on the concept that each type of terrain is expressed by a distinctive pattern on the photos.

The Directorate of Overseas Surveys stresses that resource surveys BEGIN with air photo interpretation as a basis for efficient land resource assessment.

While it is one thing to acknowledge the usefulness of interpretation it is quite another to combine it successfully with field observations so that both are used to the best advantage. Considerable thought has been given to this aspect by Buringh and Vink in Holland. Dr. Vink, in a paper entitled 'Planning of Soil Surveys in Land Development' outlines various kinds of soil survey methods in which air photographs are used in varying degrees.

- i. the 'rigid grid' survey where field observations are carried out at fixed intervals in both directions.
- ii. the 'grid' survey as a basic means with in addition, some observations on the physiographic correlation of the soils which are used to locate boundaries more accurately.
- iii. The grid survey with some physiographic observations followed by photo interpretation.
- iv. the physiographic soil survey without photo interpretation but with maximum use of data from topographic, landuse and geological maps.
- v. The survey with systematic photo interpretation.

He considers the first two methods to be outdated in reconnaissance work and that the advantages of using photo interpretation in the third are lost because it is done after fieldwork. The fourth method is only applicable in highly developed countries, but even so, a topographic map can never give the wealth of information revealed on a photo. The fifth is the only one which gives good efficient results in almost all cases where air photos of good quality are available.

Buringh has outlined a number of procedures by which interpretation and fieldwork are combined in the fifth survey method, depending on the type of detail required, the accessibility of the survey area and varying from the use of the photo as a field map to very broad extrapolations from photos with few field observations.

We have attempted to apply a systematic airphoto interpretation in a reconnaissance survey over an area of approximately 7,000 square miles in the Sandakan and Kinabatangan Districts of Sabah. The area is scheduled to be completed in two years and mapped at a scale of 1:50,000. Approximately half is likely to be unsuited for agricultural development there being large coastal expanses of mangrove and nipah and extensive tracts of steep land in the interior. Access by boat is generally good although smaller rivers are obstructed by sewn logs and by natural tree fall. We suggest that it would be impossible to complete such an area in that time without systematic airphoto interpretation.

After 6 months in Sabah, 2 of which have been spent in the field and four in administration and preparation we have some observations to make on the use of photographs, neither of us having attempted this approach before.

Choice of Photographs

Good photography is absolutely essential and ideally the photography should be flown specifically for the project. It is argued that to fly for a project is wasteful but it has been proved (not by us) that the cost of such photography is 'negligible' in relation to total cost. We have inherited photography varying from RAF scale 1:25,000 flown in 1948-54 with flight lines from N-S, E-W, and NE-SW; RAF, scale 1:50,000-60, flown 1962-64, Lands and Surveys scale 1:25,000 flown in 1966 & 1967 plus some additional flights by Huntings for timber companies at odd scales.

Quality as well as scale is variable and, in addition, some of it still regarded as strategic importance such that the Government authorities are reluctant to release them.

We have encountered the following difficulties:-

- a. The same landform appears differently on photography at different scales. In addition, there is a tendency to delineate more detail at the larger scale, 1:25,000, which does not warrant separation or which would be ignored at the 1:50,000 scale.
- b. Old photography obviously does not show the existing landuse and access routes. Access, in particular, is vital in reconnaissance surveys and there must be up-to-date information of new tracks and railways so that time is not lost in cutting unnecessary rentises. In Sabah timber extraction proceeds rapidly and logging roads and railways are being constructed. It would be better not to cut an 80 chain rentis and find that there is a railway at the other end. Planning of the survey is made more effective by having this information and time and money could be saved - money which might be spent on new photography.
- c. Using 1:25,000 photography involves handling up to four times as many prints as at 1:50,000 scale, partly because the overlaps of the older photos are very variable while recent techniques are more standardised. It is not just a ratio of two. The numbers can be confusing and tedious especially where flight lines are also at variance.
- d. For the production of a land system map we recommend that photography should be at about 50,000 scale. It has been recommended before but we have found that this scale allows an excellent overall picture of the land while with a x3 binocular attachment detail can be observed. 1:25,000 scale photos are too detailed for this purpose although they are more suited for orientation in the field. In addition a good idea is gained of which units can be mapped at the 1:50,000 scale.

Photo preparation

It is important that photos are prepared prior to interpretation. Preparation involves the marking and transferring of principal points, flight lines and match lines. It is a time consuming task, particularly when using 1:25,000 scale photos, but can be adequately done by trained cartographic staff. It ensures that no duplication of interpretation occurs and that all interpretation lines join up between photos.

Photo Interpretation

The object of the photo analysis is to divide a region into physiographic landscape units or landtypes which can both be detected on the photographs and located on the ground. This is the first stage in determining land systems, a term which we use in the same sense as it is used in Australia being a natural unit of the land surface with distinct geology, relief and drainage pattern, soil type and vegetation association and which can be mapped and delineated on the ground. The information on geology, soil and vegetation may initially be inferred but is substantiated by field work.

We have had no difficulty in delineating landscape units or landtypes on photos in areas covered by primary forest, although there are the inevitable problems of exactly where to draw the line when units merge. We did it independently, each being responsible for different 1:50,000 sheets, and came up with the same sort of units. However, we each established our own interpretation legend in terms of the landform, relief, drainage and vegetation, incorporating existing geological information and making broad inferences on soils. As we have decided that the field is the best place for us to reach agreement as to the soils we find we are working in close proximity. This means also that we must each be familiar with the others interpretation, agree on an overall legend and plan with care that we do not duplicate. This ideal was not attained before field work began except in the areas of immediate interest where we have examined each others interpretation using the Old Delft Scanning Mirror stereoscope which we highly recommend for this purpose. It enables two people to look at the same area stereoscopically at the same time.

The interpretation lines were sketched onto Print Laydowns (P.L.D.'s) or uncontrolled mosaics, where overall patterns and spatial relationships can be studied. Even before interpretation much can be obtained from a study of these if the quality is good (and we were fortunate to find an almost complete set stored at the Directorate of Overseas Surveys. The disadvantage is that it is not always easy to transfer detail from 1:50,000 photos onto P.L.D.'s assembled from old 1:25,000 photos of very variable quality. Nevertheless its usefulness lies in being able to see where access is available and where sampling can most usefully be carried out, being able to plan where field work should be concentrated to avoid duplication, the aim being to obtain the maximum amount of information from the minimum number of sorties in the time available. The advantages of this are lost if insufficient time is allowed for the interpretation, construction of a legend, planning and field reconnaissance and this is easily done if field work must be concentrated within a certain period and if other factors are allowed to interfere.

Preliminary reconnaissance

We believe that before beginning field work a brief reconnaissance should be made within the survey area. The main purposes of this are:-

- a. To discover main access routes, involving checking logging roads and railway lines where recent photos are not available, checking the navigability of rivers.
- b. Examining possible campsites, facilities for obtaining stores, availability of fresh water etc.
- c. A public relations exercise to inform local people, native

chiefs, police etc. of our intentions so that our labour force is not mistaken for marauding pirates of whom there is still considerable fear in this part of Sabah.

d. To examine briefly some of the interpreted landforms on the ground.

To date we started the survey of one district without this reconnaissance and have experienced sufficient problems to prove to us just how valuable this visit would have been. On the other hand we have managed to undertake such a reconnaissance of an area about to be surveyed - a period of one week - in which all access was investigated, all kampongs, timber camps and estates visited, campsites and accommodation located, local boats employed and familiarity with the area obtained.

Field work

Fieldwork is undertaken with two objectives in mind, to establish and classify the soil units within the systems delineated and to check the existence of boundaries in areas which are doubtful. For example, we find that areas of low relief and gentle slopes covered by trees appear much flatter than they actually are and cannot easily be differentiated from level ground unless striking differences of vegetation exist. In fact, overall we find that ground conditions are generally much steeper than the photos would suggest owing to the tree cover. It is estimated that under normal survey 80% of all observations made in the field are needed for locating boundaries, the other 20% being used to describe soils while using interpretation boundary observations may be reduced to 10% of the total thereby reducing total observations to 30%. Careful planning of field traverses is important and some sort of compromise between what might be the best area and a less suited but more accessible area must be arrived at. We believe that carefully selected short routes are demanded which at the same time achieve the two objectives of classification and boundary checks.

The final problem is logistical. How many assistants and labourers, boats and boatmen etc. are required to carry the fieldwork quickly and efficiently?

Panton states that under Malaysian conditions and using the grid method of survey "much of the time of the soil surveyor is taken up with purely logistical problems such as how many men he should employ, or how much road or riverine transport will be necessary for a large scale jungle exploration and how many days rations and other supplies will be required by his parties". He apparently has to spend so much of his time doing this because his method demands that he employs large numbers of men and assistants, so that he has little time to spend in the field himself. As a result the labourers and assistants cut and describe sections in detail, sample and describe auger borings at fixed intervals and take samples back to the surveyor in his office or base camp. We suggest that these are the type of observations required for establishing boundaries since the surveyor could not permit an assistant to classify, and that therefore most of this is not necessary where systematic interpretation is used and neither are the numbers of assistants and labourers.

We have inherited and so far accepted this system of large field parties in Sabah. We do/wish to decry a method that has in /not the past achieved excellent results but we have come to the conclusion that it is outmoded. Large parties of about thirty labourers and 3-5 assistants are not compatible with a method that demand mobility and more emphasis on observations directed to establishing units. It is pertinent to examine the functions of the various personnel involved.

Soil Surveyor

We feel that this requires little comment since the responsibility for the whole survey depends on him, save to observe that his duties should be directed primarily to examination, description and classification of soils and physiography and presentation as mapping units. The CSIRO have indicated that for one field season survey of about 15-18 months the time for the various phases are as follows:

- i. Pre-fieldwork including photo interpretation and planning, 3 months.
- ii. Fieldwork, 3 months.
- iii. Final airphoto interpretation - 3 months.
- iv. Specialist evaluation of the field data, coordination of land systems and report writing, 6-9 months.

What is significant here is the relative amounts of time spent on the various stages rather than totals, about 25% being spent in the field.

Assistants

If it is accepted that the surveyor collects his own information in the field then there is no place for assistants making routine observations. Under a grid system the assistant can be relied on, once his capacities have been assessed to describe soil colour and texture and stone content and measure slopes thereby presenting a reasonable cross-section showing the differences that occur. Where short rentises are used the fixed interval of sampling is not applicable, rather sampling must be carried out depending on the individual sites which occur, a task that can only be undertaken by the surveyor. We therefore question the value of assistants in the scientific aspects of the work and suggest that his main value is in organising labour, campsites, stores and equipment all of which are vital to the smooth running and success of a project.

Labourers.

Regardless of the method of survey under forested conditions labourers are needed for portorage, rentis cutting and pit digging. The optimum number is debatable. The more you have available, the more work has to be found for them to justify their employment, the more time has to be spent in organising that work and finally in keeping abreast of it, some sort of variation of Parkinsons Law since more boatmen and support staff are also required. Fewer men means saving of money other wise spent which form a substantial part of total expenditure. We do not pretend to have an answer but suggest that a dozen or so labourers and at most 2 assistants are likely to be adequate. In a year or so time we would like to think that we could have a more factual basis for this sort of argument.

In summarising we would like to emphasis the following points:-

1. The need for up-to-date photography at round the scale 1:50,000 and Printlaydowns assembled from that photography.
2. Any method using systematic airphoto interpretation requires considerable preparation and coordination and a legend must be established prior to the commencement of fieldwork.

3. A preliminary reconnaissance is vital particularly where surveyors are strangers to the country and it cannot be considered time wasted.

4. The function of assistants in reconnaissance soil surveys are limited to logistics, unless they be considered as counterparts or on-the-job students. Their training for routine sampling is more suited to detailed surveys for projects.

5. Substantial savings on the labour costs might be made and channelled into photography or other items that may be looked on as luxuries.

CHARACTERISTICS OF SOME SOILS DERIVED FROM
IGNEOUS ROCKS OF WEST MALAYSIA

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INTRODUCTION

A wide range of soils derived from igneous rocks has been mapped in West Malaysia during the Schematic Reconnaissance Soil Survey. As this survey is now completed, this is an opportune time to take stock of the various soils mapped and correlate field observations with laboratory data. This paper attempts to compare some field properties like colour, degree of horizonation and texture with analytical data. It also examines the role of the parent material in influencing the chemical characteristics of the soil developed on it.

The igneous rocks mapped in West Malaysia comprise of extrusive and intrusive rocks. Both these suites of rocks can further be sub-divided into acid, intermediate and basic rocks.

A. PHYSICAL CHARACTERISTICS

Soils Derived From Extrusive Igneous Rocks

A number of extrusive igneous rocks have been mapped in West Malaysia - they include basalts, andesites, tuffs, dacites and rhyollites. Six different soils have been mapped on these various rocks.

Kuantan Series

This soil, developed on basaltic parent materials occurs on rolling to hilly terrain and is characterized by indistinct horizonation. The soil has uniform reddish brown colours and clayey textures. This deep soil exhibits strong fine crumb structure and friable consistence. The occurrence of massive or closely packed lateritic nodules at depths of five feet or more is not uncommon.

Segamat Series

Derived from andesitic parent materials, the Segamat Series has been mapped on rolling to hilly terrain. This soil also shows indistinct horizonation and clayey textures but has yellowish red colours. It exhibits a strong medium subangular blocky structure and friable consistence which may become firm at depth. Laterite when present occurs as a narrow band of nodules at depths greater than four feet.

Katong Series

Soils of the Katong Series are developed over quartz andesites on rolling and hilly terrain. They have a fairly distinct Ae/Bt horizonation. The colours are yellower - yellowish brown to strong brown and textures more silty than those of the Segamat Series. Structures are moderate medium subangular blocky and consistence friable.

Jempol Series

This soil, developed from agglomerates, andesitic tuffs and tuffaceous shales, has a fairly distinct Ae/Bt horizonation. The textures are variable though silty clay loams are common and the colours reddish brown to yellowish red. Consistence becomes firm with depth and the structures are weakly developed. Lateritic nodules are common as a narrow band at depths of three feet.

Yong Peng Series

The Yong Peng Series, mapped on undulating and steep terrain is derived from dacitic parent material. It is characterized by fairly distinct horizonation, reddish to yellowish red colours and clay loam textures. The structures are moderately developed subangular blocky and consistence friable to firm. A narrow band of lateritic nodules is not uncommon at depths of three feet.

Kulai Series

This soil, developed from a mixture of rhyolitic and volcanic tuffs, is found on hilly terrain. The Kulai Series has fairly distinct horizonation and clayey textures. The colours are yellowish brown to yellow and structures moderately developed and consistence firm. The occurrence of lateritic nodules or

laterised parent material is not uncommon in this soil.

Soils Derived From Intrusive Igneous Rocks

Intrusive igneous rocks are more widespread than extrusive rocks in West Malaysia. These include gabbros, norites, diorites, granodiorites and granites. Of the many soils derived from these rocks only two soils are widespread - the Rengam and Jerangau Series.

Senai Series

Soils of the Senai Series, developed on rocks of gabbroic or noritic composition, occur on rolling to hilly terrain. They are rather shallow, lateritic soils - the shallowness of which is often emphasised by erosion. These soils are characterized by indistinct horizonation, uniform silty clay to clay textures and yellowish red colours. The structures are strong fine crumbs and consistence friable. The lateritic nodules occur at depths of two feet though deeper phases of this soil without any lateritic to depths of four feet have also been encountered.

Kampong Kolam Series

Developed from quartz diorites, soils of the Kampong Kolam Series occur on rolling to hilly terrain. It is commonly associated with soils of the Jerangau and Rengam Series. Horizonation is weakly distinct and subsoil colours yellowish red to reddish brown. Textures are clay loams though occasionally quartz grits may also be present. Structures are strong medium subangular blocky and consistence, which is friable, becomes firmer with depth.

Jerangau Series

Mapped on undulating to hilly terrain, the Jerangau Series is developed on granodioritic parent materials. They resemble soils of the Rengam Series but have finer textures and stronger colours. Horizonation is a fairly distinct Ae/Bt. The textures are fine sandy clay loams with strong brown colours. Structures are less well developed and the friable consistence becomes firmer with depth.

Rengam Series

The Rengam Series is the most widespread soil mapped on igneous rocks and is developed on granitic parent material on undulating terrain. This soil is characterized by a fairly pronounced Ae/Bt horizonation, sandy clay loam or coarse sandy clay loam textures and brownish yellow colours. The colours become stronger with depth. These deep soils have weakly developed structures and friable consistence but becomes firm with depth.

Kala Series

On hilly and steep terrain where porphyritic granites occur the Kala Series has been located. This is a comparatively shallow soil but deeper phases often transitional to the Rengam Series occur on gentler slopes. The peculiar feature of this soil is the occurrence of resistant phenocrysts of microcline and orthoclase feldspars in the parent material. Horizonation is weakly distinct and colours are brownish yellow to strong brown and textures coarse sandy clay loams. Structures are weakly developed and consistence firm.

Tampin Series

Soils of the Tampin Series, developed on very acid granites have been mapped in association with the Rengam Series on undulating to rolling terrain but tends to occupy the lower slope position to the Rengam Series. It has a fairly distinct Ae/Bt horizonation and sandy clay textures. Colours range from pale brown to olive yellow, consistence becomes firm with depth and structures are weak.

Table 1

Physical Characteristics of Soils
Derived from Igneous
Rocks

Rock	Soil Series	Colour	Texture	Consistence	Development of Structure	Clayskin	Horizonation
Basic	Kuantan	Reddish Brown	c	mfr	strong	weak	indistinct
	Senai	Yellowish Red	sic	mfr	strong	weak	indistinct
Inter-mediate	Segamat	Yellowish Red	c	mfr	strong-moderate	weak	indistinct
	Katong	Yellowish Brown - strong brown	sic	mfr	moderate	moderate	fairly distinct Ae/Bt
	Jempol	Reddish brown - yellowish red	sicl	mfr	weak	moderate	fairly distinct Ae/Bt
	Kg.Kolam	Yellowish red - reddish brown	cl	mfr	strong	moderate	weakly distinct
Acid	Yong Peng	Red - strong brown	cl	mfr-mfl	moderate	moderate	fairly distinct Ae/Bt
	Jerangau	Strong brown	fscl	mfr-mfl	moderately weak	moderate	fairly distinct Ae/Bt
	Kulai	Yellowish brown - yellow	c	mfl	moderate	moderate	fairly distinct Ae/Bt
	Rengan	Yellowish brown	cscl-scl	mfr-mfl	weak	moderate	fairly distinct Ae/Bt
	Kala	Brownish yellow - strong brown	cscl	mfl	weak	moderate	weakly distinct
	Tampin	Pale brown - olive yellow	sc	mfr-mfl	weak	moderate	fairly distinct Ae/Bt

B. LABORATORY DATA

In West Malaysia, where the climate is relatively uniform and the weathering intense, the parent material has been found to play a dominant role in profile development although chemically the intense weathering has narrowed differences amongst them. According to Ng (1966) five criteria are most useful in differentiating Malayan soils viz.,

- (i) Clay Content in relation to movement
- (ii) Iron - 6N HCl Extractable
- (iii) Nutrients - 6N HCl Extractable
- (iv) Cation Exchange Capacity
- (v) Clay Mineralogy

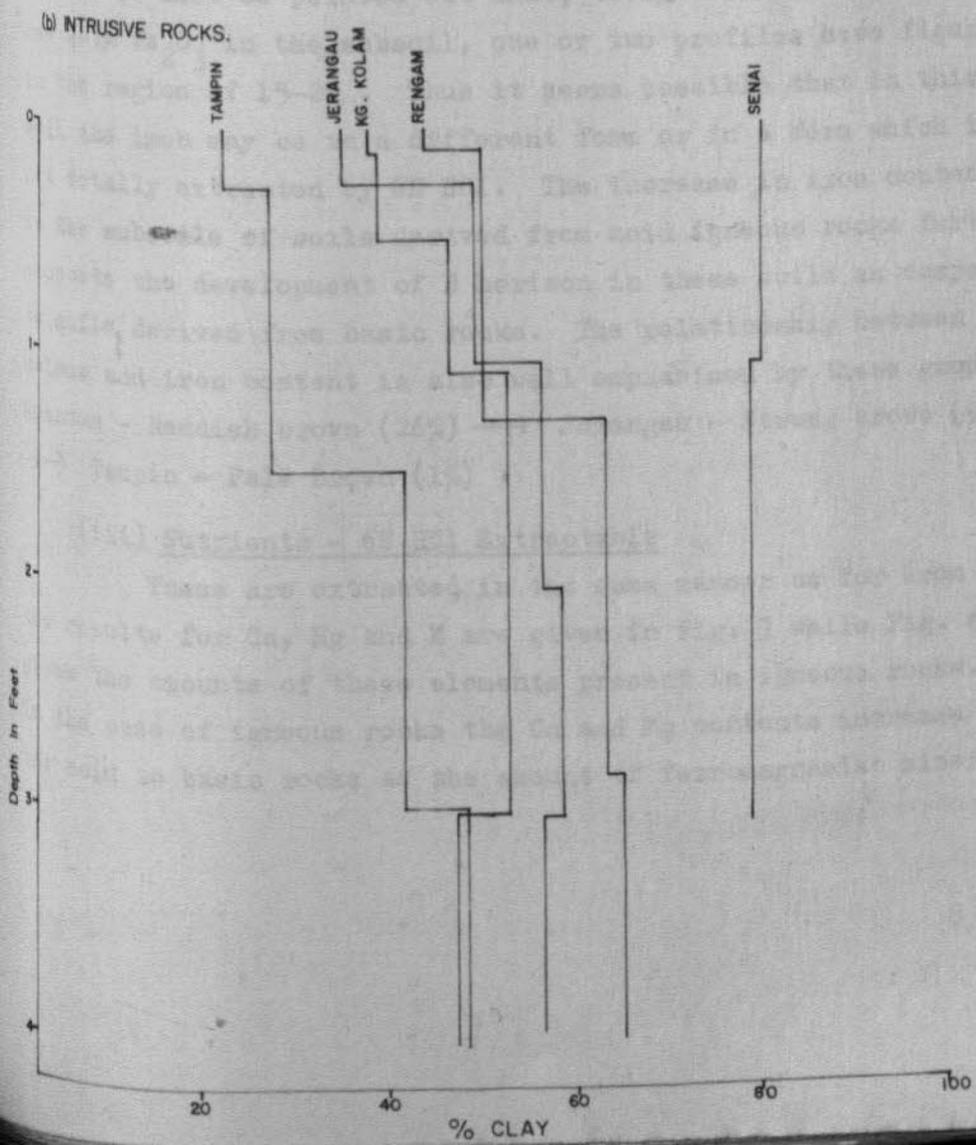
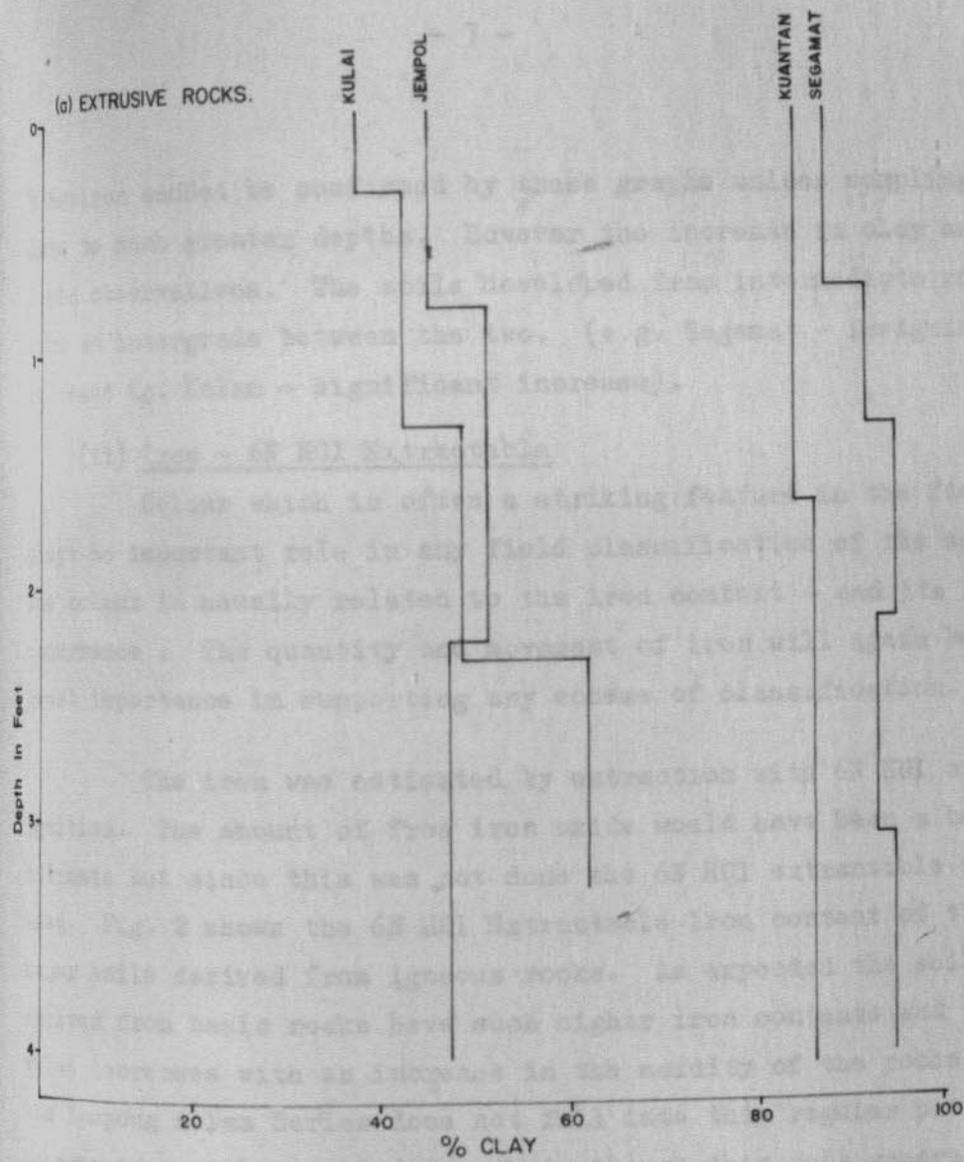
(i) Clay Content

Texture is an important criterion used by soil surveyors to determine the degree of horizon development in a profile. At the higher levels of classification the presence or absence of a diagnostic horizon in a soil determines the Great Soil Group into which it is placed. Field assessment of texture must be supported by laboratory determinations. The movement of clay down a profile and subsequent deposition causes the development of a textural B horizon. The clay content of the common soils derived from igneous rocks is shown on Fig.1.

These graphs show that soils derived from basic and intermediate rocks (e.g. Kuantan, Segamat, Senai) have high clay contents, while soils derived from acid rocks have lower clay contents. Comparing two soils derived from chemically equivalent rocks e.g. Kuantan-Senai; Kampong Kolam-Segamat; it can be seen that the soils derived from the finer grained extrusive rocks have higher clay contents than those derived from the coarse grained igneous rocks.

The degree of horizon development is poor in soils derived from basic igneous rocks (e.g. Kuantan, Senai), while in soils derived from acid igneous rocks (e.g. Rengam, Tampin, Kulai), there is a significant increase in the clay content in the subsoils. Whether this increase indicates the development of a textural is

FIG. 1 CLAY PROFILES OF SOILS DERIVED FROM IGNEOUS ROCKS.
 (Modified from S. K. Ng 1966)



B horizon cannot be confirmed by these graphs unless sampling is done to much greater depths. However the increase in clay supports field observations. The soils developed from intermediate rocks form an intergrade between the two. (e.g. Segamat - insignificant increase Kg. Kolam - significant increase).

(ii) Iron - 6N HCl Extractable

Colour which is often a striking feature in the field plays an important role in any field classification of the soils. The colour is usually related to the iron content - and its mode of occurrence. The quantity and movement of iron will again be of great importance in supporting any scheme of classification.

The iron was estimated by extraction with 6N HCl after ignition. The amount of free iron oxide would have been a better estimate but since this was not done the 6N HCl extractable was used. Fig. 2 shows the 6N HCl Extractable Iron content of the major soils derived from igneous rocks. As expected the soils derived from basic rocks have much higher iron contents and the value decreases with an increase in the acidity of the rocks. The Kampong Kolam Series does not fall into this regular pattern. However it must be pointed out that, though this soil generally has 4-7% Fe_2O_3 in the subsoil, one or two profiles have figures in the region of 15-20%. Thus it seems possible that in this soil the iron may be in a different form or in a form which is not totally extracted by 6N HCl. The increase in iron content in the subsoils of soils derived from acid igneous rocks further supports the development of B horizon in these soils as compared to soils derived from basic rocks. The relationship between colour and iron content is also well emphasised by these graphs -
Kuantan - Reddish brown (26%) → Jerangau - Strong brown (9%)
→ Tampin - Pale Brown (1%)

(iii) Nutrients - 6N HCl Extractable

These are extracted in the same manner as for iron and the results for Ca, Mg and K are given in Fig. 3 while Fig. 4 gives the amounts of these elements present in igneous rocks. In the case of igneous rocks the Ca and Mg contents increase from the acid to basic rocks as the amount of ferromagnesian minerals

Depth In Feet

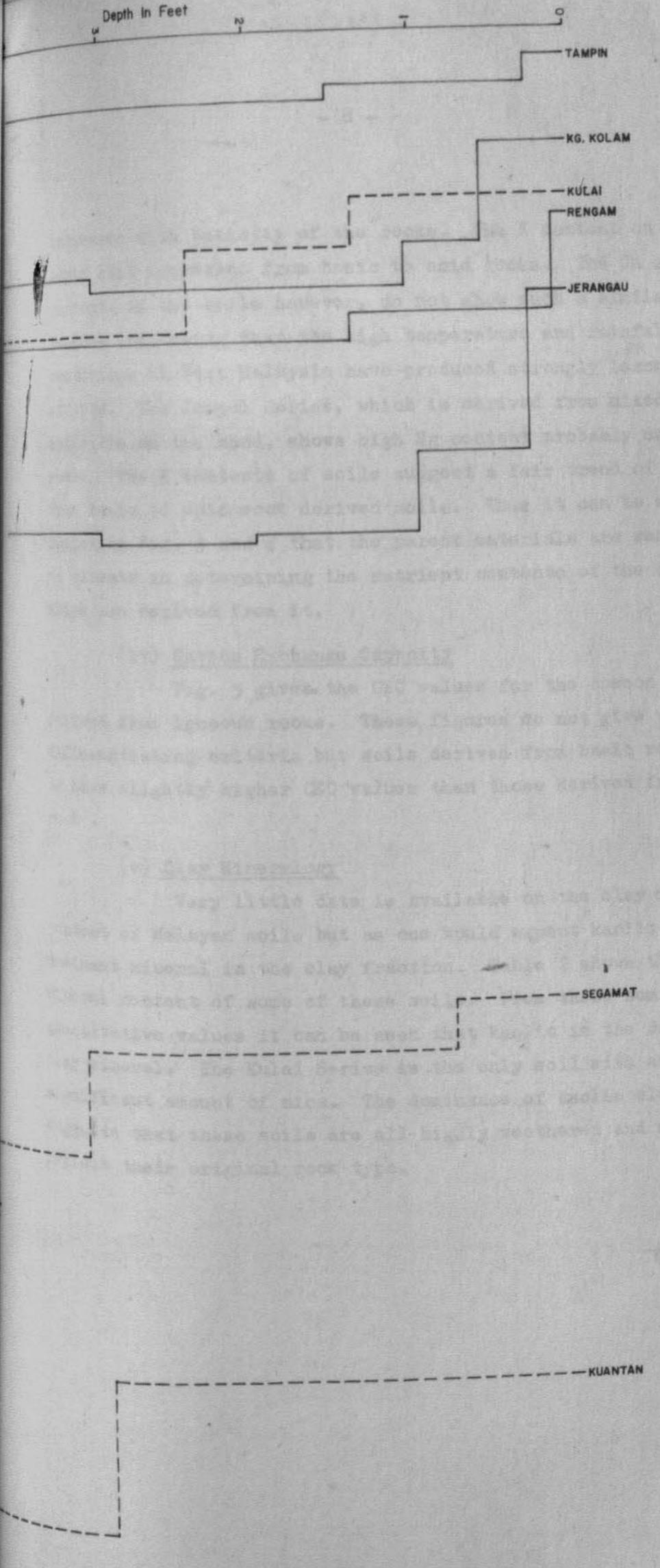


FIG. 2. 6N-HCl EXTRACTABLE Fe₂O₃ (Modified from S.K. Ng 1966)

increases with basicity of the rocks. The K content on the other hand increases from basic to acid rocks. The Ca and Mg contents of the soils however, do not show such a similar trend - indicating that the high temperature and rainfall conditions in West Malaysia have produced strongly leaching effects. The Jempol Series, which is derived from mixed parent materials on the hand, shows high Mg content probably due to the shale. The K contents of soils suggest a fair trend of increase from basic to acid rock derived soils. Thus it can be seen by comparing Fig. 3 and 4 that the parent materials are secondary to climate in determining the nutrient contents of the soils which are derived from it.

(iv) Cation Exchange Capacity

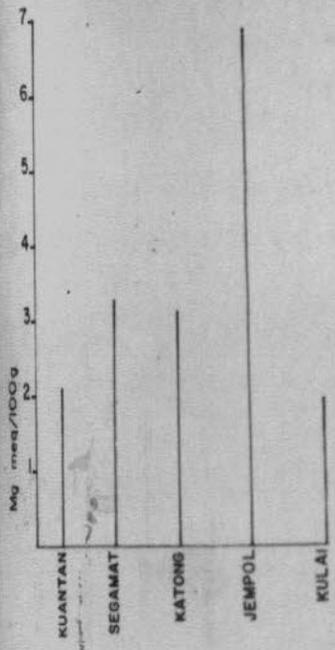
Fig. 5 gives the CEC values for the common soils derived from igneous rocks. These figures do not give very good differentiating criteria but soils derived from basic rocks tend to have slightly higher CEC values than those derived from acid rocks.

(v) Clay Mineralogy

Very little data is available on the clay mineral content of Malayan soils but as one would expect kaolin is the dominant mineral in the clay fraction. Table 2 shows the clay mineral content of some of these soils. From these semi-quantitative values it can be seen that kaolin is the dominant clay mineral. The Kulai Series is the only soil with any significant amount of mica. The dominance of kaolin clearly suggests that these soils are all highly weathered and no longer reflect their original rock type.

FIG. 3. TOTAL NUTRIENT CONTENTS IN SUBSOILS.

EXTRUSIVES



INTRUSIVES

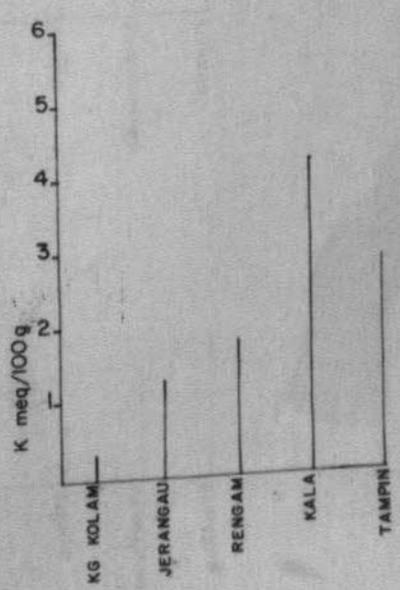
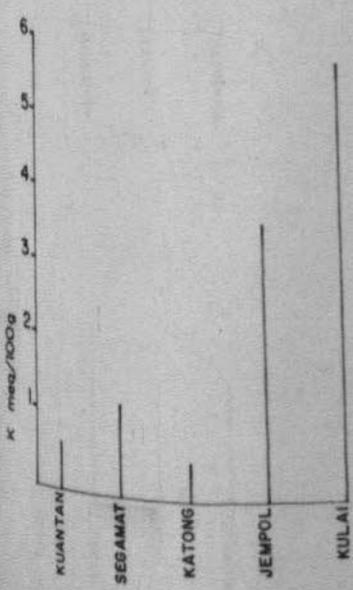
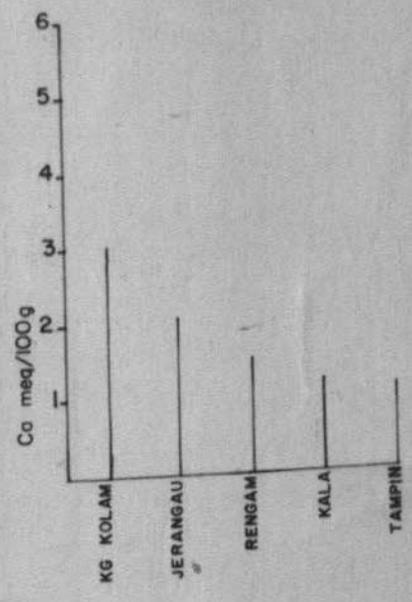
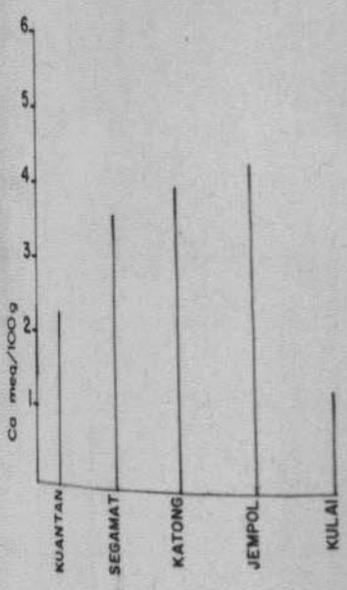
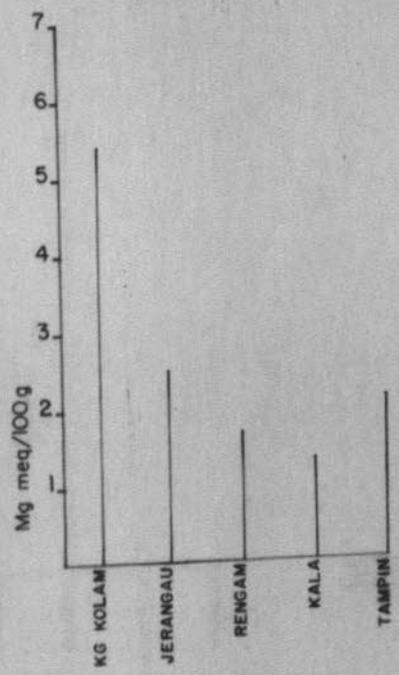


FIG. 4. MEAN ELEMENT CONTENTS OF SOME IGNEOUS ROCKS.
 (Based on Alexander et al. 1964)

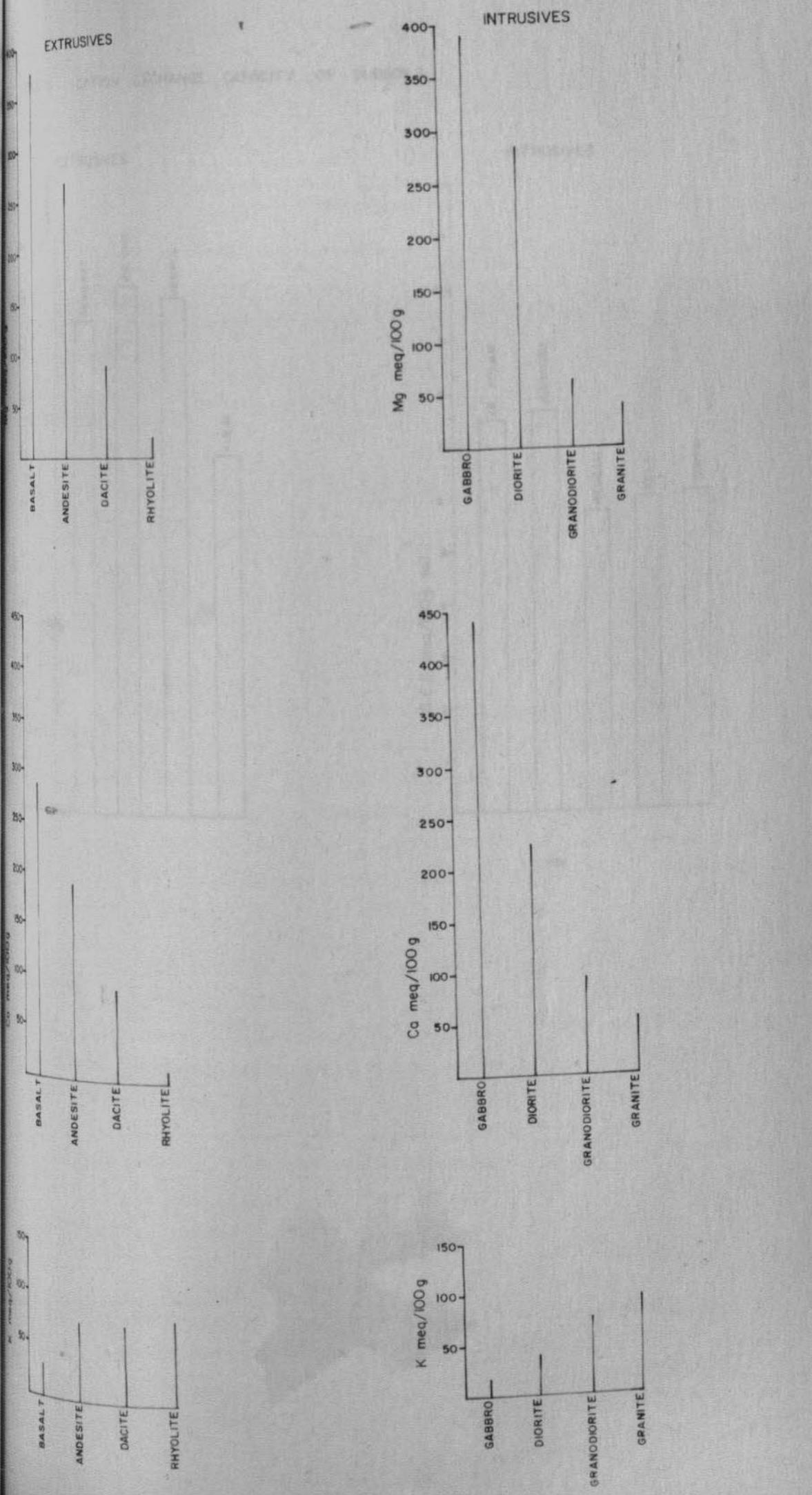


FIG. 5. CATION EXCHANGE CAPACITY OF SUBSOILS.

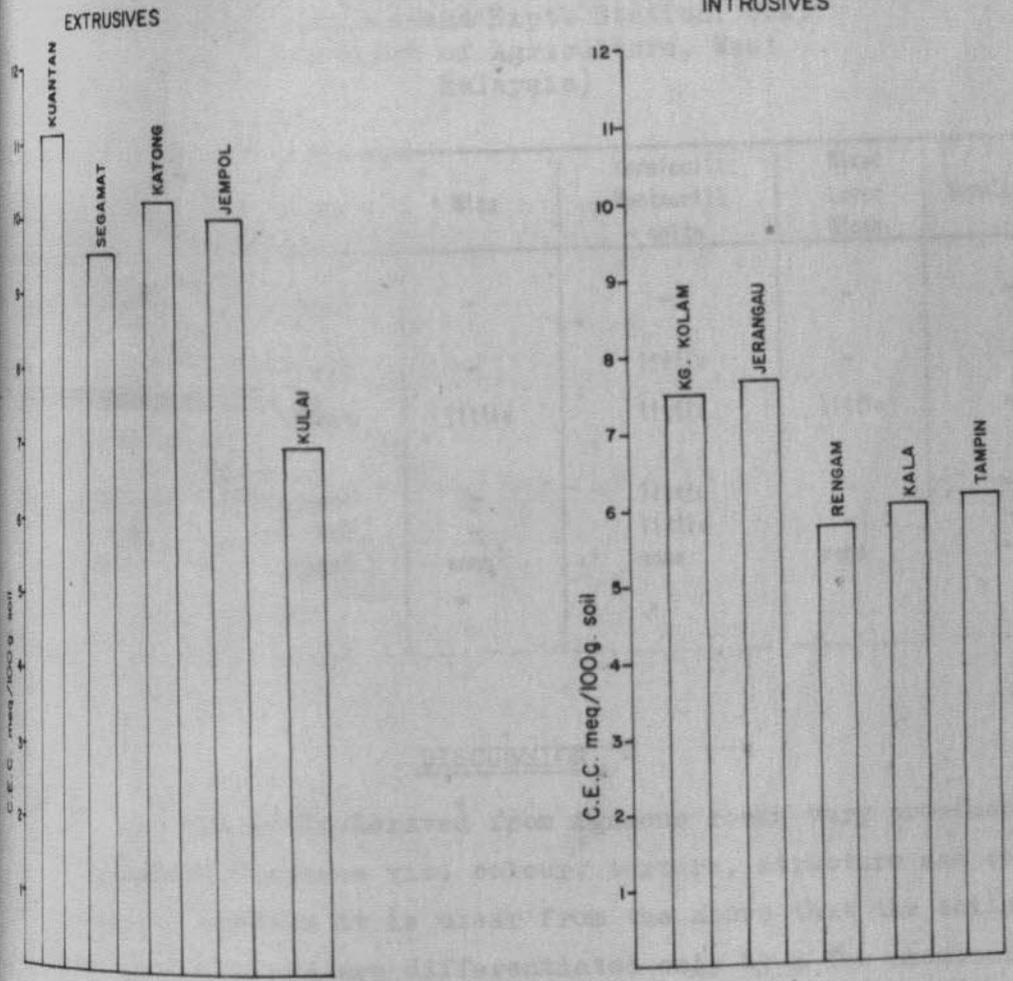


Table 2

X-ray Analysis of Clay Fractions of Some
Soils Derived from Igneous Rocks

(Unpublished results of analysis carried out by Rothamstead Expt. Station, U.K. for Department of Agriculture, West Malaysia)

Rock	Soil Series	Kaolin	Mica	Vermiculite - Montmorill - onite	Mixed Layer Micas	Vermiculite
Basic	Kuantan	dominant	-	-	-	-
Inter- mediate	Segamat	dominant	-	little	-	-
	Kampong) Kolam)	dominant	little	little	little	-
Acid	Jerangau	dominant	-	little	-	-
	Rengam	dominant	-	little	-	-
	Kuala	dominant	much	some	some	-

DISCUSSION

The soils derived from igneous rocks vary prominently in some profile features viz. colour, texture, structure and consistence. However it is clear from the above that the soils derived from igneous rocks are differentiated only by a few chemical criteria. The important are clay and iron contents. These two factors correspond in most cases very well with field observations and thus are good criteria for classification.

The results suggest that the scheme of classification proposed by Leamy (1966) need re-examination in respect of some soil families. The Kampong Kolam and Jempol Families which include the Kampong Kolam, Jerangau, Jempol and Katong Series have been classified as oxisols. The clay and iron content figures for these soils show a fairly good development of a B horizon and thus they seem to be closer to the ultisols than the oxisols. Probably they form an intergrade between these two Great Soil Groups.

The 6N HCl Extractable Iron is a useful indicator for inherent Fe content of soils derived from rocks rich in iron but has limitations in confirming iron movement in profiles of soils

derived from very acid granites of low iron content. Thus the Tampin Series which shows a good development of a B horizon with clay figures does not show this with the iron figures.

In conclusion it can be said that the soils derived from igneous rocks vary fairly widely in profile characteristics and some of these differences are corroborated by a few laboratory criteria. There is a need, however, to develop better correlation between field observations and laboratory analysis but present techniques appear adequate on a broad basis.

ACKNOWLEDGEMENTS

The writer wishes to record his sincere appreciation to the soil correlator, Enche Law Wei Min for his valuable advice and comments. The writer is also indebted to Enche Yap Keng Kong, Laboratory Assistant, for carrying out the chemical analyses especially the 6N HCl Extracts.

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Kuala Lumpur,
25th April, 1968.

A study of the environment and characteristics of
Podsols occurring in the Tropical lowland of Sarawak (spodosol, 7th Approx).
(East Malaysia) *

by

J. P. Andriesse.

Summary

A study of the environment, profiles and analytical data of humus podsols occurring in the humid tropical lowlands of Sarawak confirms that the soils are morphologically similar to those developing in temperate regions. Causes for the development are not however, identical. These are for Sarawak related mainly to kind of parent material and topography. Organic surface horizons develop because of the low decomposition rate due to wet, poorly drained conditions combined with the occurrence of acid, highly lignitic litter, poor in bases. The podsolization process is similar to that found in temperate regions but does not need to include an 'initiation' process. The position of illuvial humus horizons is in many cases related to the bisequent nature of the parent materials and, in the absence of this, to the ground water level, while the causes for the accumulation of humus in these horizons are: lack of lateral flow of ground water to drain off water rich in humic materials and periodically drying out of surface horizons mainly through evaporation.

Introduction

That podsols occur at low altitudes in the tropics is a well established fact. Following discoveries in the Indonesia Archipelago by Hardon (1937) and Richards (1941) many such occurrences have been reported in the last twenty years. In a recent paper Klinge (1965) summarizes much of the present knowledge on these soils but it appears that although much information has been accumulated on the occurrences of podsols in tropical lowlands not many detailed studies have been carried out. Those published are mainly studies of single profiles or occurrences and it is difficult to estimate the relevance of the information outside the sites studied.

Although it is possible to arrive at some general conclusions by comparing the data available from many widely-scattered tropical countries there still remain many unsolved questions regarding the origin of podsols in tropical areas.

* The contents of this paper will be published elsewhere. Until formal publication reference to this paper should be made as: private communication.

This paper deals with studies which were particularly made to provide an overall picture of the environmental conditions and the characteristics of humus podsols (hereafter called podsols) occurring in Sarawak, the north western part of Borneo from which the earlier now classic discoveries were reported by Hardon and Richards (op cit.).

These studies involved the collecting of data obtained on podsols during a 7 years routine surveying period, and the extracting of salient factors involved in the genesis of these soils, the following up by detailed investigations in selected areas to confirm certain indications drawn from the earlier observations and the processing of analytical data from profiles, carefully selected with a view to establish the norm rather than the exception.

Environmental conditions

(1) Climate

Characteristic features are a heavy rainfall, a comparatively uniform high temperature (average daily temperature 25.5°C) and high humidity (84% daily average). Mean annual rainfall is between 2,500 and 5,000 mm, fairly well distributed, with no single month in any locality where the rainfall is below 100 mm. Thus, according to Mohr's rainfall classification the climate is 'continuously wet', (Mohr, 1944).

(2) Altitude

Although podsols do occur above an altitude of 1,000m, in order to omit possible effects from climatic variations in the development of podsols at different altitudes only those occurring below 330m have been studied. The latter are found at all heights from sea level to 330 meter.

(3) Parent materials

These can be divided into two distinct groups:-

- (a) Material of alluvial origin - old (mainly Pleistocene) terrace deposits (both riverine and marine).
- (b) Material of sedentary origin - sandstones and conglomerates (mainly of Tertiary age).

The first group of materials commonly consists of alternating layers of quartz sand and quartz gravel frequently interlayered with sandy clays. Mineralogical analyses show that the source of these terrace materials can in many places be traced to Tertiary sandstone and conglomerates and the parent materials of alluvial origin can, therefore, be regarded as very similar to parent materials of sedentary origin, but even more impoverished.

Alluvial parent material

The terrace materials are extremely poor in bases and sesquioxides (particularly iron) and consist largely of crystalline quartz; the clays also consist mainly of quartz with subordinate micas, kaolinite (fire clays) and illite. The heavy mineral association of the sand fraction invariably shows concentrations of zircon, tourmaline and titaniferous minerals in which rutile is dominant, followed by anatase and brookite. The content of opaque minerals is usually high (more than 60%) and ilmenite is dominant, although leucoxene and various intergrades between ilmenite and non-opaque titaniferous minerals are commonly also present.

The thickness of the alluvial deposits varies but is generally greater in marine than in riverine deposits. Gravel beds are uncommon in the former, which generally consists of alternating sands and clays. In the case of riverine deposits in which gravel and boulder beds commonly occur layers of contrasting texture frequently alternate within a range of as little as 5 feet, while in the marine deposits individual layers may reach a thickness of more than 20 feet.

The heavy mineral associations of parent materials of humus podsoles is distinctly different from those found in material on which iron podsoles form. The latter only occur on specific parent materials. Profile 4 (see Diagram 3) illustrates that a significant difference is the high concentration of hornblende in the parent material of the iron podsol which presumably forms the source of the iron oxides which following weathering of the hornblende are released. Iron podsoles being of very minor importance in Sarawak are further not considered in this study.

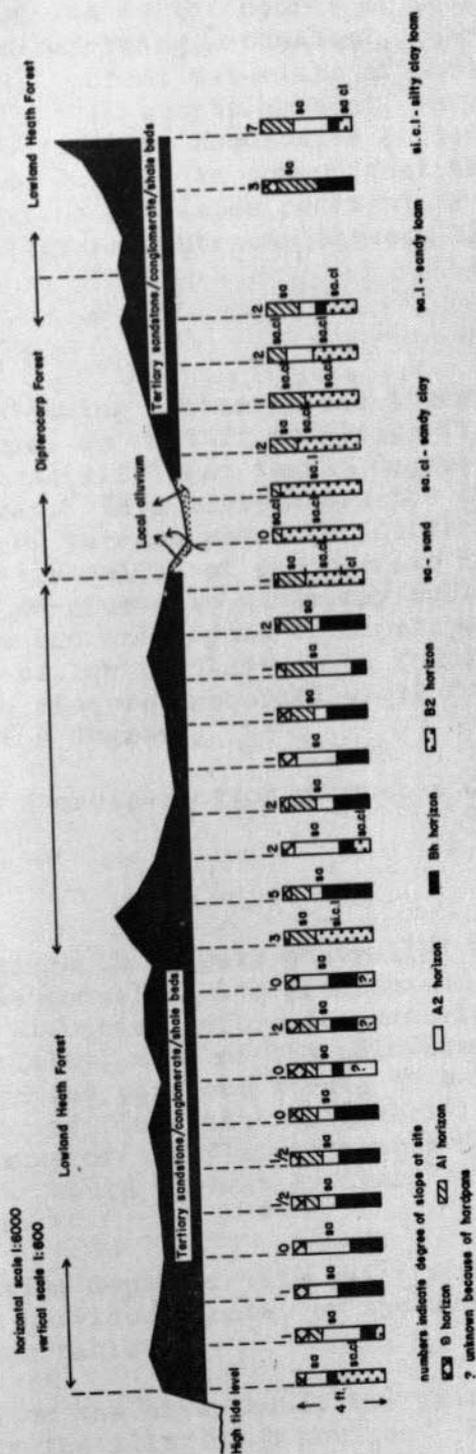
Sedentary parent material

The sandstones are generally coarse to medium-textured and highly quartzitic as is the case with the conglomerates. In certain areas the sandstones may have as the only weatherable mineral a moderate content of orthoclase but since Red-Yellow Podsollic soils and Podsoles occur in association on these sandstones and deposits with and without orthoclase occur likewise, the fact whether the parent materials of the podsoles do or do not contain orthoclase cannot be established.

Heavy mineral associations are very similar to those found in the terrace materials. At low levels it is frequently very difficult to distinguish between terrace deposits and Tertiary sediments and particularly so when the terrace morphology has been disturbed by erosion and/or the Tertiary rocks in the area are known to be poorly consolidated.

Alternating beds of sandstone, conglomerates and clay/silt deposits generally appear to be considerably less thick than those generally found in the terrace materials.

FIGURE 1
 CROSSSECTION OF DIPSLOPE AREA UNDERLAIN BY TERTIARY POORLY CONSOLIDATED SEDIMENTS



Although, according to Jenny (1941, p.54) ' the exact evaluation of the composition of the parent material involves considerable speculation and is the source of much uncertainty in the investigation of soil-forming processes', there can be little doubt that in Sarawak all parent materials of podsoils are essentially characterised by a high total quartz content, very low weatherable mineral content, low to very low sesquioxide content and a very low clay content. They have further in common that they are either unconsolidated or poorly consolidated sedimentary materials which show generally strong texture contrasts between the different strata.

(4) Topography

The most outstanding factor in the topography of land on which podsoils have formed is that it is always flat or very gently sloping. Slopes are generally less than 5 degrees, particularly on summit areas of terraces. Invariably where the slope steepens, as on dissected portions of terrace remnants, different soil types are found. Commonly the microrelief of the terrain is hummocky showing low undulations where surplus rain water may collect. Podsoils on consolidated sediments are only found on dipslope areas with very gentle slopes. The same low undulations as found on the terrace sites occur here. The steepest recorded slope for such areas where podsoils have formed is 8 degrees.

Fig. 1 shows a cross-section of such a dipslope area.

(5) Drainage

Present drainage is largely controlled by duripans which have formed during the podsolization process and does not therefore reflect the drainage situation before the podsoils formed. It is considered that, initially, most of the rainwater was able to percolate quickly through the pervious strata it being slowed down only by either a layer of fine textured material or by groundwater. Run-off was slow because of the flat to almost flat topography, and most surplus rainwater would ultimately drain off laterally over a subsurface clay layer.

The penetration depth of this water would be dependent on the thickness of the pervious strata, or the distance to a regular or perched groundwater table.

At present, on the other hand, the penetration depth is largely influenced by the illuvial B horizon. Where a hardpan occurs the water will not percolate deeper than the pan and if the slope is sufficient, flows off laterally over it. Perched watertables form in times of high rainfall on such pans and the soils are saturated up to the surface, resulting in stagnant water on flat areas and an increase in the run-off rate on sloping land. In the case of soft illuvial horizons the percolation rate is only slowed down and although saturation may occur the situation is never so extremely wet as is the case when hardpans exist. The connection between slope, drainage and soil texture is, therefore, an important one and will be discussed later.

(6) Vegetation

All natural vegetation on podsoles is characterised by Lowland Heath Forest (locally called 'Kerangas') which on air photographs shows a dense, even to slightly uneven, canopy with generally indistinguishable small crowns.

The number of species in this forest type can be considerable and there is wide local variation, depending much on drainage. There is, on the other hand, very little variation between the vegetation found on podsoles developed in terrace materials and on those occurring on Tertiary sedimentary rocks. Brunig (1963) referring to a specific area, which is however, typical for this type of forest, records the following species:-

Ground vegetation

<i>Eugeissonia insignis</i>	-	on better drained places
<i>Eugeissonia minor</i>	-	throughout
<i>Pinanga</i> spp.	-	scattered, locally common
<i>Licuala bidentata</i>	-	" " "
<i>Teymanniana altifrons</i>	-	on better drained sites.

Common other species are:- *Tristania* spp., *Whiteodendron moultonianum*, *Palaquium* spp., *Payena* spp., *Cratoxylon glaucum*, *Melanorrhoea* spp., *Ploiarium alternifolium*, *Calophyllum* spp., *Xylocarpus borneensis*, Lauraceae, *Hopea* spp., *Parastemon spicata*, *Xantophyllum* spp., *Linthocarpus* spp., *Garcinia* spp., *Ternstroemia* spp., Euphorbiaceae, *Aetoxylon sympetalum*, *Kokoona ovato-lanceolate*, *Pseudosindora leiocarpa*.

Other reports also mention: *Casuarina sumatrana* which like *Whiteodendron moultonianum*, tends to become dense when areas within or near its natural range are disturbed. Lowland Heath Forest areas when disturbed through fire or cultivation, frequently develop into open parkland in which *Casuarina sumatrana* and *Whiteodendron* are dominant, the ground cover consisting mainly of sedges, mosses, pitcher plants and orchids (Wall, p.95) much like the 'padang' vegetation described by Hardon (1937).

PROFILE CHARACTERISTICS

All podsoles under natural vegetation have dark brown thick organic surface horizons. The acid, highly lignitic, coarse organic debris decomposes extremely slowly and where poor drainage conditions prevail thick peaty surface horizons are formed.

Most feeding roots of the ground vegetation are in this horizon which is virtually the only one containing any plant food.

The A1 horizon is usually well developed and is of a dark brownish grey colour. The total carbon content is high. The mineral part of this horizon is formed mainly by coarse sand grains with very little cohesion with the organic matter.

After clearing and removal of the O horizon by burning, the organic matter in the top part of this horizon oxidizes rapidly. A very loose, white coloured surface horizon 1 to 2 inches in thickness is formed which overlies a more normally coloured A1 horizon. The lower boundary of the A1 horizon usually forms the lower limit of the feeding roots, and this reflects the general absence of bases beyond that depth.

The eluvial A2 horizon is very well developed and if very porous sand forms the parent material it can be as thick as 9 feet. Such horizons are found in marine terraces on homogenous sand deposits. More commonly the A2 horizon is of a medium sand texture and 6 to 18 inches thick.

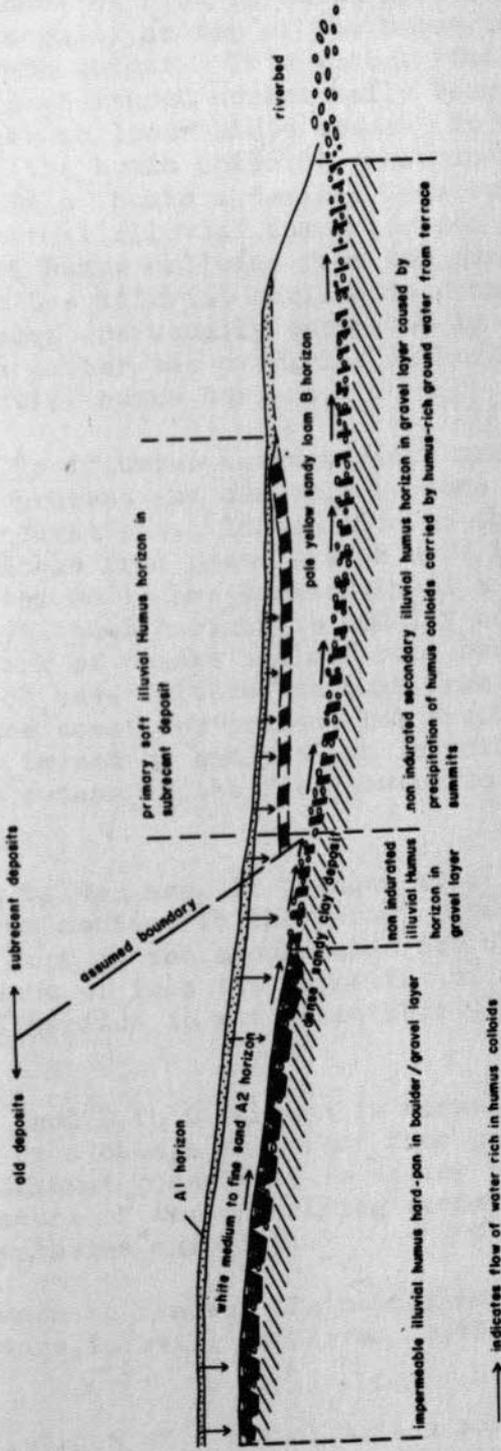
Fragipans usually form in the A2 horizon, the consistency of which is then very hard when dry. The occurrence of such pans is usually related to a high content of quartz silt in the A2 horizon which is thought to be formed by physical weathering of larger quartz particles. Actual cementation does not seem to occur and in wet condition the densely packed horizon flows out of the profile face when exposed in a pit.

Under natural vegetation this horizon is usually weakly mottled brown due to humus staining of the sand particles; under secondary jungle, with a thin O horizon, not much staining is found and the horizon is usually pinkish white in colour.

The boundary with the underlying illuvial humus horizon is commonly very abrupt but frequently a 1 inch-thick transitional horizon is present. This presumably indicates the flushing down of humic colloids over an uninterrupted front through the A2 and their subsequent deposition on top of the illuvial humus horizon which is thus growing upwards.

The nature of the illuvial humus-horizon varies considerably and its condition is related to stage in profile development, parent material, topography and drainage. It can be soft to very hard and cemented (a duripan). Because of the extreme hardness of many such pans their thickness cannot be easily assessed, since only with explosives they can be broken up. The maximum reported depth is 2 feet 6 inches. The horizon is usually more strongly developed (i.e. is thicker and harder) on flat-lying terrace summits than on sloping land such as found in terrain underlain by Tertiary consolidated sediments. The highest points of the terraces are usually places where the most strongly cemented pans form. If layers with a strong texture contrast occur in the profile (or at least where they have been seen within a depth of 5 feet) the horizon usually forms in a coarse-textured layer overlying a finer-textured layer. In extreme cases pans form in gravel and boulder beds where they overlie dense clays. In deep homogenous coarse-textured material, on the other hand, the lower boundary of the horizon frequently coincides with the highest watertable level or slightly above it. Because of the very low watertable levels in old marine terraces, where such conditions exist, the illuvial humus horizon is in many cases beyond the normal profile depth and a proper study of it is difficult.

Fig. 2
 CROSS-SECTION OF PLEISTOCENE TERRACE SHOWING
 DEVELOPMENT OF SECONDARY ILLUVIAL HUMUS HORIZON
 IN FOOT-SLOPE AREA.



Secondary illuvial humus horizons may form if certain conditions are met. This is illustrated in Figure 2 which shows a situation in which groundwater rich in humus colloids is apparently flowing off laterally on top of the humus hardpan, the latter formed on the terrace summit. This water, finding its way through pervious coarse-textured horizontally bedded strata, brings down humic materials to lower slope areas. In dry periods when these layers dry out the humic colloids precipitate and coat the soil particles. (a film of humic materials develops around boulders and gravel) A normal illuvial humus horizon formed by vertical transportation of humus colloids from the surface horizon and subsequent lodging in the illuvial horizon is found above the secondary one. The horizons are usually separated by a B2 horizon which is more clayey than either the overlying A2 horizon or the underlying secondary illuvial humus horizon.

Horizons below the illuvial humus horizon are difficult to study if hardpans are present and can only be done in either road cuttings or other excavations. Information on these horizons is therefore mainly available from podsoils with soft illuvial humus horizons. The latter soils are dominantly of a residual nature. The lower part of the B horizon is usually of a pale yellow colour with a dense network of cracks and old root channels filled with humic materials which have filtered through from the Bh. Illuvial clay coatings are sometimes present but frequently this part of the B horizon is formed by sandy clays in which it is difficult to distinguish cutans in the field owing to the dense packing of the material.

Mottles of iron oxides are, if present at all, weakly expressed because the iron content in the parent materials is very low. They tend to form in and around old root channels. Because of the near-absence of iron the formation of an illuvial Bir horizon under the Bh horizon is not detectable either in the field or in analyses.

The transition from B to C horizon is normally indistinct and usually marked only by a change in colour from pale yellow to almost white. In the residual podsoils it is easier to recognise since the original structure of the underlying sandstone is often well-preserved in the weathered material.

It is not uncommon to find on flatbedded sandstone podsoils in which the rock structure is still preserved in the illuvial humus horizon.

Detailed descriptions of a podsol with a soft humus pan on terrace material and of a podsol with a medium hardpan on Tertiary sediments are found in the appendix. A third profile description is added for comparison, this being a typical Grey-White Podsollic soils (Soil Survey Staff, Sarawak, 1966) derived from carbonaceous shale. The parent material of this soil type is as poor in bases, iron and weatherable minerals as the parent materials of the podsoils. The basic difference is texture, the podsollic soil having a much higher clay content than the podsoils.

Analytical studies

Detailed analytical investigations were carried out on the three profiles mentioned above.

The following methods were employed:

C.E.C. - N. Ammonium Acetate pH 7 (Schollenberger and Simons 1945; Peech, 1945). Leachate from C.E.C.: Na and K by E.E.L. Flame Photometer, Ca and Mg by E.D.T.A. Exch. Al by method T.L. Yuan (Soil Science 1959 88, p.164). Mechanical analyses by Piper's Pipette method (1950, pp. 59-74), % C by Walkley-Black's method (Jackson, 1958, p.219). Total chemical analysis by fusion with sodium carbonate, using Dobutskaya's method (1962).

Mineralogical analyses were carried out according to the method described by Mohr and van Baren (1954, p.219-220), while the clay mineral analyses were carried out using a Philips 2KW X-ray diffractometer with CoK radiation. The results of the latter have been expressed as relative amounts using the method described in the 7th Approximation (U.S. Soil Survey Staff, 1960/67).

Discussion

Sarawak podsoles under natural vegetation are morphologically similar to the turfy-strongly podsolitic soils in Russia (Rode, 1962, p.314-334), those with disturbed natural vegetation and partial absence of the Al horizon can be compared with Rode's podsoles. (op cit.) There may be genetic reasons for distinguishing between such soils in Russia, but the difference in Sarawak is man-made and can be neglected for classification purposes. They can also be compared with the 'humus podsoles' of central and western Europe (Kubiena, 1953) developed on quartz sands and have strong similarities with the Humic Podsoles of Canada where they would possibly mainly belong to the hydromorphic type (Damman, 1962). They can further be compared with Australian Podsoles and Groundwater Podsoles (Stephens, 1956).

According to the U.S. 7th Approximation to a universal classification system all Sarawak podsoles belong to the suborder of Aquods (Order Spodosols), these under natural vegetation and poor drainage conditions belong to the subgroup of Histic Tropaquods while those under secondary vegetation and weakly developed O horizons are best classified under the Typic Tropaquods. Possibly Duraquods occur as well. The podsoles with very thick albic horizons such as occur in old deep sandy marine deposits cannot be classified as Typic Tropaquods and must be classified under the order of Entisols (Soil Group Quartzipsamments). As these Spodosols and Entisols are genetically the same, it appears that, from the viewpoint of Sarawak soils, the thickness of the albic horizon is over-emphasised in this system.

Common to all the podsoles mentioned above, regardless under what other environmental conditions they have formed, is the fact that the parent materials are dominantly of a sedimentary nature, are sandy, porous, and quartzitic and have low contents of bases and total iron.

The chemical analyses (Diagrams 1, 2 and 3) show the extreme poorness of the parent materials in Sarawak. The relative increase in total SiO_2 content (Diagram 1, profiles 1 and 2) in the upper horizons is clearly visible and according to Rode (op cit.) is characteristic for a podsolization process. It is accompanied by a decrease in the finer fractions, notably the clay fraction, and an increase of these in the B horizon. Noteworthy is the increase of the silt fraction in the lower horizons of Profile 3 which may indicate that this fraction is also affected by a 'lessivage' (Duchaufour, 1951) or illimerization process in podsol soils. (Fridland, 1958).

In the absence of micromorphological studies it cannot be assessed by visual means whether the clay increase in the B horizon is due only to leached clay transported in suspension or whether clay destruction also takes place in the A2 horizon followed by leaching of their components and possibly subsequent new formation of clay in the illuvial horizon.

Some conclusions may, however, be drawn from the analytical data. It is generally accepted that kaolinite is the least easy clay mineral to remove under a podsol weathering process, it being in comparison with double-lattice clays difficult to disperse (Graduvov, et al, 1961, p.752). The general relative decrease of this mineral in the upper horizons may therefore point to break down of this clay mineral particularly since this is accompanied by a relative increase of clay size quartz in these horizons. This would point to a podsolization process (Fridland, op cit.). The total absence of montmorillonite/vermiculite clays in the upper horizons may be due to their relative unstable nature under the reigning weathering process, and they may have been either decomposed or removed by illimerization.

The contrast between the podsol and the podsol soil is most marked in the mineral composition of the clay fraction, (see Table 1). In the former there is a relative decrease of quartz in the clay fraction down the profile, while in the latter the relative amounts of quartz remain virtually constant. The composition of lattice clay minerals in the latter is, however, varied and shows changes from illite into montmorillonite/vermiculite minerals in the top horizons, a much similar change was found in studies summarised by (Gorbunov, 1965). There is little destruction and removal of kaolinite apparent in this profile. The increase of clay in the B horizon (Diagram 1) is not accompanied by a relative increase in any one clay mineral and is therefore, probably mainly due to mechanical transport of all clay-size particles except for montmorillonite/vermiculite and gibbsite which may either have been destroyed during the process or they are newly formed in the top horizon through destruction of the illite which may point to weak podsolization in these horizons. (Gradusov, 1961). The process in the profile is, however, mainly one of illimerization.

The difference in the nature of the clay in the podsol and podsol soils is illustrated by Diagram 2 which shows the relation between C.E.C., % C and clay content. In the podsol, because of the high quartz content in the clay fraction, the exchange complex is mainly a function of the organic compounds while in the podsol soils it is directly related to clay content.

CLAY MINERAL COMPOSITION IN SARAWAK PODSOLS
Table 1

Horizon	Quartz	Anatase	Kaolinite	Montmorillonite/ Vermiculite	Gibbsite	Illite	Feldspar
A1	xxxx	x	x				
A1-2	xxxx	Tr					
A2	xxxx	xx	x				Tr
A3	xxxx	xx	Tr				Tr
B1.1	xxxx	xxx	xx				x
B1-2	xxxx	xx	x				Tr
B2	xxx	xx	xx	x			
B3	xx	xx	xx	Tr	x		
C	Tr	Tr	xx	Tr			

Profile 1—Humus podsol on old alluvium
(well-developed)

Horizon	Quartz	Anatase	Kaolinite	Montmorillonite/ Vermiculite	Gibbsite	Illite	Feldspar
A1	xxxx	x	x				Tr
A1-2	xxxx	xx	xx				Tr
A2	xxxx	xx	xxx				Tr
B1	xx	x	xxx	xx			
B2	xx	xx	xxx	xx			
C	xx	x	xx	x		Tr	

Profile 2—Humus podsol on quartzitic sandstone
(strongly developed)

Horizon	Quartz	Anatase	Kaolinite	Montmorillonite/ Vermiculite	Gibbsite	Illite	Feldspar
A1	xx	x	xx	xx	Tr	Tr	
A2	xxx	x	xx	x	Tr	x	
B1-1	xxxx	x	xx		Tr	x	Tr
B1-2	xxx	Tr	xx			xx	Tr
B2-1	xxx	x	xx			xx	Tr
B2-2	xxxx	x	xx			xx	Tr
B3	xxx	x	xx			x	
C	xxxx	Tr	xx			x	
C/D	xxxx	x	x			xx	Tr
D	xxxx	x	xx			xx	Tr

Profile 3—Grey-white podsol soil
on carbonaceous shale

A study of the heavy mineral association (Diagram 3) underlines the possibility that quite a number of podsolts have developed in bisequent parent materials. In Profile 2 no field evidence indicated that within the profile the soil material was heterogenous, the textural contrast between A2 and B being in any case typical for podsolts. Mineralogical analyses suggest, however, that the textural B may in fact be partly caused by weathering of shale material found in this horizon. On the other hand, shaly material may have been initially present throughout the profile but has been totally weathered in the upper horizons and no bisequence may be implied.

Profile 4 has been added to show the impact of a podsolitic weathering process on weatherable minerals. The breakdown of hornblende in the upper horizons is clearly indicated. The slight increase in the O horizon is probably due to addition of wind blown sand from fresh deposits. Cady (1960) reports an almost identical breakdown of hornblende in podsolts developed over glacial deposits in the northwest of the United States.

The question of whether bases and sesquioxides are moving down as humate colloids or as soluble metal-organic complexes (chelates) does not arise because of the poorness of the parent materials in bases and sesquioxides. The humus is undoubtedly transported as almost pure humus colloids during periods of high rainfall when the organic topsoils are extremely wet.

The organic compounds flush through the porous A2 horizon possibly in intermittent stages as indicated by the wavy bands in the lower A2 horizon. A very similar process is involved in the formation of Canadian podsolts (Stobbe and Wright, 1959).

The reason or reasons for the precipitation of the humus colloids in the Humus B horizon has been the subject of much speculation (Stobbe and Wright, 1959). The present study may clarify at least some points. In Sarawak there are no significant variations in chemical characteristics within the profile depth which could influence precipitation of the humus colloids, but there are some outstanding physical variations which either singularly or in combination give rise to the formation of illuvial humus horizons.

In locations where a strong texture contrast exists the humus B horizon forms on top of the layer with the higher clay content. Frequently this is a sandy clay deposit overlain by sand. In a number of localities the sand and sandy clay deposits are separated by a gravel and boulder layer in which invariably a humus hardpan has formed.

In areas where the upper sand deposit is very deep as is the case in many old marine terraces the humus B horizon is found at great depths (sometimes more than 6 feet) and is then always situated just above that part of the profile which during the wettest part of the year is saturated.

It is suggested that initially the percolation rate of the water rich in humus colloids is slowed down owing to the textural change. Due to the almost flat terrain lateral movement of this water is very slow and a perched watertable forms on top of the more or less impermeable substrata. The surface layers are able to dry out intensively during the dry spells in the less wet season and the humus colloids precipitate and coat the sand particles. The drying out process is essentially one of evaporation and not lateral drainage. This may be the reason why on slopes of more than 8 degrees (and in the case of very coarse material much less) illuvial B horizons do not form. Lateral drainage is sufficiently fast that humus colloids are carried away by the groundwater and not deposited following evaporation.

This coating process is necessarily one of long duration but once the pores of the underlying material have been sealed and conditions for a perched watertable formed the process may accelerate. The humus B horizon then grows upward. Systems of classification in which the thickness of the A2 horizon is taken as an indication to the intensity of the podsolization process (Rode, op cit.) are under such conditions without any meaning since the thickness of the A2 horizon is merely reciprocal to the thickness of the Bh horizon, and it is the latter which should be emphasised. This may be the reason why the thickest and hardest hardpans are found on the summits of terraces where the most dry conditions prevail during the least wet season. This possibly indicates that it is the intensity of the drying out process which controls the formation of hardpans.

In conditions where contrasting textures do not control and check the percolation of groundwater the base of the humus B horizon is found at the depth to which the drying-out process extends which depends again on the texture and the depth of the groundwater. Capillary movement may be expected in material containing some clay, in the case of pure sand this is almost nil and the humus B is formed almost directly above the ground watertable.

In otherwise uniform environmental conditions Podsoles do not form in materials which have a texture heavier than sandy loam, and this fact deserves some attention. Two explanations are suggested. Firstly, it is possible that through capillary action in a material heavier than sandy loam most water is evaporated at the surface and that any humus colloids it contains are again added to the surface horizon. Secondly, it has been noticed that although the soil parent materials are chemically as poor as those on which podsoles form, the forest is always of a better quality. These soils have a higher clay content and therefore higher exchange capacity. It is therefore also possible that most plant nutrients remain in the soil-vegetation-litter-soil cycle, and little is lost through leaching, while in a pure sand any nutrients not immediately taken up by the plant roots after decomposition of the plant litter are lost and carried away by the groundwater. While both light and heavy textural soils are poor therefore there is no tendency in the latter for nutrients to be depleted even further to the point where changes occur in the vegetation and character of the litter which might induce a podsol process.

Figure 1 illustrates the occurrence of texture contrasts in the profiles formed on Tertiary sediments. The absence of podsoils on materials with textures heavier than sandy loam in the surface horizons is worth noting.

Conclusions

Podsoils occurring in the tropical lowlands of Sarawak are morphologically similar to most humus podsoils found in regions with a temperate climate. The cause for their development is, however, not necessarily identical.

It appears that environmental conditions must be specific. The nature of the parent material is regarded as of overall importance. It must be extremely poor in plant nutrients to induce the growing of plant species which produce litter with a very low base and an extremely high C/N quotient. The parent materials are in this playing an equivalent role of that of climate in temperate region podsoils. Impoverishment of soil material does not initiate the process of podsolization in Sarawak, or only in the very early stages and then it is of short duration. The chemical processes involved are almost from the onset of soil development entirely controlled by the dominance of humus compounds and SiO_2 .

One could regard the whole profile depth as being initially a deep A2 horizon over which, through physical processes humus colloids are distributed and deposited giving as the end result a podsol morphology. Apart from being chemically almost inert the parent materials must also be highly porous, at least in the top layers, to allow the flushing through of water rich in humus colloids. These are deposited through a drying out process essentially involving evaporation of the groundwater to a certain depth in the profile where the humus colloids precipitate. The topography must be near flat to prevent quick lateral drainage through which the humus colloids might be carried away before they can be deposited. Textures heavier than sandy loam in the top horizon may result in drawing up this water through capillary action and the humus colloids are returned to the surface.

The oxidation of surface litter which according to orthodox pedological theories would prevent podsolization in the tropics appears to be strongly retarded by the wet, sterile conditions in the highly acid organic matter. Such conditions are very similar to those giving rise to the development of peat deposits in tropical lowlands with a high watertable.

The podsolization process in Sarawak is thus essentially the same as that occurring outside tropical areas, the difference being only that the initiation process (Stobbe and Wright, 1959) is absent, this in the temperate regions being a factor of the vegetation induced by atmospheric climatical factors. Removal of bases and sesquioxides from surface horizons, although only present in minor quantities, does take place; clay destruction happens in the A2 horizon and removal of both clay particles and clay particle constituents occurs. Possibly breakdown of clay particles is dominant in the double-lattice clay minerals while kaolinitic minerals are more stable. In the podsollic soil (Profile 3) illimerization is

dominant for most clay size material while breakdown of particles is only taking place in the surface horizon and mainly for double-lattice clays. This may point to a weak podsol process in this horizon which is not accompanied however by transport of humus colloids. Precipitation of removed materials takes place in the illuvial horizon but because of the generally low clay content which is related to the lack of weatherable minerals in the parent materials, pronounced textural B horizons can never form. These are, therefore, of little significance in Sarawak podsols. The position of the illuvial humus horizon in the profile is mainly either related to abrupt textural changes in the profile which in many cases are a result of the bisequent nature of the parent materials (the texture contrast may be amplified by deposition of some leached clay from the surface horizons) or to the depth of the ground watertable. The latter is true only for deep homogenous sandy materials in which there is no physical hindrance to percolating surplus rainwater. In textures somewhat heavier than sand capillary action may play a role in the formation of the illuvial humus horizon slightly above the watertable.

Periodic drying out of the surface horizons is essential to allow the humus colloids to precipitate. This is consistent with the ideas of Duchaufour (1956, p.203). It is suggested that not only in Sarawak podsols but also in podsols in and outside other tropical regions the bisequent nature of the parent materials is playing an important role in the development and position of the illuvial humus horizon.

The podsols in Sarawak are typically Intrazonal and it is perhaps ironical that the podsol profile originally taken as being a typical example of zonality in soils has proved to be as intrazonal as many other soils.

In fact, podsols as occurring in Sarawak could be used equally well to prove the overall importance of parent material on soil development; one could perhaps classify the latter as edaphic podsols while those occurring in temperate regions could be best regarded as climatic podsols.

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Profile descriptions

Profile 1 - Humus podsol on old terrace deposits - non-indurated illuvial Humus horizon.

- 0 - 7 inch 5YR 3/1, very dark grey, loamy medium to fine sand (finer fraction is mainly organic), crumbly, friable to smeary, moist. Porous. Many roots - approximately 50% of bulk material, clear regular boundary to
- 1.2 7 - 9 " 5YR 4/1, dark grey, loamy medium sand with inclusions of pinkish grey, structureless, porous, wet. Few small roots, clear regular boundary to
- 2 9 - 12 " 10YR 7/2, pinkish grey, loamy medium to fine sand with dark grey medium sand washed in from above in old root channels (many lateral). Very moist, very few living roots. Structureless. Porous. Weak staining (10YR 6/2) pale brownish grey. Clear, regular boundary to
- 3 12 - 15 " 7.5YR 5/2 dark brown, loamy fine to medium sand with 10YR 6/2 (light brownish grey) - 50/50%. Dark colour is confined to filled in old root channels. Structureless, porous, soft, moist. Some large cracks show a film of humic material of smeary consistency. Clear, regular boundary to
- 4.1 15 - 18 " 7.5YR 3/2 dark brown, and 7.5YR 8/2, pinkish white loamy fine sand - 50/50%, dark material confined to filled in old root channels, structureless, few living roots. Slightly moist. Clear, wavy boundary to
- 4.2 18 - 24 " Weakly indurated humus pan. Maximum accumulation of humic material. 5YR 3/3 and 3/2, dark reddish brown silty to fine sandy loam. Darker coloured material in old root channels, structureless, weakly cemented. Slightly moist. Clear, wavy boundary to
- 5.2 24 - 28 " 10YR 7/3, very pale brown, medium to fine sandy loam, compact. Structureless. Dark humic material has leached down through old large root channels, this material is wet and smeary. Few living roots. Few faint mottles (10YR 7/8). Gradual boundary to
- 6.3 28 - 50 " 10YR 8/2, white, medium to fine sandy loam, structureless. If dried out (in exposed places) this horizon displays strong columnar structure. Many vertical old root channels filled in with clayey material of dark brown colour. Many small rootlets. Moist. Gradual change to
- 7 50 - 80 " 10YR 8/1, white, sandy clay loam, plastic, compact, moist. Gradual change to
- 8 80 - 108 " 10YR 8/1 white, sandy clay, very compact, plastic, non-sticky. Few distinct 10YR 7/8 mottles. Moist.

Remark:

Watertable at location 13 feet.
Below 50 inches material probably bisectant.

Profile 2 - Humus podsol on quartzitic sandstone
(strongly developed)

- 0 - 2 inches Partly decomposed, 5YR 2/2, dark reddish brown, organic matter with few sand grains, mixed with dense rootmat of fine roots mainly, some large roots, slightly moist. Clear over
- 2 - 5 " 5YR 3/2, dark reddish brown, sand, with much organic matter, friable, crumbly, moist. Individual sand grains are white in colour and clear. Abrupt, wavy boundary to
- 5 - 9 " 5YR 5/2, reddish grey, medium sand (humus stained), with few roots, moist, single grain, firm clear but wavy change to
- 9 - 13 " 10YR 7/1, light grey, medium sand with reddish grey staining in places (75% light grey - 25% reddish grey). Single grain, firm. Some veins of humic material run through this horizon without any apparent direction. No roots, abrupt over
- 13 - 18 " 5YR 2/2 and 3/2, dark reddish brown loamy medium sand, weakly cemented. Some fine roots at boundary with horizon above. Irregular but clear change to
- 18 - 22 " 10YR 6/4, light yellowish brown, fine sandy loam, slightly wet. Many old decomposed roots. Small pockets of 5YR 2/2 colour where material is cemented. Platy structure with humus accumulation between structure elements; distinct change to
- 22 - 33 " 10YR 7/3, very pale brown, loamy sand - sandy loam, compact, structureless, slightly wet. Many old root channels with organic material which also accumulates along fracture planes. Clear change to
- 33 - 44 " 2.5Y 8/4, pale yellow sandy clay with 10YR 6/6, brownish yellow mottling, in some places as lateral bands in others along old root channels. Sticky and plastic. Some quartz pebbles (rounded), at 44 inches becoming more sandy and resembling sandstone.
- 44 - 68 " White medium sandstone. (Deep augering confirms occurrence of white clay bed at 68 - 76 inches). Perched watertable at 48 inches.

Profile 3 - Grey-White Podsollic Soil Derived from carbonaceous shales.

- 0 - 3 inches 2.5Y 7/2, light grey, sandy clay loam. Weak humus staining from 2 - 3 inches, surface gleying also present. Weak platy structure, densely rooted, moist. Clear regular boundary to
- 3 - 15 " 2.5Y 7/2, light grey, sandy clay loam with faint few light grey (10YR 7/1) and yellow (10YR 7/8) mottles. Massive, compact. Large cracks give rise to formation of large prisms when soil dries out. In the cracks dense root systems, remainder of soil sparsely rooted. Clayskins along cracks. Gradual increase in occurrence of yellow small mottles, moist. Gradual change to
- 15 - 30 " 2.5Y 8/0, white clay, maximum concentration of 10YR 7/8, yellow mottles, particularly where quartz grit is present. Quartz grit occurs in pockets and as disturbed thin stonelines (possibly from quartz strings in parent material). Roots only present in extending cracks from surface horizons, massive, compact, moist.
- 30 - 60 " 2.5Y 8/0, white clay, with pockets of quartz-grit, weakly mottled yellow. Light grey colour of A horizon persists along cracks (possibly clay illuviation). Roots mainly confined to cracks. Massive, compact, moist. Gradual change to
- 60 - 100 " 10YR 7/1, light grey clay, massive and compact with small common strong brown 7.5YR 5/8 mottles. Illuvial clay noticeable in large cracks. No roots. Pockets of quartzgrit. Moist. Abrupt but irregular boundary to
- 100 - 172 " 10YR 7/1, light grey, silty clay, massive and very compact. No cracks or roots, slightly moist, abrupt irregular boundary to
- 172 - ? " Soft, easily cut black shale with quartz-strings. Inclusions of fossil roots and olive yellow coloured pyritic material particularly along fracture planes.

Remarks: B2 subsampled:

62 - 69	inches as B2.1
90 - 98	inches as B2.2
124 - 136	inches as B3
160 - 172	inches as C.

Diagram 1

TEXTURE AND CHEMICAL COMPOSITION OF SARAWAK PODSOLS AND GREY-WHITE PODSOLIC SOIL

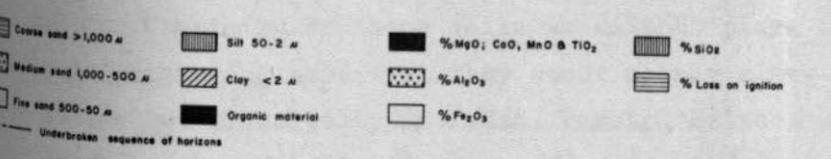
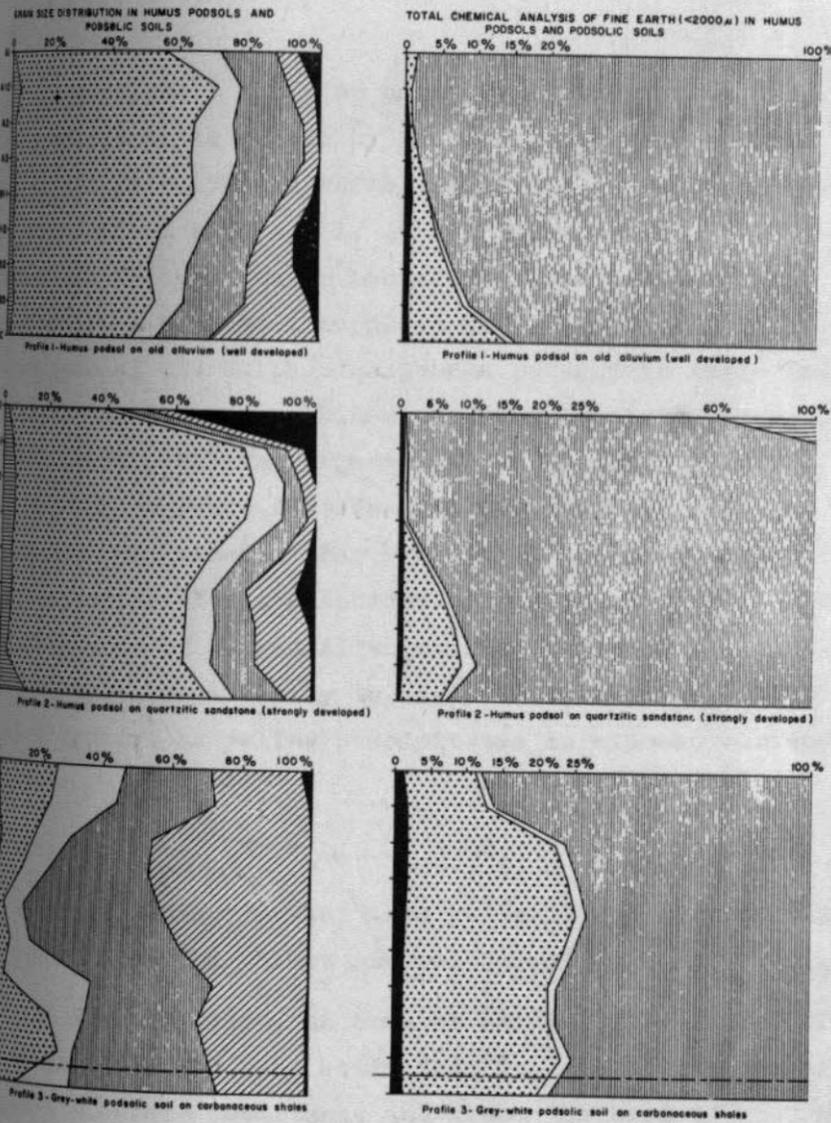


Diagram 2

NATURE OF EXCHANGE COMPLEX IN SARAWAK PODSOLS AND GREY-WHITE PODSOLIC SOIL

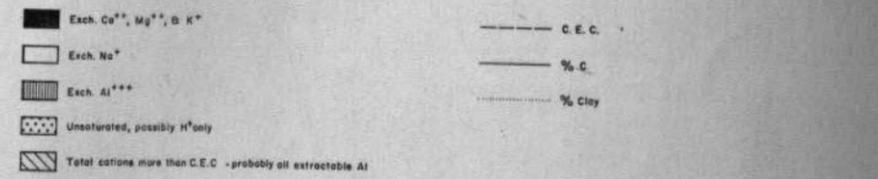
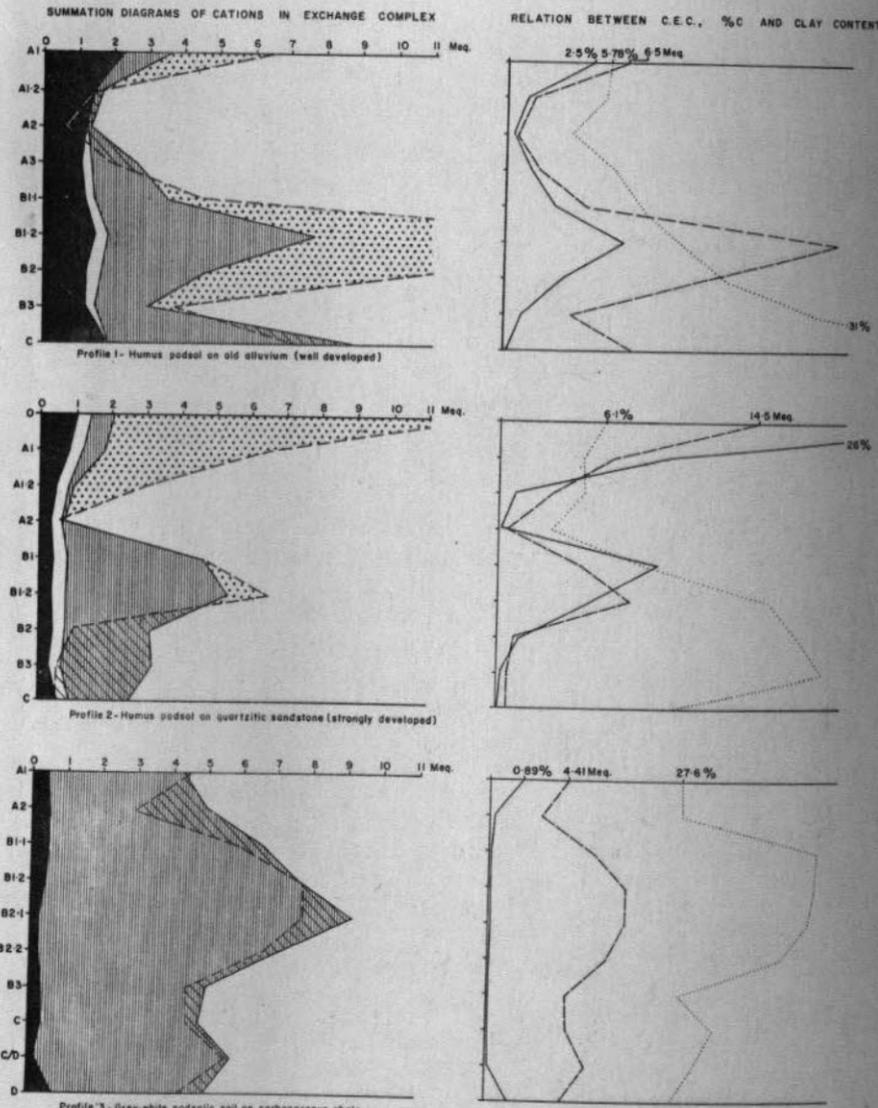
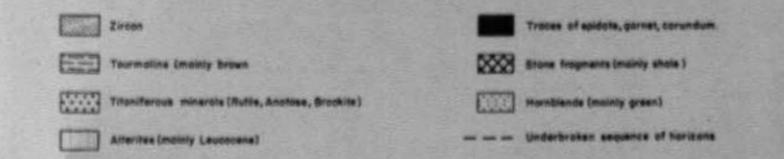
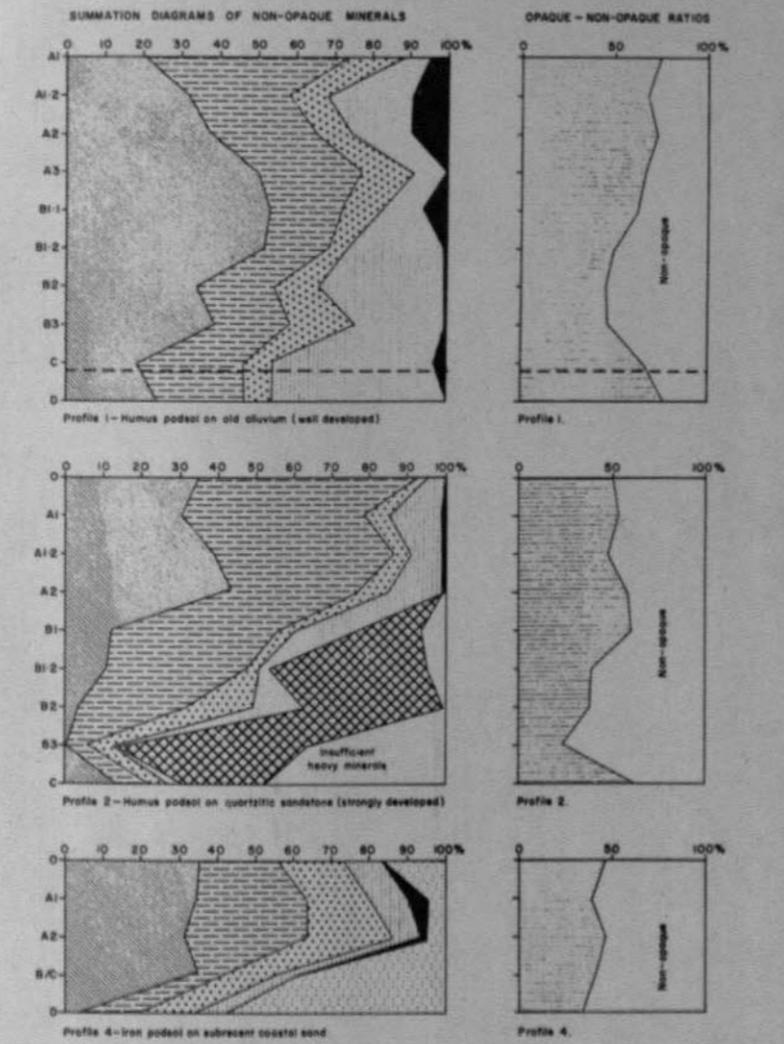


Diagram 3

HEAVY MINERAL ASSOCIATIONS OF THE FINE SAND FRACTION 250-50 μ IN SARAWAK PODSOLS

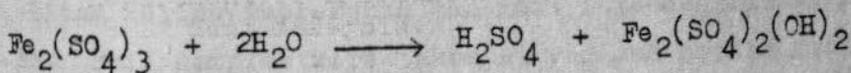


A PRELIMINARY STUDY ON ACID SULPHATE SOILS IN WEST MALAYSIA

by

Chow Weng Tai
Department of Agriculture,
West Malaysia.

Acid sulphate soils or commonly known as 'cat-clays' are highly acidic soils caused by the formation of sulphuric acid and Al and Fe sulphates which are acidic in reaction, when they are drained and aerated (1, 4, 7). They are usually derived from marine and brackish water sediments which contain high amounts of sulphur compounds supplied from the sea. Under reducing conditions, the sulphur compounds present in these sediments will be reduced to sulphides of iron, mainly pyrites (FeS_2), some monosulphide (FeS) and organic sulphur compounds in the peculiar vegetation found in these soils. When the reducing conditions are terminated either by natural means or artificial drainage, oxidation of the sulphides occurs to give sulphuric acid and sulphates of Fe and Al which are acidic in reaction. Ferrisulphate hydrolyses easily to basic ferrisulphate, $Fe_2(SO_4)_2(OH)_2$ which appears as yellow precipitates in exposed surfaces of the soil (1):



There is also evidence (3) that this yellow basic ferrisulphate can be converted to the yellow mineral jarosite, $K Fe_3^{3+}(SO_4)_2(OH)_6$.

In West Malaysia, an area of about 200,000 acres of acid sulphate soils had been estimated (8)^{9, 10}. Thus they are of considerable economic importance and hence the need to know more about the sulphur Chemistry of these soils as sulphur plays the primary role in generating acidity. They occur mainly along the Western Coastline but principally in Kedah, Perlis, Malacca and South West Johore. About 60-80,000 acres of acid sulphate soils are marginal padi land while the remaining area is either uncleared land or under other crops like coconut, oil palm and rubber (3, 8)^{9, 10}. The yields of crops cultivated on this soil are usually poor. Acid sulphate soils have been mapped as the Linau, Telok and Guar Series in West Malaysia (8, 9, 10). Guar Series is essentially

confined to padi land. These three soils have a generally organic topsoil with moderate to very strong smell of hydrogen sulphide and abundant plant remains. The parent material is usually a greenish or bluish grey structureless, sticky clay which turns black on first exposure to air and sunlight. Prolonged oxidation, say a few months, produces a yellow incrustation on the surface.

While descriptions of these soils in West Malaysia and other countries in South-East Asia, i.e. Vietnam and Thailand (5, 6, 8) ^{9, 10} have been given, relatively little has been carried out on the nature of sulphur contents in such soils and on their relation with other soil properties. As such information is considered important for the eventual amelioration of such soils in West Malaysia, investigations on the nature and distribution of sulphur contents in acid sulphate soils were started. This paper presents results obtained so far in this study.

Materials

Soils

Ten profiles of Linau Series, eight profiles of Telok Series and four profiles of Guar Series were selected for investigation. Linau Series represents the most intense acid sulphate conditions. Soil samples were taken at various depths from either virgin jungles or sites under old rubber, oil palm and padi which were unlikely to have received any sulphate fertilization. The soils were sun dried, ground and passed through a 2 mm sieve before analysis.

Methods

Determination of pH

pH was determined for the fresh and dried soil at a soil: water ratio of 1:2.5 using a PLE pH meter, after letting the suspension to stand for two hours or overnight.

Water Soluble Sulphate

This was determined gravimetrically. 100 mls of water were added to 20 gms of soil and this was then shaken for one hour in an end-over-end shaker. An aliquot was taken to be precipitated with 10% Barium Chloride solution and hydrochloric

acid. The BaSO_4 precipitated was then filtered, washed, dried, ignited and weighed, from which the percentage of sulphate in the soil was calculated.

2N HCl Soluble Sulphate (3)

This was also determined gravimetrically. 2.5 gms of the soil were digested with 50 mls. of 2N HCl for two hours on a water-bath. The clear liquid was decanted into a 100 ml volumetric flask and the residue digested again with 25 mls of 2N HCl as before. This was filtered into the flask again and the volume made up to 100 mls with distilled water. An aliquot was taken and the BaSO_4 precipitated as for water soluble sulphate, but in this case, the considerable amount of ferric ion present was precipitated first with sodium hydroxide. This sulphate extracted comes mainly from the insoluble Fe and Al sulphates in the soil.

Total Sulphur (After Bloomfield [2, 3])

This was determined by combustion of the soil with vanadium pentoxide, V_2O_5 to the oxides of sulphur which were absorbed in dilute hydrogen peroxide, H_2O_2 , and the resulting sulphuric acid titrated with standard alkali. Briefly, 0.5-1.0 gm of finely ground soil were thoroughly mixed with 1 gm of V_2O_5 in a small agate mortar. This was placed in a silica combustion boat which was then heated strongly in a quartz combustion tube connected to an adaptor and absorption tube. The oxides of sulphur evolved were absorbed in 40 mls. of 5% H_2O_2 placed in an absorption tube. The resulting sulphuric acid was titrated with N/20 sodium hydroxide. From this, the percentage of total sulphur in the soil was calculated.

Results

Water and 2N HCl Soluble Sulphate-Sulphur

The results in Table 1 give the ranges and means of pH and sulphur values of the Linau, Telok and Guar Series. As expected, the water soluble sulphate-sulphur is less than that for the 2N HCl soluble for all the three acid sulphate soils studied. These two types of sulphur content increase similarly with depth. There is a general tendency for the lowest horizon (below 2 ft.) to be always higher than the top-soil (0-6"). This indicates that there has been removal of sulphur contents from the upper soil horizons in profile development. In the Linau and Telok Series, the

Table 1

Range and Mean of pH values and Sulphur Contents in Acid Sulphate Soils

Soils	Depth (Ins)	pH						Sulphur Contents in % of Dry Soil					
		W e t		D r y		H ₂ O-Soluble SO ₄ -S		2N HCl Soluble SO ₄ -S		Total S			
		Range	Mean	Range	Mean	Range	Mean	Range	Mean	Range	Mean		
1) Linau	0-6	3.2-3.7	3.5	3.3-5.0	3.7	< 0.01-0.08	0.02	0.05-0.17	0.10	0.13-0.47	0.29		
	6-12	2.9-3.6	3.2	3.0-5.0	3.5	< 0.01-0.10	0.03	0.04-0.22	0.11	0.16-0.73	0.35		
	12-24	2.7-3.4	3.0	2.5-4.4	3.1	< 0.01-0.20	0.07	0.08-0.62	0.24	0.22-0.95	0.63		
	Below 24	2.6-2.9	2.8	2.0-2.6	2.3	0.19-0.90	0.53	0.35-1.94	0.87	0.77-4.06	2.13		
2) Telok	0-6	3.5-7.0	4.5	3.5-4.3	4.1	< 0.01-0.07	0.04	0.04-0.11	0.07	0.16-0.43	0.29		
	6-12	3.4-4.3	3.8	3.2-4.2	3.7	< 0.01-0.03	0.02	0.03-0.09	0.06	0.13-0.48	0.28		
	12-24	2.8-4.0	3.5	2.3-3.8	3.3	< 0.01-0.28	0.12	0.03-0.64	0.31	0.12-1.19	0.63		
	Below 24	3.7-4.7	3.8	2.3-3.7	3.1	0.01-0.52	0.22	0.05-0.94	0.46	0.16-2.64	1.08		
3) Guar	0-6	3.7-4.2	3.9	3.5-3.8	3.7	0.01-0.03	0.02	0.04-0.13	0.10	0.24-0.32	0.28		
	6-12	3.6-4.1	3.8	3.3-3.7	3.5	0.01-0.03	0.02	0.04-0.12	0.08	0.22-0.22	0.22		
	12-24	3.5-3.9	3.7	3.0-3.8	3.4	0.01-0.04	0.02	0.07-0.11	0.09	0.16-0.31	0.23		
	Below 24	2.5-3.4	3.1	2.3-3.2	2.7	0.15-0.66	0.37	0.30-0.86	0.54	0.43-1.47	0.91		

mean values of these two sulphur contents for the depth 0-6" are about the same as that for the depth 6"-12". There is, however a distinct increase in the 12"-24" horizon. The values for the depth below 24" show a considerable increase over the previous three depth intervals. For the Guar Series, the values do not increase till the layer below 24". Mean values show that below 24", Linau has the highest content of these two fractions.

Total Sulphur

The total sulphur content is usually much higher than the sulphate-sulphur content extracted by water and 2N HCl. From this, it can easily be deduced that, in addition to the sulphates, there are other forms of sulphur compounds which are more resistant to leaching. Similar to the water and 2N HCl soluble sulphate-sulphur fractions, there is a general tendency for the lowest horizon of the subsoil to have a higher total sulphur content than the top-soil. The pattern of distribution of the total sulphur contents with depth for the Linau, Telok and Guar Series is similar to that of the water and 2N HCl soluble sulphate-sulphur. Again mean values show that Linau Series contains the highest content below 24".

pH

Comparing the pH values for fresh (wet) and dry soils, it can be seen that there is a general tendency for the pH to decrease on drying the lowest horizon. This clearly shows that oxidation of the sulphides to sulphates must have taken place in the process of drying thus decreasing the pH value. For the top-soil, the pH remains either the same or decreases slightly on drying. This greater difference is probably due to the higher total sulphur contents in the lowest horizon. Fig. ¹ shows a graph of pH (dry) values plotted against depth for all the samples analysed. It shows that there is a good negative linear relation of pH with depth demonstrating the more acid nature of the subsoil.

Correlation Among Water, 2N HCl Soluble Sulphate-Sulphur and Total Sulphur

The correlation coefficients amongst the above three pairs of variables were determined.

Fig. 1. Relation between pH and Soil Depth

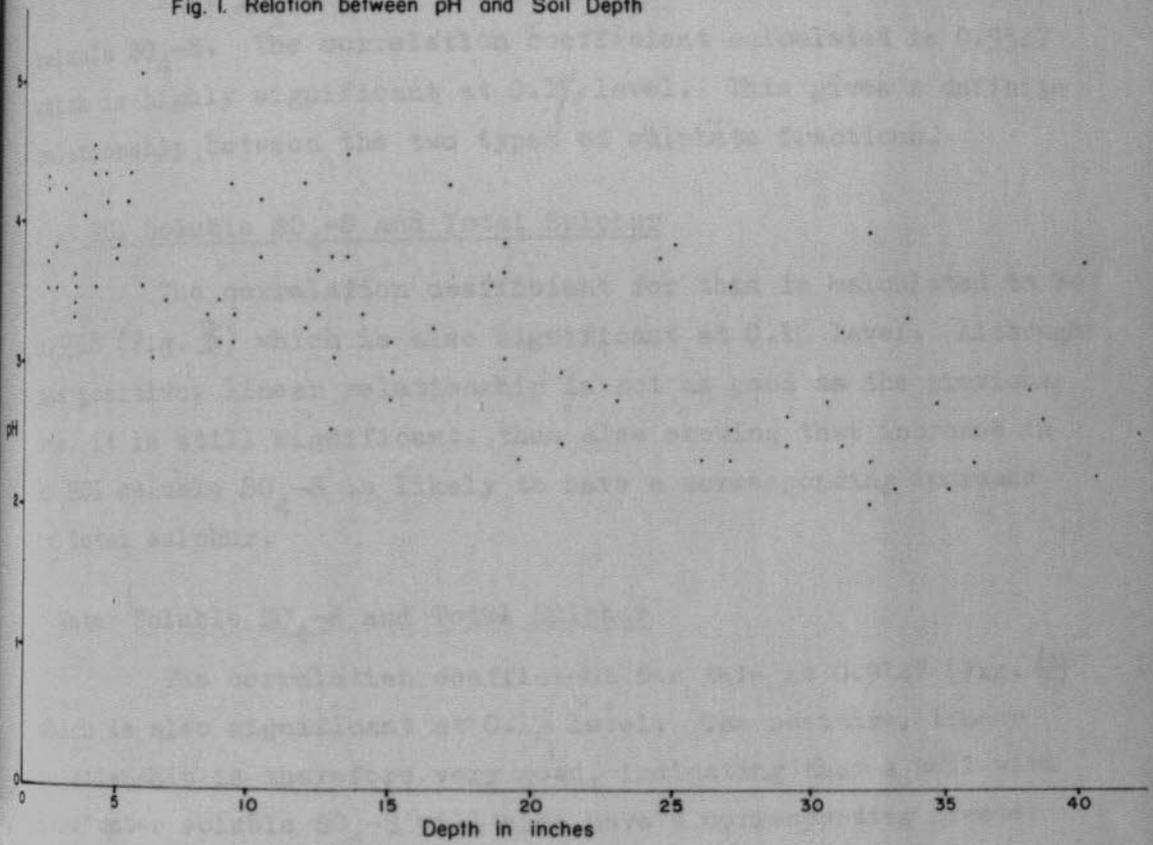
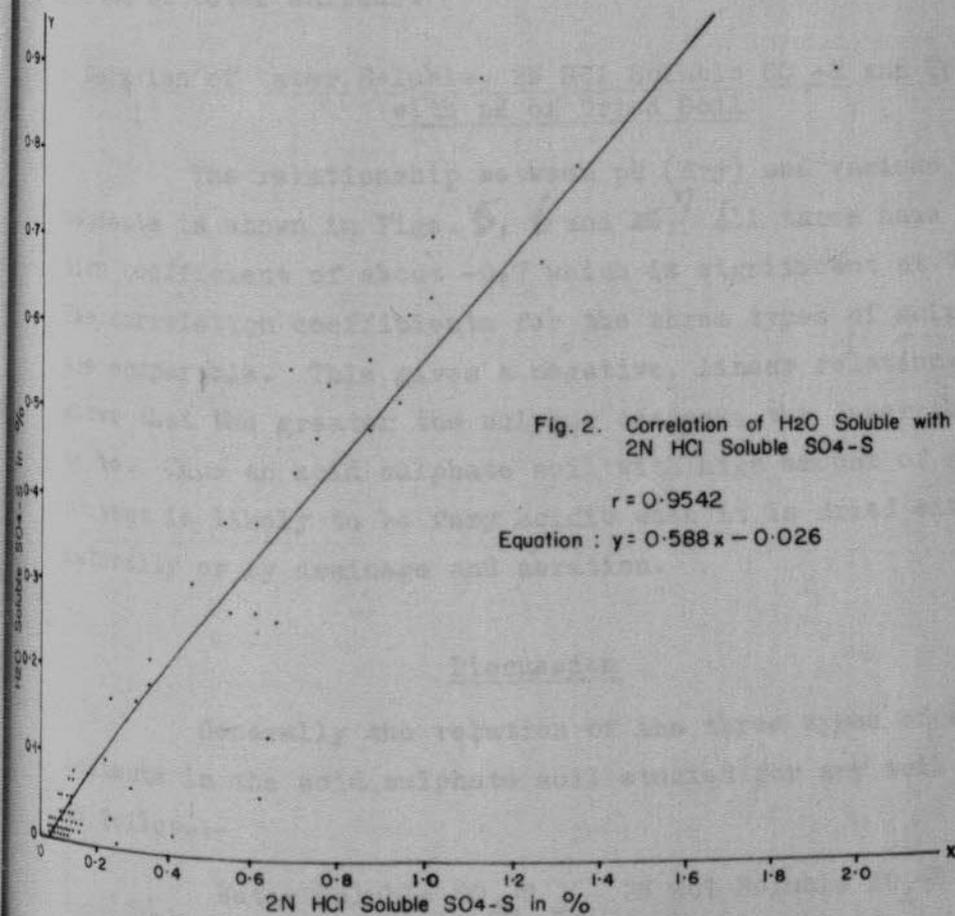


Fig. 2. Correlation of H₂O Soluble with 2N HCl Soluble SO₄-S

$$r = 0.9542$$

$$\text{Equation : } y = 0.588x - 0.026$$



Water and 2N HCl Soluble Sulphate-Sulphur

Fig. 2 shows the relationship between water and 2N HCl soluble SO_4-S . The correlation coefficient calculated is 0.9542 which is highly significant at 0.1% level. This gives a definite relationship between the two types of sulphate fractions.

2N HCl Soluble SO_4-S and Total Sulphur

The correlation coefficient for this is calculated to be 0.5518 (Fig. 3) which is also significant at 0.1% level. Although the positive, linear relationship is not as good as the previous one, it is still significant, thus also showing that increase in 2N HCl soluble SO_4-S is likely to have a corresponding increase in total sulphur.

Water Soluble SO_4-S and Total Sulphur

The correlation coefficient for this is 0.9147 (Fig. 4) which is also significant at 0.1% level. The positive, linear relationship is therefore very good, indicating that a soil with more water soluble SO_4-S will also have a corresponding greater amount of total sulphur.

Relation of Water Soluble, 2N HCl Soluble SO_4-S and Total Sulphur with pH of Dried Soil

The relationship between pH (dry) and various sulphur contents is shown in Figs. 5, 6 and 7. All three have a correlation coefficient of about -0.7 which is significant at 0.1% level. The correlation coefficients for the three types of sulphur contents are comparable. This gives a negative, linear relationship which shows that the greater the sulphur content, the lower the pH tends to be. Thus an acid sulphate soil with high amount of sulphur content is likely to be very acidic when it is dried either naturally or by drainage and aeration.

Discussion

Generally the relation of the three types of sulphur contents in the acid sulphate soil studied for any soil horizon is as follows:-

$$\text{Water soluble } SO_4-S < 2N \text{ HCl Soluble } SO_4-S < \text{Total sulphur}$$

Fig. 3. Correlation of HCl Soluble $\text{SO}_4\text{-S}$ with Total S

$$r = 0.5518$$

$$\text{Equation: } y = 0.447x - 0.024$$

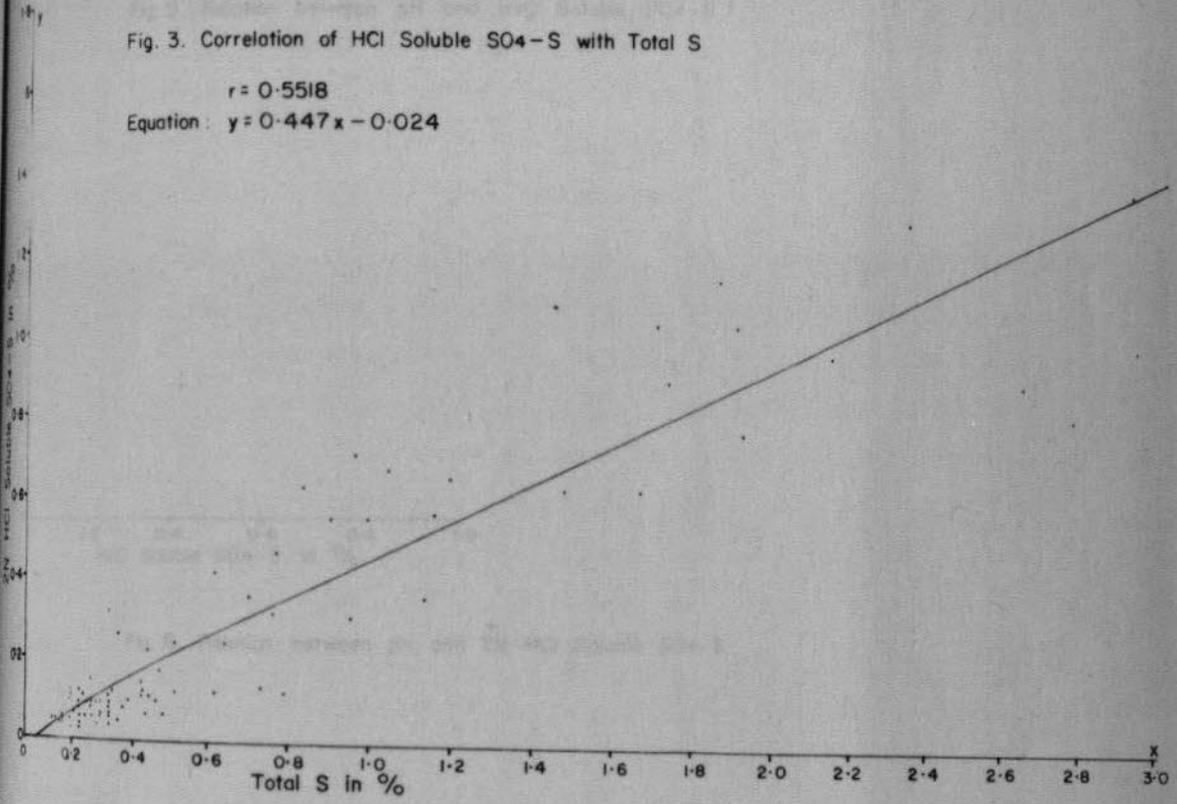


Fig. 4. Correlation of H_2O Soluble $\text{SO}_4\text{-S}$ with Total S

$$r = 0.9147$$

$$\text{Equation: } y = 0.268x - 0.044$$

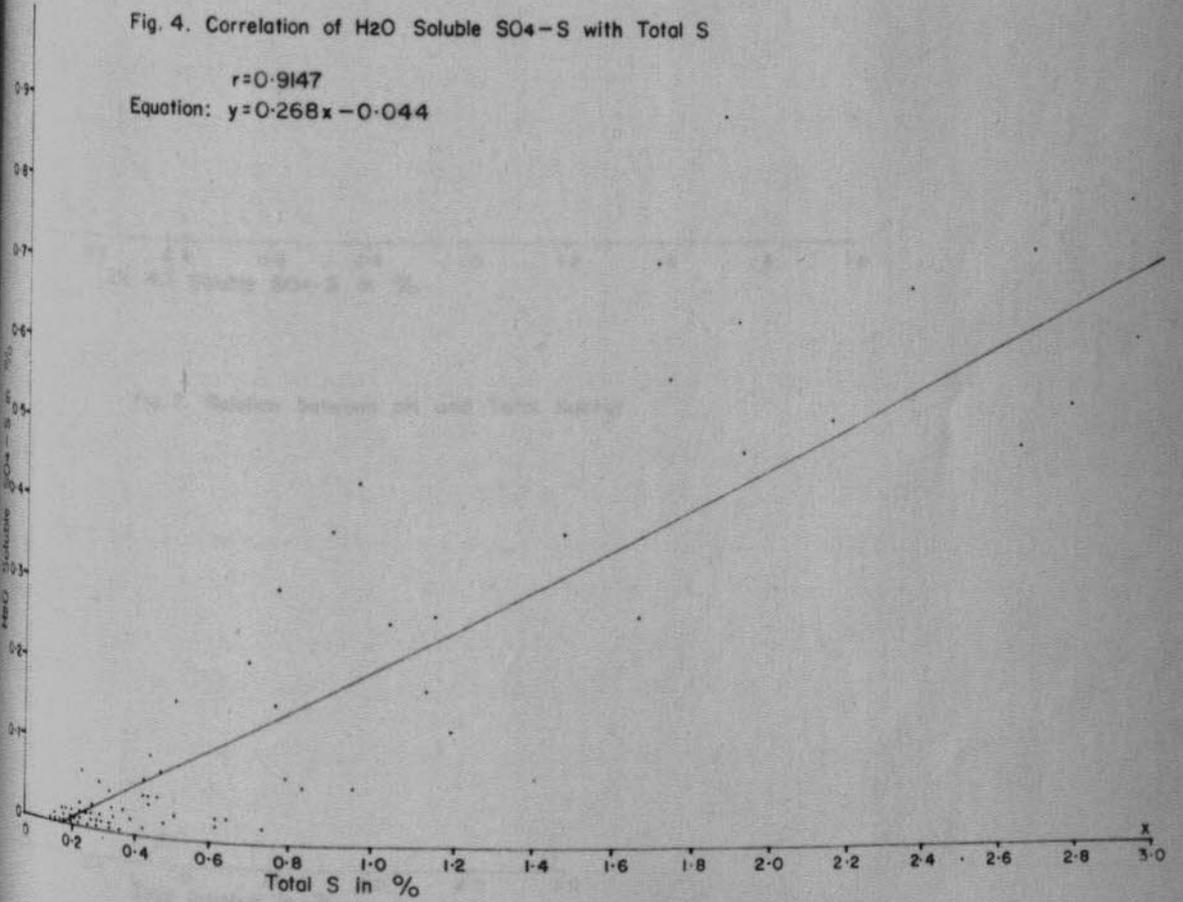


Fig. 5. Relation between pH and H₂O Soluble SO₄-S

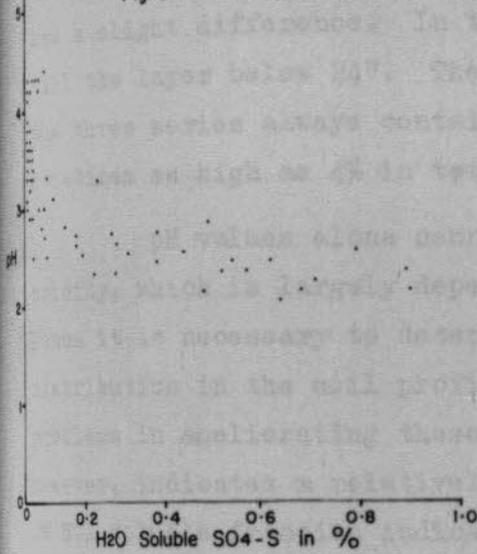


Fig. 6. Relation between pH and 2N HCl Soluble SO₄-S

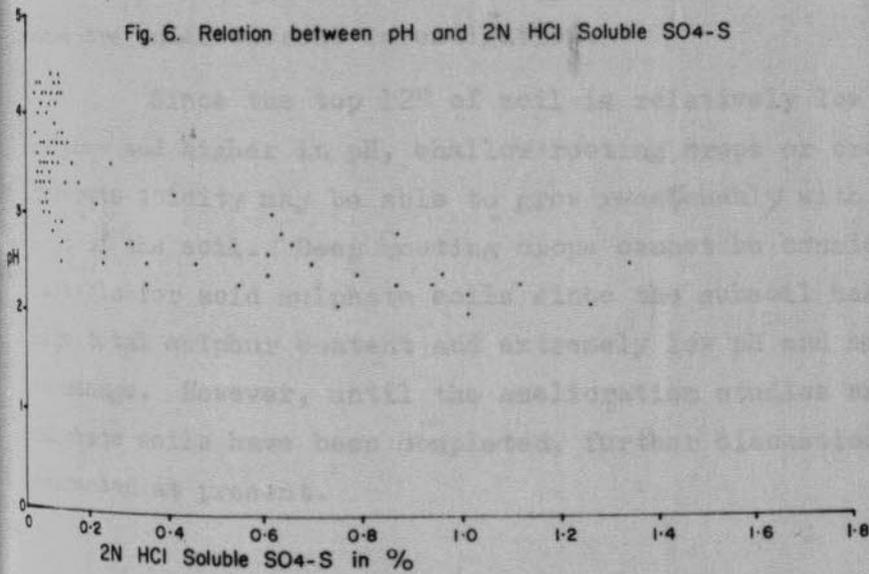
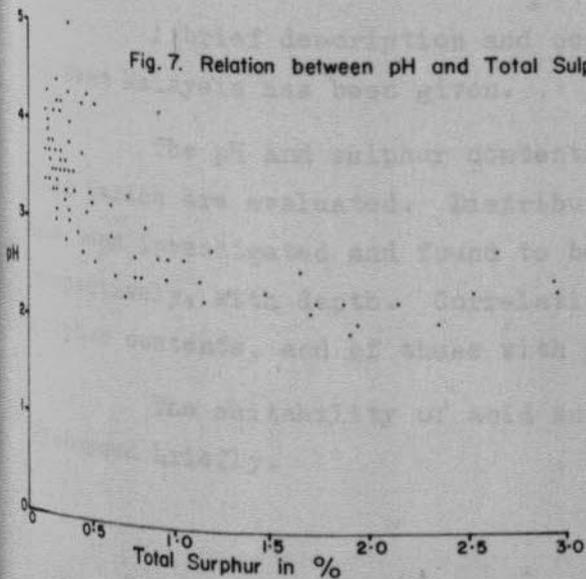


Fig. 7. Relation between pH and Total Sulphur



The distribution of each of these down the profile is similar for all the three series studied except that in the Guar Series which has a slight difference. In the Guar Series, values do not rise till the layer below 24". The lowest horizons (below 24") of all the three series always contain a high amount of sulphur contents, sometimes as high as 4% in total sulphur.

pH values alone cannot indicate the magnitude of potential acidity, which is largely dependent on the total sulphur content. Hence it is necessary to determine total sulphur in soil and its distribution in the soil profile further indicates the extent of problems in ameliorating these soils. The total sulphur content, however, indicates a relatively more resistant material while the 2N HCl soluble fraction indicates a more active component. Possible methods of amelioration and the rapidity with which this can be done are under current investigation.

Since the top 12" of soil is relatively low in total sulphur and higher in pH, shallow rooting crops or crops which can tolerate acidity may be able to grow reasonably with proper management of the soil. Deep rooting crops cannot be considered as suitable for acid sulphate soils since the subsoil has a relatively high total sulphur content and extremely low pH and hence difficult to manage. However, until the amelioration studies on acid sulphate soils have been completed, further discussion is not warranted at present.

Summary

A brief description and occurrence of acid sulphate soils in West Malaysia has been given.

The pH and sulphur contents of the Linau, Telok and Guar Series are evaluated. Distribution of pH and sulphur contents has been investigated and found to be decreasing and increasing respectively, with depth. Correlations among the three types of sulphur contents, and of these with pH are found to be good.

The suitability of acid sulphate soils for crops was discussed briefly.

Dept. of Agric.,
Kuala Lumpur.
15th April, 1968.

CWT/lsl.

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RECOMMENDATIONS OF SUB-COMMITTEE ON STANDARDISATION
OF SOIL ANALYTICAL METHODS.

STAGE I.

The Sub-Committee on Analytical Methods comprising Drs. Shao, I.T., Guha, M.M. Ng Siew Kee and Mr. Sim, E.S., met on 12th May, 1968 in the Soils Laboratory, Kuching, to consider the results of laboratory investigations on routine analysis carried out in Stage I. Also present were interested soil chemists from various organizations participating in the 3rd Malaysian Soil Conference. As a result of the deliberations, certain recommendations were made in respect of Stage I analysis. These are as follows:-

1. pH

Measurements are to be made both in water and potassium chloride solution, using a 1:2.5 soil/solution ratio. In the case of water, measurement is to be made after 16 hours.

2. Organic carbon

The commonly used Walkley and Black Method gives satisfactory results and its use is to be continued.

3. Nitrogen

The present micro-Kjeldhal method used by the four laboratories is satisfactory and will continue to be used.

4. Cation Exchange Capacity

The ammonium acetate method is to be the common procedure for determining C.E.C. The time of leaching is to be regulated at 5 - 6 hours.

5. Exchangeable Cations

Potassium is to be determined by flame photometry.

The EDTA method for determining calcium and magnesium is unsatisfactory and where used, should be abandoned as quickly as possible. It should be substituted by atomic absorption.

The cations in the extract are to be determined directly, without destruction of the ammonium acetate.

6. Easily Soluble P

The acidified ammonium fluoride extraction (Bray's No. 2.) is to be the standard method. Hand shaking is to be regulated at 30 gentle inversions/min. The suitability of the 0.1 N NaOH method as a routine method is to be investigated.

7. Total P

As the results were not entirely conclusive, further investigations are to be carried out to test:-

a) HF/HNO₃ digest, and

b) Na₂CO₃ fusion,

and determination of P in solution by:-

- i) Method of Fogg & Wilkinson and
- ii) The Vanado-molybdate Method.

Laboratory Staff

To achieve and sustain reliability of laboratory results, it is strongly recommended that laboratory staff actually performing analyses should possess a Grade II qualification in the Malaysian Certificate of Education or the Cambridge Overseas School Certificate.

Future Programme

In order to monitor the accuracy of each laboratory, a set of 6 check samples should be distributed to the laboratories from one rotating source once every three months. The results of such checks are to be compiled and circulated to the laboratories by whoever is responsible for distributing the check samples.

The Sub-Committee should meet in Kuala Lumpur in mid 1969 to deliberate upon:-

- a) results of remaining studies in Stage I and
- b) analyses to be studied in Stage II of the Standardisation Programme.

Sub-Committee
on Analytical Methods.

Report on recommendations of stage II to be expected in 1969, this meeting will be held in Kuala Lumpur.



Land Capability Classification
in West Malaysia

AN EXPLANATORY
HANDBOOK

Economic Planning Unit
Prime Minister's Department
Malaysia

Supplement to:

LAND CAPABILITY CLASSIFICATION IN WEST MALAYSIA

AN EXPLANATORY HANDBOOK, 1967

As a result of experience gained during the early stages of the Land Capability Classification Programme, revisions have been made to the mineral, forest, and land capability classifications, which now read as follows:

Revised Mineral Resource Classification (Geological Survey and Department of Mines Joint Contribution)

- (1) Probable mining land as deduced from prospecting results and geological evidence.
- (2) Areas under mining lease or certificate, or areas in which active mining is taking place.
- (3) Possible mining land as deduced from geological evidence.
- (4) Areas which on geological evidence might contain mineral deposits.
- (5) Areas for which no geological or other information is available.
- (6) Non-mining land.

Revised Forest Resource Classification (Forest Department Contribution)

- (1) Treated or regenerated forest or a forest plantation.
- (1M) Productive Mangrove Forests.
- (2A) Forest of high potential productivity with a basal area of all species of at least 80 sq. ft. or an equivalent volume of 64 tons round timber, including at least 50 sq. ft. or an equivalent volume of 40 tons round timber of commercial species per acre.
- (2B) Forest of high potential productivity with a basal area of all species of at least 80 sq. ft. or an equivalent volume of 64 tons round timber, but including less than 50 sq. ft. or an equivalent volume of 40 tons round timber of commercial species per acre.
- (3A) Forest of average potential productivity with a basal area of all species of 60-80 sq. ft. or an equivalent volume of 48-64 tons round timber, including at least 35 sq. ft. or an equivalent volume of 28 tons round timber of commercial species per acre.

- (3B) Forest of average potential productivity with a basal area of all species of 60-80 sq. ft. or an equivalent volume of 48-64 tons round timber, but including less than 35 sq. ft. or an equivalent volume of 28 tons round timber of commercial species per acre.
- (4A) Forest of marginal productivity with a basal area of all species of 40-60 sq. ft. or an equivalent volume of 32-48 tons round timber, including at least 20 sq. ft. or an equivalent volume of 16 tons round timber of commercial species per acre.
- (4B) Forest of marginal productivity with a basal area of all species of 40-60 sq. ft. or an equivalent volume of 32-48 tons round timber, but including less than 20 sq. ft. or an equivalent volume of 16 tons round timber of commercial species per acre.
- (5) Forest of limited potential productivity with a basal area of all species of less than 40 sq. ft. or an equivalent volume of 32 tons per acre.
- (5M) Unproductive Mangrove Forests.

NOTE—

1. "Commercial" species are those included in Classes A and C of the Forest Department Linear Sampling (L.S.) List of Species.
2. Sub-classes "A" tend to have a higher economic value present than Sub-classes "B".
3. Tonnage figures are gross estimates without allowance for defects.

Revised Land Capability Classification

- Class I ... Land possessing a high potential for possible mineral development.
- Class II ... Land possessing a high potential for possible agricultural development with a wide range of crops.
- Class III ... Land possessing a moderate potential for possible agricultural development, because of a limitation in the range of crops.
- Class IV ... Land possessing a high potential for possible productive forest development.
- Class V ... Land possessing little or no mineral, agricultural or productive forest development potential, but suitable for possible alternative development purposes, such as protective forest reserves, water catchment areas, game reserves, recreation areas, etc.

These new classifications will apply for Land Capability Classification studies carried out during the First Malaysia Plan period in all States, except Pahang, Johore and Malacca, for which the earlier classifications apply.

Present Land Use (Department of Agriculture and Directorate of National Mapping Joint Contribution)

In addition to the foregoing, a present land use survey has recently been initiated. This survey involves the preparation of maps showing land use detail interpreted from 1:25,000 aerial photography exposed in 1966, according to the following classification:

- (1) Urban and Associated Areas (1U).
- (2) Estate Buildings and Associated Areas (1E).
- (3) Tin Mining Areas (1T).
- (4) Other Mining Areas (1X).
- (5) Power Line Right of Ways (1P).
- (6) Market Gardening (2M).
- (7) Mixed Horticulture (2H).
- (8) Agricultural Stations (2E).
- (9) Rubber (3G).
- (10) Oil Palm (3O).
- (11) Coconut (3C).
- (12) Pineapple (3N).
- (13) Coffee (3K).
- (14) Tea (3T).
- (15) Cocoa (3A).
- (16) Pepper (3P).
- (17) Sage (3S).
- (18) Banana (3B).
- (19) Fibre Crops (3F).

- (20) Orchards—(Rambutans, Durians, Citrus, Cloves, Nuts, etc.) (3X).
- (21) Fish and Hyacinth Ponds (3H).
- (22) Annual or Diversified Crops (4C).
- (23) Padi (4P).
- (24) Shifting Cultivation (4X).
- (25) Improved Permanent Pasture (5).
- (26) Lalang, Unimproved Coarse Pasture and Scrub-Grassland (6).
- (27) Forest (7F).
- (28) Scrub (7S).
- (29) Cleared Land (7C).
- (30) Swamp, Marshland and Wetland Forests (8).
- (31) Unproductive Land (9).
- (32) Unclassified (10).

These areas are differentiated on the maps by the symbols shown in brackets above. The land use maps are compiled and published on a scale of 1:25,000, and not 1:63,360 as is the case with the other land capability classification programme data described in the handbook.

Revised Report Presentation

With the exception of Pahang, for which separate reports for each district were prepared, land capability classification reports for the States in West Malaysia are in the form of comprehensive reports for each State, and these reports include statistical information derived from the contributed data.

Revised Map Presentation

With the exception of the reports for Pahang which have been completed, other State reports may include mineral, soil and forest resource maps on a scale of four miles to an inch in addition to, or instead of a land capability classification map, wherever it is considered that the additional information provided will be of use to facilitate development planning.

This method of presentation will enable areas of resource use conflict to be more readily identified, and thus aid in the identification of regions where further investigation, feasibility studies, etc., will have to be carried out. In addition, areas only suitable for one particular resource development purpose can be more fully delineated.

ECONOMIC PLANNING UNIT,
PRIME MINISTER'S DEPARTMENT,
MALAYSIA
17th October, 1967



Land Capability Classification in West Malaysia

AN EXPLANATORY HANDBOOK

Prepared by the Natural Resource Capa-
bility Section of the Economic Planning
Unit, under the direction of the Technical
Sub-Committee on Land Capability
Classification of the National Development
Planning Committee

[Signature]
DEPUTY PRIME MINISTER

DI-CHEK DI-JABATAN CHTAK KERAJAAN
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KUALA LUMPUR

1967



Deputy Prime Minister,
Malaysia,
Kuala Lumpur

CONTENTS

FOREWORD

The wise use of natural resources is the very foundation of a nation's economic progress and prosperity, and the Malaysian Government is well aware of the contribution which science and technology can make towards the utilisation of these resources within a sound conservation context. In order that the maximum benefit can accrue it is important that the scientific and technological research and surveys should be co-ordinated and the recommendations from the investigations of workers in many fields presented in a clear and unambiguous manner. Only then may the results be applied with confidence to problems of development by all sections of the community.

In the field of land use and natural resource development the need for an expert consensus on land use potentials is particularly desirable, for land can be rich in many resources, and used for many purposes, but not all of these uses may be equally desirable, and some may be extremely harmful, leading in extreme cases to complete spoilation of the land with serious consequences for future generations.

Land Capability Classification is one way of indicating the most desirable manner of utilising the land for the best economic purposes, while ensuring that certain areas of low development potential, or of particular aesthetic or scientific merit, will be conserved in their natural state for the long term benefit of the nation. The co-operation of scientists of many disciplines is involved in the Land Capability Classification Programme for West Malaysia which is described in this explanatory handbook.

Malaysia is fortunate in having considerable reserves of natural resources, principally minerals, soils, forests, and water and in planning to develop these resources she can learn from the experiences of others which was often gained through a disregard of scientific principles or through the unrestricted play of human greed. It is the intention of the Malaysian Government to prevent such misuse by wise land administration, and the Land Capability Classification Programme described in the following pages is a major step towards this objective.

(TUN ABDUL RAZAK BIN HAJI HUSSEIN)
DEPUTY PRIME MINISTER

Kuala Lumpur,
24 January, 1967.

CONTENTS

	PAGE
What Land Capability Classification is about	1
Why Land Capability Classification is needed	1
How Land Capability Classification is carried out	2
Programme	4
Specifications	5
Base Maps (Survey Department)	5
Land Alienation and Gazettement (State Survey Office and Land Office)	5
Aborigines Reserves (Aborigines Department)	6
Game Reserves (Game Department)	6
Veterinary Reserves (Veterinary Department)	6
Mineral Resource (Geological Survey and Department of Mines)	7
Soil Resource (Department of Agriculture)	7
Forest Resource (Forest Department)	7
Water Resource (Drainage and Irrigation Department, Public Works Department and National Electricity Board)	8
Data Compilation (Natural Resource Capability Section)	8
(1) Land Alienation and Gazettement Map	9
(2) Land Capability Classification Map	9
(3) Land Capability Classification Report	10
(4) Statistical Summary of Planimetric Data	10

LAND CAPABILITY CLASSIFICATION

What Land Capability Classification is about

The process of classifying land according to the use potential of its natural resources is known as Land Capability Classification. The need for such a classification, which is a type of economic land classification, has become increasingly apparent in Malaysia in recent years. It is designed to indicate the purpose for which different areas of land should be used in order to make the best use of the inherent resources.

The land capability classification is used as the legend for classification maps which are easily understandable to a wide variety of persons who are interested in making the best use of the land. Such a classification is therefore relatively simple, as it is designed to meet the needs of persons who are not necessarily well informed about technical details.

Why Land Capability Classification is needed

It is known that much valuable information about our natural resources, particularly minerals, soils, forests, and water is not made use of by non-technical personnel, either because it is unpublished and has been half forgotten in departmental archives, or else because the reports and papers which contain this information are written in specialised jargon which is unintelligible to most people. Much of this information is worth publishing in a more understandable form because of its great value in matters of land use planning and natural resource development.

Such studies, which in Malaysia should embrace a study of mineral, soil, forest, and water potential, and evaluate the development potential of the land in terms of these natural resources, are of particular value in drawing up development plans at both a local and national level, and they help to ensure that development expenditure, particularly in the rural areas, is devoted to the right purposes, and exploited in an economically beneficial manner.

The success of the Rural Development Programme during the second Malayan Five-Year Plan period and the key role played by this programme by the Red Book, is now universally acknowledged. In retrospect, it is apparent that much of this success has been occasioned by the way in which the spirit of Gotong Royong has been inculcated amongst Government staff and the people, and the degree of co-operation and co-ordination which has resulted has been highly impressive.

The very satisfactory overall rate of progress attained was partly due to the manner in which the drawing up and execution of local development plans was made the responsibility of the District Development Committees. These Committees were able to draw up their proposals with the minimum of delay, and then allowed to implement these proposals without a surfeit of possibly conflicting advice.

Unfortunately, the success of a development scheme can be severely jeopardized if the technical and scientific evidence is not properly appraised by the developers, and experience during the past years of active development has given rise to the suggestion

that a closer degree of co-operation should be attained in the technical field of natural resource evaluation so that the development committees can take advantage of unambiguous technical advice. This springs from a realization that if the technical interests involved could reach a measure of agreement with regard to the optimum use of the land containing these resources, they then prepare maps embodying a classification which reflects optimum use, the recommendations and suggestions which would follow from such an exercise would be of immense value in matters of national planning.

The Land Capability Classification Reports, accompanied by maps, which are prepared are therefore made the joint responsibility of the technical and scientific specialists who are normally engaged in carrying out basic natural resource surveys.

How Land Capability Classification is carried out

Plans for carrying out these studies on a district basis for West Malaysia have been prepared by the Technical Sub-Committee on Land Capability Classification of the National Development Planning Committee, and a section which is known as the Natural Resource Capability Section has been set up within the Economic Planning Unit for the specific purpose of co-ordinating such studies. The programme for West Malaysia commenced in 1961 and should be completed within a period of about three years.

A high degree of co-ordination is expected from the technical departments of government which are concerned with the survey and development of Malaysian natural resources, and all these departments together with other interested organizations are represented on the Technical Sub-Committee. They include the departments of Survey, Lands, Mines, Agriculture, Forest, Geological Survey, Game, Aborigines, Veterinary, Town and Country Planning, Drainage and Irrigation, Public Works, and the National Electricity Board, Federal Land Development Authority, Rubber Research Institute, and the University of Malaya. The programme adopted in carrying out these studies calls for the contribution of the departments to prepare resource maps which define the relative value of the individual resource potentials (mineral, soil, forest, water) by means of a simple classification, and copies of these maps, which are drawn up largely by reference to existing resource maps, are stored within the Natural Resource Capability Section, where they constitute a valuable source of professional and technical information, not otherwise available for reference in one place.

A co-ordinator, who is on the Economic Planning Unit staff, is responsible for preparing Land Capability maps from the resource maps and the classification used on the capability maps differentiates between those areas known to have a high mineral development potential; a high or medium agricultural development potential; a high productive forest potential; and a relatively negligible potential for any of these purposes.

Up-to-date land alienation and gazettelement maps are also prepared, and both these maps are based on the most accurate available topographic sheets supplied by the Survey Department.

Current departmental proposals, for additional water catchment areas, forest, game, aborigine, and grazing reserves, are also collected

that these proposals may be contrasted and compared with the land capability classes in the same way as is possible for the present land alienation and gazettement data.

A short explanatory report summarises the resource potentials of the area, highlights the major possibilities for future development, and suggests very broadly the manner in which development might take place within a sound conservation context designed to ensure the orderly exploitation of the natural resource potentials.

Each district is treated in a similar fashion, and district maps and reports are completed at intervals of a few weeks. By combining the maps for each district in any State, a valuable appraisal is made of the resource potentials for the State as a whole, and a similar appraisal can ultimately be made for all the States in West Malaysia.

The value of the information shown on these maps, at National, State, and District levels is incalculable, and it is hoped that these studies will be found helpful to District and State Development Committee amongst others, in providing professional advice in a readily understandable form.

It is especially important to note that these reports do not constitute plans. They should be considered as guides to sound planning, and the maximum benefit is likely to accrue if the more detailed physical planning is made the responsibility of professional officers on the State establishment.

It will be appreciated that this classification programme depends for its success on a measure of State and Federal Government co-operation, although no large burden of extra responsibilities is imposed on the State Governments, as most of the compilation work necessary for the preparation of the resource and capability maps is undertaken by Federal staff within the Federal Headquarters of the technical departments. The various Federal officers engaged in this programme, and particularly the co-ordinator in charge of the Natural Resource Capability Section within the Economic Planning Unit consult State Government officers with regard to existing development plans and seek local advice and opinion with regard to future development proposals. The officers most able to assist in this manner are the State Secretaries; State Commissioners for Lands and Mines; State Development Officers; District Officers; and the heads of State Agricultural, Survey, and Forest Departments.

The need for accurate and up-to-date alienation detail is essential for the proper execution of the land capability classification programme, and the most satisfactory sources of such detail are the State Survey Offices and the Land Offices. These departments therefore co-operate by supplying an outline of the alienated land boundary, reduced to 1 inch to a mile, for each individual district. A base map on which this information is superimposed is supplied by the co-ordinator, and the work of the State departments involves transferring the boundaries by tracing from 1 inch to a mile originals, if these exist in the State Survey Offices or the District Operation Rooms, or reducing the information from larger scale cadastral or land alienation sheets where up-to-date 1 inch maps showing this detail are not already avail-

Plans to carry out a systematic present land use survey for West Malaysia, based on a complete 1: 25,000 aerial photographs cover obtained during 1966, are also being formulated, and the results of this factual survey will later be compared with the data which is already being collected.

The Federal departments contribute by supplying maps showing the suitability for development of the resource for which they are responsible, or of the present or proposed use pattern in which they may have interests.

Programme

The programme for West Malaysia has been drawn up to cover all of the States to be treated consecutively, and land capability classification maps and reports for individual districts are prepared at intervals of a few weeks.

The order in which the State and District maps and reports are being prepared is listed below. Sub-districts are shown in brackets and are included in the maps and reports for the main district.

- | | |
|-------------------------------|-----------------------------------------------|
| 1. PAHANG— | 28. Kuala Lumpur
(Kepong, Sungai Besi) |
| 1. Kuantan | 29. Klang |
| 2. Bentong | 30. Kuala Selangor
(Tanjong Karang) |
| 3. Temerloh | 31. Sabak Bernam |
| 4. Pekan (Rompin) | 32. Ulu Selangor
(Rawang) |
| 5. Raub | |
| 6. Cameron Highlands | |
| 7. Lipis | |
| 8. Jerantut | |
| 2. JOHORE— | 6. PERAK— |
| 9. Mersing | 33. Batang Padang |
| 10. Kota Tinggi | 34. Lower Perak
(Tanjong Malim) |
| 11. Johore Bharu (Kulai) | 35. Dindings |
| 12. Pontian (Rengit) | 36. Kinta (Gopeng,
Kampar) |
| 13. Batu Pahat (Yong
Peng) | 37. Kuala Kangsar
(Parit, Sungai Sepilang) |
| 14. Muar (Tangkak,
Lenga) | 38. Larut and Matang
(Selama) |
| 15. Kluang | 39. Krian |
| 16. Segamat | 40. Upper Perak (Kinta,
Lenggong) |
| 3. MALACCA— | 7. PENANG AND PROVINCE
WELLESLEY— |
| 17. Jasin | 41. Nibong Tebal |
| 18. Malacca | 42. Butterworth |
| 19. Alor Gajah | 43. Bukit Mertajam |
| 4. NEGRI SEMBILAN— | 44. Penang Island |
| 20. Tampin (Gemas) | 45. Penang Northeast |
| 21. Kuala Pilah (Bahau) | |
| 22. Rembau | |
| 23. Port Dickson | |
| 24. Seremban (Mantin) | |
| 25. Jelebu | |
| 5. SELANGOR— | 8. KEDAH— |
| 26. Kuala Langat
(Sepang) | 46. Bandar Bahru |
| 27. Ulu Langat | 47. Kulim |
| | 48. Kuala Muda |
| | 49. Baling |

- 50. Sik
- 51. Yen
- 52. Kota Star
- 53. Padang Terap
- 54. Kubang Pasu
- 55. Langkawi

- 60. Tumpat
- 61. Kota Bahru
- 62. Bachok
- 63. Machang
- 64. Pasir Puteh

11. TRENGGANU—

- 9. PERLIS—
- 56. Perlis

- 65. Besut
- 66. Ulu Trengganu
- 67. Kuala Trengganu
- 68. Marang
- 69. Dungun
- 70. Kemaman.

10. KELANTAN—

- 57. Ulu Kelantan
- 58. Tanah Merah
- 59. Pasir Mas

After the programme of Land Capability Classification has been completed for all the districts in a State, the district maps and reports are consolidated for the State, and State Land Capability Classification maps and reports are prepared. When all the districts have been completed a national appreciation for West Malaysia will be made from the State maps and reports.

The possibility of carrying out similar classification studies for the East Malaysian States before the end of the First Malaysia Plan period is also being considered.

Specifications

Specifications for the purpose of the Land Capability Classification Programme for each district are as follows:

Base Maps (Survey Department Contribution)

Prepare and supply copies of the most up-to-date one inch to a mile topographical maps covering each district.

Land Alienation and Gazettement (State Survey Office and Land Office Joint Contribution)

Prepare a map showing alienated and gazetted land detail for single or contiguous areas exceeding ten acres in size, with subdivisions into ten groups as follows:

- (1) Land alienated for all country (agricultural land) purposes, including approved applications, but excluding land held on T.O.Ls and also land allocated for agricultural schemes in course of development.
These areas are edged by black lines and hatched with horizontal black lines.
- (2) Land alienated on mining leases and mining certificates.
These areas are edged by black lines and hatched with broken horizontal black lines.
- (3) Land gazetted as Malay Reserves.
These areas are edged by yellow lines.
- (4) Land gazetted as Grazing Reserves.
These areas are edged by brown lines.
- (5) Land gazetted as Aborigine Reserves.
These areas are edged by red lines.

- (6) Land gazetted as Forest Reserves.

These areas are edged by green lines.

- (7) Land gazetted as Game Reserves.

These areas are edged by blue lines.

- (8) Land alienated as town or village land, which occurs in local authority areas (Municipality, Town Council, Local Council areas).

These areas are edged by black lines and hatched with a pattern of horizontal and vertical black lines.

- (9) Land reserved for government purposes other than those shown separately above.

These areas are shaded grey.

- (10) Land covered by current prospecting permits.

These areas are edged by broken red lines.

Aborigine Reserves (Aborigines Department Contribution)

Prepare a map showing the following:

- (1) Land gazetted as aborigine reserves larger than ten acres.

These areas are edged by red lines.

- (2) Land classified as approved aborigine reserves larger than ten acres (i.e. areas approved by the State Executive Council but not yet gazetted).

These areas are edged by broken red lines.

- (3) Land classified as proposed aborigine reserves larger than ten acres [i.e. areas which in accordance with current proposals the department is anxious to see included in category (1) but which have not yet reached the stage of category (2)].

These areas are edged by dotted red lines.

Game Reserves (Game Department Contribution)

Prepare a map showing the following:

- (1) Land gazetted as game reserves larger than ten acres.

These areas are edged by blue lines.

- (2) Land classified as approved game reserves larger than ten acres (i.e. areas approved by the State Executive Council but not yet gazetted).

These areas are edged by broken blue lines.

- (3) Land classified as proposed game reserves larger than ten acres [i.e. areas which in accordance with current proposals the department is anxious to see included in category (1) but which have not yet reached the stage of category (2)].

These areas are edged by dotted blue lines.

Veterinary Reserves (Veterinary Department Contribution)

Prepare a map showing the following:

- (1) Land gazetted as grazing reserves larger than ten acres.

These areas are edged by green lines.

- (2) Land classified as approved grazing reserves larger than ten acres (i.e. areas approved by the State Executive Council but not yet gazetted).

These areas are edged by broken green lines.

- (3) Land classified as proposed grazing reserves larger than ten acres [i.e. areas which in accordance with current proposals the department is anxious to see included in category (1) but which have not yet reached the stage of category (2)]. These areas are edged by dotted green lines.

Mineral Resource (Geological Survey and Department of Mines Contribution)

Prepare a map showing the mineral development potential for the entire district sub-divided into four groups as follows:

- (1) *Current Mining Land*—Land covered by current mining leases.
- (2) *Potential Mining Land*—Land shown by prospecting results or inferred from geological records to contain more than 0.2 kati of cassiterite per cubic yard, or workable surface deposits of other minerals, e.g. iron-ore.
- (3) *Possible Mining Land*—Land for which present evidence indicates a possible mineral potential but which needs to be more thoroughly examined before commercial development can take place; or unprospected areas which on geological evidence might contain a mineral potential; or unknown areas.
- (4) *Non-Mining Land*—Land which has been prospected and shown to have no mineral potential, or which on geological evidence is unlikely to have any mineral potential.

These areas are edged by purple boundary lines and either shaded purple (Class 1) or hatched with right sloping, purple continuous (Class 2) or broken (Class 3) lines, or left blank (Class 4).

Soil Resource (Department of Agriculture Contribution)

Prepare a map showing the soil suitability for the entire district sub-divided into five groups as follows:

- (1) Soils with no limitations to agricultural development.
- (2) Soils with few minor limitations to agricultural development.
- (3) Soils with at least one serious limitation to agricultural development.
- (4) Soils with more than one serious limitation to agricultural development.
- (5) Soils with at least one very serious limitation to agricultural development.

These areas are edged by brown boundary lines and hatched with left sloping, brown, continuous (Classes 1 and 2) or broken (Class 3) lines, or left blank (Classes 4 and 5).

Forest Resource (Forest Department Contribution)

Prepare a map showing the forest productivity potential for the entire district, sub-divided into four groups as follows:

- (1) Highly productive forest with a basal area of commercial species of at least 50 square feet, or an approximate equivalence of at least 25 tons of round timber per acre.

- (2) Productive forest with a basal area of commercial species between 35 and 50 square feet, or an approximate equivalence of 15 to 25 tons of round timber per acre.
- (3) Marginal forest with a basal area of commercial species between 20 and 35 square feet, or an approximate equivalence of 10 to 15 tons of round timber per acre.
- (4) Unproductive forest with a basal area of commercial species below 20 square feet or an approximate equivalence of less than 10 tons of round timber per acre.

These areas are edged by green boundary lines and are hatched with vertical, green, continuous (Classes 1 and 2) or broken (Class 3) lines, or left blank (Class 4). Boundaries of gazetted forest reserves and areas which in accordance with current proposals the department is anxious to see included in the gazetted forest reserve category are also shown, and are respectively by continuous or broken green lines.

Water Resource (Drainage and Irrigation Department, Public Works Department and National Electricity Board Joint Contribution)

Prepare maps showing the following:

- (1) Existing catchments, necessary for ensuring an effective water supply for existing schemes, including hydro-electric generation and potable and irrigation water supplies.
These areas are edged by blue lines, and hatched with horizontal blue lines.
- (2) Proposed catchments, necessary for ensuring an effective water supply for proposed schemes, including hydro-electric generation and potable and irrigation water supplies.
These areas are edged by blue lines, and hatched with broken horizontal blue lines.
- (3) Existing irrigation scheme areas, being areas presently supplied with irrigation water for agricultural purposes.
These areas are edged by red lines and hatched with horizontal red lines.
- (4) Proposed irrigation scheme areas, being areas which are proposed will be supplied with irrigation water for agricultural purposes.
These areas are edged by red lines and hatched with broken horizontal red lines.
- (5) Isohytes, showing rainfall depths at 10 inch intervals.

Data Compilation (Natural Resource Capability Section Contribution)

This Section of the Economic Planning Unit is responsible for coordinating the work of the contributing departments in respect of the land capability classification programme, and for compiling two series of maps, known as Land Alienation and Gazetted Maps, and Land Capability Classification Maps, to cover each District and State. The Section is also responsible for compiling reports to accompany the maps for each District and State, and for preparing statistical summaries of the planimetric data contained on the contributed maps. The statistical summary

prepared with the assistance of the mechanical processing section of the Department of Statistics.

(1) LAND ALIENATION AND GAZETTEMET MAP

This map shows areas of alienated and gazetted land and other present and proposed land use categories; sub-divided into the following groups:

- (1) Land alienated for agricultural purposes, including approved applications, and land allocated for agricultural schemes in course of development, but excluding land held on T.O.Ls.
These areas are edged by black lines and hatched with horizontal black lines.
- (2) Land alienated for mining, including land covered by mining titles and mining certificates.
These areas are edged by black lines and hatched with broken horizontal black lines.
- (3) Land gazetted as Malay Reserve.
These areas are edged by black lines and hatched with broken vertical black lines, and differentiated from the other reserves by the abbreviation MAL.
- (4) Land gazetted as Grazing Reserves.
These areas are edged by black lines and hatched with broken vertical black lines, and differentiated from the other reserves by the abbreviation GZG.
- (5) Land gazetted as Aborigine Reserves.
These areas are edged by black lines and hatched with broken vertical black lines, and differentiated from other reserves by the abbreviation ABO.
- (6) Land gazetted as Forest Reserves.
These areas are edged by black lines and hatched with broken vertical black lines, and differentiated from the other reserves by the abbreviation FOR.
- (7) Land gazetted as Game Reserves.
These areas are edged by black lines and hatched with broken vertical black lines, and differentiated from the other reserves by the abbreviation GME.
- (8) Land alienated on Town Land Title or Village Land Title, or utilised for other non-agricultural or non-mining purposes, including approved applications but excluding land held on T.O.Ls.
These areas are edged by black lines and hatched with a pattern of horizontal and vertical black lines.
- (9) State Land, being those areas not alienated or gazetted or reserved for special purposes and shown in other categories of this classification.
These areas are left blank.

(2) LAND CAPABILITY CLASSIFICATION MAP

This map shows the relative capability of the land for mining, agriculture, productive forestry, protective forestry or other conservation use purposes, in a simple classification. The boundaries are derived from equivalent boundaries on the contributed resource maps for minerals, soils, and forests.

Class I—Land possessing a high potential for mineral development and therefore best suited to mining.

Class II—Land possessing a high potential for agricultural development with a wide range of crops and therefore best suited to diversification agriculture.

Class III—Land possessing a moderate potential for agricultural development with a restricted range of crops and therefore best suited to agricultural development with crops having a wide range of soil tolerance.

Class IV—Land possessing a potential for productive forest development and therefore best suited to commercial timber exploitation.

Class V—Land possessing little or no mineral, agricultural or forest development potential but suitable for development as protective reserves for conservation, water catchment, game, recreation, or similar purpose, or possibly suitable in the future for productive forest plantations with introduced species.

The land alienation and gazettelement map and the land capability map are both prepared on a scale of one inch to a mile and copies are distributed to the State and District Development Committees. Reduced copies, on a scale of one inch to four miles, are also prepared for inclusion in the Land Capability Classification Report.

The land capability classification map is reproduced as a transparent overlay to the land alienation and gazettelement map, to facilitate comparison between the capability and the present use of the land.

(3) LAND CAPABILITY CLASSIFICATION REPORT

The Report summarises the data shown on the maps and discusses the development opportunities which exist in the district. Liaison officers in the resource survey departments contribute material to this report, which is edited by the co-ordinator.

(4) STATISTICAL SUMMARY OF PLANIMETRIC DATA

The alienation, gazettelement, proposed land use, and resource maps which comprise the basic data of the Land Capability Classification programme are a most valuable source of information concerning the present and proposed use of the land and the potentiality in respect of minerals, soils, forests, and water. This information is presented on the maps in the form of curved lines for the resource data, reflecting the natural boundaries of the mineral, soil and forest types, and usually in the form of an intricate pattern of straight line boundaries for the alienation, gazettelement and proposed land use data, reflecting the cadastral survey boundaries of the alienated and gazetted land areas.

A knowledge of the areas covered by the different land alienation and resource classes is very useful for surveying, development planning and administrative purposes, and where the pattern is relatively simple, and free of overlapping boundaries, as is usually the case on a single map, the area can be determined by the

method of planimetric measurement. However, it is often possible to have planimetric data for land categories made up of a combination of land use and resource qualities, which must be obtained by measurement from several maps. In such cases the boundaries of the different categories overlap and if all these lines are to be superimposed on one map the pattern would consist of an indecipherable maze of small irregular shaped units which would defy measurement by planimeter. Fortunately, mechanical processing methods, using punch cards, can be used for this purpose and a numerical code which takes account of all the land use and resource categories shown on the contributed maps is assigned to each district in turn.

Advantage is taken of the fact that the one inch topographical maps series for West Malaysia has a uniform grid superimposed on the maps dividing the country into 1,000 yard grid squares. The intersection points of the squares are used as the data recording stations and the quality of the land at each point is read off from the different land alienation and resource maps and recorded on punch cards for mechanical processing. By this method of systematic line sampling the area of any combination of categories shown on the maps can be assembled for individual mukims, for districts, for states, and for the nation as a whole.

THE LAND CAPABILITY CLASSIFICATION OF
WEST MALAYSIA.

Several Government Departments in West Malaysia have been undertaking programmes of natural resource evaluation for a long time, and a need for closer co-operation between these different groups has always been felt, particularly as the results of surveys carried out often revealed a conflict in the use potential of the land surveyed. In recent years it has become increasingly apparent that the data from these surveys were important for national development planning, particularly following a Ford Foundation Report to the Malayan Government in 1962 on agricultural diversification, when a sub-committee of the National Development Planning Committee, which later became the sub-committee on Land Capability Classification, was formed to draw up a programme for data collection, analysis and presentation, designed to be carried out during the First Malaysia Plan period and to be completed in good time for it to be applied to the preparation of the Second Malaysia Plan in 1970. This sub-committee included representatives from all government departments involved in resources survey and several of the major land and natural resource use interests.

Technical assistance was sought and obtained from the Canadian Government in the form of aerial photography covering the whole country, and several specialist personnel in field and economic geology, land use survey, forest inventory and wild life evaluation. Finally, the Natural Resources Section of the Economic Planning Unit was set up in 1965 to co-ordinate the above programme and apply the results to the work of the Economic Planning Unit.

Basically the Land Capability Classification Programme depends on the contribution of data by three main natural resource survey groups on mineral potentiality, soil suitability and forest productivity. In addition data on water resource, land use and wild life are also provided. Land use data was originally presented only in the form of boundary details reflecting the legal land alienation and gazettelement status, but with the completion of the 1966/7 aerial photography, actual land use survey data based on photo interpretation is also being provided. This latter survey has been initiated by some of the Canadian specialist personnel referred to above, working with Department of Agriculture and Directorate of National Mapping personnel.

The data from the three main resource surveys are evaluated to determine conflicts in land capability potentials and from this is derived a simple land capability classification. The details of these classifications are shown in the accompanying hand-book and the attached supplement, but certain features of the classifications and their relation to the land capability classification need to be emphasized.

The mineral resource potential classification indicated the potential of an area for mining development based on evidence from field prospecting results and interpretation of the geological pattern as determined by the past work of the Geological Survey. In the classification adopted, only those areas which have been shown from actual prospecting results as containing

probable economic mineral deposits or are actually under mining lease are considered to have a high potential for mining. Such areas are placed under Class I of the land capability classification. It may be mentioned here that priority is given to mining development. This has been adopted since from past experience and trends for the foreseeable future it appears that where economic deposits of minerals occur mining development would provide a better return in comparison to other forms of land use. For the same reason agricultural development has been given priority over forestry development.

The significant feature of the soil suitability classification which has been adopted is that it lays emphasis on identifying soils suitable for the cultivation of the two main economic tree crops in West Malaysian agriculture - oil palm and rubber. Accordingly it has quite important limitations and would not be generally applicable where interest centres on a wider range of crops. These limitations are beginning to be felt even in West Malaysia where, in response to an increasing need to further diversify the agricultural crop pattern, areas suitable for large-scale cultivation of crops such as maize, tapioca, sugar-cane, etc. are being sought. It is hoped that in a second stage project a revised classification will include sufficient details for such areas to be identified.

The soils classification is based on increasing limitations of the soils to crop growth, the best soils being those with no limitations and therefore suitable for the cultivation of a wider range of crops. These limitations depend on a variety of factors including terrain conditions, physical factors limiting root development such as water-logging, shallow soils, soil compaction and lateritic horizons, or chemical limitations such as nutrient deficiency, toxicity or excessive acidity.

The soils with no or only minor limitations are considered suitable for the cultivation of oil palm and areas with these soils, unless there is conflict with a mining potential are placed under Class 2 of the Land Capability Classification. Areas of soils under a lower category of the soil suitability classification with a potential for the cultivation of rubber are placed under Class 3 of the Land Capability Classification. The remaining soils, which without major soil improvement practices are unsuitable for continued agricultural use, including swampland, worked out mining land and steep land with a slope of greater than $18\frac{1}{2}^{\circ}$ are considered best suited for forestry development. Areas of such soils where they have a potential for productive forest development are placed under Class 4 of the Land Capability Classification, while those areas which appear to have only a potential for protective forest development are placed under Class 5 of the Land Capability Classification.

The data is presented in the form of Tables showing the resource potentials, with cross-tabulations to show conflicts in resource use as well as other restraints on resource development such as legal land alienation or gazette status, rainfall or contour levels. The analysis of these data is facilitated by coding the data according to the 1000 yard-grid intersection points of the 1 inch to 1 mile (1:63,360) topographic sheets and analysing these mechanically. In addition $\frac{1}{4}$ inch maps of

the three major resources of minerals, soils and forests, a land capability map and a land alienation and gazettelement map are presented with the reports which are now presented for individual states.

The results of the programme when completed for individual States are applied as appropriate and based on the completed programmes for the State of Pahang and Johore, areas have already been identified as suitable for further detailed studies to facilitate planning for the development of these areas. At the present time the emphasis is on agricultural development, but planning will also include the development of forest and mining industries. These areas have been selected due to the relative ease of access, the availability of relatively large areas of land suitable for agricultural development and the minimum of conflicts arising from alternative uses of land.

In conclusion it is emphasized that the Land Capability Classification programme is not intended to provide plans for development. Its objective is to provide the necessary background data on which decisions determining long range prospects for development of land and natural resources may be based. In practical application it may be regarded as a first approximation to determining the future land use prospects of the country at a National, or Macro-planning level, from which areas may be selected for more detailed studies of particular resource potentials in order that sound, economically viable, development may take place in areas of major opportunity.

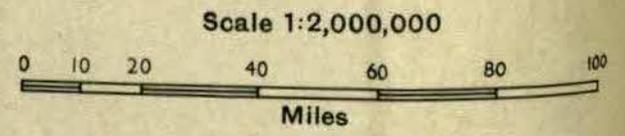
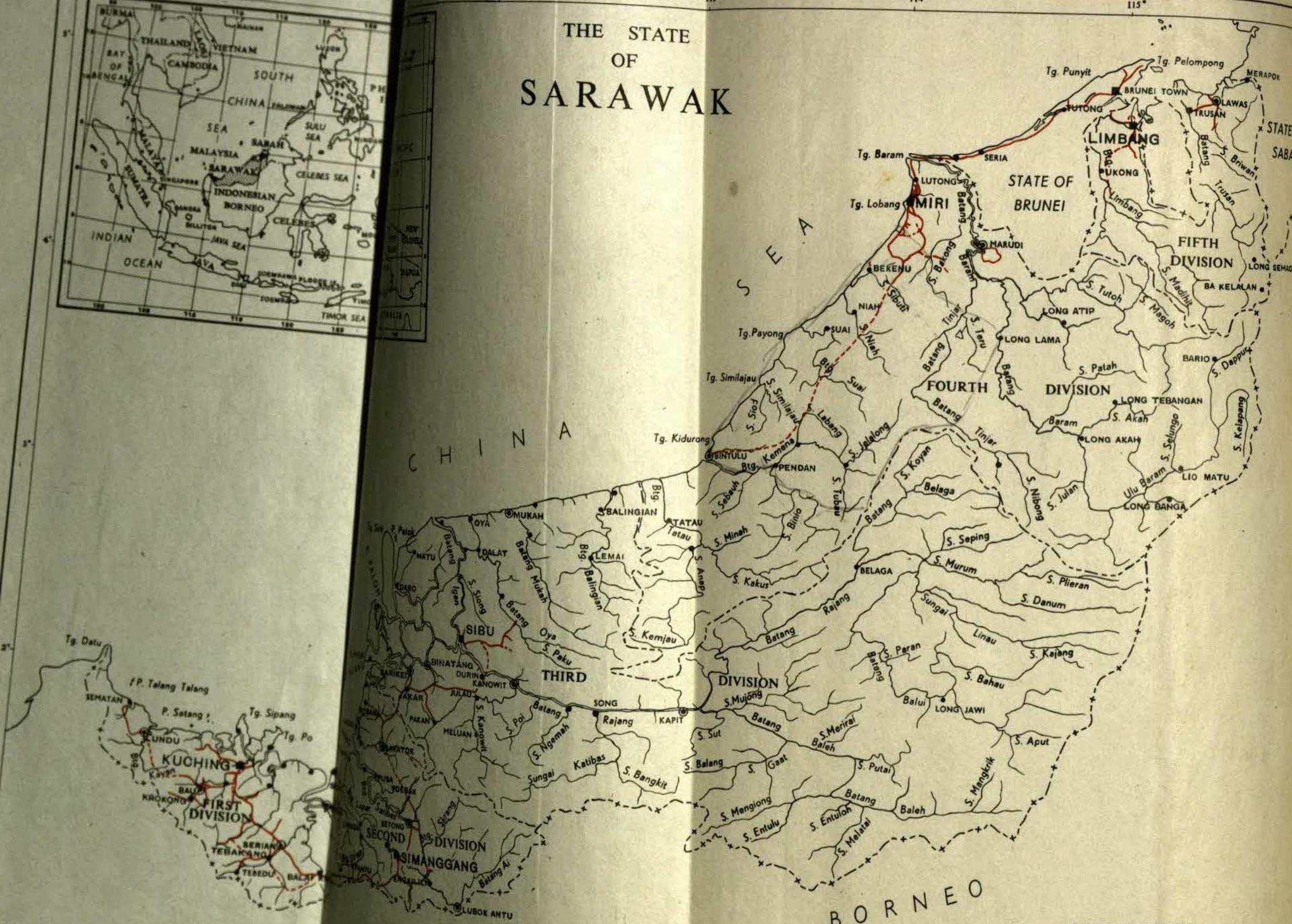
Economic Planning Unit,
14th May, 1968.

Development Planning and Land Analysis Techniques
with special reference to Sarawak

by

Russell Gwilliam

THE STATE OF SARAWAK



112° 113° 114° 115°

LEGEND	
.....	Divisional Boundary
.....	Divisional Headquarters
.....	District Headquarters
.....	Bazaars and Other Settlements
.....	Existing Road
.....	Road Under Construction

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Sarawak Series No.13
Compiled and drawn by Land and Survey Dept., August, 1965.

SARAWAK - SCHEMATIC SOIL MAP



Hilly and mountainous terrain. SKELETAL and shallow RED-YELLOW PODSOLIC soils dominant. LATERITIC soils and PODSOLS locally important.



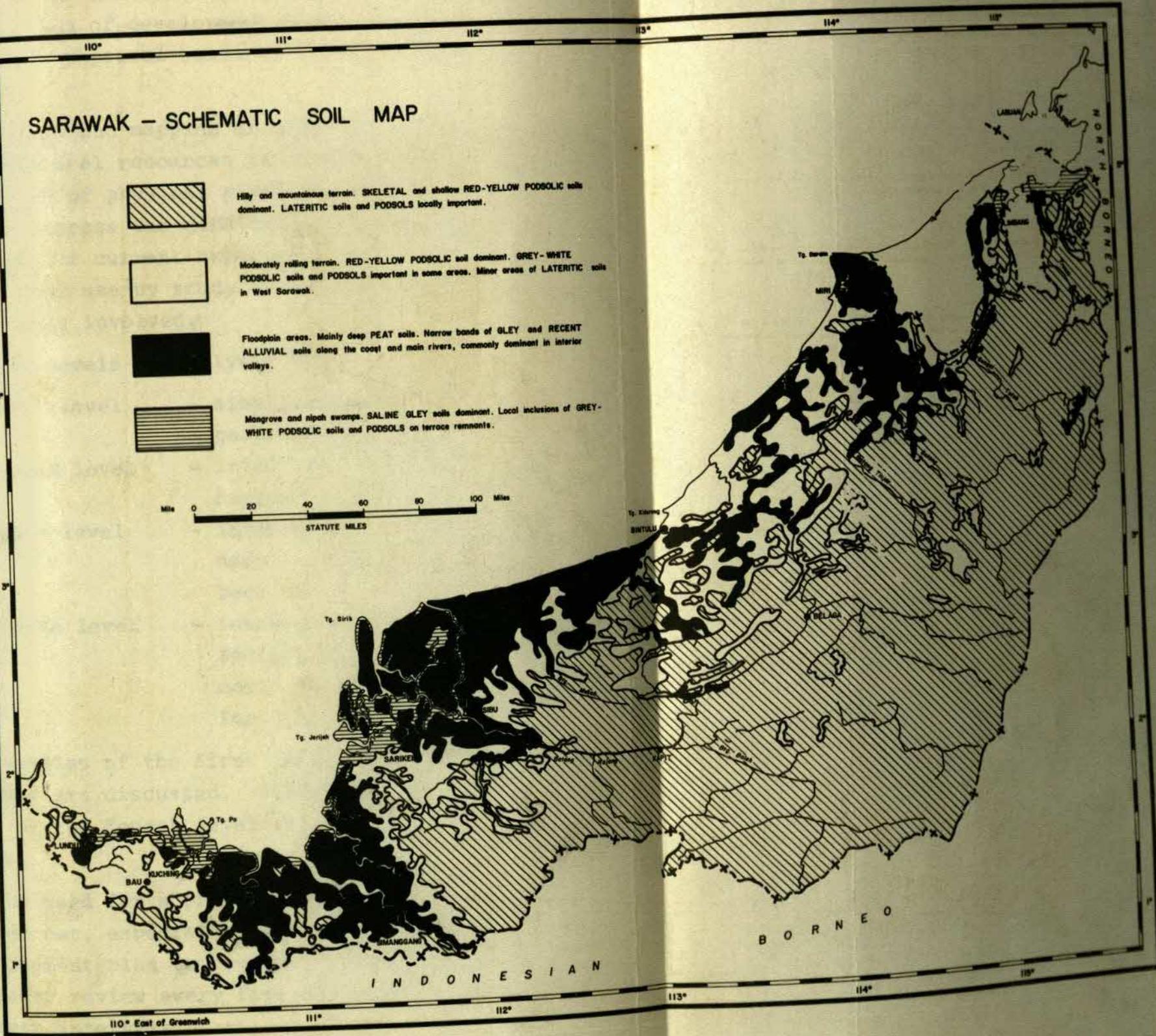
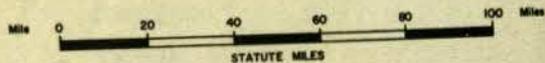
Moderately rolling terrain. RED-YELLOW PODSOLIC soil dominant. GREY-WHITE PODSOLIC soils and PODSOLS important in some areas. Minor areas of LATERITIC soils in West Sarawak.



Floodplain areas. Mainly deep PEAT soils. Narrow bands of GLEY and RECENT ALLUVIAL soils along the coast and main rivers, commonly dominant in interior valleys.



Mangrove and nipah swamps. SALINE GLEY soils dominant. Local inclusions of GREY-WHITE PODSOLIC soils and PODSOLS on terrace remnants.



Summary

After an initial emphasis on economic planning in the preparation of development plans the need for a complementary physical basis to such plans is now being recognised.

Surveys and mapping of geographical factors, including natural resources in objective scientific terms are the basis of physical planning. Land analysis techniques express the data collected in terms meaningful in the light of current experience, and make recommendations for land use by study of the inter-relationships of the factors involved.

Four levels of analysis are distinguished:-

- (i) First level - simplified expression of geographical factors.
- (ii) Second level - inter action of geographical factors on one possible use.
- (iii) Third level - inter action between possible uses - choice of highest and best use.
- (iv) Fourth level - introduction of economic factors e.g. markets, transport costs - assessment of ripeness for development.

Examples of the first three from West Malaysia and Sarawak are discussed. Studies of the problems of analyses at the Fourth level will shortly be commenced in Sarawak.

The need for a process of continuous analysis is pointed out, especially related to the tendency for the development plan to become a rolling programme with a major review every five years and a minor review at 30-month intervals.

Development Planning and Land Analysis Techniques
with special reference to Sarawak

The concept of the development plan as a programme for planned development has now become firmly accepted. The first simple plans were prepared in the immediate post-war years - Sarawak had a 1947-56 development plan - but the real stimulus as far as S. E. Asia was concerned came in 1951, when the Consultative Committee of the Colombo Plan first invited each country within the region to prepare a development programme.

As a result of this invitation in 1951 Sarawak undertook a revision of the 1947-56 plan to cover the period 1951-57. Subsequently two further plans were prepared, the 1958-63 and the 1964-68 Sarawak Development Plans, each covering the five-year period which now seems to have become standard. The Sarawak Development Plan 1964-68 was incorporated in the First Malaysia Plan 1966-70.

In the period since 1951 very considerable progress has been made in evolving planning techniques. The plans prepared have changed from what might be termed simple shopping lists to broad economic plans, based on a careful analysis of the national economy and development potential. The emphasis on economic planning naturally resulted from the expressed reason for the original Colombo Plan request i.e. to clarify the needs of each country in terms of external aid. The resulting plans have been essentially finance orientated; and they give relatively little attention to the physical problems of implementing the proposals they make, or to the need for full co-ordination of development programmes if the best value is to be obtained for every dollar spent.

The realisation that an economist can only decide what is economic when he knows what is physically possible has been growing rapidly over the last few years. In Malaysia in 1965, the National Development Planning Committee set up a Technical Sub-committee on Land Capability Classification to assess how best to evaluate the development potential of land in terms of natural resources, and the Economic Planning Unit set up a Land Capability Classification Section, headed by a Co-ordinator, to

organise and implement the necessary studies. In Sarawak the importance of this type of work was recognised when the Planning Section of the Land and Survey Department was expanded to a Branch on 1.1.1964, and a programme of mapping for development was commenced.*

At present it has been recognised throughout Malaysia that greater attention must be given to physical planning if economic targets are to be fully realised. To this end natural resource inventories are being compiled throughout Malaysia, and analysis techniques, aimed at ensuring these resources are put to their best use, are being evolved. This paper is concerned with a description and discussion of these techniques, in general terms for Malaysia as a whole, and more specifically for the State of Sarawak.

Natural Resources and Geographical Factors

Natural resource is a positive term, implying something which, in the light of current experience, is valuable. It is also one which is widely understood. Minerals, soils, forests are all natural resources of economic significance. Hence the logic which calls for the mapping and recording of these resources is readily understood.

Natural resources are only one sector of a larger group of geographical factors which affect development. Topography and climate are two such factors, not generally regarded as resources; but which nevertheless exercise a profound influence. Population is another although this is sometimes recognised as a resource, but under the name "labour supply". Existing land use is one of the most important of all, illustrating the status quo, the starting point for all future development works.

Any logical approach to physical planning will therefore require a careful survey of all geographical factors which influence, or could influence development. It will also require that the survey be objective rather

* See Appendix I: The Development Map Series commenced at this time were to supplement existing resource inventory programmes. In the absence of this data comprehensive analysis was impossible.

subjective, and that the data which is collected be recorded in absolute terms rather than current performance standards. It is true that no such survey can be entirely objective; the establishment of priorities for detailed study requires that some value judgements be made in the light of current experience. Nevertheless, the scientific approach should be maintained; the basic surveys of Geographical factors should measure and record rather than interpret. For example a survey of mineral resources should record the occurrence of mineral ores, and their richness or leanness; but not attempt to assess the economic viability of exploiting the deposit. Similarly a forest inventory should record the actual existing timber stand, rather than attempt to assess which species, having regard to locality and communications; could be economically extracted. A soil survey should normally classify soils into great soil groups and families with recognisable common characteristics; and whilst, in the more precise classifications* soil classification units are frequently closely related to crop potential, this is not the primary object in view when the classification is established.

The reasons for an objective approach are fundamental to the whole concept of land analysis. Surveys of Geographical factors are expensive and, worse still, take a very considerable time. However, if recorded in absolute terms the data does not change, or at best changes but slowly.** On the other hand the development of new techniques of exploitation frequently give previously uneconomic resources a potential value; whilst price fluctuations, changes in taste, or introduction of competing products can render a previously economically viable produce valueless. It will be seen from this that survey and record should be kept entirely separate from

* (e.g. The USDA (1960) Soil Classification: a comprehensive system: 7th approximation USDA Soil Conservation Service).

** This is not true of population, (hence the need for decennial censuses of population) nor of existing land use. Existing Land Use Mapping is under continuous revision in Sarawak; as new photography is taken it is interpreted and working sheets are brought up to date. This both enables progress to be reviewed, and provides the most up to date picture of development which is available.

analysis and synthesis. Such an approach emphasises the place of survey in its broadest sense as the foundation on which the whole structure of land analysis is erected; for no amount of analysis will transform a poor resource survey into a good one.

Land Analysis Techniques - general

The object of land analysis is to establish in terms of current techniques and conditions, knowledge and experience, the practical value of the geographical factors mapped by the various surveys. The picture of what is economically viable which is obtained is one which changes constantly. Thus the introduction of the cyanide process into gold mining made many low grade ore deposits (and even tailings from former mine operations) economic to exploit. The interest in pepper planting declines when prices fall; and were the prices of white pepper to remain below \$95/- per picul for an extended period there is little doubt, other things being equal, that production in Sarawak would virtually cease. The change in taste in interior furnishings from dark to bleached woods and back to dark over the last thirty years has considerably affected the economic viability of certain timber resources. Little need to be said about the effect on rubber of the competition from the synthetic product. It is at the analytical stage that such factors as new techniques, price fluctuations, changes in taste or competition must be given their proper weight; and it is for these reasons that development plans must be regularly reviewed in order to keep up with changing world conditions and technological improvements.

If the maximum benefit is to be derived from land analyses it is essential that a systematic approach be adopted. To facilitate this in Sarawak four levels of analysis have been distinguished, ranging from a simple subjective interpretation of one geographical factor or resource survey to an assessment of the effect of the complex inter-relationships which exist between various geographical factors and the influence upon these of such economic factors as transport costs and potential markets.

These levels are briefly described below:-

First Level Analysis

A first level analysis is one which expresses the data collected by the basic resource inventory in terms which are meaningful in the light of current experience. In its simplest form land classes are described in purely subjective terms, e.g., a soil may be categorised as being either suitable, marginal or unsuitable for agriculture, whilst in more advanced forms the classification adopted may be expressed in precise quantitative terms. Nevertheless whatever the form, the first level analysis is characteristically inward looking, seeking to clarify the implications of the data provided by one geographical survey or resource inventory only. Such analyses are frequently included in the presentation of results of surveys; but should never replace the scientific description.

West Malaysia: First level techniques have been widely used in West Malaysia. Many of the contributions to the Land Capability Classification* (see page 9) by the resource survey department fall into this category.

A summary of the classifications used in these first level analyses is given in Appendix II. From this it will be seen that the Soil Suitability Classification is completely subjective, but with some attempt at precision; the Mineral Resources Classification is semi-precise, defining a workable deposit of tin in quantitative terms; and that the Forest Resource Classification is precise, using quantitative definitions for the boundaries of each class.

Sarawak: The need for systematic analysis of land potential was recognised in Sarawak when the preparation of the Sarawak Development Plan 1964-68 was commenced. The plan itself was largely economic in content, and confined itself to aims, intentions and aspirations, although certain physical possibilities, such as oil palm development in the Fourth Division, were mentioned in

* The Land Capability Classification is a simple third level analysis. It is also being adopted by the State of Sabah.

general terms. This plan was backed up by Divisional Development Plans, which attempted to set down the physical possibilities for development and which contained the first simple analyses of land.* The Fourth Division plan identified "Tentative areas suitable to marginal for agriculture", whilst the First Division Plan, prepared somewhat later in December 1962, included the first Land Suitability Map, which identified the following six classes of land:-

- (1) Land Suitable for agriculture
- (2) Land marginal to suitable for agriculture
- (3) Land unsuitable to marginal for agriculture
- (4) Land unsuitable for agriculture (deep peat)
- (5) Land unsuitable for agriculture (other)
- (6) Mixture of 1 and 5, where topography excludes some parts within a generally fertile area.

This classification is defined in subjective terms; but although it was largely related to soils criteria it recognised (see class 6) the effects of topography. It should, then, probably be regarded as an embryo second level analysis.

At a somewhat later date the Soil Survey Division of the Department of Agriculture introduced the only true precise first level analysis which has yet been undertaken in Sarawak. The Terrain classification (see Appendix II) is a precise quantitative first level analysis of the basis Topographic survey. It has been widely used; both in its own right, and in the preparation of second level analyses at the second level.

The only other first level analysis made so far is the Mineral Resources Series of development maps. This adopts a subjective classification. There are no large surface deposits of useful minerals to compare with tin in West Malaysia, although Kaolinitic Clay and glass sand do occur, and bauxite has been mined in the past. The economic viability of these deposits is not sufficiently well established to permit a more quantitative classification at the present time.

* For a summary of the development of the Land Suitability Classification in Sarawak see Appendix III.

Second Level Analysis

A second level analysis may be defined as one which is concerned with the inter action or inter-relationships of two or more geographical factors, and the impact of such interaction on development potential for one use or product. To give a simple example one area may have a climate suitable for growing rice, but the wrong soils, another might have suitable soil, with insufficient rainfall. Only when the two geographical factors of soil and climate are combined is there a natural potential for rice growing.

Second level analyses in Malaysia have largely related to potential for agricultural purposes; but providing that the basic resource inventories are adequately expressed in absolute terms there is no reason why such techniques should not be applied to both forest and mineral resources. For example, suitability of land for opencast mining of bauxite might depend both on the richness of the deposit, and on the depth of overburden. Similarly the value of a given stand of timber might be related not only to the basal area of commercial species, but to the relative preponderance of valuable species. Analyses which introduce factors such as this may well prove valuable in the future.

Nevertheless, however applied, the context of the second level analysis is that it relates two or more geographical factors in a more precise assessment of the development potential of an area for a particular use or product.

West Malaysia: As far as has been discovered second level techniques have not been widely used in West Malaysia. A recent example, which relates to land suitability for growing oil palm is given in Appendix III*. It will be seen from this that the classification is based on both soil and terrain factor. However, it is interesting to note that in the discussion on the paper in which the classification was made the beneficial effects of a regular rainfall are noted, raising yields on certain marginal land to levels more normally associated with suitable soil and terrain conditions. This emphasises the need for introducing climatic studies of climate

* This table is extracted from "Soil suitability for oil palms in West Malaysia" by Ng Siew Kee; Proceedings of First Malaysian Oil Palm Conference, 1968.

would pay worthwhile dividends.

Sarawak: A number of second level techniques have been evolved in assessing suitability of land for agriculture in Sarawak. Of these the more widely used for general purposes is the Land Suitability Classification adopted by the Planning Branch of the Land & Survey Department, which was evolved with the continued advice and assistance of the Soils Survey Division of the Department of Agriculture. Appendix IV traces the development of the classification from its origins at the first level of analysis to the present day. Initially only terrain and soil factors were combined in this analysis, but recently a further factor, drainage, has been introduced to give a more complete picture of conditions as they exist. Table I in Appendix IV sets out the relationship between soil families, terrain and land suitability classes.

A more elaborate form of second level analysis of land suitability for agriculture was introduced in September 1966 by Andriesse in Soil Survey Report No. 94, The Sebang-an-Simunjan-Batang Krang Area (see Appendix V). In this report he describes and uses a system of land rating which recognises four degrees of difficulty in bringing land under cultivation, and relates these in sub-categories to problems of soil, terrain and drainage, or combinations thereof.

More recently in December 1967 in Soil Survey Report No. 113, The Tanjong Jol Area, Scott introduced a classification of land suitability for flood plain and coastal areas (see Appendix V). This recognises five main drainage classes, and divides each class (with the exception of Class DV which is accorded little or no development potential at this time) into two sub-categories based on soil or sub-soil.

Both of these classifications are extremely valuable in that they attempt to assess the potential for improvement. Such information is of the greatest value in detailed studies at higher level where factors related to potential alternative uses, and the effect of economic factors are introduced.

Third Level Analysis

Third level analysis attempts to assess the relative value of various possible land uses, and to allocate land accordingly, either in space, time, or both. Such analyses will usually be based on a combination, or sieving out, of factors brought out by analyses at the first or second level, or both. As yet no attempt has been made to formally differentiate between different grades of third level analysis, although clearly those which depend on information derived by second level techniques will usually be of greater value than those derived from first.

West Malaysia: The Land Capability Classification used in West Malaysia is a first class example of an analysis at this level. It attempts to establish what might be called, in valuation terms, land's highest and best use; and allocates it accordingly in a simple classification (see Appendix VI). In third level terms it is a simple analysis, relying entirely on information derived by first level techniques. Nevertheless it has already proved its worth in many ways, e.g.

- (i) by demonstrating that large areas of potentially valuable First Class agricultural land were being reserved for permanent forest estate.
- (ii) by reducing the likelihood of a high level of agricultural investment in areas likely to be developed for tin mining in the near future.

The classification, which is also being adopted in Sabah, is clearly an extremely useful tool in development planning.

Sarawak: In Sarawak reconnaissance studies at the Third level have just been commenced (see Appendix VII). For studies at this third level, however, the Land Capability Classification has not been adopted as it is felt that the classification, which was derived for West Malaysia, is much less applicable in Sarawak, where problems tend to be related to land tenure and the shortage of State land suitable for agriculture rather than conflicting claims between agricultural, mineral and forestry interests.

The established first objects of the Sarawak analysis

were to:-

- (1) locate areas of above average agricultural potential which were under primary forest. This was aimed at both establishing priorities for exploitation of timber, and for locating unencumbered State land for development projects;
- (2) define those areas of land at present farmed only for hill padi and held by Natives under native customary tenure which would produce the greatest return for investment in terms of agricultural diversification and agricultural intensification (i.e., replacement of shifting cultivation by settled cultivation);
- (3) relate these areas to the distribution of population in order to establish in which there is likely to be the greatest pressure for development;
- (4) select on the basis of these criteria tentative development blocks for detailed study with a view to producing a Regional Plan for each, and to select the order in which these studies should be undertaken; and
- (5) present the findings of the analysis in a form which could be readily understood by non-technical personnel (i.e. the ultimate decision-takers).

With these objects in view a sieve* of the whole State (except the remoter areas of Third and Fourth Divisions) was made, eliminating land in Suitability Classes III to VI inclusive, developed land, and indicating those areas which were farmed by Natives under shifting cultivation. The areas thus isolated were plotted using the Distribution of Population Map (Sarawak Series 18(P)) as a base map. A reduced version of this map is given at Figure I, which also shows the eleven tentative development blocks which have been selected.

* See Appendix VII for the classifications used.

A second third level analysis has been made which related existing forest cover to Land Suitability. This has been prepared to provide data for the F.A.O. team which is to survey the hill forest resources of Sarawak and make recommendations as to their future exploitation. This is, in fact, a very simple kind of third level analysis, as the forest survey does not as yet indicate the quality of the forests, but only their type. Nevertheless when supplemented by the full forest resource inventory it will enable meaningful decisions to be taken regarding the future extent of the permanent forest estate.

Fourth Level Analysis

A fourth level analysis is one which introduces such economic factors as market price, transport costs and proximity to markets into analysis of land i.e. to adopt an urban term, it attempts, by introducing economic factors, to assess the ripeness for development of any area of land for any particular purpose.

As far as is known, no fourth level techniques have been used in Malaysia as yet, although land analyses which do not take these factors into account are clearly of reduced value. In Sarawak there are many obvious examples of economic forces at work e.g. despite favourable physical conditions temperate vegetables are not grown in the Kelabit highlands because transportation costs to potential markets by light aircraft are too great. In contrast Triboh family soils are intensively developed around Kuching. The Soil Survey Division reports that "Triboh Soils are coarse textured, chemically poor and expensive to farm. These soils are only intensively used around Kuching where, through incorporation of much organic matter such as dung, vegetable production is economically possible".* In other words, the economic advantages of proximity to market outweigh the expense of soil improvements. In fact, because of this it may well be possible to make a case for releasing certain areas of forest reserve which have Triboh Soils, and are in

* A Classification of Sarawak Soils, Technical Paper No.2 by the Soil Survey staff, Research Branch, Department of Agriculture, Sarawak.

close proximity to Kuching, for vegetable production.

Before fourth level analysis techniques can be used in Sarawak careful investigation will be necessary. It is possible that the U.N. Transportation Survey Team at present working in Malaysia will provide useful information. Bonney's paper "The Relation between Road Transportation & Rural Development in North Borneo"* gives a number of pointers but his conclusions do not appear to have been used to any great extent.

However, even before the necessary techniques have been evolved, it is possible to envisage how the results could be used. A first result would be an assessment of ripeness for development in relationship to existing conditions; but it would also be possible to evaluate the changes which might be brought about by a new road, or a new port. For example, the construction of a new port at Kuala Baram in Sarawak might reduce the F.O.B. price of Palm Oil (compared to using the port at Muara in Brunei) by \$25/- per ton, due to savings in lorry transport. This would have a definite effect on the economic viability of oil palm in certain areas of the Fourth Division of Sarawak. Similarly the effects of road improvements, to permit bigger units and reduce costs per ton could be assessed in terms of effect on land potential. The prospects for using this type of study seem very wide.

Conclusions

It must by now be clear that a land analysis is only accurate at the time at which it is made, and that for this reason must be distinguished from resource surveys which must record data in a scientific manner, unprejudiced, as far as possible, by subjective judgments. In this way the basic data, which changes but slowly, is always available for re-analysis in the light of new conditions.

It is generally true to say that the higher the level of the analysis, the greater is the number of factors involved, and the more prone is the analysis to be affected by change. There is hence a case for

* RPS Bonney BSC, Proceedings of the Town & Country Planning Summer School, Overseas Section 1963.

a process of continuous analysis, and for plan revision as and when warranted by the need to take advantage of economic changes, evolving techniques and changing demands, rather than at any set time interval. Planning in Malaysia seems to be moving in this direction: the mid term revision of the First Malaysia Plan 1966-70 requires a first appraisal of development proposals for the first half of the 1971-75 plan be made so that in practice the development plan eventually will become a rolling programme with a major review every five years, and a minor review every $2\frac{1}{2}$ years. This is probably the greatest degree of flexibility that can be attained, or is even desirable. Plan revision (as opposed to updating) should not be undertaken lightly; and radical changes in physical targets should only be considered when economic projections* show well established long term trends. Decisions relating to proposed land use taken as a result of a fourth level analysis should not be rescinded on the basis of short term price fluctuations.

In Malaysia generally, and certainly in Sarawak, there is a need for more basic surveys. It is true that compared with many, if not the majority, of developing countries progress in mapping natural resources has been rapid; but climatic and hydrological investigations have probably not been given sufficient weight, and hence their potential influence on development tends to be neglected. Similarly very considerable progress has been made in the field of land analysis; but there is still a great deal to be done, both in evolving and refining techniques, and in ensuring that the findings of such analyses are used when development plans are framed.

* Even the best documented economic projection is unreliable enough. In the words of the Statistician M. J. Moroney:- "Economic forecasting, like weather fore-casting in England, is only valid for the next six hours or so. Beyond that it is sheer guesswork." (Facts from Figures, revised 1965).

The development plan has come a long way since the first "Colombo Plan" models were produced. It progressed first from a shopping list to an Economic Plan, and is now in process of becoming physically orientated; or to put it bluntly, of getting both feet on the ground. There is no doubt that development planners at all levels are becoming increasingly conscious of the need to assess the physical practicability of what is economically desirable. The importance of Land Analysis, and of Land Analysis techniques, in such circumstances can hardly be over-emphasised.

Geographical Surveys and Natural Resource
Inventories in Sarawak

Data is available from the following sources:-

Geology

- (i) **Geological** Memoirs with illustrative maps at 1:125,000, or 1:250,000 covering the whole state.
- (ii) **Geological** Reports, with illustrative maps covering selected areas of especial interest. Coverage by such reports is being steadily expanded.
- (iii) Annual Reports of the Geological Survey Department, which include detailed studies of specific mineral resources.
- (iv) 1:250,000 Geological Map, at present being compiled (see Mapping for Development).

Soils

- (i) Reports of the Soil Survey Division of the Department of Agriculture.
- (ii) 1:250,000 Reconnaissance Soils Map of Sarawak (see Mapping for Development).
- (iii) 1:500,000 Generalised Soils Map.

Forests

- (i) Forest inventories undertaken by the Forestry Department. These have been completed for the swamp forests, and a start has been made on the hill forests.

Hydrology

- (i) Sarawak Hydrological year books.

Climate

- (i) Monthly Abstracts of Meteorological Observations for Malaya, Singapore, Sarawak and Sabah.
- (ii) Daily meteorological returns retained by the Director of Civil Aviation.

Mapping for Development

The Land & Survey Department programme of mapping for development has produced six Development Map Series to date, at a scale of 1:250,000, all on the same base map. These are:-

- (i) Land Suitability*: Sarawak Series 17(P).
- (ii) Population: Sarawak Series 18(P) and 18.
- (iii) Land Classification: Sarawak Series 19(P).
- (iv) Land Alienation: Sarawak Series 20(P).
- (v) Mineral Resources*: Sarawak Series 21(P) and 21.
- (vi) Land Use: Sarawak Series 22(P) and 22.

The (P) Series are preliminary series based on the Sarawak Series 14 base map. The plain numbered Series will be printed on the most recently revised base map; Series T503 (New Specifications). These series are described in a booklet "Mapping for Development" which is published by the Land & Survey Department. In addition the Soils Survey Division has produced a generalised Soil Survey Map of Sarawak on the same base map, and the Geological Survey have in hand the compilation of the 1:250,000 Geological Map.

* These two series have been included in the list for the sake of completeness. In fact the Mineral Resources Series and the Land Suitability Series are first level and second level analyses respectively.

First Level Analyses: West Malaysia

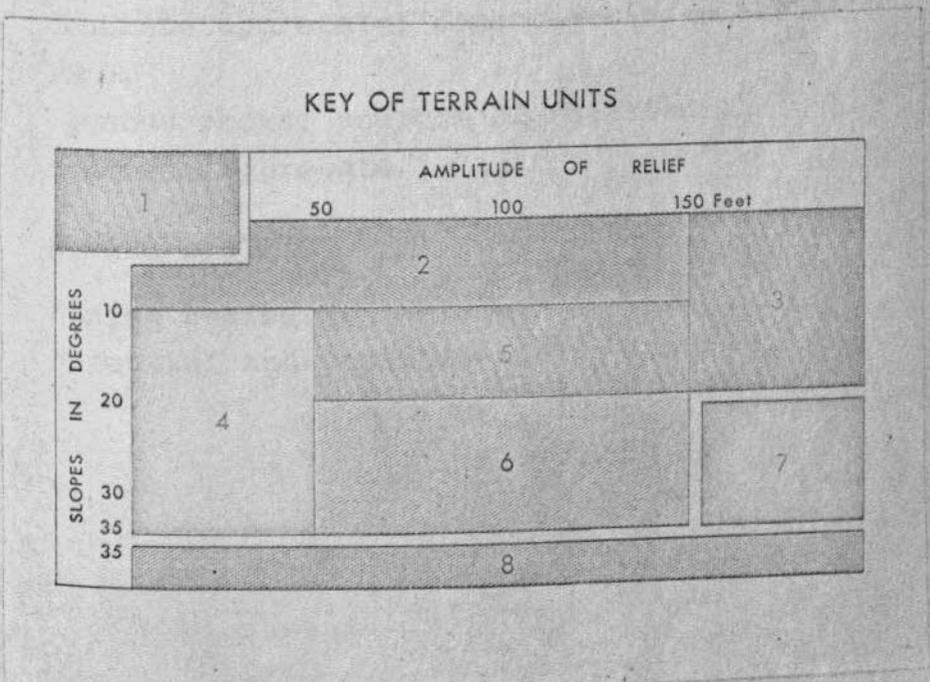
- (i) Soil suitability classified as follows:-
- (1) Soils with no limitations to agricultural development.
 - (2) Soils with few minor limitations to agricultural development.
 - (3) Soils with at least one serious limitation to agricultural development.
 - (4) Soils with more than one serious limitation to agricultural development.
 - (5) Soils with at least one very serious limitation to agricultural development.
- (ii) Mineral Resources classified as follows:-
- (1) Current Mining Land
Land covered by current mining leases.
 - (2) Potential Mining Land
Land shown by prospecting results to contain more than 0.2 kati of cassiterite per cubic yard, or workable surface deposits of other minerals, e.g. iron-ore.
 - (3) Prospecting Reserve
Flat land, possessing a significant mineral potential, which may be allocated for other short-term uses until adequately definitive prospecting has been completed.
 - (4) Possible Mining Land
Land for which present evidence indicates a possible mineral potential but which needs to be more thoroughly examined before commercial development can take place; or unprospected areas which on geological evidence might contain a mineral potential; or unknown areas.
 - (5) Non-mining Land
Land which has been prospected and shown to have no mineral potential, or which on geological evidence is unlikely to have any potential.

(iii) Forest Resources classified as follows:-

- (1) Highly productive forest with a basal area of commercial species of at least 50 square feet, or an approximate equivalence of at least 25 tons of round timber per acre.
- (2) Productive forest with a basal area of commercial species between 35 and 50 square feet, or an approximate equivalence of 15 to 25 tons of round timber per acre.
- (3) Marginal forest with a basal area of commercial species between 20 and 35 square feet, or an approximate equivalence of 10 to 15 tons of round timber per acre.
- (4) Unproductive forest with a basal area of commercial species below 20 square feet or an approximate equivalence of less than 10 tons of round timber per acre.

First Level Analyses: Sarawak

(i) Terrain Classes defined as follows:-



(ii) Mineral Resources classified as follows:-

MINERAL OCCURRENCES

Asbestos	Gravel
Aluminium	Mercury
Gold	Dolomite
Coal	Manganese
Limestone	Nickel
Chromium	Phosphate
Copper	Lead
Kaolinitic Clay	Antimony
Iron	Glass sand

STATUS AND TYPE OF DEPOSITS OR OCCURRENCES

Mine(s)
 Mine(s) disused
 Oilfield
 Deposit with proved reserves
 Prospect unevaluated
 Other occurrences
 Principal quarry
 Suggested quarry site for Sarawak trunk road
 Principal gravel pit
 Borehole with oil indications

CONSTRUCTIONAL MATERIAL

Limestone hills sources of roadstone;
 concrete aggregate; cement-making material;
 lime.
 Igneous rocks; sources of roadstone;
 concrete aggregate

MINING DISTRICT

Mining Leases
 Potential and possible mining land

Example of Second Level Analysis from West Malaysia
Soil suitability for oil palms (Ng Siew Kee 1967)*

Table 1: Major criteria used in assessing soil suitability for oil palms.

Property	Grade		
	Favourable	Marginal	Unfavourable
Terrain	< 12	12-20°	> 20°
Effective soil depth in relation to impenetrable sub-soil layer or permanent water table	> 30 in.	15-30 in.	< 15 in.
Texture	loam or heavier	sandy loam	loamy sand or sand
Structure and consistency	strongly developed, friable to moderately firm	moderately developed and firm	weak or and extremely firm
Laterite	nil	fragmental 6-12 in. thick	fragmental > 12 in. thick or massive
pH	4.0-6.0	3.2-4.0	< 3.2
Peat layer (thickness)	0-2 ft.	2-5 ft.	> 5 ft.
Permeability	moderate	rapid or slow	very rapid or very slow

Table 2. Soil classification based on the criteria of suitability.

Classification	Criteria
Highly suitable	Soils possessing all scheduled properties within favourable grade.
Moderately suitable	Soils possessing not more than two properties in marginal grade.
Marginal	Three or more properties under marginal grade plus one property in unfavourable grade.
Unsuitable	Two or more properties under unfavourable grade.

* Soil Suitability for oil palm in West Malaysia by Ng Siew Kee; Proceedings of the First Malaysia Oil Palm Conference 1968.

The development of the Land Suitability Classification in Sarawak

Land Suitability Classification as used by the Planning Branch of the Land & Survey Department has been developed from very simple beginnings in 1961. It is a general purpose classification, and in its present form represents a compromise between the need for precision and the desire to keep the classification as simple as possible. The stages in development of the classification were as follows:-

- I. Fourth Division Development Plan Classification (1961)
 - Class 1 : Tentative areas suitable to marginal for agriculture.
 - Class 2 : Other areas
- II. First Division Development Plan Classification (1962)
 - Class 1 : Land suitable for agriculture
 - Class 2 : Land marginal to suitable for agriculture
 - Class 3 : Land unsuitable to marginal for agriculture
 - Class 4 : Land unsuitable for agriculture (deep peat)
 - Class 5 : Land unsuitable for agriculture (other)
 - Class 6 : Mixture of 1 and 5, where topography excludes some parts within a generally fertile area.
- III. First Classification for 1:250,000 Land Suitability Series (Sarawak Series 17P) (1964)
 - Class I Flat to gently undulating terrain (slopes less than 5°) with soil of no or few limitations. Suitable for agriculture. Risk of flooding may exist.
 - Class II Gently undulating to moderately dissected hilly terrain with slopes less than 20° (including some hills less than 50 feet high with some slopes between 20° to 35° . Soil with no or few limitations. Suitable for agriculture. But soil conservation measures needed on the steeper slopes.

- Class III Flat to hilly terrain (slopes less than 20°) with soil with several limitations.
Marginally suitable for agriculture due to adverse soil factors.
Expensive soil improvements needed.
- Class IV Strongly dissected terrain with slopes generally between 20° to 35° . Soil with no or few limitations.
Marginally suitable for agriculture owing to extreme danger of erosion.
Very expensive soil conservation measures required.
- Class V Flat to gently undulating with severe soil limitations (mainly mangrove, nipah and peat swamp areas).
Not suitable for agriculture at present owing to adverse soil factors.
- Class VI Rugged country with slopes exceeding 35° in general; or with slopes of less than 35° occupied with soil with severe limitations.
Unsuitable for agriculture.

IV. Second Classification for 1:250,000 Land Suitability Series (Sarawak Series 17P) (1968)

Class	Definition	Suitability for Agriculture
I	Slopes less than 5° (flat to gently undulating terrain); soil with no or minor limitations.	Suitable - risk of flooding may exist.
II	Slopes 5° - 20° (gently undulating) to moderately dissected hilly terrain) including some hills less than 50' high with some slopes of 20° - 35° ; soil with no or minor limitations.	Suitable - soil conservation measures necessary on steeper slopes
IIIa	Slopes less than 5° with moderate soil and/or drainage limitations	Expensive soil and/or drainage improvements needed
IIIb	Slopes 5° - 20° with moderate soil limitations	Expensive soil improvements needed
IV	Slopes 20° - 35° (strongly dissected terrain); soils with few or minor limitations	Danger of erosion; expensive soil conservation measures required
V _{sw} S.	Slopes less than 5° with severe soil and/or drainage limitations	Very expensive soil and/or drainage improvements needed
VI	Slopes exceeding 35° (rugged country) or slopes of less than 35° with severe soil limitations	Unsuitable for agriculture

Sarawak Series 17(P) is a reconnaissance series based on the best material available, at the worst relying on the 1:250,000 Reconnaissance Soil Survey map and air photo interpretation of terrain. The series is subject to regular revision as better material, both in the form of contoured maps (either the T.735 Series at 1:50,000, or the Land & Survey Department's own mapping at 1:10,000) and/or soil survey reports become available. To facilitate interpretation of the soils data a table (see Table 1), which defines land suitability in terms of soil families and terrain classes, has been compiled and this enables revision to be undertaken by staff at the level of technical assistant. Drainage, the third factor to be taken into account, has been related to soil family in the splitting of the old Class III into two sub-classes, a and b. It has not been considered necessary to sub-categorise land in Class V.

Table I

LAND SUITABILITY (AGRICULTURAL) CLASSES

Topographic Categories	1	2	3	4	5	6	7	8
	Flat Land. No appreciable amplitude of relief	Land with slope not 10° amplitude of relief up to 150'	Land with slope not 20° amplitude of relief 150'.	Land with slopes of 10-35° amplitude of relief 50'	Land with slopes of 10-20° amplitude of relief 50-150'	Land with slopes of 20-35° amplitude of relief 50-150'	Land with slopes of 20-35° amplitude of relief 150'	Land with slopes of 35° amplitude of relief 150'
	-	II	II	II/IV	II	IV	IV	VI
	IIIb ^{10°}	-	-	-	-	-	-	-
	V	-	-	-	-	-	-	-
	V	-	-	-	-	-	-	-
	-	II	II	II/IV	II	IV	IV	VI
	-	VI	VI	VI	VI	-	-	-
	-	II	II	II/IV	II	IV	IV	VI
	V	-	-	-	-	-	-	-
	I	II	-	-	-	-	-	-
	I	I	-	-	-	-	-	-
	IIIa	-	-	-	-	-	-	-
	V	VI	VI	VI	VI	-	-	-
	IIIa	-	-	-	-	-	-	-
	III	III	-	-	-	-	-	-
	V	VI	-	-	-	-	-	-
	IIIb	-	-	-	-	-	-	-
	IIIa	III	-	-	-	-	-	-
	IIIa	-	-	-	-	-	-	-
	III	-	-	-	-	-	-	-
	I	-	-	-	-	-	-	-
	IIIb	-	-	-	-	-	-	-
	I	II	II	II	II	IV	IV	VI
	-	IIIb	IIIb	IIIb	IIIb	VI	VI	VI
	IIIba	-	-	-	-	-	-	-
	-	IIIb	IIIb	IIIb	IIIb	VI	VI	-
	IIIa	-	-	-	-	-	-	-
	IIIa	-	-	-	-	-	-	-
	IIIb	IIIb	IIIb	IIIb	IIIb	-	-	-
	V	-	-	-	-	-	-	-
	I	II	II	II/IV	-	-	-	-
	I	II	-	-	-	-	-	-
	-	II	II	IIIb	IIIb	VI	VI	VI
	IIIa	-	-	-	-	-	-	VI
	-	VI	VI	VI	VI	VI	VI	VI
	-	II	II	II/IV	II	IV	IV	VI
	V	VI	VI	VI	VI	-	-	-
	I/IIIa	-	-	-	-	-	-	-
	V	VI	VI	-	-	-	-	-
	IIIa	-	-	-	-	-	-	-
	-	II	II	II/IV	II	IV	IV	VI
	I	-	-	-	-	-	-	-
	IIIa	-	-	-	-	-	-	-
	V	-	-	-	-	-	-	-
	I	I	-	-	-	-	-	-
	-	III	III	III	-	-	-	-
	I	II	II	II/IV	II	-	-	-
	-	III	III	III/VI	III	VI	VI	-
	I	I	-	-	-	IV	IV	VI
	-	II	II	II/IV	II	-	-	-
	I	-	-	-	-	-	-	-
	IIIb	IIIb	IIIb	IIIb	IIIb	-	-	-
	IIIb	-	-	-	-	-	-	-
	I	II	-	-	VI	-	-	-
	-	VI	VI	VI	VI	-	-	VI
	-	II	II	II	II	IV	IV	-
	IIIa	-	-	-	-	-	-	-
	I	-	-	-	-	-	-	-
	IIIb	IIIb	IIIb	IIIb	IIIb	-	-	-

APPENDIX VSpecial Purpose second level analysis of land suitability
for agriculture in Sarawak

(i) Land Rating (Andriess 1966)**

<u>Categories</u>	<u>Sub-categories*</u> (limiting factors)
Category I	a - drainage
Category II	b - soil
Category III	c - topography
Category IV	

THE RATING OF LAND INTO CATEGORIES IS BASED ON THE INCREASING AMOUNT OF EFFORT, TIME AND EXPENSE NEEDED TO REMOVE MAIN LIMITATIONS FOR AGRICULTURAL USE AS INDICATED BY THE SUB-CATEGORIES.

CATEGORY IV REPRESENTS LAND OF THE LOWEST VALUE IN SARAWAK.

* Combinations of sub-categories for land with more than one main limitation are possible.

** Soil Survey Report No. 94, The Sebang, Simunjan, Batang Krang Area by J. P. Andriess 1966.

(ii) Drainage Requirement and Development Potential Classification for Flood Plains and Coastal Areas (Scott 1967) *

CLASS D.I : NO DRAINAGE IMPROVEMENT REQUIRED

CLASS D.IA

Definition: Land on which a wide range of crops can be grown with little improvement. Minor fertility problems. Possible minor drainage problems. Possible intermittent flooding hazard.

Soil families: MALANG. SEDUAU.

Recommended use: Coconut or oil palm (but where other areas are available for these crops such land is best reserved for fruit trees, vegetables, etc.)

CLASS D.IB

Definition: Land on which a limited range of crops can be grown at present. No drainage problems. Moderate fertility problems. All problems easily rectified.

Soil families: KABONG. SEMATAN.

Recommended use: Coconut.

CLASS D.II : MINOR DRAINAGE IMPROVEMENT REQUIRED

CLASS D.IIA

Definition: Land on which wet padi can be grown at present. If drainage improved a wider range of crops is possible. Minor fertility problems. Only minor drainage improvement necessary but for large-scale development Government assistance required in most areas.

Soil families: BIJAT. SEBANDI. MUKAH (10-20 inches peat). PENDAM. JOL.

Recommended use following improvement:

Coconut or oil palm.

* Soil Survey Report No.113, The Tanjong Jol Area by I.M. Scott 1967.

CLASS D.IIB

Definition: As for Class D.IIB but fertility problems moderate to great.

Soil families: TATAU. MATU. NONOK. KAYAN. IGAN (10-20 inches peat).

Recommended use after improvement: Coconut.

CLASS D.III : MODERATE DRAINAGE IMPROVEMENT REQUIREDCLASS D.IIA

Definition: Land not recommended for agriculture without prior improvement of drainage conditions. Where areas are large drainage problems can only be rectified through a major drainage scheme (although where small areas of this class occur in an area of dominantly Class D.II land the entire area can appropriately be considered as the latter for the purpose of planning improvements). Minor fertility problems. Suitable for a range of crops following improvement.

Soil families: MUKAH (20-40 inches peat). ANDERSON 1 (40-60 inches peat; where underlain by sand).

Recommended use after improvement: Coconut

CLASS D.IV : MAJOR DRAINAGE IMPROVEMENT REQUIRED

Definition: Land in which the drainage problems are so great that no agricultural use can be considered unless a regional drainage scheme can be undertaken (and in many areas such a scheme is known to be impracticable). Where small areas of this class occur in an area of dominantly Class III land the entire area can be considered as the latter for the purpose of planning development. Only long-term benefits can be expected from this portion of the area, however.

Soil families: ANDERSON 1 (60-80 inches peat). ANDERSON 2. ANDERSON 3.

Recommended use after improvement: Where peat is underlain by clay, as for Class D.IIIA. Where peat is underlain by sand, as for Class D.IIIB.

CLASS D.V. : DRAINAGE REQUIREMENT UNCLASSIFIED

Definition: Land in which drainage and salinity problems are so great that large-scale improvements would be extremely expensive. It is considered, however, that the agricultural returns from such land are likely to be sufficiently high to justify the cost of such improvements. Such land cannot at present be considered for development where the acreage is large unless a regional drainage improvement scheme can be provided. However, where the acreage is small and adjoins large areas of Class D.IIB land it should be rated as Class D.II land also and included in any drainage improvement scheme planned for the adjacent area.

Soil families: RAJANG.

Recommended use after improvement: There is insufficient data for recommendations to be made, but this land is likely to be appropriate for coconut, oil palm or wet rice after drainage and leaching of salts.

APPENDIX VIThird Level Analyses (West Malaysia and Sabah):Land Capability Classification (Scale 1:63,360)

- Class I Land possessing a high potential for mineral development and therefore best suited to mining. }
- Class II Land possessing a high potential for agricultural development with a wide range of crops and therefore best suited to agricultural diversification.
- Class III Land possessing a moderate potential for agricultural development with a restricted range of crops and therefore best suited to agricultural development with crops having a wide range of soil tolerance.
- Class IV Land possessing a potential for productive forest development and therefore best suited to commercial timber exploitation.
- Class V Land possessing little or no mineral, agricultural, or forest development potential but suitable for development as protective reserves for conservation, water catchment, game, aborigine, recreation, or similar purpose, or possibly suitable in the future for productive forest plantations with introduced species.

APPENDIX VIIThird Level Analyses - Sarawak
Sarawak Land PotentialStudy I: Sieve-Agricultural potential.

The following factors were sieved out:-

Settled cultivation and urban areas	dark violet
Land suitability Classes V and VI	light violet
Land suitability Class IV	yellow
Land Suitability Class III	green
Shifting cultivation	red hatch

This left all Land Suitability Classes I and II which are under primary forest white, and all of Land Suitability Classes I and II which are under shifting cultivation white with a red cross hatch.

Study II: Tentative Development Blocks

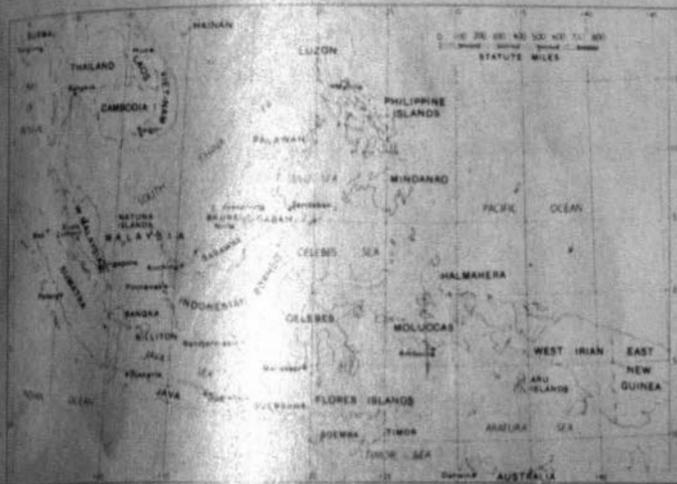
This study shows undeveloped land most suitable for agriculture, related to population and roadstone deposits.

Land Suitability Classes I and II under primary forest	green
Land Suitability Classes I and II under shifting cultivation	yellow
Quarries or potential quarries	red dots
Roadstone deposits	brown border
Base Map	1:250,000 Population Sarawak Series <u>18(P)</u>

On the basis of this study eleven tentative Development Blocks have been identified for further study.

Study III: Permanent Forest Estate

This study relates primary forest to land suitability classes:

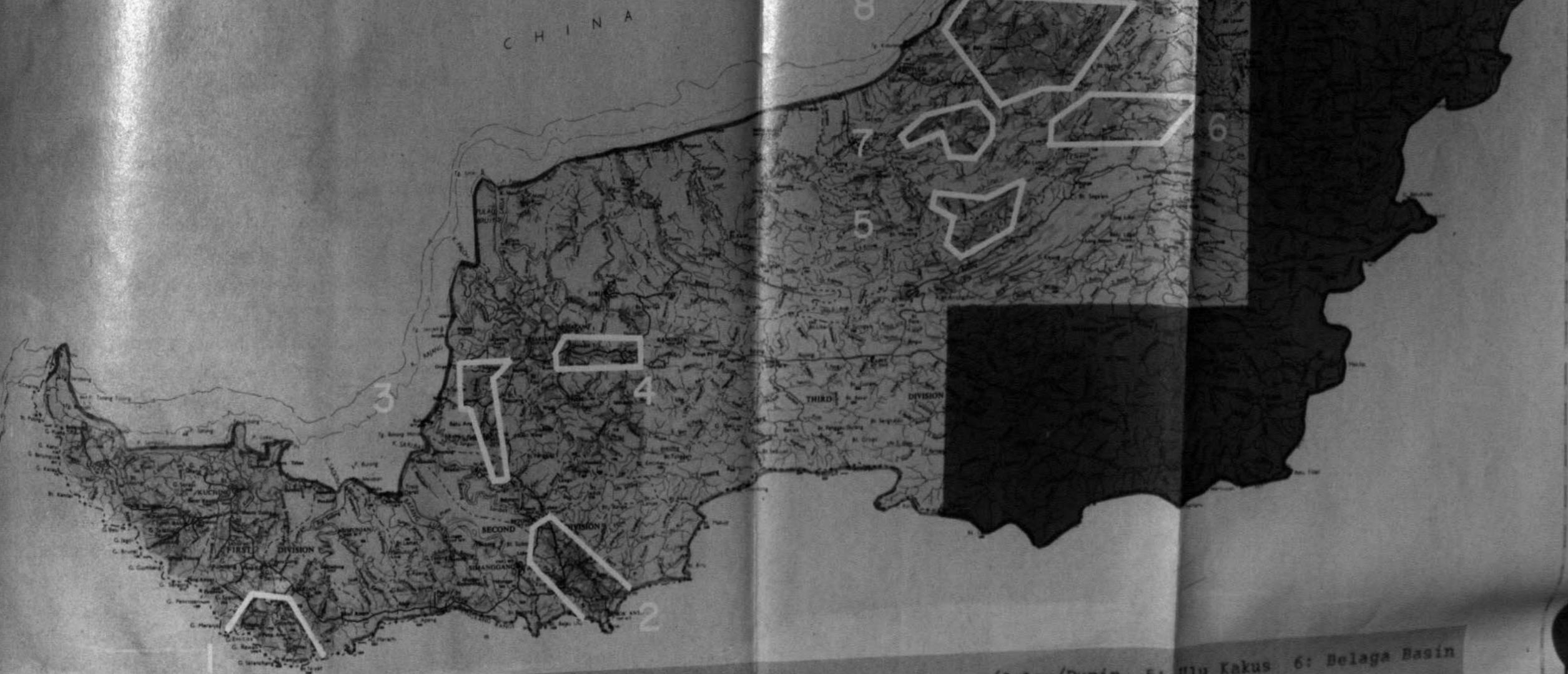


Reconnaissance Study of

SARAWAK LAND POTENTIAL

Tentative Development Blocks comprising large areas of undeveloped land with no discernable factors adverse to development.

Misc. Plan 71055/1 Scale 1:2,000,000



DEVELOPMENT BLOCKS 1: Tebedu/Terbat 2: Skrang/Ai 3: Saratok/Selalang 4: Kelupu/Julau/Durin 5: Ulu Kakus 6: Belaga Basin
7: Ulu Sebauh 8: Kemena/Similajau 9: Extended Lambir/Subis 10: Ulu Teru 11: Limbang Crescent

Session/8

KAOLINITIC CLAY IN THE BALAI RINGIN-ABOK AREA, WEST SARAWAK

By C.H. Kho

Geological Survey, Borneo Region, Malaysia

Kaolinitic clay suitable for ceramic and refractory purposes and paper manufacture occurs in the Balai Ringin-Abok area along the Serian-Simanggang Road in West Sarawak. Prospecting by the Nippon Coal Mining Company during 1962 and 1963 in the 7 deposits out by the road has proved over 4 million tons of clay, of which about 2.7 million tons is considered to be economically workable. Investigations by the Geological Survey, in conjunction with the Mines Department, Borneo Zone, Malaysia in 1967 have discovered 25 new deposits containing more than 9 million tons of clay in areas back from the trunk road. Further substantial reserves are almost certainly present and further work is being continued in 1968.

The kaolinitic clay in this area is thought to be derived by kaolinization of andesitic dykes and sills and partly from weathering of the hydrothermally altered acid igneous rock, probably microgranite.

GEOGRAPHIC AND GEOLOGIC SETTING

The Balai Ringin-Abok area lies in the southeastern part of the First Division and the southwestern part of the Second Division, about 58 to 77 miles southeast of Kuching; it was included in the reconnaissance survey of the Strap and Sadong Valleys by N.S. Haile (Mem. 1). The area is drained by tributaries of the Sadong and Strap Rivers, which discharge into the South China Sea. Many of these headwater tributaries rise on the steep slopes of the Klingkang Range and fall rapidly in a general north direction to the plain before joining the main rivers. The lower reaches of these rivers flow mainly through swampy low-lying country and in consequent are typically choked with fallen trees and floating logs and debris, and the water is generally stained brown by peat-humus. The swamp forest predominates in the low-lying areas, and secondary forest growing in areas of shifting cultivation covers most of the hilly area. Stretches of primary hills still remain on granite hills north of the road and along the steep slopes of the Klingkang Range.

The topography of the district is closely related to the geology (fig. 1). To the north, much of the area is swampy country from which rise a few isolated hills and groups of hills reaching to more than 2,000 feet (e.g. Gunung Buri, 2,442 feet); these hills are formed of volcanic and metamorphic rocks of the Upper Triassic Serian Volcanic and Sadong Formations, pre-Tertiary granite and Tertiary intrusions. The rocks which are covered by the surrounding swamp are for the most part the less resistant formations of the Upper Triassic sediments, probably mainly Sadong Formation shale. To the south, along the Serian-Simanggang Road, the swamp gives way to low undulating country about 50 to 100 feet above sea level, which is probably an erosional feature developed in late Tertiary times; it is formed largely by the shale formations of the Upper Triassic Sadong Formation and lower Tertiary Silantek Formation. On some of the low hills is terrace alluvium generally occurring as a capping. From this low undulating country rise hilly areas reaching as much as 1,000 feet, formed by the resistant rocks such as pre-Tertiary granite and volcanic and siliceous rocks, and sandstone and igneous stocks of Tertiary age. Farther south, the foot-hills of the Klingkang Range rise from the plain giving way to the steep scarp edge of the range, underlain by the gently dipping strata of the Tertiary Silantek and Plateau Sandstone Formations. The crest is mostly 2,500-3,000 feet, and the watershed of this range forms the international boundary between Sarawak and Kalimantan.

The trunk road from Kuching to Simanggang passes through gently undulating country between Balai Ringin and Abok, exposing gently to steeply dipping strata of the Sadong and Silantek Formations, and several small sills and dykes of igneous rocks, of acid to intermediate composition, which intruded into sedimentary rocks.

KAOLINITIC CLAY DEPOSITS

Kaolinitic clay are found along the Serian-Simanggang Road (figs. 2 and 3), and most of the deposits occur in the Telagus area near Mile 65. For the convenience of description, the Balai Ringin-Abok area may be divided into the Telagus Section (in the west) and the Abok Section (in the east). A summary of the main features and field relations of the two sections is given below.

Telagus Section

Occurrence.

Kaolinitic clay is found mostly in areas which are covered largely by the grey-white podsollic soils of the Saratok and Triboh families (Andriesse, 1966). The deposits are pods on the surface and occur mainly in the low undulating hills about 10 to 50 feet above the surrounding swampy alluvium. The clay is most extensive in area northwest of Kampong Telagus and extends as far as 4 miles north of the road, where deposits more than a quarter of a square mile in area are found. The clay, which is usually white to yellowish-white, forms a bed about 11 feet on average, but ranging from 6 to 33 feet, beneath a cover of soil and yellowish-grey to orange, tainted clay as much as 7 feet thick. In a few places, the clay is overlain by a layer 2 to 6 feet thick of terrace sand and gravel consisting mainly of rounded vein quartz pebbles mostly less than an inch across. The clay was shown in boreholes to pass downwards into dark-grey or grey shale at depth ranging from 8 to more than 33 feet. The transition from the white or light-coloured clay to underlying shale is abrupt, but in many cases the white clay near the contact contains small pieces or lenses of dark-grey shale, in which the sedimentary texture is still discernible. The dark-grey shale is probably carbonaceous xenoliths occurring at the junction of the sill or dyke with the country rock, where intimate mixing of the igneous rock with shale has taken place. This mode of occurrence suggests that igneous activity has probably been partly responsible for the formation of the white clay.

Mineralogical and Chemical Composition

X-ray diffraction studies, chemical analyses and electron photomicrographs of the clay samples made by the Nippon Coal Mining Company show that the clay from the road cuttings consists predominantly of kaolinite with appreciable quartz, and subordinate halloysite, montmorillonite, and sericite. The chemical composition of the clay is given in table 1. A clay sample from a cutting near Mile 63 $\frac{1}{2}$ has also been examined by the Mineral Resources Division of Overseas Geological Surveys, London, and the analytical results are summarized in table 2. The sample has the chemical characteristics of a good siliceous fireclay with silica, alumina, and water together accounting for more than 97 per cent of the total composition. The heavy mineral present was found to

TABLE 1. ANALYSES OF KAOLINITIC CLAY FROM BALAI RINGIN - ABOK AREA, WEST SARAWAK.

Sample No.	Locality	Chemical Analyses (percent)										pH	
		Mois- ture	Loss on Ignition	SiO ₂	Al ₂ O ₃	TiO ₂	Fe ₂ O ₃	CaO	MgO	K ₂ O	Na ₂ O		White- ness (per- cent)
B3	Mile 63.5	1.49	7.83	62.61	25.12	0.75	0.55	0.04	0.31	1.23	1.03	81.5	6.5
B8-4A	Mile 65.2	1.31	6.94	64.85	23.49	0.77	0.49	0.18	0.28	1.43	1.07	78.0	6.5
B8-4B	Mile 64.8	1.87	8.01	61.03	25.37	0.83	0.69	0.06	0.34	1.38	1.20	81.0	6.5
B9	Mile 72.5	1.67	5.63	70.04	19.81	0.19	0.47	0.16	0.03	1.65	1.13	89.0	6.6
B10	Mile 74	1.21	4.57	72.26	19.40	0.14	0.47	0.19	0.04	1.14	1.29	88.5	6.7
B11	Mile 76	2.12	5.45	68.30	21.64	0.18	0.33	0.16	0.08	1.62	1.06	84.25	6.8

Analyses by the Nippon Coal Mining Company

TABLE 2. ANALYSES OF KAOLINITIC CLAY FROM TELAGUS AREA,
WEST SARAWAK.

Sample number	S 9015
Location on Kuching-Simanggang Road	63½
Probably derived from	acid igneous rock
<u>Chemical composition</u>	<u>percent</u>
SiO ₂	63.94
TiO ₂	0.20
Al ₂ O ₃	24.23
Fe ₂ O ₃ and FeO	0.68
MgO	0.16
CaO	nil
Na ₂ O and K ₂ O	1.28
SO ₃	0.09
<u>Inferred mineralogical composition</u>	<u>percent</u>
Quartz	36
Mica	9
Kaolinite	52
<u>Size analyses</u>	<u>percent</u>
+ 350 mesh B.S.	20.5
- 350 mesh + 10 microns	12.0
- 10 microns	67.5
Analyses summarized from a report by Mineral Resources Division, Directorate of Overseas Geological Surveys, London, 1963	

consist almost entirely of pale-yellow platy grains of anatase, probably secondary in origin, with very subordinate zircon. This restricted assemblage of heavy minerals suggests that clay is probably derived from an acid igneous rock.

Origin

The origin of the clay is still uncertain, but preliminary field and laboratory investigations suggest that the clay is probably derived from kaolinization of andesitic sills and dykes which intrude sedimentary rocks in the area. Nevertheless, the problem of genesis of the kaolinitic clay is rather complicated, and more detailed mapping and laboratory work will be required to establish the origin of the clay. Samples from a few typical clay profiles have been sent to C.S.I.R.O. Australia for detailed mineralogical studies, in the hope that identification of the clay minerals present might provide some clue to the nature of the parent material.

Abok Section

Occurrence

Only 4 deposits of clay are found in this section (between Miles 70 and 77), 3 of which are exposed in road cuttings. Much of this area is covered by soils that has been classified as an association of grey-white podsollic soils of the Saratok family and red-yellow podsollic soils of the Merit family (Andriesse, 1966). The clay occurs mainly in the low undulating country about 10 to 50 feet above the local riverine alluvium. The clay was shown in boreholes to range from 7 to 32 feet, averaging about 18 feet; it is overlain by a cover of soil and yellowish-grey to orange, tainted clay as much as 10 feet thick, and is usually underlain by weathered microgranite.

Mineralogical and Chemical Composition

Detailed examination of clay samples from road cuttings by the Nippon Coal Mining Company showed that the clay consists of kaolinite and quartz, with a little halloysite, sericite, and feldspar; and the chemical composition is given in table 1. It is interesting to note that the percentage of silica in the clay is higher than that in the Telagus area, and alumina and iron are

both low. X-ray diffraction studies made by Dr P.L.C. Grubb of C.S.I.R.O. Melbourne, Australia on a sample from a deposit back from the trunk road showed that it consists essentially of kaolinite, illite, and some quartz.

Origin

Field evidence and laboratory results indicates that the clay in the Abok area was formed from the weathering of microgranite dykes and sills.

TRANSFORMATION PHENOMENA IN KAOLINITIC CLAY

During the investigation of the kaolinitic clay deposits in the Abok area, it was observed that white clay from below the water table at 15 feet in some of the boreholes changed to a reddish-brown colour on exposure to air; samples above the water table remained unaffected. Two samples were examined in detail by Dr Grubb (Bulletin 9, in press) with a view to determine the cause and possible remedy of this phenomena. Infrared adsorption spectra plus X-ray powder diffraction analyses showed that the sample above the water table consists predominantly of kaolinite, with some quartz and possibly a little albite, whereas the sample from below the water table contains essentially halloysite and hydrohalloysite with subordinate quartz and a little albite, weddelite, and a trace of montmorillonite. It was found that the colour change is due to the oxidation of finely disseminated siderite to a rather amorphous goethite. At the same time, partial dehydration cause flat hydrohalloysite and halloysite sheets to curl up, this being accompanied by the disappearance of the hydrohalloysite phase. Removal of the undesirable brown colouration on a commercial scale is probably uneconomic.

USES AND ECONOMIC PROSPECTS

Experiments made by the Nippon Coal Mining Company show that the clay in the Balai Ringin-Abok area is suitable for ceramics, refractory materials, paper manufacture, and rubber industry. The clay in Telagus area was considered to be comparable to the kaolinitic clay obtained from Cornwall of Britain and Georgia of the United States in regards to glossiness, smoothness, and printing suitability which are the requirements in the manufacture of paper.

After washing and chemical treatment, the clay from the deposit near Sungai Jagu (Mile 63) is considered to be suitable for use as coating and filler purposes in the manufacture of paper. The clay from the new deposits appear identical with that at Sungai Jagu, and may be of the same quality and suitable for the paper manufacture. Most deposits are situated conveniently close to the main trunk road from Kuching to Simanggang, and transport could be by the trunk road for about 64 miles to a shipping point at the Tanah Puteh Port, where a 25-foot draft ship with a capacity of about 10,000 tons is able to berth. However, the existing Kuching-Serian Road is considered to be unable to stand the extra traffic involved, and improvements of the existing road are essential.

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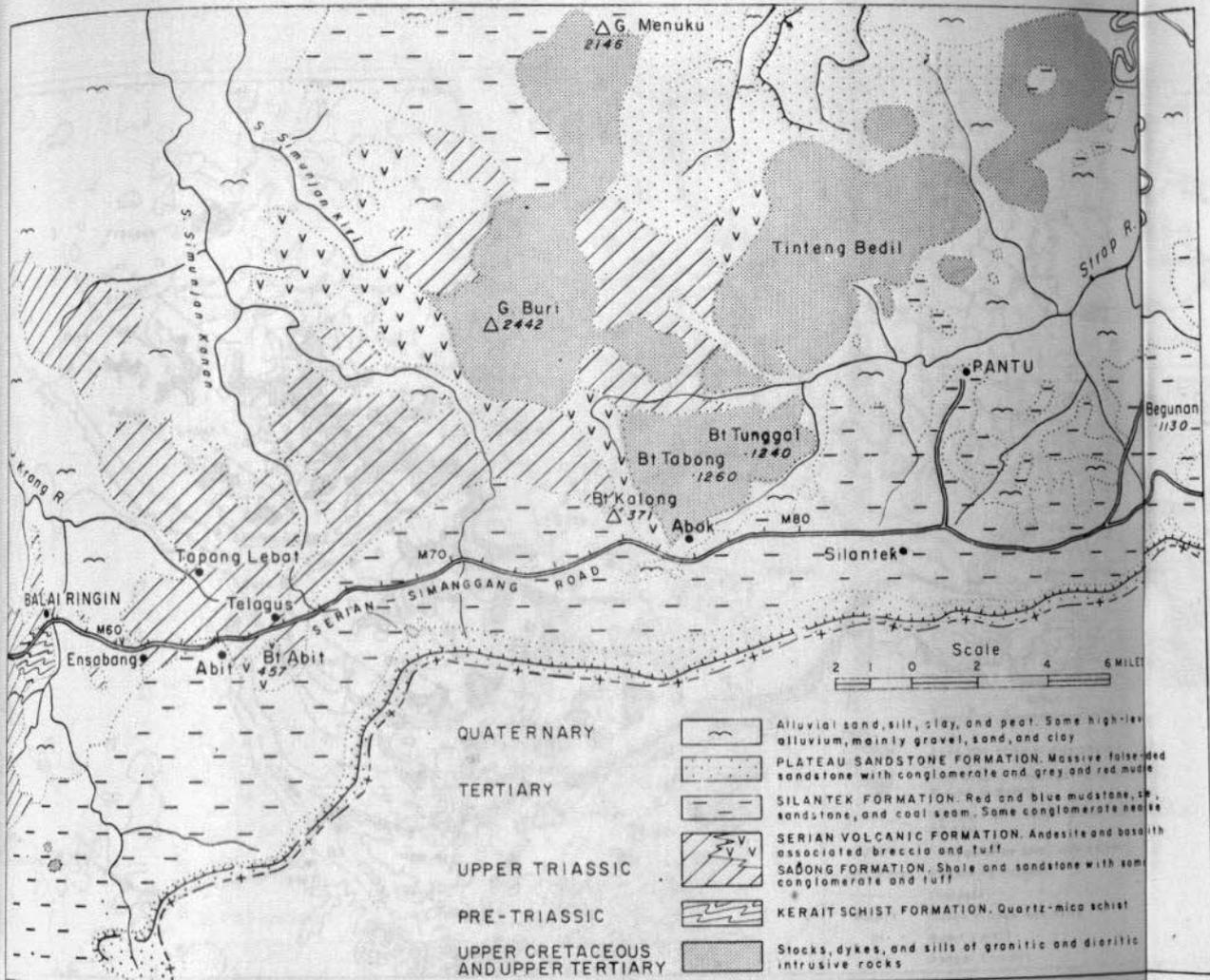


FIGURE 1. Simplified Geology between Balai Ringin and Silantek, West Sarawak

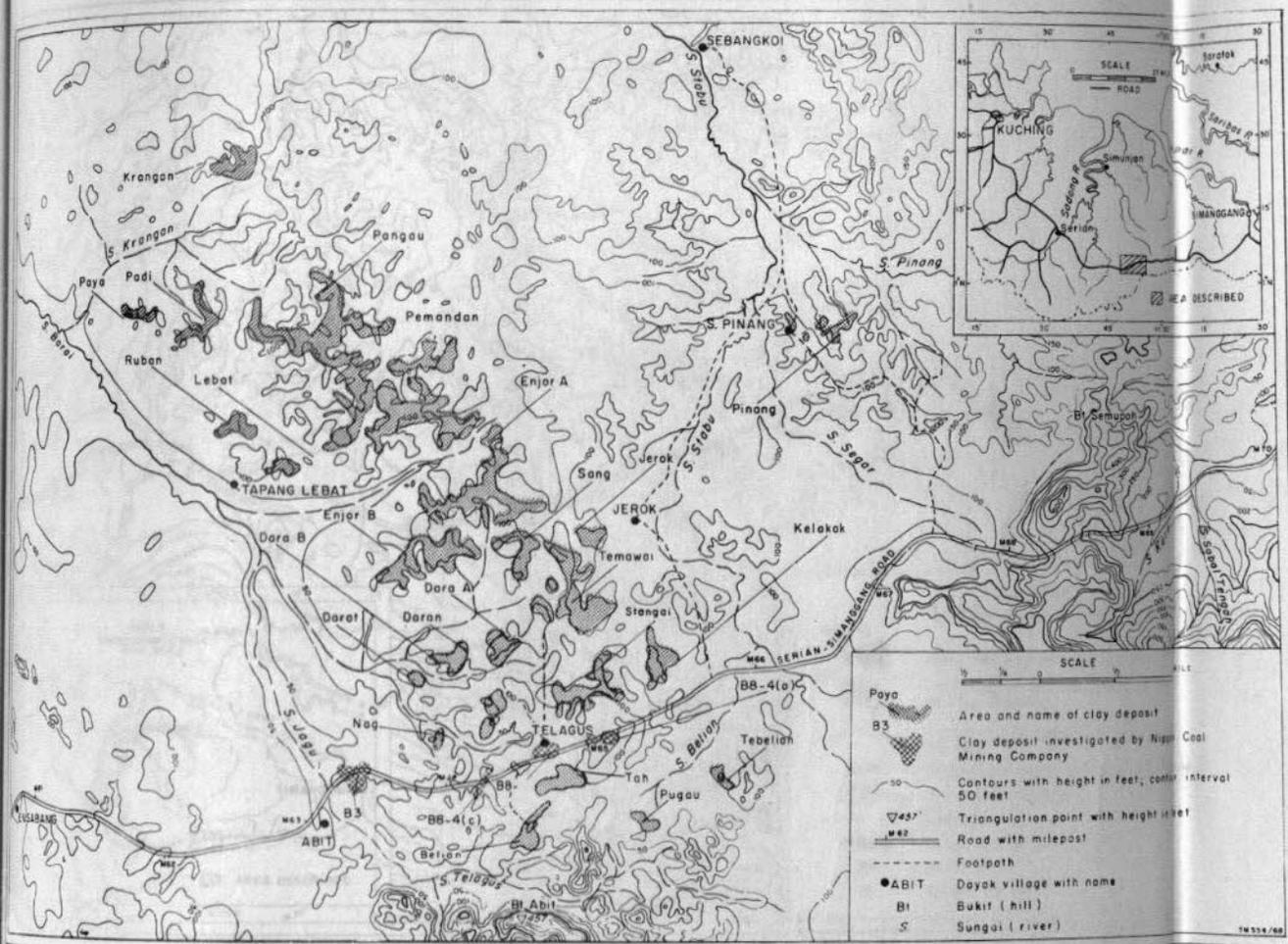


FIGURE 2. Kaolinitic clay deposits in the Telagus area, West Sarawak

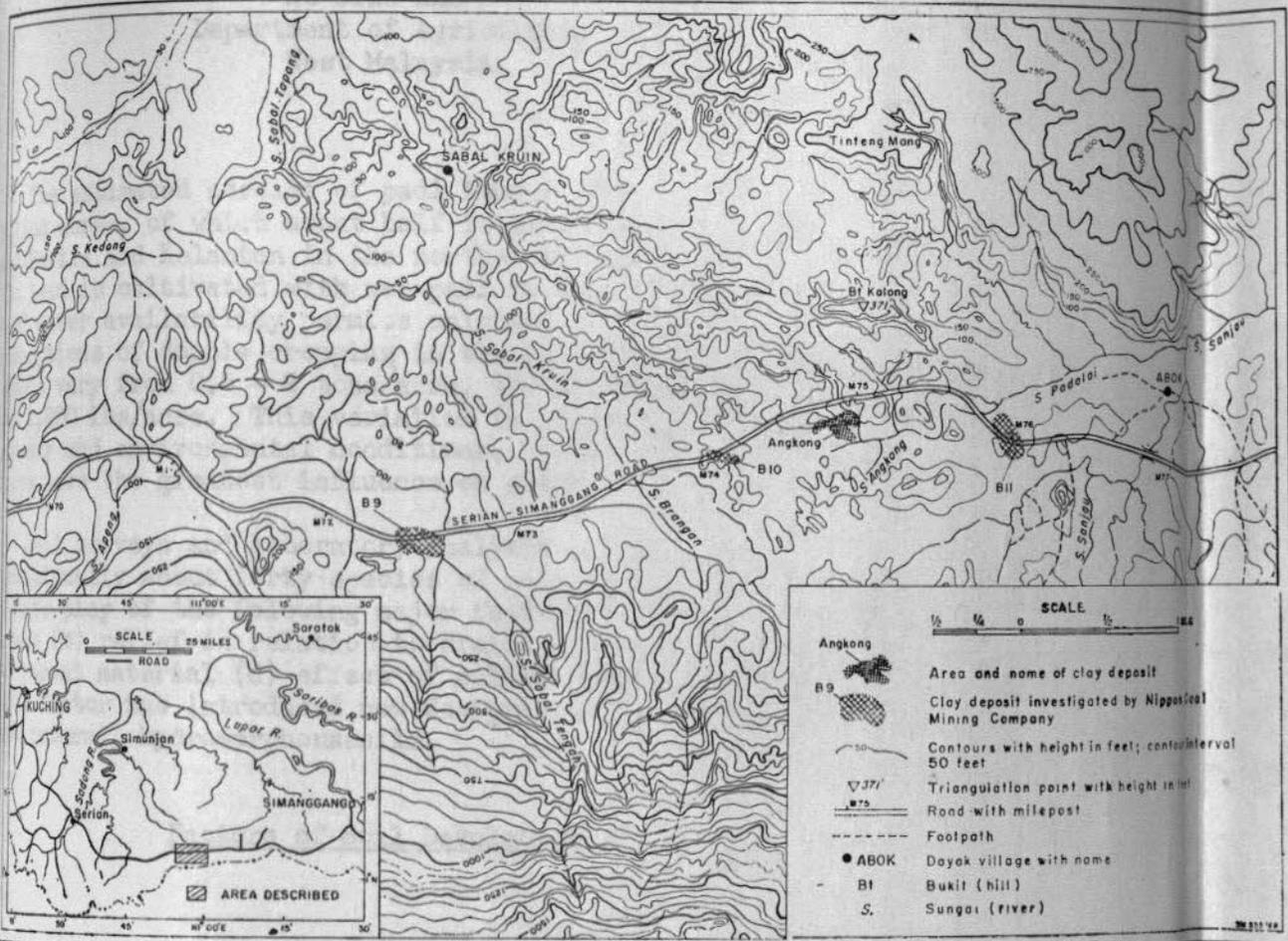


FIGURE 3. Kaolinitic clay deposits in the Abok area, West Sarawak

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The estimated acreage of padi land in West Malaysia is approximately 10 million acres, of which about half is accounted for by the coastal plains of Perlis and Kelantan in the north-west and north-east respectively. This land is cultivated with wet padi on flat terrain and hitherto, the lack of water availability permits only one crop per year, with relatively few exceptions of double cropping in the States of Penang and Selangor. Yields vary from 0.5 - 2 tons/acre, the national average being estimated at about 1,800 lbs/acre. This variation in yields is attributed to factors of soil fertility and environmental conditions. Of the latter, soil and water conditions have the greatest influence on yield.

Soil surveys and laboratory analysis carried out so far have identified provisionally about forty species of padi soils. These have resulted from an interplay of the following major factors of soil formation viz. (a) climate (b) relief in relation to drainage status or water regime in the area (c) parent material (d) effect of cultivation by man and (e) time. The human factor has introduced new features in the soil which distinguish them from natural, hydromorphous soils.

Factors of Soil Development

West Malaysia has a hot, humid tropical climate. Day temperatures are mostly in the eighties (°F) while at night, they are about 10°F lower. The main element which affects the development of these soils is the distinct dry season of about two to three months' duration beginning from the time of the rice harvest. For illustration, the rainfall figures for Alor Star and Kota Bharu are given in Table 1. During this period, the ground water-table is usually below four feet and wide cracks develop on the heavy marine clays on the coast, except in the very poorly drained localities. This pronounced desiccation and subsequent wetting and swelling of the clays has definitely influenced the development of mottles and structures in most soils. The advent of large scale double cropping in future is expected to reverse this long term effect.

Table 1: Main Rainfall Data for Alor Star and Kota Bharu (Ins)

	MONTH												Total
	J	F	M	A	M	J	J	A	S	O	N	D	
Alor Star	2.2	1.9	5.7	8.7	10.2	7.5	7.8	10.4	11.6	12.5	8.5	4.3	91.3
Kota Bharu	10.0	4.1	5.7	4.5	5.3	6.1	5.7	6.7	8.4	10.1	24.6	22.3	113.5

Soil and Drainage Status

Almost all the padi soils are below the 50 ft. contour line and on the coastal flood plains, they are below 25 ft. above sea level. Only the soils on terraces or levees are above the 25 ft. contour. Thus the majority of padi soils are subject to a very high water-table or flooding during

season of heavy rains. Under this alternate waterlogging and drying
reduction and oxidation processes operate and these are influenced
differences of micro-relief which induce varying degrees of hydromorphism
the padi plains. These degrees of wetness constitute the major criteria
separating the soils below the great soil group level.

Parent Materials

Alluvial deposits form the parent materials of padi soils in West
Malaysia and they are grouped according to their geogenesis as follows:-

1. Recent marine sediments.

- (a) Fine sediments of clays and silts in coastal plains. These are the most extensive and predominate in the west coast.
- (b) Coarse sediments of mainly sand with some fine materials. These are minor in extent and localised in the east coast.

2. Riverine alluvium.

- (a) Flood plain deposits of major rivers such as the Sg. Kelantan and Sg. Trengganu. These deposits are mainly found in the east coast.
- (b) Flood deposits in low lying tracts in more inland situations. These as narrow strips commonly occur along the banks of rivers.

In these riverine deposits, the presence of fine sand is generally noticeable.

3. Sub-recent alluvium.

This occurs in low terraces which are slightly above the level of present flood plains and consists of transported material weathered from older country rocks. These are found mostly in Perak, Perlis and Kelantan.

4. Mixed marine-fluvial deposits.

There is evidence that where riverine flood deposits came into contact with the marine sediments, a mixed alluvium resulted and this gave rise to intergrades in soil evolution.

Man's Cultivation

Man's introduction of rice cultivation into these naturally wet soils has considerably influenced profile development. In West Malaysia, the most striking characteristic is the presence of a distinct ploughsole or hardpan within 2 - 6 inches of the surface horizon. This ploughpan has been produced by the continuous shallow ploughing and compaction of the topsoil and varies from 1 - 4 inches in thickness. It is very sticky and impervious when wet and hard like a briquette when dry. It is this impervious pan which creates a perched water-table at the early part of the rainy season when the ground water-table is still well down in the profile. The ploughsole is essentially a gleyed horizon created by Man and this has produced a surface water gley in the A horizon within a natural ground water gley. This creates the unusual situation where a lower horizon is relatively more oxidised than an upper horizon and this feature is quite characteristic of padi soils in West Malaysia.

A second activity of Man is the construction of drainage and irrigation canals which have accelerated profile development in these natural hydro-morphic soils.

This has affected profile development principally in two ways. One is the age of the alluvia, as in the marine sediments where younger profiles tend to occur in the fringe of the main coastal plain. The other is the history of padi cultivation as less prominent ploughsoles are developed on the more recently opened land.

Profile Morphology and Drainage Classification

The most significant pedogenetic phenomenon which governs the development of profile characteristics in these soils is hydromorphism. Dynamic soil processes are those involving mobilization of soil constituents, mainly iron and manganese, in the more reduced zones and their subsequent immobilization in the oxidised parts of the profile. Reactions are thus largely governed by soil conditions and as these vary in relation to micro-relief and parent material, varying degrees of hydromorphism are produced as reflected by the intensity of mottling, gleying, concretion formation, as well as structural development.

These major distinguishing features are therefore used to determine the drainage status of a particular padi soil.

Padi soils in West Malaysia can be grouped into the following drainage classes. It should be pointed out that this differentiation is specifically for wet padi soils and is not applicable to general usage.

Poorly drained soils

These occur in the most low lying parts of flood plains or river tracts and are submerged for the greater part of the year. During the dry season, however, the surface horizon is generally aerated. These soils are characterised by a dark organic topsoil with few mottles overlying a gleyed subsoil which is often sulphurous. These soils are therefore very acid. A 'B' horizon is absent. The horization is thus: ApgG - AsG - (AG) - G where s denotes ploughsole. A typical example is the Telok Series, found mainly in Kedah, Perlis and Perak.

Imperfectly drained soils

These are relatively better drained than those of the previous group and are characterised by a moderately developed B horizon which is mottled and has mainly very coarse to coarse structures of firm consistence. However, gleying has not advanced to such an extent as to completely alter the original gley horizon and gleying is still prominent in this horizon. The common horization is ApgG - AsG - (AgG) - BgG - G. These soils are mainly derived from marine and river alluvium. Examples are Kuala Kedah and Jelawat (tentative).

Moderately well drained padi soils

These soils possess a distinct B horizon in the profile. This horizon has many prominent yellowish and reddish brown mottles and structures are generally medium to fine subangular blocky generally of firm to friable consistence. Slickensides can occur in the BgG horizon and occasionally, blotches of soft iron concretions may be found. The common horization is Apg - AsG - (AgG) - Bg - BgG - G. Examples are Rotan and Chengai and Kadok (tentative). These soils are most extensive on marine and marine-fluvial deposits in the coastal area.

Well drained soils

These soils are either situated in relatively higher elevations or on lighter textures. They are characterised by a prominent B horizon which generally dominates the soil profile and the G horizon is commonly below 30 cm. The B horizon is not only profusely mottled but abundant concretions of

and manganese are also distributed in this horizon. Structures are typical of fine to medium sub-angular blocky with friable to firm consistence. Common horizonation is Apg - ApgG - (AgG) - Bg(ir-mh) - BgG.

These soils are largely found on river, terrace or mixed alluvium. Examples are Kangar, Sembrim and Sedaka.

Very well drained soils

These are the most well drained padi soils and differ from those of the previous group in that a large portion of the manganese concretions has been concentrated in a separate horizon (or horizons) within the B horizon. In some soils, two horizons containing manganese concretions may be found. Structures are relatively more sandy and structures finer. The horizonation is usually:

Apg - ApgG - Bg(ir) - Bgmn - Bgir
 or " " - Bgmn - Bgir - Bgmn

It can be said that the B horizon is mainly oxidised for the greater part of the year. Examples are Batu Hitam and Bachok, found on the higher levees of the major rivers and beach sands respectively.

Major Properties

The relatively more important properties of the padi soils are shown in Table 2. (by courtesy of K. Kawaguchi).

Table 2: Major Properties of Padi Soils (Plough layer)

Property	Parent Material				
	Marine Clays	River Alluvium	Terrace Alluvium	Marine Sand	Mixed Sediments
Number of profiles studied	14	14	2	1	6
Texture	light to heavy clay	clay loam to heavy clay	clay loam to silty clay	fine sandy loam	light to heavy clay
Mineralogy					
Kaolinite %	25-35	70-90	90	60	45-55
Illite %	5-10	5-10	5	5	5-10
Montmorillonite %	50-70	5-20	5	35	40-50
Vermiculite %					
Ca (M, Ac) m.e.%	15-29	2.4-7.0	2.4	2.0	8-16
Mg m.e.%	8-20	1-3	1.0	0.4	1-5
Co "	2-12	0-5	1.2	2.0	2-5
K "	0.2-1.8	0.1-0.4	0.3	0.08	0.1-0.4
CS	1.6-9.5	1.1-3.5	2.2	0.6	1-7.5
NS	0.1-0.7	0.1-0.3	0.15	0.05	0.1-0.9
pH	3.6-6.5	4.2-5.2	5.2	5.2	3.9-4.7
Available P (ppm)	0.4-7.5	0.3-0.9	2.0	0.1	0.4-6.0

The data show that the majority of padi soils in West Malaysia are textured and that clay mineralogy, cation exchange capacity and organic content provide the most useful bases for differentiating padi soils. Illite-vermiculite predominates in the marine clay soils whereas kaolin is dominant in soils derived from river and trace alluvium. A fairly even mixture of these minerals in soils occupying intermediate positions between the marine alluvium and river or terrace alluvium indicates a mixing of these minerals. Exchangeable cations, especially magnesium and potassium are distinctly higher in the marine clays. Organic matter and nitrogen contents are generally higher in soils derived from marine and mixed sediments but they are also more variable. Similarly, pH values in these soils are also more variable. Easily available phosphate contents are higher and more variable in marine clays and sediments than in the others although all indicate a low phosphate status.

Genetic Classification

Padi soils in West Malaysia have not been classified beyond the 'Series' level so far. Under the classification of Thorp and Smith (1949), they would be classified as Humic gleys or Low Humic gleys in the Hydromorphous Sub-order Entisol soils. By the 7th Approximation of the U.S. Department of Agriculture (1960), they would probably be under the Inceptisol and Entisol Orders, suborders being Aquept or Aquent. However, present field and laboratory data are not comprehensive enough to justify further division according to the nomenclature of the 7th Approximation or its amendment.

For the present however, it is feasible to classify padi soils in West Malaysia below the Great Soil Group level by following broadly the scheme proposed by Kanno (1962) for Japanese rice soils. At the Sub-group or Family level, the drainage regime of a soil as depicted by its genetic horizonation is the criterion of separation. In this manner, five drainage Families can be established as described previously. At the 'Series' or preferably Genus level, clay mineral composition and presence of peaty or organic surface horizons form the criteria. Twelve genera are proposed to accommodate the various soils and they are shown as follows:

<u>Family</u>	<u>Genus</u>
1. Poorly drained soils	1. Telok
2. Imperfectly drained soils	1. Kuala Kedah
	2. Jelawat*
3. Moderately drained soils	1. Rotan
	2. Kadok*
	3. Tulang
4. Well drained soils	1. Sedaka
	2. Kangar
	3. Sembrin
	4. Pasir Puteh
5. Very well drained soils	1. Batu Hitam
	2. Bachok*

* - Provisional

It is unlikely that the number of Genera would be appreciably increased when more of the padi soils were covered by detailed studies.

At the next lower level, species are distinguished mainly according to differences in texture and to a lesser extent structure. Since more species are likely to be encountered than hitherto, it is not attempted to classify at this level at present.

Soil Fertility and Padi Yields

As no systematic and comprehensive measurements of padi production on different soil species have been undertaken, only broad observations can be made. Generally, the lowest yielding soils are the poorly drained, where acid sulphate and deep water conditions often retard establishment and in some seasons large areas are abandoned. Liming is a pre-requisite to amelioration but this has not been found to be economic so far because of the high cost of lime. Next higher yields are the very well drained soils where low nitrogen and phosphate status, and rapid drainage are the major limitations. Where irrigation is provided, high yields are obtained. Soils of the remaining three drainage Families on alluvial plains comprise the best padi soils but differences in yield within each Family can be generally greater than those between Families. These differences are due to various factors of nutrient status, chiefly nitrogen and phosphate, and water conditions. In this respect, the marine clays within these Families are on the whole more productive than those derived from river and terrace allu-

Tang and Vamathevan (1967) carried out adaptability trials with varieties of padi on some of these soils and their mean results over four seasons are presented below in Table 3.

Table 3: Mean Yields (4 seasons) of 28 Padi Varieties on Different Padi Soils in West Malaysia

<u>Soil Genus Represented</u>	<u>Padi Yields lbs./acre</u>
1. Telok	2569 (with liming)
2. Kuala Kedah	2921 ; 2038
3. Rotan	3300 ; 3200
Tualang	2770 ; 3675
4. Kangar	2526
Sembrim	2535
Pasir Puteh	2429
5. Batu Hitam	2668* ; 1682 ; 1365 and 1203
Bachok	2173

From the range of yields obtained, it can be seen that there is considerable room to improve yields in West Malaysia, through better soil and water management. In soil management, nitrogen and phosphate needs require the most attention.

* - Irrigated

Acknowledgement

I wish to thank Prof. K. Kawaguchi and Dr. K. Kyuma, Kyota University, for chemical data and clay mineral analysis. Grateful thanks are also due to my colleagues, Messrs. Law Wei Min, Ignatius Wong Fen Thau and K. Selvadurai for valuable discussion and comments.

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Introduction

Throughout the world, resource surveys are prompted by growing pressures of population on the land and with the realisation that solutions can only be found by the complete development of the resources available. Lands presently unproductive must be brought under the plough and the land use in areas of older settlement must be intensified or changed.

The aim of a Land Use Survey is to present, in some form or other, a picture of existing land utilisation. The method of execution and the form of presentation depends on the scope of the Survey, the degree of accuracy required, and the basic materials available. The usual end-products are a cartographical display and/or an area account of existing utilisation.

The word "present" often qualifies this type of survey and places emphasis on the status quo nature of the information. The value of "present" information decreases with time and the use of this word also means that the importance of producing information in a speedy fashion is realised.

Up till now in West Malaysia the best cartographical display of land use has been contained in the National Topographical Mapping Series derived from State maps at smaller scales depicting land alienation. The information obtainable from this mapping is undetailed, often out-of-date, and in many places misleading (land alienation often bearing no relationship to actual use). Acreage statistics of major crops and some land use sub-categories are obtainable from various Government Departments, but the validity and accuracy of such acreages are dependent on the survey methods employed with the result that values are not always completely accurate. Also it is often difficult to relate such results to specific geographical locations.

The Present Land Use Survey attempts to produce a complete, quick and accurate picture of land use both cartographically and statistically, so that a complete account of all significant forms of land utilisation are given and displayed for every Mukim, District and State in the Country. The Planner is thus supplied with a complete statistical inventory of the present land use, geographically displayed and with this full understanding of the situation the formulation of development plans is facilitated. Large and small scale mapping combined with acreages listed for all political units ensures the comprehensive supply of "bench mark" media both for the Local and National Planner.

The tangible end-products of the Survey are:-

- a) Present Land Use Mapping (1966) at a scale of 1:25,000
- b) " " " " " " " " " " 1:250,000
- c) Acreage statistics of all land use sub-categories.

Malaysian Agriculturists and Planners have realised for some time the need for such information, but it was not until the drawing up of the First Malaysia Plan that the requirement was crystallised into action. Under the Malaya Development Plan, the Canadian Government was requested to conduct a resource type survey over West Malaysia, which from a land use point of view, would entail the supply of medium scale aerial photography and the execution of a Present Land Use Survey.

The Canadian Government contracted Lockwood Survey Corporation of Canada to conduct this Survey and Canadian aircrew and aircraft commenced the aerial photographic phase in early 1966. Aerial photography at the scale of 1:250,000 was taken of the entire area of West Malaysia by early 1967 and the Present Land Use Survey could then commence.

Methodology

An understanding of the methodology can best be obtained by briefly describing the four distinct and interlocking phases of the Survey.

Interpretation:

Aerial photography is stereoscopically inspected and interpreted by the application of a land use classification legend. This legend is substantially the same as the one recommended by the Commission on World Land Use Survey and only slightly modified to suit Malaysian conditions. The actual photography being interpreted is photography printed from the original negative but scaled to fit the National topographic mapping base of 1:25,000. On this photography land use sub-categories are bounded by inked lines and this photography becomes a permanent record of the Survey. This classification legend is included as Appendix A.

Manuscript Compilation:

The interpreted scaled photography is keyed to the transparent compilation bases of the 1:25,000 National mapping series and the land use information is traced on to a manuscript on stable film. At this stage a certain amount of planimetric detail and all local political boundaries are added to facilitate future field orientation of the final mapping.

Area Measurement and Area Tabulations

The manuscript is the basis for both the final phase of fair-drawing and area measurement.

On each 1:25,000 land use manuscript an acreage count is made for each sub-category and these acreages are tabulated by Mukims. At this stage a valuable control check is obtained as the cumulative acreage of a great number of small sub-category units must obviously equal that of the total acreage of the gridded sheet.

Whenever a District has been interpreted and mapped in manuscript form it is possible to compile a District Abstract of land use acreages where all acreages are listed under Mukims. From this abstract a separate District Summary sheet of acreages is compiled for each District, where land use sub-category acreages are also presented as percentages of the land use category of the District as a whole. The total agricultural acreage is given and presented as a percentage of the District while agricultural sub-categories are shown as a percentage both of agricultural land and of the District as a whole. A State Summary of land use acreages (the one for Malacca is Appendix B of this paper) follows substantially the same outline as the District Summary with the combined State Land use acreage and percentages being listed as well as those for the component District.

The interpreted scaled photography is keyed to the transparent compilation bases of the 1:25,000 National mapping series and the land use information is traced on to a manuscript on stable film. At this stage a certain amount of planimetric detail and all local political boundaries are added to facilitate future field orientation of the final mapping.

Fair-drawing:

Land use mapping at a scale of 1:25,000 is being prepared for the entire country conforming to the National 1:25,000 Mapping series. Seven hundred and twenty eight sheets make up this coverage, but it is estimated that about one hundred and thirty of the sheets contain nothing but forest and will therefore not justify being published. So roughly six hundred sheets similar to Map A of the Appendix will be produced.

The final map sheet is compiled by a fairdrawn tracing of the manuscript on stable film (Durafilm). This is the final record from which printed maps or dyeline copies can be made; these may then be hand coloured by the user according to a recognised colour system suggested by the Commission on World Land Use. In view of the anticipated limited market, the cost of publishing a printed colour series at this scale is not considered.

A printed coloured land use map series at a scale of 1:250,000 conforming to the national mapping series at that scale will be published. Fourteen sheets cover the country and it is considered that land use mapping at this scale would be useful as an overall picture of the present condition as well as an aid in regional planning.

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Appendix A.

THE LAND USE CLASSIFICATION LEGEND OF WEST MALAYSIA

Introduction

The Land Use classification, developed for West Malaysia, is one based on the format presented by the Commission on World Land Use Survey for international application. It has been modified to more precisely meet the requirements of Land Use as found in West Malaysia, while still conforming to the internationally recognized and established system. The obvious advantage being that actual photographic interpretation and subsequent mapping will be immediately readable and understandable to a wide and growing group of specialists continually dealing with Land Use Classification, Land Capability and Agricultural Development Programmes.

The development of the classification legend now presented has taken five months during which time preliminary legends were applied on a production basis to three different areas in West Malaysia, while reconnaissance trips were made to other areas possessing distinctive land use patterns. The writer believes that this legend; allows photo-interpretation to be accomplished with the minimum of deliberation; keeps field checking to a minimum; and yet enables the identifications of all categories necessary for the subsequent compilation of meaningful Land Use Mapping and area measurements.

Classification Modifications

In developing the system of classification used for mapping land use in West Malaysia, two important requirements have been kept in mind. The first requirement is that any classification system should conform as closely as possible to an internationally used and accepted classification. The second requirement is that any classification system must include all significant land use types found within the area for which it is to be used. It is believed that this classification embodies these qualities and only in a minor way do the local modifications differ from the internationally accepted framework.

Two slight changes in nomenclature were considered necessary. First, the Commission's category 6, "Unimproved Grazing Land", has been re-named "Grasslands" because, although it is possible to interpret and map areas of low vegetative cover that might or might not be used for grazing, it is not always possible to accurately determine whether or not these areas are actually used for this purpose. In fact most small herds of cattle graze within and on the boundaries of some of the other categories. e.g. on road right of ways, within settlement areas, inside small holding rubber areas and on some padi areas during the "off-season". Second, the Commission's category 9, "Unproductive Land" has been re-named "Unused Land" as it is considered unwise to negate the possibility of future use under hitherto unknown practices.

Category 8 "Swamps and Marshes" has been enlarged in concept to include vegetation types growing permanently in fresh or salt water and associations found in areas of permanently high water table where the surface may only dry out for a few weeks each year. It seems illogical to include this type of vegetation in the forest category as its very existence depends on a swamp environment and without this condition it would cease to exist.

The sub-categorisation of category 7 "Forest Land" has been kept to a minimum with the knowledge that the National Forestry Department are in fact presently executing a comprehensive forestry classification interpretation on the same photography.

Category 5, "Improved Permanent Pasture" has been maintained although the total national acreage is exceedingly small. The few areas that do exist are being grown on an experimental basis but it is anticipated that this land use type will expand in the future. A detailed explanation of this Classification Legend and a Generalized Legend follows.

PRESENT LAND USE CLASSIFICATION LEGEND FOR WEST MALAYSIA FOR THE
INTERPRETATION OF 1:25,000 PHOTOGRAPHY TAKEN DURING 1966

1. Settlements and Associated Non-Agricultural Lands

1U: Urban and Associated Areas

The truly built-up areas of cities, towns, kampongs with associated and surrounding parks and open spaces. Also detached industrial sites, settlement areas, reservoirs etc. Fringes of large urban centres, strip developments and most kampongs may be included in Category 2H if the settlement density does not appear dense and the vegetation indicates that the land use emphasis is that of "Mixed Horticulture". Areas obviously in the process of being cleared for future urban expansion and areas containing road patterns but presently without buildings are also included.

1E: Estate Buildings and Associated Areas.

All areas of estate housing, schools, hospitals, administrative buildings and recreational land. When groups of these exceed three acres they are interpreted but individual and isolated buildings occupying less than this acreage are ignored.

1T: Tin Mining Areas

All areas previously laid waste; areas being worked at present and cleared land obviously designated for tin mining. Within these areas all water bodies greater than three acres are identified and given the code (W).

1P: Power Lines

Power lines or transmission lines of a width greater than one hundred feet are interpreted where they interrupt the land use of the areas they transverse. If there is no disruption of the land use activity the presence of a power line is ignored. e.g. a wide power line crossing a block of padi may not prevent the homogeneous development of the padi area. When a transmission line traverses and interrupts the continuous activity of a sub-category then the actual land use of the line should be indicated in parenthesis e.g. IP (6) would indicate a power line swath with a ground cover of grassland.

2. Horticultural Lands

2H: Mixed Horticulture

This is a very wide and extensive sub-category including all the typical diversified "garden cultivation" found in a haphazard fashion around a family unit. It may be better visualised if it is realised that the terms, "Dusun", "Minor Cultivation", "Domestic Cultivation" and "Domestic Horticulture" were all considered as possible descriptions.

The essential basis is the family settlement unit with emphasis on the production of diversified crops for family needs with the possibility of small surpluses being sold locally. Included are mixed vegetables, yams, tapioca, chillies, pine-apples, fruit trees, bananas, papaya, coconuts etc.

The complexion of this sub-category changes according to geographical location, soil condition and local traditions but the essential feature is always diversification and the activity is intense and focused around the family unit.

Often this sub-category, although existing, is completely overshadowed by the importance of the activity within which it exists. For example, if it is present in small patches within an area of intense smallholding coconuts, then the area will merely be designated as coconuts. Also, where units of more than three acres of other sub-categories appear with a background of Mixed Horticulture, they are then, of course, separately identified. It is not uncommon to find five to twenty acre lots of small holding coconuts, rubber and orchards within and on the periphery of "Mixed Horticulture".

The most common location is along roads and waterways forming buffer strips between estate and smallholding crops.

The interpreters decision to designate an area as 2H is taken when homogeneous units of other sub-categories are not discernible and the intense land use activity is focussed around rural settlement. Mixed tree crops (often very dense) intermingled with small garden plots, footpaths and housing are the cumulative criteria necessary for designation as 2H.

2M: Market Gardening:

Areas where the obvious emphasis is on the commercial production of fresh vegetables. The pattern is that of intense neatness and use with individual units being small. These areas should not be confused with the larger areas of "Diversified Cropland" (4G) where the individual units are bigger and "high" crops such as tapioca, sugar and maize are obvious.

Most market garden areas occur near large urban centres or in areas favourable to temperate crops.

2E: Government Agricultural Stations:

1. Tree, Palm and Other Permanent Crops

(The following sub-categories cover crops at all stages of growth and under various forms of management)

3G: Rubber

3O: Oil Palm

3C: Coconut

3N: Pineapple

3K: Coffee

3T: Tea

3A: Cocoa

3P: Pepper

3S: Sago

3B: Banana

3F: Fibre Crops

3X: Orchards (Rambutan, durian, citrus, cloves, nutmeg, etc.)

3H: Fish and Hyacinth Ponds

When two of the above crops are found growing in a traditionally mixed fashion the area is designated by the number 3 followed by the letter of the tree or palm crop and then by the cover crop. e.g. 3CK describes an area of coconuts with intensive coffee cultivation beneath the coconuts.

4. Cropland

4P: Padi

Double and single cropping padi areas.

4C: Diversified Crops

This sub-category covers a wide range of crops growing in reasonably large areas although the individual units (fields) may be quite small (3 to 20 acres). The size of the fields make it difficult to interpret the actual crop, especially when the same crop may be present at different stages of maturity within a mixed crop area which may also contain areas of fallow. Crops found in this sub-category are almost entirely annuals, with tapioca occupying the largest acreage. Other crops include maize, sugar, yams, sweet potatoes, tobacco etc.

4X: Shifting Cultivation

Shifting cultivation, also referred to as "ladang" cultivation, describes an activity carried on by the Aborigines where primary forest areas are selected for cultivation, then cleared and planted with crops, and finally abandoned after a year or two as the soil loses its initial "fertility". The most common crops planted are, upland rice (hill padi), tapioca, sweet potatoes, yams and maize. General areas of shifting cultivation are recognized by the cell-like appearance of small clearings in various stages of regenerating vegetation as well as newly cleared ladangs. Only the areas presently in use are identified and areas previously in use, but now abandoned, are identified according to the present vegetative cover. The sizes of these clearings vary between three and twenty acres.

5. Improved Permanent Pasture

This category at present covers an extremely small proportion of the country but is a category likely to expand. It also includes land where selective grasses are being grown and harvested for fodder.

6. Grasslands

Because of the difficulties created by detailed interpretation combined with the relative unimportance of this Category, it has been decided not to sub-categories and so this Category includes areas of Lalang, Unimproved Coarse Pasture and Scrub-Grassland. The general appearance of the Category is grassland and areas are only included when shrubs and trees (generally below 15 feet) cover less than 50% of the area. When the scrub component covers more than 50% of an area it is designated as 7S Scrub Forest.

Lalang, often occurring in "sheets" over extensive areas comprises an important part of this Category as do the grasses inhabiting the beach ridges ("permatang") of the east coast.

It is not always possible to accurately determine which areas within this Category are actually used for grazing and therefore it should be remembered that the title "Grassland" does not imply an area of grazing. Only in a few localised areas of the country are cattle intentionally grazed within this Category, which for the most part, is devoid of cattle.

Forest Land

7F: Forest

All dryland forests are present in this Category. It includes all primary forest and secondary forest or high "belukar", above about 15' in height. In a few areas the symbol 7F(R) denotes re-afforestation and "treated" forests.

7S: Scrub Forest

This sub-category is used when more than 50% of an area is covered by shrubs, bushes, and young or dwarf trees, having a height of less than approximately 15 feet. It includes (a) low "belukar", or secondary growth, which is in the first stage of regeneration to mature forest, and (b) scrub vegetation whose occurrence is due to edaphic factors, such as the xerophytic scrub of the dry permatang.

Normally 7S would also include the dwarf Montane and Sub-Montane Forest growing on the thin soils of mountain summits and ridges of the interior. In these areas of primary forest this edaphically controlled dwarf scrub forest is not mapped. This sub-category is the only sub-category of land use that is mapped discontinuously. The reasons being the difficulties presented in the interpretation of a relatively inconsequential type and also because a comprehensive forestry interpretation is being carried out by the Forestry Department.

7C: Newly Cleared Land

These are newly cleared and possibly drained areas where it is impossible to determine the land use. For convenience these areas have been placed within the forest Category but it should be realised that they are not necessarily always areas cleared from forest e.g. Areas cleared from older rubber awaiting replanting into oil palm and areas cleared and drained from swamp would come under this sub-category. These areas are recognized not only by a very "clean" appearance, but also by the presence of felled trees and traces of burning.

Swamp, Marshland and Wetland Forests

This category includes Mangrove, Nipah, Gelam and other Wetland Forest Associations.

Unproductive Lands

All areas, which, by present practices, are unproductive. e.g. sand dune areas and exposed rock.

(R.D. DONALDSON.)

Colombo Plan Land Use Co-ordinator.

Land Use Survey,
Department of Agriculture,
Raffles Road,
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APPENDIX A (contd.).

GENERALISED PRESENT LAND USE LEGEND FOR WEST MALAYSIA

- For Interpretation of 1:25,000 Aerial Photography -

1. Settlements and Associated Non-Agricultural Lands

- 1U : Urban and Associated Areas
- 1E : Estate Buildings and Associated Areas
- 1T : Tin Mining Areas
- 1X : Other Mining Areas
- 1P : Power Line Right of Ways

2. Horticultural Lands

- 2H : Mixed Horticulture
- 2M : Market Gardening
- 2E : Agricultural Stations

3. Tree, Palm and other Permanent Crops

- 3G : Rubber
- 3O : Oil Palm
- 3C : Coconut
- 3N : Pineapple
- 3K : Coffee
- 3T : Tea
- 3A : Cocoa
- 3P : Pepper
- 3S : Sago
- 3B : Banana
- 3F : Fibre Crops
- 3X : Orchards - (Rambutans, Durian, Citrus, Cloves, Nutmeg, etc.)
- 3H : Fish and Hyacinth Ponds

4. Cropland

- 4P : Padi
- 4C : Diversified Crops
- 4X : Shifting Cultivation

5. Improved Permanent Pasture

6. Grasslands

- 6 : Lalang, Unimproved Coarse Pasture and Scrub-Grassland.

7. Forest Land

- 7F : Forest
- 7S : Scrub
- 7C : Newly Cleared Land

8. Swamp, Marshlands and Wetland Forests

- 8 : Mangrove, Nipah, Galam and other Wetland Forest Associations.

9. Unused Land



Land Capability Classification
in West Malaysia

AN EXPLANATORY
HANDBOOK

Economic Planning Unit
Prime Minister's Department
Malaysia



Land Capability Classification in West Malaysia

AN EXPLANATORY HANDBOOK

Prepared by the Natural Resource Capa-
bility Section of the Economic Planning
Unit, under the direction of the Technical
Sub-Committee on Land Capability
Classification of the National Development
Planning Committee

DI-CHETAK DI-JABATAN CHETAK KERAJAAN
OLEH THOR BENG CHONG, A.M.N., PENCHETAK KERAJAAN,
KUALA LUMPUR

1967

Supplement to:

LAND CAPABILITY CLASSIFICATION IN WEST MALAYSIA

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As a result of experience gained during the early stages of the Land Capability Classification Programme, revisions have been made to the mineral, forest, and land capability classifications, which now read as follows:

Revised Mineral Resource Classification (Geological Survey and Department of Mines Joint Contribution)

- (1) Probable mining land as deduced from prospecting results and geological evidence.
- (2) Areas under mining lease or certificate, or areas in which active mining is taking place.
- (3) Possible mining land as deduced from geological evidence.
- (4) Areas which on geological evidence might contain mineral deposits.
- (5) Areas for which no geological or other information is available.
- (6) Non-mining land.

Revised Forest Resource Classification (Forest Department Contribution)

- (1) Treated or regenerated forest or a forest plantation.
- (1M) Productive Mangrove Forests.
- (2A) Forest of high potential productivity with a basal area of all species of at least 80 sq. ft. or an equivalent volume of 64 tons round timber, including at least 50 sq. ft. or an equivalent volume of 40 tons round timber of commercial species per acre.
- (2B) Forest of high potential productivity with a basal area of all species of at least 80 sq. ft. or an equivalent volume of 64 tons round timber, but including less than 50 sq. ft. or an equivalent volume of 40 tons round timber of commercial species per acre.
- (3A) Forest of average potential productivity with a basal area of all species of 60-80 sq. ft. or an equivalent volume of 48-64 tons round timber, including at least 35 sq. ft. or an equivalent volume of 28 tons round timber of commercial species per acre.

- (3B) Forest of average potential productivity with a basal area of all species of 60-80 sq. ft. or an equivalent volume of 48-64 tons round timber, but including less than 35 sq. ft. or an equivalent volume of 28 tons round timber of commercial species per acre.
- (4A) Forest of marginal productivity with a basal area of all species of 40-60 sq. ft. or an equivalent volume of 32-48 tons round timber, including at least 20 sq. ft. or an equivalent volume of 16 tons round timber of commercial species per acre.
- (4B) Forest of marginal productivity with a basal area of all species of 40-60 sq. ft. or an equivalent volume of 32-48 tons round timber, but including less than 20 sq. ft. or an equivalent volume of 16 tons round timber of commercial species per acre.
- (5) Forest of limited potential productivity with a basal area of all species of less than 40 sq. ft. or an equivalent volume of 32 tons per acre.
- (5M) Unproductive Mangrove Forests.

NOTE—

1. "Commercial" species are those included in Classes A to C of the Forest Department Linear Sampling (L.S.) List of Species.
2. Sub-classes "A" tend to have a higher economic value at present than Sub-classes "B".
3. Tonnage figures are gross estimates without allowance for defects.

Revised Land Capability Classification

- Class I ... Land possessing a high potential for possible mineral development.
- Class II ... Land possessing a high potential for possible agricultural development with a wide range of crops.
- Class III ... Land possessing a moderate potential for possible agricultural development, because of a limitation in the range of crops.
- Class IV ... Land possessing a high potential for possible productive forest development.
- Class V ... Land possessing little or no mineral, agricultural or productive forest development potential, but suitable for possible alternative development purposes, such as protective forest reserves, water catchment areas, game reserves, recreation areas, etc.

These new classifications will apply for Land Capability Classification studies carried out during the First Malaysia Plan period in all States, except Pahang, Johore and Malacca, for which the earlier classifications apply.

Present Land Use (Department of Agriculture and Directorate of National Mapping Joint Contribution)

In addition to the foregoing, a present land use survey has recently been initiated. This survey involves the preparation of maps showing land use detail interpreted from 1:25,000 aerial photography exposed in 1966, according to the following classification:

- (1) Urban and Associated Areas (1U).
- (2) Estate Buildings and Associated Areas (1E).
- (3) Tin Mining Areas (1T).
- (4) Other Mining Areas (1X).
- (5) Power Line Right of Ways (1P).
- (6) Market Gardening (2M).
- (7) Mixed Horticulture (2H).
- (8) Agricultural Stations (2E).
- (9) Rubber (3G).
- (10) Oil Palm (3O).
- (11) Coconut (3C).
- (12) Pineapple (3N).
- (13) Coffee (3K).
- (14) Tea (3T).
- (15) Cocoa (3A).
- (16) Pepper (3P).
- (17) Sago (3S).
- (18) Banana (3B).
- (19) Fibre Crops (3F).

- (20) Orchards—(Rambutans, Durians, Citrus, Cloves, Nutmegs, etc.) (3X).
- (21) Fish and Hyacinth Ponds (3H).
- (22) Annual or Diversified Crops (4C).
- (23) Padi (4P).
- (24) Shifting Cultivation (4X).
- (25) Improved Permanent Pasture (5).
- (26) Lalang, Unimproved Coarse Pasture and Scrub-Grassland (6).
- (27) Forest (7F).
- (28) Scrub (7S).
- (29) Cleared Land (7C).
- (30) Swamp, Marshland and Wetland Forests (8).
- (31) Unproductive Land (9).
- (32) Unclassified (10).

These areas are differentiated on the maps by the symbols shown in brackets above. The land use maps are compiled and published on a scale of 1:25,000, and not 1:63,360 as is the case with the other land capability classification programme data described in the handbook.

Revised Report Presentation

With the exception of Pahang, for which separate reports for each district were prepared, land capability classification reports for the States in West Malaysia are in the form of comprehensive reports for each State, and these reports include statistical information derived from the contributed data.

Revised Map Presentation

With the exception of the reports for Pahang which have been completed, other State reports may include mineral, soil and forest resource maps on a scale of four miles to an inch in addition to, or instead of a land capability classification map, wherever it is considered that the additional information provided will be of use to facilitate development planning.

This method of presentation will enable areas of resource use conflict to be more readily identified, and thus aid in the identification of regions where further investigation, feasibility studies, etc., will have to be carried out. In addition, areas only suitable for one particular resource development purpose can be more fully delineated.

ECONOMIC PLANNING UNIT,
PRIME MINISTER'S DEPARTMENT,
MALAYSIA
17th October, 1967

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ECONOMIC PLANNING UNIT,
PRIME MINISTER'S DEPARTMENT,
MALAYSIA

17th October, 1967

Telephone No. 88350



Deputy Prime Minister,
Malaysia,
Kuala Lumpur

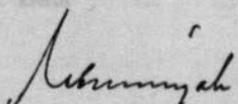
FOREWORD

The wise use of natural resources is the very foundation of a nation's economic progress and prosperity, and the Malaysian Government is well aware of the contribution which science and technology can make towards the utilisation of these resources within a sound conservation context. In order that the maximum benefit can accrue it is important that the scientific and technological research and surveys should be co-ordinated and the recommendations drawn from the investigations of workers in many fields presented in a clear and unambiguous manner. Only then may the results be applied with confidence to problems of development by all sections of the community.

In the field of land use and natural resource development the need for an expert consensus on land use potentials is particularly desirable, for land can be rich in many resources, and used for many purposes, but not all of these uses may be equally desirable, and some may be extremely harmful, leading in extreme cases to complete spoliation of the land with serious consequences for future generations.

Land Capability Classification is one way of indicating the most desirable manner of utilising the land for the best economic purposes, while ensuring that certain areas of low development potential, or of particular aesthetic or scientific merit, will be conserved in their natural state for the long term benefit of the nation. The co-operation of scientists of many disciplines is involved in the Land Capability Classification Programme for West Malaysia which is described in this explanatory handbook.

Malaysia is fortunate in having considerable reserves of natural resources, principally minerals, soils, forests, and water and in planning to develop these resources she can learn from the experiences of others which was often gained through a disregard of scientific principles or through the unrestricted play of human greed. It is the intention of the Malaysian Government to prevent such misuse by wise land administration, and the Land Capability Classification Programme described in the following pages is a major step towards this objective.


(TUN ABDUL RAZAK BIN HAJI HUSSEIN)
DEPUTY PRIME MINISTER

Kuala Lumpur,
3rd January, 1967.

LAND CAPABILITY CLASSIFICATION

What Land Capability Classification is about

The scope of classifying land according to the use potential of different resources is known as Land Capability Classification. The word 'land use' is a descriptive word which is a type of economic

CONTENTS

	PAGE
What Land Capability Classification is about	1
Why Land Capability Classification is needed	1
How Land Capability Classification is carried out	2
Programme	4
Specifications	5
Base Maps (Survey Department)	5
Land Alienation and Gazettement (State Survey Office and Land Office)	5
Aborigines Reserves (Aborigines Department)	6
Game Reserves (Game Department)	6
Veterinary Reserves (Veterinary Department)	6
Mineral Resource (Geological Survey and Department of Mines)	7
Soil Resource (Department of Agriculture)	7
Forest Resource (Forest Department)	7
Water Resource (Drainage and Irrigation Department, Public Works Department and National Electricity Board)	8
Data Compilation (Natural Resource Capability Section)	8
(1) Land Alienation and Gazettement Map	9
(2) Land Capability Classification Map	9
(3) Land Capability Classification Report	10
(4) Statistical Summary of Planimetric Data	10

The very satisfactory overall rate of progress obtained was partly due to the manner in which the drawing up and execution of local development plans was made the responsibility of the District Development Committees. These Committees were able to set up their proposals with the minimum of delay, and then proceed to implement these proposals without a surfeit of costly and fruitless efforts.

Unfortunately, the success of a development scheme can be seriously jeopardised if the technical and economic aspects are not properly appraised by the developer, and experience during the past years of active development has proved that the suggestion

LAND CAPABILITY CLASSIFICATION

What Land Capability Classification is about

The process of classifying land according to the use potential of the natural resources is known as Land Capability Classification. The need for such a classification, which is a type of economic land classification, has become increasingly apparent in Malaysia in recent years. It is designed to indicate the purpose for which given areas of land should be used in order to make the best use of the inherent resources.

The land capability classification is used as the legend for classification maps which are easily understandable to a wide variety of persons who are interested in making the best use of the land. Such a classification is therefore relatively simple, as it is designed to meet the needs of persons who are not necessarily well informed about technical details.

Why Land Capability Classification is needed

It is known that much valuable information about our natural resources, particularly minerals, soils, forests, and water is not made use of by non-technical personnel, either because it is unpublished and has been half forgotten in departmental archives, or else because the reports and papers which contain this information are written in specialised jargon which is unintelligible to most people. Much of this information is worth publishing in a more understandable form because of its great value in matters of land use planning and natural resource development.

Such studies, which in Malaysia should embrace a study of mineral, soil, forest, and water potential, and evaluate the development potential of the land in terms of these natural resources, are of particular value in drawing up development plans at both a local and national level, and they help to ensure that development expenditure, particularly in the rural areas, is devoted to the right purposes, and exploited in an economically beneficial manner.

The success of the Rural Development Programme during the second Malayan Five-Year Plan period and the key role played in this programme by the Red Book, is now universally acknowledged. In retrospect, it is apparent that much of this success has been occasioned by the way in which the spirit of Gotong Royong has been inculcated amongst Government staff and the people, and the degree of co-operation and co-ordination which has resulted has been highly impressive.

The very satisfactory overall rate of progress attained was partly due to the manner in which the drawing up and execution of local development plans was made the responsibility of the District Development Committees. These Committees were able to draw up their proposals with the minimum of delay, and then allowed to implement these proposals without a surfeit of possibly conflicting advice.

Unfortunately, the success of a development scheme can be severely jeopardized if the technical and scientific evidence is not properly appraised by the developers, and experience during the past years of active development has given rise to the suggestion

that a closer degree of co-operation should be attained in the technical field of natural resource evaluation so that the development committees can take advantage of unambiguous technical advice. This springs from a realization that if the technical interests involved could reach a measure of agreement with regard to the optimum use of the land containing these resources, and then prepare maps embodying a classification which reflects this optimum use, the recommendations and suggestions which would follow from such an exercise would be of immense value in matters of national planning.

The Land Capability Classification Reports, accompanied by maps, which are prepared are therefore made the joint responsibility of the technical and scientific specialists who are normally engaged in carrying out basic natural resource surveys.

How Land Capability Classification is carried out

Plans for carrying out these studies on a district basis for West Malaysia have been prepared by the Technical Sub-Committee on Land Capability Classification of the National Development Planning Committee, and a section which is known as the Natural Resource Capability Section has been set up within the Economic Planning Unit for the specific purpose of co-ordinating such studies. The programme for West Malaysia commenced in 1965, and should be completed within a period of about three years.

A high degree of co-ordination is expected from the technical departments of government which are concerned with the survey and development of Malaysian natural resources, and all these departments together with other interested organizations are represented on the Technical Sub-Committee. They include the departments of Survey, Lands, Mines, Agriculture, Forest, Geological Survey, Game, Aborigines, Veterinary, Town and Country Planning, Drainage and Irrigation, Public Works, and the National Electricity Board, Federal Land Development Authority, Rubber Research Institute, and the University of Malaya. The procedure adopted in carrying out these studies calls for the contributing departments to prepare resource maps which define the relative value of the individual resource potentials (mineral, soil, forest, water) by means of a simple classification, and copies of these maps, which are drawn up largely by reference to existing records, are stored within the Natural Resource Capability Section, where they constitute a valuable source of professional and technical information, not otherwise available for reference in one place.

A co-ordinator, who is on the Economic Planning Unit staff, is responsible for preparing Land Capability maps from these resource maps and the classification used on the capability maps differentiates between those areas known to have a high mineral development potential; a high or medium agricultural development potential; a high productive forest potential; and a relatively negligible potential for any of these purposes.

Up-to-date land alienation and gazetteement maps are also prepared, and both these maps are based on the most accurate available topographic sheets supplied by the Survey Department.

Current departmental proposals, for additional water catchment, forest, game, aborigine, and grazing reserves, are also collected in

order that these proposals may be contrasted and compared with the land capability classes in the same way as is possible for the current land alienation and gazetteement data.

A short explanatory report summarises the resource potentials of the area, highlights the major possibilities for future development, and suggests very broadly the manner in which development might take place within a sound conservation context designed to ensure the orderly exploitation of the natural resource potentials.

Each district is treated in a similar fashion, and district maps and reports are completed at intervals of a few weeks. By combining the maps for each district in any State, a valuable appraisal is made of the resource potentials for the State as a whole, and a similar appraisal can ultimately be made for all the States in West Malaysia.

The value of the information shown on these maps, at National, State, and District levels is incalculable, and it is hoped that these studies will be found helpful to District and State Development Committee amongst others, in providing professional advice in a readily understandable form.

It is especially important to note that these reports do not constitute plans. They should be considered as guides to sound planning, and the maximum benefit is likely to accrue if the more detailed physical planning is made the responsibility of professional officers on the State establishment.

It will be appreciated that this classification programme depends for its success on a measure of State and Federal Government co-operation, although no large burden of extra responsibilities is imposed on the State Governments, as most of the compilation work necessary for the preparation of the resource and capability maps is undertaken by Federal staff within the Federal Headquarters of the technical departments. The various Federal officers engaged in this programme, and particularly the co-ordinator in charge of the Natural Resource Capability Section within the Economic Planning Unit consult State Government officers with regard to existing development plans and seek local advice and opinion with regard to future development proposals. The officers most able to assist in this manner are the State Secretaries; State Commissioners for Lands and Mines; State Development Officers; District Officers; and the heads of State Agricultural, Survey, and Forest Departments.

The need for accurate and up-to-date alienation detail is essential for the proper execution of the land capability classification programme, and the most satisfactory sources of such detail are the State Survey Offices and the Land Offices. These State departments therefore co-operate by supplying an outline of the alienated land boundary, reduced to 1 inch to a mile, for each individual district. A base map on which this information is superimposed is supplied by the co-ordinator, and the work of the State departments involves transferring the boundaries by tracing from 1 inch to a mile originals, if these exist in the State Survey Offices or the District Operation Rooms, or reducing the information from larger scale cadastral or land alienation sheets where up-to-date 1 inch maps showing this detail are not already available.

Plans to carry out a systematic present land use survey for West Malaysia, based on a complete 1: 25,000 aerial photographic cover obtained during 1966, are also being formulated, and the results of this factual survey will later be compared with the other data which is already being collected.

The Federal departments contribute by supplying maps showing the suitability for development of the resource for which they are responsible, or of the present or proposed use pattern in which they may have interests.

Programme

The programme for West Malaysia has been drawn up to allow all of the States to be treated consecutively, and land capability classification maps and reports for individual districts are prepared at intervals of a few weeks.

The order in which the State and District maps and reports are being prepared is listed below. Sub-districts are shown in brackets, and are included in the maps and reports for the main districts:

- | | |
|------------------------------|--------------------------------------------|
| 1. PAHANG— | 28. Kuala Lumpur
(Kepong, Sungei Besi) |
| 1. Kuantan | 29. Klang |
| 2. Bentong | 30. Kuala Selangor
(Tanjong Karang) |
| 3. Temerloh | 31. Sabak Bernam |
| 4. Pekan (Rompin) | 32. Ulu Selangor
(Rawang) |
| 5. Raub | |
| 6. Cameron Highlands | |
| 7. Lipis | |
| 8. Jerantut | |
| 2. JOHORE— | 6. PERAK— |
| 9. Mersing | 33. Batang Padang |
| 10. Kota Tinggi | 34. Lower Perak
(Tanjong Malim) |
| 11. Johore Bharu (Kulai) | 35. Dindings |
| 12. Pontian (Rengit) | 36. Kinta (Gopeng,
Kampar) |
| 13. Batu Pahat (Yong Peng) | 37. Kuala Kangsar
(Parit, Sungei Siput) |
| 14. Muar (Tangkak,
Lenga) | 38. Larut and Matang
(Selama) |
| 15. Kluang | 39. Krian |
| 16. Segamat | 40. Upper Perak (Kroh,
Lenggong) |
| 3. MALACCA— | 7. PENANG AND PROVINCE
WELLESLEY— |
| 17. Jasin | 41. Nibong Tebal |
| 18. Malacca | 42. Butterworth |
| 19. Alor Gajah | 43. Bukit Mertajam |
| 4. NEGRI SEMBILAN— | 44. Penang Island |
| 20. Tampin (Gemas) | 45. Penang Northeast |
| 21. Kuala Pilah (Bahau) | |
| 22. Rembau | |
| 23. Port Dickson | |
| 24. Seremban (Mantin) | |
| 25. Jelebu | |
| 5. SELANGOR— | 8. KEDAH— |
| 26. Kuala Langat
(Sepang) | 46. Bandar Bahru |
| 27. Ulu Langat | 47. Kulim |
| | 48. Kuala Muda |
| | 49. Baling |

- | | |
|------------------|-----------------|
| 50. Sik | 60. Tumpat |
| 51. Yen | 61. Kota Bahru |
| 52. Kota Star | 62. Bachok |
| 53. Padang Terap | 63. Machang |
| 54. Kubang Pasu | 64. Pasir Puteh |
| 55. Langkawi | |
9. PERLIS—
56. Perlis
10. KELANTAN—
57. Ulu Kelantan
58. Tanah Merah
59. Pasir Mas
11. TRENGGANU—
65. Besut
66. Ulu Trengganu
67. Kuala Trengganu
68. Marang
69. Dungun
70. Kemaman.

After the programme of Land Capability Classification has been completed for all the districts in a State, the district maps and reports are consolidated for the State, and State Land Capability Classification maps and reports are prepared. When all the districts have been completed a national appreciation for West Malaysia will be made from the State maps and reports.

The possibility of carrying out similar classification studies for the East Malaysian States before the end of the First Malaysia Plan period is also being considered.

Specifications

Specifications for the purpose of the Land Capability Classification Programme for each district are as follows:

Base Maps (Survey Department Contribution)

Prepare and supply copies of the most up-to-date one inch to a mile topographical maps covering each district.

Land Alienation and Gazettement (State Survey Office and Land Office Joint Contribution)

Prepare a map showing alienated and gazetted land detail for single or contiguous areas exceeding ten acres in size, with subdivisions into ten groups as follows:

- (1) Land alienated for all country (agricultural land) purposes, including approved applications, but excluding land held on T.O.Ls and also land allocated for agricultural schemes in course of development.
These areas are edged by black lines and hatched with horizontal black lines.
- (2) Land alienated on mining leases and mining certificates.
These areas are edged by black lines and hatched with broken horizontal black lines.
- (3) Land gazetted as Malay Reserves.
These areas are edged by yellow lines.
- (4) Land gazetted as Grazing Reserves.
These areas are edged by brown lines.
- (5) Land gazetted as Aborigine Reserves.
These areas are edged by red lines.

- (6) Land gazetted as Forest Reserves.
These areas are edged by green lines.
- (7) Land gazetted as Game Reserves.
These areas are edged by blue lines.
- (8) Land alienated as town or village land, which occurs within local authority areas (Municipality, Town Council, and Local Council areas).
These areas are edged by black lines and hatched with a pattern of horizontal and vertical black lines.
- (9) Land reserved for government purposes other than those shown separately above.
These areas are shaded grey.
- (10) Land covered by current prospecting permits.
These areas are edged by broken red lines.

Aborigine Reserves (Aborigines Department Contribution)

Prepare a map showing the following :

- (1) Land gazetted as aborigine reserves larger than ten acres.
These areas are edged by red lines.
- (2) Land classified as approved aborigine reserves larger than ten acres (i.e. areas approved by the State Executive Council but not yet gazetted).
These areas are edged by broken red lines.
- (3) Land classified as proposed aborigine reserves larger than ten acres [i.e. areas which in accordance with current proposals the department is anxious to see included in category (1) but which have not yet reached the stage of category (2)].
These areas are edged by dotted red lines.

Game Reserves (Game Department Contribution)

Prepare a map showing the following :

- (1) Land gazetted as game reserves larger than ten acres.
These areas are edged by blue lines.
- (2) Land classified as approved game reserves larger than ten acres (i.e. areas approved by the State Executive Council but not yet gazetted).
These areas are edged by broken blue lines.
- (3) Land classified as proposed game reserves larger than ten acres [i.e. areas which in accordance with current proposals the department is anxious to see included in category (1) but which have not yet reached the stage of category (2)].
These areas are edged by dotted blue lines.

Veterinary Reserves (Veterinary Department Contribution)

Prepare a map showing the following :

- (1) Land gazetted as grazing reserves larger than ten acres.
These areas are edged by green lines.
- (2) Land classified as approved grazing reserves larger than ten acres (i.e. areas approved by the State Executive Council but not yet gazetted).
These areas are edged by broken green lines.

- (3) Land classified as proposed grazing reserves larger than ten acres [i.e. areas which in accordance with current proposals the department is anxious to see included in category (1) but which have not yet reached the stage of category (2)]. These areas are edged by dotted green lines.

Mineral Resource (Geological Survey and Department of Mines Joint Contribution)

Prepare a map showing the mineral development potential for the entire district sub-divided into four groups as follows:

- (1) *Current Mining Land*—Land covered by current mining leases.
- (2) *Potential Mining Land*—Land shown by prospecting results or inferred from geological records to contain more than 0.2 kati of cassiterite per cubic yard, or workable surface deposits of other minerals, e.g. iron-ore.
- (3) *Possible Mining Land*—Land for which present evidence indicates a possible mineral potential but which needs to be more thoroughly examined before commercial development can take place; or unprospected areas which on geological evidence might contain a mineral potential; or unknown areas.
- (4) *Non-Mining Land*—Land which has been prospected and shown to have no mineral potential, or which on geological evidence is unlikely to have any mineral potential.

These areas are edged by purple boundary lines and either shaded purple (Class 1) or hatched with right sloping, purple continuous (Class 2) or broken (Class 3) lines, or left blank (Class 4).

Soil Resource (Department of Agriculture Contribution)

Prepare a map showing the soil suitability for the entire district sub-divided into five groups as follows:

- (1) Soils with no limitations to agricultural development.
- (2) Soils with few minor limitations to agricultural development.
- (3) Soils with at least one serious limitation to agricultural development.
- (4) Soils with more than one serious limitation to agricultural development.
- (5) Soils with at least one very serious limitation to agricultural development.

These areas are edged by brown boundary lines and hatched with left sloping, brown, continuous (Classes 1 and 2) or broken (Class 3) lines, or left blank (Classes 4 and 5).

Forest Resource (Forest Department Contribution)

Prepare a map showing the forest productivity potential for the entire district, sub-divided into four groups as follows:

- (1) Highly productive forest with a basal area of commercial species of at least 50 square feet, or an approximate equivalence of at least 25 tons of round timber per acre.

- (2) Productive forest with a basal area of commercial species between 35 and 50 square feet, or an approximate equivalence of 15 to 25 tons of round timber per acre.
- (3) Marginal forest with a basal area of commercial species between 20 and 35 square feet, or an approximate equivalence of 10 to 15 tons of round timber per acre.
- (4) Unproductive forest with a basal area of commercial species below 20 square feet or an approximate equivalence of less than 10 tons of round timber per acre.

These areas are edged by green boundary lines and hatched with vertical, green, continuous (Classes 1 and 2) or broken (Class 3) lines, or left blank (Class 4). Boundaries of gazetted forest reserves and areas which in accordance with current proposals the department is anxious to see included in the gazetted forest reserve category are also shown, edged respectively by continuous or broken green lines.

Water Resource (Drainage and Irrigation Department, Public Works Department and National Electricity Board Joint Contribution)

Prepare maps showing the following:

- (1) Existing catchments, necessary for ensuring an effective water supply for existing schemes, including hydro-electric generation and potable and irrigation water supplies.

These areas are edged by blue lines, and hatched with horizontal blue lines.

- (2) Proposed catchments, necessary for ensuring an effective water supply for proposed schemes, including hydro-electric generation and potable and irrigation water supplies.

These areas are edged by blue lines, and hatched with broken horizontal blue lines.

- (3) Existing irrigation scheme areas, being areas presently supplied with irrigation water for agricultural purposes.

These areas are edged by red lines and hatched with horizontal red lines.

- (4) Proposed irrigation scheme areas, being areas which it is proposed will be supplied with irrigation water for agricultural purposes.

These areas are edged by red lines and hatched with broken horizontal red lines.

- (5) Isohytes, showing rainfall depths at 10 inch intervals.

Data Compilation (Natural Resource Capability Section Contribution)

This Section of the Economic Planning Unit is responsible for co-ordinating the work of the contributing departments in respect of the land capability classification programme, and for compiling two series of maps, known as Land Alienation and Gazettement Maps, and Land Capability Classification Maps, to cover each District and State. The Section is also responsible for compiling reports to accompany the maps for each District and State, and for preparing statistical summaries of the planimetric data contained on the contributed maps. The statistical summary is

prepared with the assistance of the mechanical processing section of the Department of Statistics.

(1) LAND ALIENATION AND GAZETEMENT MAP

This map shows areas of alienated and gazetted land and other present and proposed land use categories; sub-divided into the following groups:

- (1) Land alienated for agricultural purposes, including approved applications, and land allocated for agricultural schemes in course of development, but excluding land held on T.O.Ls.

These areas are edged by black lines and hatched with horizontal black lines.

- (2) Land alienated for mining, including land covered by mining titles and mining certificates.

These areas are edged by black lines and hatched with broken horizontal black lines.

- (3) Land gazetted as Malay Reserve.

These areas are edged by black lines and hatched with broken vertical black lines, and differentiated from the other reserves by the abbreviation MAL.

- (4) Land gazetted as Grazing Reserves.

These areas are edged by black lines and hatched with broken vertical black lines, and differentiated from the other reserves by the abbreviation GZG.

- (5) Land gazetted as Aborigine Reserves.

These areas are edged by black lines and hatched with broken vertical black lines, and differentiated from other reserves by the abbreviation ABO.

- (6) Land gazetted as Forest Reserves.

These areas are edged by black lines and hatched with broken vertical black lines, and differentiated from the other reserves by the abbreviation FOR.

- (7) Land gazetted as Game Reserves.

These areas are edged by black lines and hatched with broken vertical black lines, and differentiated from the other reserves by the abbreviation GME.

- (8) Land alienated on Town Land Title or Village Land Title, or utilised for other non-agricultural or non-mining purposes, including approved applications but excluding land held on T.O.Ls.

These areas are edged by black lines and hatched with a pattern of horizontal and vertical black lines.

- (9) State Land, being those areas not alienated or gazetted or reserved for special purposes and shown in other categories of this classification.

These areas are left blank.

(2) LAND CAPABILITY CLASSIFICATION MAP

This map shows the relative capability of the land for mining, agriculture, productive forestry, protective forestry or other conservation use purposes, in a simple classification. The boundaries are derived from equivalent boundaries on the contributed resource maps for minerals, soils, and forests.

Class I—Land possessing a high potential for mineral development and therefore best suited to mining.

Class II—Land possessing a high potential for agricultural development with a wide range of crops and therefore best suited to diversification agriculture.

Class III—Land possessing a moderate potential for agricultural development with a restricted range of crops and therefore best suited to agricultural development with crops having a wide range of soil tolerance.

Class IV—Land possessing a potential for productive forest development and therefore best suited to commercial timber exploitation.

Class V—Land possessing little or no mineral, agricultural, or forest development potential but suitable for development as protective reserves for conservation, water catchment, game, recreation, or similar purpose, or possibly suitable in the future for productive forest plantations with introduced species.

The land alienation and gazettelement map and the land capability map are both prepared on a scale of one inch to a mile and copies are distributed to the State and District Development Committees. Reduced copies, on a scale of one inch to four miles, are also prepared for inclusion in the Land Capability Classification Report.

The land capability classification map is reproduced as a transparent overlay to the land alienation and gazettelement map, to facilitate comparison between the capability and the present use of the land.

(3) LAND CAPABILITY CLASSIFICATION REPORT

The Report summarises the data shown on the maps and discusses the development opportunities which exist in the district. Liaison officers in the resource survey departments contribute material to this report, which is edited by the co-ordinator.

(4) STATISTICAL SUMMARY OF PLANIMETRIC DATA

The alienation, gazettelement, proposed land use, and resource maps which comprise the basic data of the Land Capability Classification programme are a most valuable source of information concerning the present and proposed use of the land and the potentiality in respect of minerals, soils, forests, and water. This information is presented on the maps in the form of curved lines for the resource data, reflecting the natural boundaries of the mineral, soil and forest types, and usually in the form of an intricate pattern of straight line boundaries for the alienation, gazettelement and proposed land use data, reflecting the cadastral survey boundaries of the alienated and gazetted land areas.

A knowledge of the areas covered by the different land alienation and resource classes is very useful for surveying, development planning and administrative purposes, and where the pattern is relatively simple, and free of overlapping boundaries, as is usually the case on a single map, the area can be determined by the

usual method of planimetric measurement. However, it is often desirable to have planimetric data for land categories made up of a combination of land use and resource qualities, which must be obtained by measurement from several maps. In such cases the boundaries of the different categories overlap and if all these lines were to be superimposed on one map the pattern would consist of an indecipherable maze of small irregular shaped units which would defy measurement by planimeter. Fortunately, mechanical data processing methods, using punch cards, can be used for this task, and a numerical code which takes account of all the land use and resource categories shown on the contributed maps is applied to each district in turn.

Advantage is taken of the fact that the one inch topographical map series for West Malaysia has a uniform grid superimposed on the maps dividing the country into 1,000 yard grid squares. The intersection points of the squares are used as the data recording positions and the quality of the land at each point is read off from the different land alienation and resource maps and recorded on punch cards for mechanical processing. By this method of systematic line sampling the area of any combination of categories shown on the maps can be assembled for individual mukims, for districts, for states, and for the nation as a whole.

PRESENT LAND USE SURVEY - 1966

STATE LAND USE SUMMARY - MALACCA

BASED ON DATA TAKEN FROM 1:25,000 LAND USE MAPPING COMPILED FROM THE INTERPRETATION OF 1966 AERIAL PHOTOGRAPHY

NATIONAL AREA:- SQUARE MILES: ACRES	50,840 : 32,540,000
STATE AREA:- SQUARE MILES: ACRES	636.43 : 407,315
PERCENTAGE OF NATIONAL AREA	1.25%
POPULATION: % OF NATIONAL AREA*	397,874 : 4.79
POPULATION DENSITY:- PER SQ MILE: PER ACRE	625.16 : 0.98
AGRICULTURALLY USED LAND:- SQ MILES: ACRES	487.16 : 311,782
POPULATION DENSITY ON AGRICULTURALLY USED LAND:- PER SQUARE MILE: PER ACRE	816.72 : 1.28

LAND USE CATEGORY	DISTRICT			TOTAL	%	MAJOR LAND USE CATEGORIES IN ACRES	%	LAND UNDER AGRICULTURAL USE IN %			
	CENTRAL	NORTHERN	SOUTHERN					Major Categories	Sub-Categories		
Urban	4,591	1,590	765	6,946	1.70	URBAN AND ASSOCIATED AREAS	2.31	X			
Estate Buildings	121	456	558	1,135	0.28						
Tin Mining	1	153	271	425	0.10						
Other Mining, Quarrying	80	96	182	358	0.09						
Transmission Line	87	237	216	540	0.13						
Mixed Horticulture	5,062	6,750	4,953	16,765	4.12	HORTICULTURAL	4.51	5.38			
Market Gardening	736	601	151	1,488	0.36			0.48			
Agriculture Stations	59	63	6	128	0.03			0.04			
Rubber	30,850	115,519	100,385	246,754	60.58	TREE, PALM AND PERMANENT CROPS	64.08	79.14			
Oil Palm		240	587	827	0.20			0.30			
Coconuts	3,502	2,705	5,242	11,449	2.81			3.64			
Pineapple											
Coffee											
Tea											
Cocoa											
Pepper		15		15	0.00						
Sago		642	242	1,004	0.25			261,031	83.72	0.00	
Bananas	120	28		28	0.01					0.32	
Fibre Crops								0.01			
Fish & Hyacinth Ponds	186			186	0.04						
Orchards	159	166	443	768	0.19			0.06			
Padi	13,805	11,593	6,461	31,859	7.82	CROPLAND	7.95	0.25			
Diversified Crops	68	133	310	511	0.12			32,370	10.38	10.22	
Shifting Cultivation								0.16			
Improved Permanent Pasture											
Scrub Grassland	1,195	2,770	4,061	8,026	1.97	8,026	1.97				
Forest	4,579	12,391	31,074	48,044	11.80	Forest and Scrub	13.86				
Scrub	939	3,463	4,003	8,405	2.06			56,449	100%	100%	
Newly Cleared Land	338	749	1,569	2,656	0.65						
Swamp	6,335	3,877	4,745	14,957	3.67	14,957	3.67	Total Acreage Under Agricultural Use: 311,782			
Unused Land	189	5	9	203	0.05	203	0.05				
UNCLASSIFIED	297	510	3,031	3,838	0.94	3,838	0.94	Percentage of State area under Agricultural Use: 76.54%			
TOTAL	73,299	164,752	169,264	407,315	100%	407,315	100%				

*1966 (June) Population Estimates by the Statistics Department.

PENGGUNAAN TANAH SEKARANG

PRESENT LAND USE



PETUNJOK PENGELOMAN PENGGUNAAN TANAH

LAND USE CLASSIFICATION LEGEND

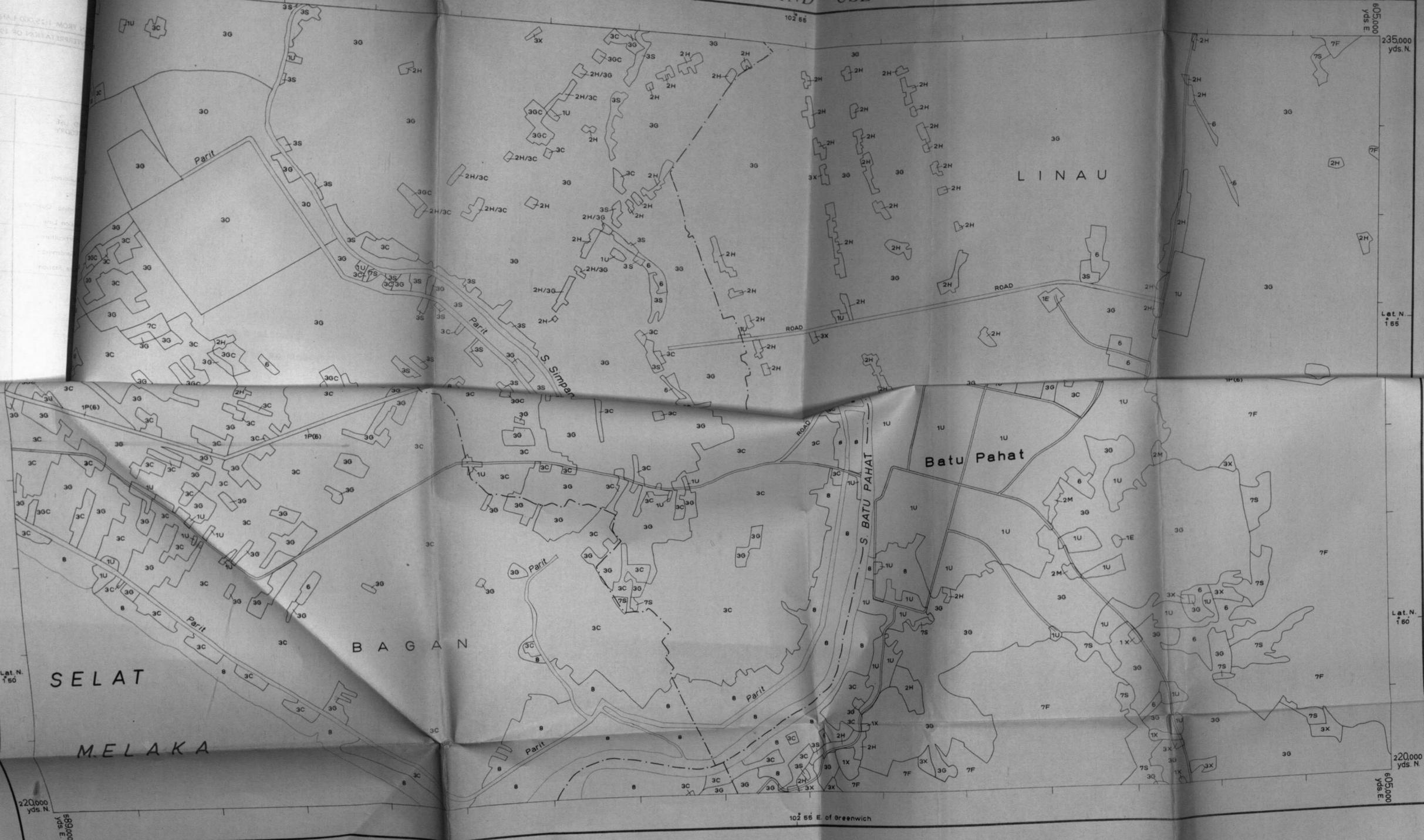
- | | |
|----|---------------------------------------------------------------------------------------------------------------------------------------------|
| 1 | KAWASAN TEMPAT TINGGAL DAN KAWASAN BERKAITAN BUKAN PERTANIAN
<i>Settlements and Associated Non-Agricultural Areas</i> |
| 1U | KAWASAN BANDARAN DAN YANG BERKAITAN
<i>Urban and Associated Areas</i> |
| 1E | KAWASAN BANGUNAN LADANG DAN YANG BERKAITAN
<i>Urban Buildings and Associated Areas</i> |
| 1T | KAWASAN LOMBONG BIJEH TIMAH
<i>Tin Mining Areas</i> |
| 1X | KAWASAN LOMBONG LAIN: GALIAN
<i>Other Mining Areas</i> |
| 1F | HAK LALU TALIAN LETRIK
<i>Power Line Right of Way</i> |
| 2 | KAWASAN PERKEBUNAN
<i>Horticultural Lands</i> |
| 2H | PERKEBUNAN CHAMPOR
<i>Mixed Horticulture</i> |
| 2M | PERKEBUNAN SAYURI DAN BENDA MAKANAN
<i>Market Gardens</i> |
| 2E | PUSAT PERCHUBAAN PERTANIAN
<i>Agricultural Stations</i> |
| 3 | POKOK, PALMA DAN LAIN2 TANAMAN KEKAL
<i>Trees, Palm and Other Permanent Crops</i> |
| 3G | GETAH
<i>Rubber</i> |
| 3O | KELAPA SAWIT
<i>Oil Palm</i> |
| 3C | KELAPA
<i>Custard</i> |
| 3N | NENAS
<i>Pineapple</i> |
| 3K | KOFI
<i>Coffee</i> |
| 3T | TEH
<i>Tea</i> |
| 3A | KOKO
<i>Coconut</i> |
| 3P | LADA HITAM
<i>Pepper</i> |
| 3S | KEMBIA
<i>Siam</i> |
| 3B | PISANG
<i>Banana</i> |
| 3F | TANAMAN GENTIAN
<i>Fibre Crops</i> |
| 3X | DUSUN-RAMBUTAN, DURIAN, LIMAU, CENGKEH, PALA, DLL.)
<i>Durians, Rambutan, Durian, Citrus, Cloves, Nutmeg, etc.</i> |
| 3H | KOLAM IKAN DAN LEMBAYONG (KIAMBANG ATAU KELADI BUNTING)
<i>Fish and Hatchery Ponds</i> |
| 4 | KAWASAN TANAMAN
<i>Cropland</i> |
| 4P | PADI
<i>Rice</i> |
| 4C | PELBAGAI TANAMAN
<i>Diversified Crops</i> |
| 4X | PENANAMAN BERPINDAH2
<i>Shifting Cultivation</i> |
| 5 | KAWASAN TERNAK KEKAL YANG TELAH DI-PERBAIKI
<i>Improved Permanent Pasture</i> |
| 5 | KAWASAN TERNAK KEKAL YANG TELAH DI-PERBAIKI
<i>Improved Permanent Pasture</i> |
| 6 | PADANG RUMPUT
<i>Grasslands</i> |
| 6 | LALANG DAN KAWASAN TERNAK YANG TERBIAR DAN/ATAU PADANG RUMPUT SEMAK
<i>Lalang and Unimproved Cattle Pasture and/or Scrub-Grassland</i> |
| 7 | KAWASAN HUTAN
<i>Forest Land</i> |
| 7F | HUTAN
<i>Forest</i> |
| 7S | SEMAK
<i>Scrub</i> |
| 7C | CHERANG BAHARU
<i>North Coastal Land</i> |
| 8 | HUTAN PAYA DAN BUYAU
<i>Swamp, Marshlands and Wetland Forest</i> |
| 8 | TERMASOK BAKAU, NIPAH, GELAM DAN LAIN: KUMPULAN HUTAN BUYAU
<i>Includes Mangrove, Nipah, Gelam and Other Wetland Forest Associations</i> |
| 9 | KAWASAN YANG TIDAK DI-USAHAKAN
<i>Unused Land</i> |
| 9 | KAWASAN YANG TIDAK DI-USAHAKAN
<i>Unused Land</i> |
| | TIDAK DI-KELASKAN
<i>Unclassified</i> |

Satu risalah tambahan yang memberi semua buah butir Pengelasan yang di atas boleh di-perolehi daripada SEKSYEN PENYELIDIK PENGGUNAAN TANAH JABATAN PERTANIAN, KUALA LUMPUR.
A Supplement giving details of the above classification is available from the PRESENT LAND USE SURVEY SECTION, DIVISION OF AGRICULTURE, KUALA LUMPUR.

Butir2 berkenaan penggunaan tanah waktu sekarang di-dapati daripada tafsiran gambafoto udara 1:25,000 yang di-ambil dalam tahun 1966.
Present land use detail by direct photographic interpretation of 1:25,000 aerial photographs taken during 1966.

Pengelasan ini berdasarkan shori yang di-buat oleh COMMISSION ON WORLD LAND USE SURVEY dengan pindaan: untuk menyesuaikan dengan keadaan di-Malaysia.
This classification is based on the recommendations of the COMMISSION ON WORLD LAND USE SURVEY, with modification to suit Malaysian conditions.

PENGGUNAAN TANAH SEKARANG PRESENT LAND USE



PETUNJOK PENGELASAN PENGGUNAAN TANAH
LAND USE CLASSIFICATION LEGEND

1	KAWASAN TEMPAT TINGGAL DAN KAWASAN BERKAITAN BUKAN PERTANIAN Settlements and Associated Non-Agricultural Areas
10	KAWASAN BANDARAN DAN YANG BERKAITAN Urban and Associated Areas
11	KAWASAN BANGUNAN LADANG DAN YANG BERKAITAN Estate Buildings and Associated Areas
12	KAWASAN LOMBONG BIJEH TIMAH Tin Mining Areas
13	KAWASAN LOMBONG LAIN2 GALIAN Other Mining Areas
14	HAK LALU TALIAN LETRIK Power Line - Right of Way
2	KAWASAN PERKEBUNAN Horticultural Lands
2M	PERKEBUNAN CHAMPOR Mixed Horticulture
2H	PERKEBUNAN SAYUR2 DAN BENDA2 MAKANAN Market Gardening
2E	PUSAT PERCHUBAAN PERTANIAN Agricultural Stations
3	POKOK, PALMA DAN LAIN2 TANAMAN KEKAL Tree, Palm and Other Permanent Crops
3G	GETAH Rubber
3O	KELAPA SAWIT Oil Palm
3C	KELAPA Coconut
3N	NENAS Pineapple
3K	KOPI Coffee

Satu risalah tambahan yang memberi semua buah butir Pengelasan yang di atas boleh di-perolehi daripada SEKSHEN PENYELIDEK PENGGUNAAN TANAH JABATAN PERTANIAN, KUALA LUMPUR.
A Supplement giving details of the above classification is available from the PRESENT LAND USE SURVEY SECTION, DIVISION OF AGRICULTURE, KUALA LUMPUR.

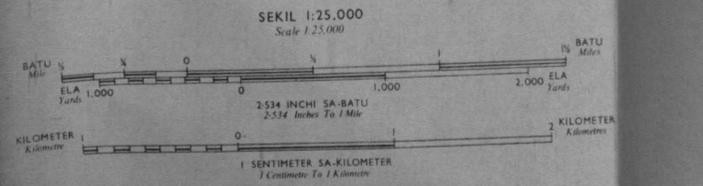
Butir2 berkenaan penggunaan tanah waktu sekarang di-dapati daripada tafsiran gambafoto udara 1:25,000 yang di-ambil dalam tahun 1966.
Present land use detail by direct photographic interpretation of 1:25,000 aerial photographs taken during 1966.

Pengelasan ini berdasarkan shor2 yang di-buat oleh COMMISSION ON WORLD LAND USE SURVEY dengan pindaan untuk menyesuaikan dengan keadaan di-Malaysia.
This classification is based on the recommendations of the COMMISSION ON WORLD LAND USE SURVEY, with modifications to suit Malaysian conditions.

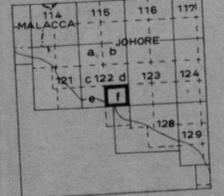
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Enquiries on the land use aspects of this map should be addressed to the DIRECTOR OF AGRICULTURE, MINISTRY OF AGRICULTURE AND COOPERATIVES, MALAYSIA, KUALA LUMPUR.

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PENUNJOK SHIT2 BERSAMBONGAN
Key To Adjoining Sheets



PETUNJOK
Reference

- SEMPADAN ANTARA-BANGSA
International Boundary
- SEMPADAN NEGERI
State Boundary
- SEMPADAN DAERAH
District Boundary
- SEMPADAN MUKIM
Mukim Boundary
- JALAN RAYA
Road
- JALAN KERETAPI
Railway
- SUNGAI, TASEK
River, Lake

LAND CAPABILITY CLASSIFICATION IN SABAH

by

P. THOMAS

Department of Agriculture, Sabah.

production. The need for a land capability classification was felt necessary in Sabah. This was mainly because experiences gained when the results of soil mapping, which are fundamentally records of basic soil characteristics, were applied in conjunction with site, climate and crop performance, to provide a basis for evaluating the physical properties of the land for agricultural development. The soil scientists engaged on such work generally felt the limited scope of this approach because it is frequently the case in Sabah that forms of development other than agriculture, must also be considered if a rational approach to land development is to be attained. During the same time workers in other technical departments engaged on natural resource appraisal work, particularly in forestry, felt a similar reaction in their work. In addition, there was serious lack of liaison between these departments. The net result of this situation was that the decision-making bodies of government were frequently given a series of conflicting proposals on technical matters of land use, thus on occasion giving rise to a situation whereby political and geographical factors were given an undue influence on such decisions.

Influenced by the results being produced by the land capability classification undertaken in Western Malaysia a new development occurred in 1966. A Technical Sub-Committee of the State Land Development Committee was charged with undertaking a systematic land capability classification of the State. The Sub-Committee consists of representatives of each of the technical departments involved in land resource investigations, and one of its first tasks was to produce a unified land capability classification agreeable to all user organizations and in particular which would be of use to government planners.

This paper describes the Classification which is being employed and based on the 1:50,000. scale series of topographic

being published for the State.

General Approach to Land Capability Classification. There are a number of Land Capability Classifications in use elsewhere, most all of which are based on agricultural interpretations of soil maps. The most widely used and tested is probably that developed by the Soil Conservation Service of the U.S.D.A. (Singer and Montgomery, 1961). It grades land according to soil potentialities and the severity of its limitations for crop production into eight Classes, the last four of which are not generally suitable for cultivation and are of limited use for other purposes. This classification, although giving invaluable information on the general agricultural aspects of the land, does not produce a comprehensive review of the potential use of its natural resources, which should be the essence of any land capability classification, particularly in a developing country. The latter approach was adopted by the Economic Planning Unit of the Prime Minister's Department (Panton, 1966), with its programme of the Land Capability Classification of Western Malaysia. This classification gives the relative economic capability of the land according to its inherent natural resources, and each resource group is arranged in order of general utility; thus giving rise to what is almost tantamount to an economic land-use classification (Hockenbury, 1948). This approach (Panton, 1966) has also been adopted in Sabah and the following resource groups have been recognised in decreasing importance: mining, agriculture, forestry, and hydrological and wild-life areas.

Principles of the Land Capability Classification. The groups involved in the Classification essentially indicate the most profitable use to be made of the land. It is an attempt to interpret and express to the best advantage current knowledge of its use and as new experience is acquired revisionary work will be required. The Classification is based on the economic yield capacity of the land under a moderately high level of management, and not necessary upon current usage. Such factors

accessibility and the pattern of land ownership and current use, although affecting decisions about development, do not influence the grading. The system employed does not attempt to indicate the specific nature of the resource type, i.e., nature of the mineral reserve, agricultural and forest crop; and in order to do this different arrangements of the resource groups would in some cases be required in order to express the concept of land capability used in the system. Similarly, no attempt has been made to establish an index-rating system, as formulated for example in the United States of America (Storie, 1960), in order to arrive at a fully objective approach to the Classification. This is because work on the relationship between soil conditions for agricultural and forest crops is still, as in almost all tropical countries, at a very preliminary stage.

Figure 1. The relationship between natural resources and land capability.

LAND CAPABILITY CLASS	DECREASING PRODUCTIVITY OF THE LAND →				
	MINING	DIVERSIFIED AGRICULTURE	RESTRICTED AGRICULTURE	FORESTRY	HYDROLOGICAL/WILDLIFE AREAS
I					
II					
III					
IV					
V					

Land Capability Classification.

Land Capability Classes. The various natural resource groups interpreted into five Land Capability Classes, and these set up so that land having the greatest theoretical alternative uses but always giving the highest return on development is Class I and the least uses in Class V, with these uses becoming progressively less between these two Classes, as illustrated in Figure 1. This indicates, for example, that although hydrological and wild-life areas can be established theoretically in all five classes, the optimum use of the land will depend on adequate levels of minerals, or its agricultural crop potential or timber exploitation capacity, in this order of importance, as set out as follows.

Land Capability Class I, which has a high potential for general development and therefore best suited for mining.

Land Capability Class II, which has a high potential for agriculture with a wide range of crops and is therefore best suited for a diversified form of agriculture.

Land Capability Class III, which has a moderate potential for agriculture with a restricted range of crops and therefore best suited for a limited variety of crops with a high level of soil tolerance.

Land Capability Class IV, which has a potential for forest resource exploitation and best suited for this purpose.

Land Capability Class V, which has no potential for forest exploitation and best suited for hydrological or wild-life purposes.

The system of classification employed at this level is identical to that employed in Western Malaysia (Panton, 1966). Therefore Land Capability Class I., although it has not been encountered in Sabah and is not likely to occur extensively, has been retained in order to facilitate direct correlation on a National basis.

Figure 2. The relationship between Natural Resource Suitability Groups and Land Capability Classes.

RESOURCE	RESOURCE SUITABILITY GROUPS							
	1	2	3	4	5	6	7	8
MINING	I							
SOILS	II		III					
FORESTRY	IV					V		
AGROLOGICAL/ MID-LIFE AREAS								

Resource Suitability Groups. The relative values given to the various resources and their grouping into the five classes is set out in Figure 2. In order to arrive at this classification a resource is defined into Resource Suitability Groups as follows.

Mining. The Mining Suitability Groups refer to mineral deposits suitable on an open-cast system of mining. They are as follows.

Group 1. Current mining land.

Group 2. Proven mining land, where economic mineral deposits have been ascertained as the result of geological prospecting.

Group 3. Possible mining land, where geological evidence of cursory nature indicates that mineralisation of economic importance might occur.

Group 4. Land with no mining potential, where there is no evidence of mineral deposits.

Soils. The Soil Suitability Groups are based on a series of limitations inherent to the soil and a moderately high degree of agricultural expertise is assumed. If, however, some of these limitations can be removed at an acceptable economic margin, only the continuing limitations are graded.

Group 1. Soils with no limitations to agricultural development. These are generally deep, permeable and well aerated soils with good reserves of moisture; and they are either well supplied with plant nutrients or readily responsive to fertilizers. They are developed on level or almost level land where the upper slope gradient is never in excess of 5°. Having no limitations to

- 6 -

Agricultural development a wide range of crops can be grown and yields can be expected to be good with a moderate input of fertilizer.

Group 2. Soils with few minor limitations to agricultural development. The limitations may include, alone or in combination, the effect of imperfect or poor drainage with a water table occurring at a significant proportion of the year within 48 inches of the soil surface, less than an ideal rooting depth usually as the result of rock or similar impenetrable material occurring between 24 inches and 48 inches of the surface, a slightly unfavourable soil structure which is usually moderately developed only, extreme soil textures, or moderate slopes generally falling within the 15° range which would not require any expensive form of anti-erosion control, or shallow peat deposits never more than 20 inches in depth. Although a wide range of crops can be grown on such soils the choice is generally more restricted and yields can be expected to be less compared to Group 1., soils.

Group 3. Soils with at least one serious limitation to agricultural development. This includes soils which are limited for agricultural development as the result of being developed on strongly sloping land in the 15 to 25° range, soils developed on deposits of peat varying in depth from 20 inches to 48 inches, very poorly drained soils in which swamp conditions sometimes prevail, very poorly structured soils, or soils with a very restricted root exploitation volume due to the presence of rock occurring at shallow depths, within 20 inches of the soil surface, or soils showing severe plant nutrient deficiencies. The range of crops suited to this Group is restricted to those which are specifically adapted to overcome these adverse soil conditions. It is therefore limited for a non-diversified form of agriculture, and the success of any agricultural pursuit would depend on very careful management.

Group 4. Soils with more than one serious limitation to agricultural development. This group would commonly include, for example, shallow soils developed on strongly sloping sites, or

low soils with acute mineral deficiencies such as is found in many Podzols with strongly indurated B horizons, ill-drained soils influenced by frequent damaging floods, and saline soils in which permanent swamp conditions prevail. These disadvantages greatly restrict the range and yield of crops and result in a high risk element for any agricultural enterprise on such land even with a high standard of management.

Group 5. Soils with at least one very serious limitation to agricultural development. This would include soils developed on steep lands in which slopes greater than 25° predominate, extremely stony, rocky and boulder strewn soils or bare rock, soils with low levels of certain elements, and peat soils greater than 48 inches in depth. Agriculture on such soils would generally be prohibitive, but they would have wide range of capability for forestry, hydrological or wild-life purposes.

Forestry. The rating employed relates essentially to timber production and emphasis is given to the forest potential inherent in the land. In so doing it is assumed that sustained timber yields can be maintained by normal silvicultural methods. Eight groups are recognised as follows.

Group 1. Good commercial forests, yielding more than 1,000 cubic feet of timber to the acre.

Group 2. Average commercial forests, yielding between 700 to 1,000 cubic feet of timber to the acre.

Group 3. Marginally commercial forests, yielding between 400 and 700 cubic feet of timber to the acre.

Group 4. Mangrove forests which although at present not commercially exploitable may have a large potential value in the distant future for the production of wood chips for the manufacture of rayon and industrial carbon.

Group 5. Poor commercial forests yielding less than 400 cubic feet of timber to the acre which would not warrant exploitation.

Group 6. Non-commercial forests consisting of montane forests and forests on hills developed on ultra-basic rock soils, which because of their species distribution are of no present commercial value.

but might be used for timber production in the future.

7. Other non-commercial forests, which would include coastal forests, swamp forests, and areas of nipah all of which have no merchandising value and no potential value in the foreseeable future.

8. Non-forested land subject to shifting cultivation, or slash-and-burn, in which the forest potential is limited to reforestation with plantations of exotic tree species such as various pines.

Hydrological and Wild-life resources are not rated into suitability groups, mainly because they are frequently difficult to define on a quantitative or qualitative basis. In the Classification, however, it is assumed that land which does not possess economic levels of minerals or cultivable soils or commercial timber stands would have one or both of the former resources.

Table 1. The relationships between the Resource Suitability Groups the Land Capability Classes and the Land Exploitation Units.

LAND CAPABILITY CLASS	LAND EXPLOITATION UNIT	RESOURCE SUITABILITY GROUPS		
		MINING	SOILS	FORESTRY
I	IA	1-2	4-5	5-8
	IIB	4	1-2	5-8
II	IIB	4	1-2	1-2
	IIC	3	1-2	5-8
	IID	3	1-2	1-2
	IIIA	4	3	5-8
III	IIIB	4	3	1-2
	IIIC	3	3	5-8
	IIID	3	3	1-2
	IVA	4	4-5	1-3
IV	IVB	3	4-5	1-3
	IVC	4	4-5	4
	VA	4	4-5	5-8
V	VB	3	4-5	5-8

Exploitation Units. Any one area of land may have one or more resource which may be economically exploitable. It follows, therefore, that on a broader scale natural groupings of land are each having similar qualities and uses in having the same order of natural resource potentials. These are defined as Land Exploitation Units and are essentially complementary to and fall within the five Land Capability Classes recognised. This concept is in some ways similar to that of the Capability Unit (Klingebiel and Montgomery, 1961) and the Management Unit (Mackney and Bibby, 1967), but differs from these mainly because the criteria employed in this Classification is based on a system of multiple resource groupings. Falling in a lower order in the Classification these units serve the purpose of providing a comprehensive range of information on the capability of the land, and thus any alternative uses. The overall recommendation, however, as to the future use of the land is defined at the Class level. The relationship between the Resource Suitability Groups and the other elements employed in the Classification is set out in Table 1. Thus each unit has a Class connotation followed by a suffix indicating the named Unit. The following fourteen Land Exploitation Units are at present recognised.

1. Land possessing a high potential for mineral development.
2. Land with a high potential for agriculture only.
3. Land with a high potential for both agriculture and timber exploitation.
4. Land with a high potential for agriculture and also a possible mining potential.
5. Land with a high potential for agriculture and timber exploitation and also a possible mining potential.
6. Land with a moderate potential for agriculture only.
7. Land with a moderate potential for agriculture and also a possible potential for timber exploitation.
8. Land with a moderate potential for agriculture and a possible mining potential.
9. Land with a moderate potential for agriculture a high potential for timber exploitation and a possible mining potential. .../10

- 1. Land with commercially exploitable timber resources only.
- 2. Land with commercially exploitable timber resources and also a possible mining potential.
- 3. Land with potentially productive mangrove resources only.
- 4. Land having no potential for agriculture, or timber and general exploitation.
- 5. Land having no potential for agriculture, or timber exploitation, but with a possible mining potential.

These Units are recognised in order to provide a framework for developmental planning of the resources of the land. This then lends itself with ease to multiple land-use planning which is considered essential in any little developed country, because alternative choices of land-use must always be considered from time to time and frequently from one region to another due to changes occurring in its economic or social structure (Hills, 1969).

Table 2. The classification of the alienation and gazettment detail.

LAND CATEGORY	ALIENATION AND GAZETTMENT UNITS
Alienated Land	Land alienated under leases and provisional leases, native titles and on field registers, settlement schemes and village reserves.
Forest Reserve	Land allocated as productive, riparian, water catchment and game reserves, fuel and mangrove forests, and national parks.
Government Reserve	Land allocated as State, cemetery, educational, military, police-station, quarry, tamu-ground, agricultural and veterinary reserves.
Drainage and Irrigation Area	Land coming under supervision of Drainage and Irrigation authorities.
Grazing Reserve	Land allocated for communal pastoral purposes.
State Land	Land not allocated for Government or private use.

Land-use and Ownership. While aspects on the current land-use are not considered in the Land Capability Classification, information on the legal status and ownership of the land is classified as Land Categories as shown in Table 2. This information is shown on the Land Capability Maps and provides valuable information for the purpose of land-use planning.

Land Capability Classification Programme. The results of the Land Capability Classification Programme are being produced as a series of reports and maps for each administrative district. The reports high-light the various opportunities for development. Two map series are published. One at the scale of 1:50,000., which utilises Land Exploitation Units, Land Capability Classes and Land Categories as basic cartographic units; and is primarily meant to assist detailed development planning at the District level by indicating the opportunities available as shown by the Land capability pattern. Supplementary detail is shown on maps of this series in the location of sources of road building material, thereby having an important bearing on decisions on road building and road alignment. The other map series is produced at the scale of 1:250,000., showing Land Capability Classes and Land Categories only. These maps are primarily meant to aid in making a natural resource appraisal, and also to facilitate regional planning, on the State and National level.

This Programme is now well under-way, and it is expected to be completed by 1971.

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SOIL SUITABILITY CLASSIFICATION IN MALAYA - SOME CRITICAL COMMENTS

By K.T. JOSEPH *

Soil Surveys in any developing country must have as its primary objective practical aims geared towards efficient Land Use.

Broadly speaking, this means that the agricultural capabilities of each mapping unit used in any soil survey material needs to be indicated. For this, agronomic work has to be carried out on the various mapping units in use so that connecting links between agricultural research and specific tracts of land can be established.

Coulter (1964) emphasises the point that some of the considerable sums of money being spent on soil surveys could be better spent on other aspects of soil research, as, for example in follow-up agronomic work. In the absence of any follow-up agronomic work, other methods have to be adopted, and the one chosen for the erection of a soil Suitability Classification in Malaya is claimed to be based on "features of the soil or its environment which limit the suitability of the soil for agriculture."

The Suitability Classes established are 5 in number and have been defined by Leamy and Panton (1965), Wong (1966) as follows :

Class 1: Soils with no limitations to agricultural development.

"These are deep, well drained, friable, well structured soils on slopes less than 12°. They are suitable for rubber and oil palm as well as a wide range of other crops."

Class 2: Soils with few, minor limitations to agricultural development.

"These soils occur on slopes less than 12° and have no serious suitability. The range of crops for which they are suitable is restricted in some cases by the type of limitation, e.g. susceptibility to flooding to 1-3 feet of peat, but apart from this, most other soils in the class are suitable for a wide range of crops including rubber and oil palm."

Class 3: Soils with at least one serious limitation to agricultural development.

"These soils will occur on a wide range of slopes up to 20° and part of them, cannot be developed satisfactorily without amelioration of the limiting factors. Their suitability tends to be restricted to certain crops under specified management practices. Some will support rubber and oil palm under a high standard of management."

Class 4: Soils with more than one serious limitation to agricultural development.

"The soils occur on slopes up to 20° and will require a high standard of development and management to produce reasonable yields. Some will support rubber but most will be restricted to specialized crops, such as pineapples on peat or to forest."

Faculty of Agriculture, University of Malaya.

Class 5: Soils with at least one very serious limitation to agricultural development.

"The obstacles to the development of these soils are so great that they should remain in forest or be allowed to regenerate to forest."

For the purpose of Land Use planning, this scheme has had very little application and serious limitations; for the simple reason that one is unable to use it in agricultural planning, particularly in regard to "crop diversification" to which the country is now committed. It is inevitable that any proposed scheme, if it is to be successful, must be directed towards specific crop possibilities. This scheme, therefore, appears not to have justified the vast sums of money that have been spent on soil survey operations in Malaya since a great deal of information used in the construction of the scheme could have been obtained directly from existing topographical and vegetational maps.

It is realised that no scheme of soil suitability can be perfect, as certain assumptions have to be made, especially in situations where exact nutrient supplying power and agronomic performance on specific soils have yet to be determined. Added to the lack of complete technological information, economic and marketing conditions which operate, fluctuate and vary with time, enhances the difficulty of the creation of a system that will satisfy at all times the users of any such scheme. Be that as it may, and despite all the possible limitations mentioned above, there is no detracting from the fact that, information is available for a more suitable approach towards the creation of a scheme of wider applicability than the present "Soil Suitability Classification for Malaya."

To do this, we have to consider the major features of the soil profile. The chemical properties of soils very often are secondary because the vast majority of Malayan soils need to be fertilized and this factor will have undoubtedly to be taken into account when knowledge accrues for a really sophisticated scheme of soil suitability. For soil properties ^{which are} ~~more~~ difficult to change, the form of research data to the land use planner will have to be a restraint in the choice of crops but even this should be based on soil/yield relationships. For the present, profile morphology must be the main factor of consideration. Andriess (1966) makes an excellent start for such a scheme in his proposals of evaluating land in Sarawak but the scheme can only have real value to policy makers if the groupings are to be geared towards specific crops. Variably the policy makers, and people who wish to use land for crop purposes want primarily to know the answers to the question: "What crop should we grow on this or that particular ground?"

The Malayan Soil Suitability Classification hardly provides any answers to the questions that users require. It is highly questionable if one could even agree with the statement associated with Class 1 Land, land described as being suitable for all crops.

Areas with a rainfall exceeding 50 inches per annum and a dry season less than 4 months are usually under closed forest and where the rainfall is above 75 inches as in most parts of Malaya, the moist evergreen forest prevails. In South East Asia the forest gives way to areas dominated in the main by lallang (Imperata cylindrica var. major). In the Philippines (Bedard 1958), estimates that some 17% of the total area is now covered with lallang where once the country was almost entirely forested. In the forest region Nye & Greenland (1960) show the rapid decline in yields with cropping. The yields in the first and second cycles of a rotation of rice, groundnuts, and cassava and a one year leguminous cover crop succeeding a forest follow in the Belgian Congo, reported by Tondeur (1956) and cited by Nye & Greenland were:

	<u>Yields (Kg./ha.)</u>	
	<u>1st cycle</u>	<u>2nd cycle</u>
Rice	2,341	565
Groundnuts	1,362	191
Cassava	45,000	30,000

Many workers have demonstrated this decline in yields including Malne (1940) who reported rapid falls in the yields of food crops following clearing of forests in British Guinea and Trinidad. Nye & Greenland (1960) stress the importance of maintaining the ecology of rain forest zones. replacement of the forest by annuals leads to a permanent lowering of the fertility of the soil.

Apart from nutrient removal losses, it is necessary to distinguish between natural erosion which will occur under the climax vegetation of the region and the accelerated erosion which may be caused by cultivation. The closed canopy of leaves, the layer of litter and the mass of surface roots all serve to reduce the surface movement of soil to a minimum. The kinetic energy of the rain drops is absorbed by the upper canopy and the force of the drips from this canopy is further lessened or cushioned by the lower canopy and the litter layer; again the surface layer beneath the litter promotes ready percolation into the soil; so erosion is minimal in such an ecological situation.

Dabin (1959) estimated losses from a small plot of 12-15% slope at Abidjian in the Ivory Coast (rainfall 85 inches per annum), of the order of 0.4 ton per acre per year over 3 years whilst a similar plot of 7-8% slope under cultivation lost 45 tons per acre per year. Nye & Greenland (1960) succinctly point out the importance of a forest climax in the statement: "The considerable depth of soil developed on steep slopes under rainfall exceeding 100 inches per annum in tropical mountainous regions is itself a testimony to the efficacy of the forest in counteracting erosion." The stripping of a forest cover will promote

sheet flow. The conversion of former forest vegetation to crops other than tree crops will bring about most serious consequences because one would have a land form adapted to forest under a vegetation associated with a totally different form. It is here that the consequences of accelerated erosion are most serious in terms of rate of removal of soil particularly by gulleying. Grove (1951) provides excellent examples of such gulleys in South Eastern Nigeria.

Are we then to take it that all Class 1 Land as defined by Leamy & Panton (1965), Wong (1966) in their scheme of suitability can be recommended for the large scale cultivation of such annual crops as maize, hill padi etc.? Apart from the question of the agricultural potential of Class 1 areas, there is also difficulty in distinguishing differences between class 2 and class 3 in the scheme proposed. Andries (1966) has suggested criteria such as slope, erosion, depth of soil, natural drainage for distinguishing various classes. The criteria are excellent, but the problem is not entirely resolved until an attempt is made to tie up features of the soil with crop adaptability. What may be deemed as Class 1 land for wet padi, would be class 5 for rubber. There is a need to construct a suitability table which can have application and the only way to begin is through attempting to relate certain soil features such as depth of profile, texture, depth of water table, soil permeability, erodibility, and features of the climate such as the presence or otherwise of a dry season to specific crop possibilities. Some crops thrive on a markedly seasonal climate, whereas others are adapted to equitable conditions throughout the year. It would be necessary to consider crops in terms of habit such as tree and shrub forms (perennials) and low storey forms such as annuals. We also need to seek profile features that can be used to indicate suitability in relation to rooting habit and adaptability. Nye and Forster (1958) working with P^{32} suggested that there were no differences in the availability of soil phosphorus for the different species. The ability of one species to take up much more of a particular nutrient from a given soil than another species may be due to root distribution and the volume of soil explored by the roots and the rate of uptake at a given activity. Drainage aspects ^{also} need to be looked into in greater detail e.g. we need to know if soils are permanently or intermittently water logged. If they are not permanently water logged, ^{to know} for what period they are free of water and to what depth. Would it be possible to grow an annual crop for the period, during which the water table is below the surface? Wong (1966) has cited the presence of laterite between 2 to 3 feet from the surface of a soil as an example of a minor limitation. Whilst this would possibly be true for tree crops such as oil palm, shallow rooting crops on areas of flat topography would be relatively unaffected by the presence of such physical impediments in

profile. Joseph (1964) proposed the use of such areas for sugar cultivation in North Kedah where the climatic features were conducive to its growth. Although erodibility of soils have been made explicit in the scheme proposed (by the use of topographical differentiation), further distinctions need to be made e.g. Terrace soils, alluvial soils, and gleys are subject to minimal erosion. Here a wide range of annual crops would be feasible as indeed, is commonly grown in such areas.

No mention has been made of nutrient supplying power. Here again, information is available to make recommendations, distinguishing areas for crop diversification e.g., areas formed from basic igneous rocks have a much higher magnesium supply power and cropping systems that lead to greater removal of magnesium by crop harvests can be sited in such areas, for example, in situations where Rubber/Oil Palm possibilities are being integrated. There is also the question of usage of areas disturbed by mining operations as well as the larger problem of the beach deposits of the East Coast of Malaya. How can we best use these areas? Groundnuts for disturbed tin-tailings? A legume/grass mixture for limited grazing under coconut palms or pine forests on the soils of Eastern Malaya? How best can we use our acid sulphate soils? Is amelioration of such soils feasible in economic terms or should we turn to more adaptable plants such as the sago palm? Suggestions have to be forthcoming, despite limitations in the lack of experimental efforts. We need to draw attention to possibilities of land use and it has to be more definitive than the current proposals for a Soil Suitability Classification for Malaya.

This conference could make a start by setting up a Committee, consisting of soil surveyors, agronomists, biometricians and crop scientists to pool knowledge obtained from soil surveys, of crop habit and of crop adaptation if we are to justify the vast sums of money which have been spent and are being spent for soil survey work in this region.

Future prospects:

The problem of translating soil survey information from the finished products (soil maps) to the creation of land use maps arises primarily because features of the soil profile have been viewed in many different ways, resulting in diverse approaches to soil classification. Whilst it is highly desirable to have one classification scheme of general applicability serving a general purpose for all soil students and users, a balance of purpose would inevitably mean that for special dissertations would be found inadequate. It would be no detraction, indeed it may be inevitable, even desirable that special classifications need to be developed along simultaneously with the general classification. The soil has been shown to give poor correlations with production whilst

better correlations are obtained between production and one or two soil properties. In Australia for example leaching losses of phosphorus encountered from some sandy soils (Hingston 1959) do not seem to occur from some loams (Williams 1950). Finck and Ochtman (1961) working on irrigated soils in the Sudan found a correlation between yield of cotton and clay content of the soil. In Malaya, soils formed on different kinds of granite (all other factors being equal to give us a geosequence) show quite marked differences in their ability to grow crops even though all the soils appear equally weathered and leached.

The more basic members give rise to soils with a higher clay content and possibly their ability to hold more moisture and retain more nutrients make them more productive soils. Texture obviously plays an extremely important part in soil/plant relationships although in almost all classification systems texture is used as a differential at the lowest levels of categorisation i.e. at the soil type level.

We cannot expect to classify soils as soils in a single operation nor can we classify soils as media of differing degrees of suitability for plant growth. A punched card scheme of soil information will enable extensions to cover various situations of detail, including situations not envisaged at present e.g. changes in soil due to fertilization, or crop removal etc. Basic data from soil surveys, soil analyses, fertilizer trials etc. are transferred to machine punched card records. Once the cards have been created and the accuracy of the punching verified no further reference to source documents is necessary. As new information becomes available this is added on to the cards. Apart from constituting a permanent and accurate record the cards can be processed in a number of diverse ways in terms of depth of water table, texture, K or Mg. status, nitrogen content, C.E.C. etc. In any soil/crop relationship a number of variables are involved. Computerisation is the only ultimate answer to the problem of solving complex data involving multivariate functions for the creation of a truly sophisticated scheme of soil suitability.

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Session 2/4

LAND USE IN MALACCA AND SOME AGRICULTURAL DEVELOPMENT POSSIBILITIES

by

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Introduction

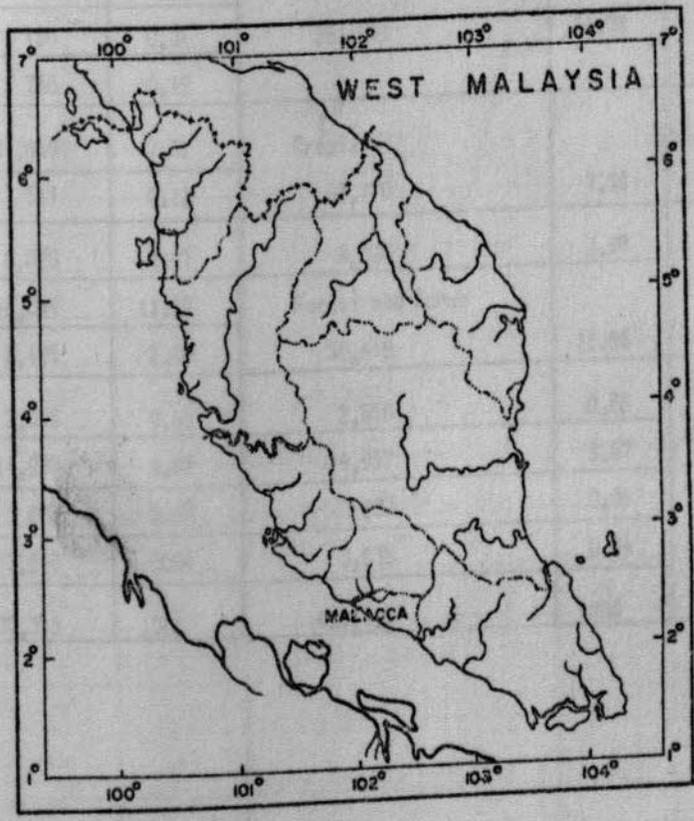
A survey of the present land use pattern of West Malaysia is currently being carried out by interpreting aerial photographs of scale 1:25,000 taken during 1966 and using a modified International Land Use Legend to suit Malaysian conditions. Land use maps of 1:25,000 scale and acreage statistics are being prepared and collected for West Malaysia. Malacca is the first State to be completed in this fashion and the results are presented in this paper.

Land Use of Malacca - 1966.

Malacca is the third smallest State in West Malaysia, covering an area of about 409,600 acres (640 sq miles) or 1.3% of West Malaysia. Its location in West Malaysia is shown in Fig 1.

Fig. 1.

Map showing location of the State of Malacca



Malacca's long history, favourable climatic conditions and suitable topography have made it a well-developed State whose cultivated land accounts for 76.54% of the State's territory. The land use statistics of Malacca (1966) are given in Table 1.

TABLE 1

PRESENT LAND USE SUMMARY - STATE OF MALACCA - 1966

Areas taken from 1:25,000 land use mapping completed from the interpretation of 1966 aerial photographs

	Acreages	%	Major land use categories in acres	%	Land under agricultural use			
					In % Major categories	sub-categories		
	6,946	1.70	Urban and Associated Areas 9,404	2.31	X			
	1,135	0.28						
	425	0.10						
Carrying	358	0.09						
Water	540	0.13						
	16,765	4.12	Horticulture 18,381	4.51	5.38			
	1,488	0.36			0.48			
	126	0.03			0.04			
	246,754	60.50			Tree, Palm and Permanent crops 261,031	64.08	79.14	
	827	0.20	0.30					
	11,449	2.81	3.64					
	15	0.00	0.00					
	1,004	0.25	0.32					
	28	0.01	0.01					
Ponds	186	0.04	0.06					
	768	0.19	0.25					
	31,859	7.82	Cropland 32,370	7.95			10.22	
	511	0.12					0.16	
	8,026	1.97	8,026	1.97	X			
	48,044	11.80	Forest and Scrub 56,449	13.86			100%	100%
	8,405	2.06						
	2,656	0.65					2,656	0.65	Total acreage under agriculture use: 311,782
	14,957	3.67	14,957	3.67			Percentage of State area under agricultural use: 76.54%	
	203	0.05	203	0.05				
	3,838	0.94	3,838	0.94				
	407,315	100%	407,315	100%				

Agricultural Land Use

About three-quarters of the land in Malacca is under cultivation giving a narrow range of crops.

Rubber, which accounts for some 80% of the cultivated land, is the most important crop and has an overwhelming dominance over the State's agricultural economy. About 43% (107,300 acres) of this is estate rubber. (Statistics Handbook 1966)

Padi, the next important crop, occupies about 10% of the State's cultivated land. It is a smallholding crop cultivated principally by Malay farmers. The acreage under double-cropping is insignificant (470 acres) in 1966 and the estimated average yield per acre for the same period is 358 bushels (Statistical Digest 1966).

Mixed horticulture or dusun, makes up 5% of the cultivated land. It is only associated with smallholdings and is usually found adjacent to villages along the roads and river-banks.

Coconut occupies less than 4% of the land under cultivation and is mainly found as smallholdings.

Oil palm, at the moment, occupies an insignificant place in Malacca's agricultural economy. However, it is expected to expand dramatically as soil and climatic conditions in the State are favourable to the crop.

Other sub-categories are found only in a very small scale, e.g. rubber trees in orchards, sago, market gardening and diversified crops including tapioca, sweet potato etc.

Agricultural Development

The result of the survey shows that Malacca is well-developed and the remaining undeveloped land is mainly under forests or swamps. The former is mainly as protected reserves. This state of development in Malacca reflects very well the present situation throughout the West Coast of West Malaysia. Consequently future agricultural developments other than opening up new lands should be geared to the following :-

- i) Broaden the base of the agricultural economy through diversification/offset the dependence on rubber and utilize scarce soil resources to better advantage.
- ii) Increase the production of the basic food crops, especially padi, to avert the threat of food shortage.

Climate and Topography

Malacca has a uniformly high temperature throughout the year. The mean monthly temperature ranges between 78°F and 82°F. The annual rainfall ranges between 75" and 100". Normally there is no severe water stress except from January to March and seldom is there a surplus of rainfall for flooding to be frequent. (Wycherley, 1967)

Malacca practically consists of flat to undulating land except in the north and east. The areas with slopes of 20° and above total about 1,600 acres representing only 4% of the State's land.

Consequently climate and topography are unlikely to limit agricultural development.

Suitability and its relationship to Present Land Use.

By super-imposing a land use transparency over a soil suitability map (prepared in 1967) on a scale of 1:85,360, the acreage of each class of soil under the different land use categories can be area-measured using a grid. The results is summarised in Table 2.

TABLE 2

LAND USE IN RELATION TO SOIL SUITABILITY
(Areas in acres)

Total Acreage	Urban	AGRICULTURAL		Cleared Land	Scrub & Forest Lands	Swamp	Total
		Rubber	Others				
130,275	3,079	106,104	5,986	1,487	13,475	164	13,639
133,906	2,186	91,299	15,025	717	20,658	4,023	24,679
70,411	275	37,753	16,361	558	14,497	1,187	15,664
47,651	1,250	9,130	25,496	93	2,294	9,408	11,702
19,252	2,094	2,468	944	-	13,552	194	13,746
5,814*	-	-	-	-	-	-	-
407,309	8,864	246,754	63,792	2,655	64,474	14,956	79,430

* This acreage includes all land which is agriculturally unused and lying outside category 1 (namely bunds, rivers, transmission lines, roads etc.)

The table shows that of the 130,000 acres of Class I soils, 13,000 acres are under scrub-grassland, scrub-forest, forest and swamp. Similarly in Classes II there are another 24,000 acres and 15,000 acres under this vegetation respectively. Considering only soils of Classes I and II which together make up 130,000 acres, which are highly suitable for agriculture, it is reasonable to say Malacca has an adequate resource of land available for future development.

Presently under Rubber.

In Malacca rubber occupies 106,000 acres or 80% of the Class I soils. It is mainly estate rubber located principally in the southern district. The soils are predominantly those of the Rengas Series derived from granitic rocks and small areas with soils of the Serdang and Munchong Series derived from sedimentary rocks. These soils are highly suitable for oil palm. (Ng 1967) Thus, good opportunities to convert these lands into oil palms are available in this category.

Under Forest Reserves.

There are 48,000 acres of forest in Malacca, 70% of which are Forest Reserves. Table 3 gives a breakdown of the main Forest Reserves under each soil suitability class.

PERCENTAGE BREAKDOWN OF SOME FOREST RESERVES INTO SOIL SUITABILITY CLASSES

Soil Suitability Class	FOREST RESERVES									
	Bukit Sedana		Bukit Senggeh		Merlimau		Ayer Panas		Total	
	Ac	%	Ac	%	Ac	%	Ac	%		
	6,406	80.2	1,179	12.1	1,267	36.0	2,826	92.3		11,678
	-	-	3,926	40.3	1,760	49.9	-	-		5,686
	794	9.9	1,140	11.7	493	14.2	-	-		2,427
	-	-	-	-	-	-	-	-		-
	787	9.9	3,487	35.8	-	-	246	7.7		4,520
Total	7,987	100	9,732	100	3,520	100	3,072	100		24,311

There are more than 17,000 acres of Classes I and II soils which are suitable for agriculture under the principal Forest Reserve areas. These are mainly of granitic origin. Presently about 70% of Malaya are covered by forest and in the national context, it is unnecessary for a developed State like Malacca to maintain these land permanently under forests especially when they are highly suited to agriculture.

Though most of the Class II soils are also suitable for oil palm cultivation, it is felt that to avoid a similar situation as rubber is at present, Class II soils, especially the Riverine Alluvium under Forest Reserves can be allocated for food and fodder crops. West Malaysia imports a variety of agricultural produces the consumption of which far exceeds its domestic production.

TABLE 4

Produce	Tons	Value(\$1,000)
Rice	207,606	90,903.3
Sugar Products	236,423	56,331.4
Maize (Unmilled)	57,324	11,717.1
Maize for animal feeds	49,072	9,816.6
Tapioca refuse	14,961	2,050.3

Source:- Statistical Digest 1968
Kementerian Pertanian dan Sharikat Kerjasama,
Malaysia Barat.

The acreage under these produces should be expanded wherever possible to reduce our dependence on imports for basic foodstuff. This also result in conserving foreign exchange and providing employment for rural population.

State Land.

Another area with potential for agricultural development is located at the lower reaches of the Kesang river. For most part it is classified by Briah Series - a Class II soil derived from River Alluvium. There is a tidal gate to control the sea water. Higher yields are obtained when the land is previously drained for padi cultivation. The area of interest occupying some 6,000 acres is presently under swamp forest and is unutilized. This area because of its topography and soil type is best suited for padi cultivation and possibly double-cropping if an effective drainage and irrigation control is instituted.

Conclusion.

The study of Malacca shows that the results of a land use survey mapping combined with available soil information, can be utilized to help analyze present land use within Malaysia. Obvious anomalies of land use in the State are brought to light and planning for a more economic use of scarce soil resource made possible.

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Session 4/1

THIRD MALAYSIAN SOILS CONFERENCE

(16-19 May, 1968, Kuching, Sarawak)

FAO'S ACTIVITIES IN THE FIELD OF SOIL FERTILITY RESEARCH

AND PROMOTION OF FERTILIZER USE

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Introduction

The developing countries of South-east Asia are confronted with a deteriorating food situation. Food production is hardly able to keep pace with the rapidly growing population, with the consequence that food imports into these countries are mounting. Taking the 1957-58 figures for food imports at 100, the figure for 1955 was only 63, while the figure in 1966 jumped up to 143. Even with all this food import, the level of nutrition in these countries is still very low, and much more food would be required to maintain the population at a reasonable nutritional standard. The population is expected to double during the next thirty years, and it has been estimated that the present food production should be increased by 3-4 times, if it is intended to feed the people even at a medium nutritional level, instead of the present level.

All the developing countries are trying to increase food production, but so far have only succeeded in barely maintaining the same per caput production, which prevailed before World War II. It is generally estimated that, with regard to cereals, over 50 percent of the production increases recorded between 1953-57 and 1959-63 was due to the extension of acreage. The past tendency in these countries has been to extend the limits of cultivation using the existing traditional technology of production. The agricultural sector, especially in countries where land is limited, has therefore encountered difficulties in responding quickly and adequately to increasing demand. Food production in the developing countries has risen mainly because of an increase in area cultivated, whilst in developed countries rising crop yields per hectare have been the principal factor.

One of the reasons for the relatively poor performance in food production has been the failure to appreciate fully the role of agriculture in economic development or the nature and scale of the programs and policies needed to bring about the required increase in production. The emphasis of the early agricultural development plans was placed on expanding the productive base of the economy through physical investment. As a result both public expenditure within the agricultural sector and external aid were directed primarily towards the construction of large-scale projects such as irrigation, land reclamation and resettlement schemes. Moreover, it was believed that agriculture constituted a "bargain sector", in which considerable increases in output could be achieved through the adoption of simple technical improvements such as, improved tillage practices, row planting, weed control, improved crop varieties, etc., without making much effort to introduce the essential cash inputs such as fertilizers, soil amendments, pest control chemicals, etc., on an extensive scale. It was not fully appreciated that although the adoption of such simple improvements provides an excellent opportunity for achieving increases in output, the possibilities they offer are soon exhausted.

Furthermore, inadequate attention was given to influencing the decisions of individual farmers in regard to production and investment by eliminating disincentives and other obstacles to increased production, and not enough emphasis was put on such strategic areas as, research of an adaptive nature, education, extension, credit, marketing, subsidies on inputs, price support of produce, land reform, etc. Consequently, output targets were not achieved, and even the benefits expected from large-scale projects of the type mentioned above failed to materialize at the planned rates. Hence, the food producing sectors of most of the developing countries continue to operate to a large extent along traditional lines, using traditional technology. Yield levels per hectare, which may be regarded as a yardstick of the technology used, have risen only slowly and remain low compared to those of modernized agriculture (Appendix I).

It is apparent that, if widespread hunger and malnutrition are to be avoided, and if the economic and social development of food deficit developing countries is to proceed smoothly and rapidly, these countries must achieve a faster rate of food production. This is a complex task involving the transformation of a relatively inert, tradition-bound agriculture into a responsive and modernized one. Fortunately, there is a greater awareness in the developing countries of the need to bring about this transformation, and efforts are being made to achieve this through national projects, supplemented by assistance from the United Nations and also bilateral aid from developed countries. The Food and Agriculture Organization is the United Nations Agency responsible for assisting Member Countries in increasing their food production as quickly as possible, through the solution of the problems mentioned above.

FAO's Activities

As is well-known increased agricultural production through the adoption of modern technology is mainly based on the introduction of: (i) controlled irrigation and drainage, (ii) soil fertility improvement and fertilizer use, (iii) high-fertilizer responsive crop varieties, (iv) plant protection measures, and (v) improved cultural practices including weed control. FAO is assisting the Member Countries in all these fields, but the present discussion would be confined to items (ii) and (iii), concerning soil fertility improvement and fertilizer use, and high-fertilizer responsive crop varieties.

Of the above production factors, chemical fertilizer is of primary importance in providing rapid and substantial increases in yields. In the developing countries, the soils are usually deficient in one or more of the main plant nutrients like N, P_2O_5 or K_2O , and there is evidence that many of them also lack some secondary elements like calcium, magnesium, iron and sulphur, and in some cases, micronutrients. Continuous cultivation has depleted the soil of nutrients, and the available farmyard manure and compost are not enough to restore soil fertility. Furthermore, the traditional practice of shifting cultivation (bush fallow) in some areas, is breaking down owing to population pressure, and with shorter fallow periods, soil fertility has often declined very rapidly. Fertilizers in conjunction with improved cultural practices are therefore essential for restoring and maintaining soil fertility under these conditions.

In comparison with other production factors, fertilizers offer certain advantages which facilitate their use among farmers. In the first place, the response from fertilizers is usually strikingly visible, and the difference in growth, colour of the plant, and the size of the crop or fruit are evident to the eye of even the illiterate farmer. Secondly, the farmer obtains a relatively quick return from their use, specially on annual crops where results are obtained within the same cropping season. At the same time, the financial outlay required is much lower than for many other improvements, and by a proper combination of other factors with fertilizers, very substantial profits may be obtained. Hence, fertilizers are in general readily accepted at an early stage in the transition from traditional techniques to scientific practices, and have been aptly called the spearhead of agricultural development. The capital investment from using fertilizers alone, enables the farmer to gradually invest more and more towards other inputs for maximum crop production. The present fertilizer use in most of the developing countries of South-east Asia is very small (Appendices II or III), and the bulk of the fertilizer is used on cash crops. Hence, considerable effort should be made to increase fertilizer use on cereals, in order to assure sufficiency of food in the future.

FAO is assisting the Member Countries to achieve the above objectives through the following:

1. The International Rice Commission.
2. Technical Assistance and Special Fund projects financed by the United Nations Development Program.
3. Projects financed by FAO's Freedom-from-Hunger Campaign.

Brief descriptions of the above follows:

The International Rice Commission

As early as 1949, FAO recognized that rice was the most important food crop in the Far East and over 92 percent of the world's rice crop was grown there. An International Rice Commission (IRC) was therefore organized, with the object of increasing rice production, not only in the Far East, but in all the rice growing countries of the world, with the following countries as members:

Australia, Brazil, Burma, Ceylon, Cambodia, Cuba, Dominican Republic, Ecuador, France, Ghana, Guatemala, Guyana, India, Indonesia, Iran, Italy, Japan, Korea, Laos, Liberia, Madagascar, Malaysia, Mali, Mexico, Nepal, Netherlands, Nigeria, Pakistan, Paraguay, Philippines, Portugal, Sierra Leone, Thailand, UAR, United Kingdom, USA, Venezuela, and Vietnam.

While the IRC discusses and plans the broad policy matters to increase rice production, it is advised by the following three Working Parties, in which the technical personnel of the Member Countries meet and focus attention on the detailed techniques which should be adopted in order to increase rice production:

1. Working Party on Rice Soils, Water and Fertilizer Practices.
2. Working Party on Rice Production and Protection.
3. Working Party on Agricultural Engineering Aspects of Rice Production, Storage and Processing.

Both the IRC and the three Working Parties meet once in two years.

The Working Party on Rice Soils, Water and Fertilizer Practices deals with soil fertility improvement and fertilizer use, in addition to soil classification and water problems. While recommendations on important lines of investigations to be undertaken for improving rice yields are made in each meeting, the Working Party adopted a Long-term Program of investigations in its 1959 session, consisting of nineteen items (Appendix IV).

The items in the long-term program are mostly self-explanatory, and have been suggested with the objective of obtaining information which would enable an investigator to advise farmers about the correct combination of different fertilizers and soil amendments to be used with ordinary and high-fertilizer-responsive rice varieties, under different soil-water-management conditions, for the most economic returns. However a few comments on some of the items are offered below:

Item 1. Simple tests on cultivators' fields

The technique of simple tests on farmers' fields has been developed within the last twenty-five years. The author, during his work of advising the extension service, in the 1930's, about the economic doses and combinations of plant nutrients to be recommended to the farmers under different soil-management conditions, had realized that the existing methods were not suitable for offering realistic advice to farmers, about the economic use of fertilizers.

The usual method for obtaining a preliminary idea of the kinds and amounts of fertilizers and soil amendments required to increase the fertility of a plot of land is to first conduct a soil test of the particular plot. This preliminary information about PH, organic matter, salt content, nitrogen, available phosphorus and potassium, Mg, S and micro-nutrients (in special cases), physical characteristics of the root zone, water table, etc., gives a fair idea of the management practices necessary to increase soil fertility. On the basis of this, tests are made by actually growing crops on this plot with different amounts and combinations of the required inputs, in order to prepare response curves for the calculation of economic dosages. Such tests are usually conducted on experiment stations and the results disseminated to the farmers over wide areas in the same soil series or type.

When the author tested such results obtained in the experiment stations, on farmers' fields, in the same soil type, it was found that entirely different kinds of requirements and responses were indicated in many of the fields. It was therefore concluded that the soil fertilities in the experiment stations and on the farmers' fields were entirely different due to the widely different management practices adopted, combined with the local variations in plant nutrient contents within the same soil series. Hence for realistic recommendations to farmers in a homogeneous soil unit, it is essential to random-sample this unit by conducting a suitable number of crop growing tests, combined with soil testing, on farmers' fields, under different management and water availability conditions.

In 1943, the author proposed that field work should be conducted on the above lines and in 1948 actually started extensive trials on farmers' fields. In 1951, the IRC recommended that such trials should be started in other countries, and FAO arranged for advise and assistance in the matter. As a result of this, this technique of simple tests on cultivators' fields has now been adopted by most developing countries in the Far East, Near East, Africa and Latin America. Full details of the technique and some of the results obtained have been described by the author (1) with sixty-six references on the subject. Some other papers on the subject are also given in the bibliography (2 to 10). The original technique is being constantly improved by numerous field workers and recently Hauser (11) has prepared a comprehensive paper, from his field experience, on the details of the field technique and the experimental designs, which will prove very useful as a handbook for field workers.

The implications of the need for extensive tests on farmers' fields for accurate recommendations about economic use of fertilizers and soil amendments is not fully understood by some soil scientists. The author would welcome critical questions and discussions on the subject from the delegates at the Conference.

This technique is meant for accurate determination of fertilizer requirements under locally variable conditions, and is necessary for the developing countries, where the farmers have a meagre extra cash to invest, and where the benefit/cost ratio between fertilizer prices and the produce is very adverse. Hence the farmer has to be advised about the most profitable investment for his small extra cash, so that he may not waste a part of it on fertilizers or amendments which are not immediately needed for a profitable return. The conditions are entirely different in the developed countries, due to higher farm incomes, cheaper fertilizers, and Government price-support for the produce. Under those conditions, it is not necessary to determine very accurately the amounts of fertilizers and amendments, and the tendency is to use maximal amounts over large areas, because the cost of fertilizers is quite small in comparison to the other farm costs and the expected return is highly profitable.

Items 2 - 6 of the Long-term Program

In addition to the simple trials on farmers' fields to determine the requirements of N, P, K, etc., it is necessary to conduct conventional trials to find out how a given amount of fertilizer can be made to work more efficiently by using the proper carrier, placing it at a depth, split application at different times; and combining it with high-fertilizer responsive varieties, controlled irrigation and drainage, better cultural practices etc.

Residual and cumulative effects of fertilizers should be determined to find out the possibility of reducing the bill for certain fertilizers, which tend to accumulate in the soil in an available form for some years.

It is also necessary to determine how the soil limitations like, acidity, alkalinity, salinity, aluminium toxicity, bad physical conditions, high water table, effects of erosion, etc., can be corrected, through the use of appropriate soil amendments, drainage etc., so that the applied fertilizer may act with full efficiency.

Items 7 and 8 of the Long-term Program

These plant nutrition studies are recommended for obtaining an insight into requirements for different nutrients by the plant at different growth stages for helping in developing proper fertilizer application techniques.

Item 9 of the Long-term Program

For accurate advice to individual farmers through soil testing, it is necessary to establish correlations between applied nutrients and crop response under field conditions. Although, fair correlations are obtained in pot tests, such correlations have not been so far obtained in tests on farmers' fields. The results obtained by FAO experts would be discussed under country reports.

Items 10 - 19 of the Long-term Program

These topics deal with studies on sampling of wet paddy soils, nutrient deficiency symptoms, water-relationships, physical condition of soils, biological diseases, paddy soil classification, micro-nutrient requirements and reclamation of organic soils. Particular items are studied under particular conditions, where they are appropriate.

The Eleventh Session of the three IRC Working Parties would be held in Manila from 2-14 September, 1968, and the Agenda for the WP on Rice Soils, Fertilizer and Fertilizer Practices is attached as Appendix V. The subjects would be introduced by papers prepared by FAO for many items, and Member Countries are expected to present papers on work conducted in their countries.

Apart from the usual topics, item 9 relates to "Factors responsible for high yields of rice". The subject of obtaining high rice yields have become important in recent years due to the growing food shortage. Since its inception in 1949, the International Rice Commission had pointed out that the varieties grown in the tropics, grow tall and lodge when higher doses of nitrogen are applied, and cannot give very high yields, like the dwarf varieties in the temperate regions. Hence, the IRC started a co-operative rice selection and breeding project to obtain dwarf varieties which would show high fertilizer response. Much work on this line has since been done, and in recent years, indica varieties like IR 8 and IR 5 in the International Rice Research Institute, ADT 27 in India, H-4 in Ceylon, BPI-76 in the Philippines, and IR 36 in Indonesia, have been evolved which show very high response to higher doses of fertilizers. However, farmers in the different tropical countries have not been able to obtain very high yields of 8-10 tons per hectare of paddy, in the prize competitions, with their indigenous tall varieties and with rather small doses of fertilizers. It appears that there are certain other factors apart from fertilizer and variety, which in proper combinations may give very high yields.

Further, in temperate climates like Japan, where dwarf high-fertilizer responsive varieties are grown, the prize-winning farmers were producing over 10 tons of paddy per hectare, but the agricultural scientists could not produce so much. But, during the last two years, the scientists have been able to produce such yields in the experiment stations as a result of concentrated study of the farmers' techniques and conditions, and a paper on the soil and fertilizer factors involved in obtaining such high yields would be presented by FAO to the next session of the Working Party. The author presented a paper on the analysis of factors responsible for very high yields in the 1966 session (8), in which the techniques of prize-winning farmers from India, Japan, Korea, Philippines, Taiwan and Thailand were discussed. It was pointed out in the above paper that farmers even manage to change the chemical and physical composition of the soils up to the root zone, and apply different nutrients in different doses and combinations at different times, in order to obtain very high yields.

A quarterly journal called IRC Newsletter is published by FAO which contains original papers either presented to the Working Parties, or communicated to the editor by research workers in the Member Countries.

Assistance in Field Work by FAO

The recommendations of the IRC have provided valuable incentive to research workers, but FAO assists in converting recommendations into field action, whenever requested by Member Countries.

The following types of field assistance are arranged by FAO:

(a) Technical Assistance (TA) Program: One FAO Expert and one Fellowship with some equipment (if necessary) is given for conducting tests on farmers' fields and experiment stations. FAO Experts have worked in Burma, Indonesia and Vietnam, and are at present working in Afghanistan, Cambodia, Nepal and Pakistan.

(b) Freedom-from-Hunger Campaign (FFHC) Program: One or two FAO Experts are provided with substantial funds for fertilizers. These are more "farmer-oriented" and "down-to-earth" projects, in which simple fertilizer trials are conducted extensively on farmers' fields, which not only provide information on economical fertilizer requirements, but serve as excellent demonstrations. As a result of awareness of the farmers towards fertilizer use through these trials and demonstrations, the demand for fertilizer increases, but as the farmers lack cash, pilot credit schemes are established for supplying fertilizer on credit, to be repaid after the harvest of the crop. The money thus obtained is used as a revolving fund for starting pilot credit schemes in other areas. Such FFHC projects are at present operating in Ceylon and twenty other countries in Near East, Africa and Latin America.

(c) UN Special Fund (SF) Program: More substantial aid is given in this program with five or six UN Experts in fields such as, soil fertility, field experiments, agronomy, soil chemistry, plant nutrition, agricultural economics, soil classification, credit and cooperative, etc., along with 6-10 fellowships, tractors, equipment etc., of which the total cost may approach one million dollars for a 5-year project. In addition to simple trials on farmers' fields, demonstrations and pilot credit schemes, investigations on soil chemistry, plant nutrition and soil classification are also conducted in these projects. One of these projects has been completed in Iran, while others are at present in progress in Korea, Philippines and Thailand. Another SF project viz., "Pilot Project for Irrigated Agriculture" in Thailand (Kalasin) deals with some difficult soil problems which arise in multiple cropping after the introduction of irrigation in very poor soils of bad physical condition. Two more SF projects have been prepared for the Governments of Nepal and Indonesia, and are awaiting approval. A summary of the purposes and organization of a normal SF project is given in Appendix V.

Brief indications of the nature of the results obtained in the field are given in the publications (12,13), and Appendix VII.

Concluding Remarks

The developing countries are facing a critical food situation due to the rapidly increasing population and continuing low per hectare yields. Efficient fertilizer use, combined with high-fertilizer responsive varieties, double cropping with controlled irrigation, and adequate plant protection measures can greatly increase production. FAO is assisting the Member Countries through "production-oriented" projects, concerning the promotion of fertilizer use among farmers. The farmers' varieties give over 50 percent yield increase with fertilizer application and the improved varieties show much higher yields. Hence, there is enormous potential for obtaining increased yields, and fertilizer has to be used as the key factor to realize this potential. If proper steps are taken now, to see that most of the farmers use fertilizers in the developing countries, there would be no danger of the threatened "hunger famine" in the foreseeable future.

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APPENDIX I

Yield per hectare of paddy and total production of paddy and all cereals

COUNTRIES	P A D D Y.				ALL CEREALS	
	Yield 100 kg/ha		Production (1000 m/t.)		Production (1000 m/t.)	
	1948/49. -1952/53	1964/65	1948/49. -1952/53	1964/65	1948/49. -1952/53	1964/65
Burma	14.6	16.4	5 481	8 151	5 571	8 313
Cambodia	9.8	11.0	1 633	2 570	1 643	2 790
Ceylon	14.2	20.0	479	1 054	503	1 086
China, Taiwan	22.1	36.5	1 682	2 795	1 710	2 866
Hong kong	22.8	14.0	37	12	37	12
India	11.1	16.1	33 383	58 098	56 064	92 728
Japan	42.5	51.5	12 736	16 802	16 146	19 498
Korea, North	29.4	-	1 158	-	-	-
Korea, Rep. of	27.5	33.3	2 567	3 974	3 379	5 182
Laos	6.4	-	540	-	556	-
Malaya	20.1	26.3	554	921	554	925
Malbah	12.6	23.9	42	85	44	88
Parawak	-	9.5	103	107	103	107
Pal	-	19.6	-	2 200	3 510	3 257
Pakistan	13.8	16.8	12 399	17 780	17 199	23 370
Philippines	11.8	12.5	2 767	3 992	3 463	5 305
Sailand	13.1	16.0	6 846	9 625	6 877	10 575
Vietnam, North	-	18.6	-	4 512	1 390	4 786
Vietnam, Rep. of	13.6	20.2	2 469	5 185	2 469	5 231
Indonesia	16.1	17.4*	9 495	11 764*	11 279	14 155*

1963/64 figures

A P P E N D I X II

Fertilizer Consumption in Relation to Arable Land - 1965/66

Country	Average consumption per 1000 ha. of arable land 1/			Total N. P ₂ O ₅ , and K ₂ O	Arable Land 1000 ha.
	N	P ₂ O ₅ 2/	K ₂ O		
	..... Metric tons				
Armenia	0.32	0.06	-	0.38	14,948
Cambodia	0.10	0.34	0.10	0.54	2,984
Egypt	22.64	0.50	18.35	41.49	1,873
China, Taiwan	162.92	41.91	50.96	255.79	882
India	3.60	0.83	0.55	4.98	162,883
Indonesia	5.57*	2.61*	0.26*	8.44*	17,681
Iran	2.07	1.72	0.17	3.96	16,850
Japan	129.08	90.94	101.10	321.12	6,042
Korea, Rep. of	89.17	42.19	17.78	149.14	2,153
Malaysia					
West Malaysia	16.10	2.42	6.04	24.56	2,484
Sabah	2.46	2.46	1.48	6.40	183
Nepal	0.55	0.01	0.03	0.59	1,831
Pakistan	5.10	0.43	0.09	5.62	25,761
Philippines	7.31	3.78	6.30	17.39	11,210
Switzerland	1.60	0.89	0.44	2.93	10,604
Viet-Nam, Rep. of	9.00	18.88	3.79	31.67	3,082

Data on arable land and land under permanent crops have been taken from FAO Production Yearbook, 1966, Vol XX, Part I, Table 1: "Land Use". Arable land includes land planted to crops (double cropped area counted only once), land temporarily fallow, temporary meadows for mowing or pastures, garden land, and land under fruit trees, vines and fruit-bearing shrubs.

Data exclude ground rock phosphate.

1963/64 figures.

Consumption of Commercial Fertilizers, 1961/62 - 1965/66

Country	NITROGENOUS FERTILIZERS				PHOSPHATE FERTILIZERS				POTASH FERTILIZERS			
	Actual Cons'n in 1961/62	Actual Cons'n in 1965/66	Estimated Domestic Re- quirements in 1965/66 <u>1/</u>	Surplus (+) or Deficit (-) in 1965/66	Actual Cons'n in 1961/62	Actual Cons'n in 1965/66	Estimated Domestic Re- quirements in 1965/66 <u>1/</u>	Surplus(+) or Deficit(-) in 1965/66	Actual Cons'n in 1961/62	Actual Cons'n in 1965/66	Estimated Domestic Re- quirements in 1965/66 <u>1/</u>	Surplus (+) or Deficit (-) in 1965/66
	.....1 000 metric tons N.....				.....1 000 metric tons P ₂ O ₅.....				..... 1 000 metric tons K ₂ O			
Afghanistan	...	...	...	...	...	...	...	...	...	...	...	...
Australia	35.0	*70.0	...	...	587.8	952.5	...	...	47.9	64.0	...	...
Burma	4.5F	*5.1	*10.0	-*4.9	1.0F	1.0F	*12.0	-*11.0	-	-	*3.0	-*3.0
Cambodia	0.1	0.3F	...	...	0.8	1.0F	...	...	-	0.3F	...	...
Ceylon	36.4	42.5	*37.0	+*5.5	1.3	0.9	*20.0	-*19.1	27.6	34.4	*18.0	+*16.4
China, Taiwan	121.5	145.0	120.0	+25.0	26.1	37.3	31.2	+6.1	34.4	45.4	42.0	+3.4
India	310.0	*582.6	1000.0	-*417.4	70.8	*134.3	400.0	-*265.7	37.0	*89.6	200.0	-*110.4
Indonesia	84.8	*60.0	*300.0	-*240.0	47.3	80.0F	*150.0	-*70.0	4.0	11.0F	*10.0	+*1.0
Iran	7.3	*24.0	...	...	4.3	20.0F	...	...	2.2	2.0F	...	...
Japan	695.2	775.0	706.0	+69.0	452.5	546.0	541.0	+5.0	492.8	607.0	595.0	+12.0
Korea, Rep. of	216.9	201.2	204.6	-3.4	82.1	95.2	141.1	-45.9	17.1	40.3	55.2	-15.1
Laos	...	...	...	...	...	...	...	...	...	...	...	...
Malaysia	...	...	...	...	...	...	...	...	...	...	...	...
West Malaysia	25.3	40.0F	...	...	5.8	6.0F	...	...	10.0	15.9F	...	...
Sabah	0.4	0.5F	...	...	0.3	0.5F	...	...	0.4	0.3F	...	...
Nepal	0.1	1.0F	...	...	-	-	...	...	-	-	...	...
New Zealand	6.0	8.5	...	...	207.7	410.1	...	...	82.4	108.6	1.0	1.0
Pakistan	62.1	132.7	*123.0	+*9.7	10.6	11.2	*90.0	-*78.8	6.0	2.3	*18.0	-*15.7
Philippines	35.8	*58.0	80.0	-*22.0	16.0	*30.0	50.0	-*20.0	27.6	...	50.0	-
Singapore	6.0F	5.0F	...	...	1.5F	0.5F	...	...	3.0F	1.0F	...	...
Thailand	11.1	18.0F	22.8	-*4.8	4.7	10.0F	5.3	*4.7	2.1	5.0	14.0	+1.0
Viet-Nam, Rep. of	15.6	26.4	26.4	-	1.9	55.4	46.2	9.2	5.3	11.1	15.4	-4.3
Total	1674.1	2195.8	...	...	1522.5	2391.9	...	...	799.8	1087.1	...	...

F = FAO Estimate; - = None, in negligible quantity (less than one half of the unit indicated or entry not applicable);
 * = Unofficial figure; ... = Data not available.

1/ Data taken from "Anticipated Requirements of Chemical Fertilizers in the Region up to 1975" presented by FAO Secretariat at the Conference on the Development of Fertilizer Industry in Asia and the Far East, held in Bombay in 1963.

APPENDIX IV

FOOD AND AGRICULTURE ORGANIZATION OF THE UNITED NATIONS

INTERNATIONAL RICE COMMISSION

LONG-TERM PROGRAM IN THE FIELD OF RICE SOILS, WATER AND FERTILIZER PRACTICES

Following the recommendations made by the International Rice Commission at its Seventh Session in 1959, a suggested long-term program of research has been formulated with three major objectives. These are:

- (a) To aid and support national efforts.
- (b) To strengthen collaboration and co-operation among the various countries; and
- (c) To help fill any important gaps in the technical programs of Member countries.

The Long-Term Program has been revised to include the following suggested research projects which are not listed in any special order of priority. Countries implementing their own programs are urged to consider their local needs and priorities and establish their own priorities. Suggested projects are:

1. Simple fertilizer tests on cultivators' fields, testing responses to N, P and K, etc.
2. Efficiency of different fertilizer materials and lime
3. Time and method of fertilizer application.
4. Interaction of fertilizers with varieties, irrigation and cultural practices.
5. Residual and cumulative effects of fertilizer use.
6. Amelioration of problem soils where adverse factors other than nutrient deficiency operate, viz. acidity, alkalinity, salinity, aluminium toxicity, physical conditions, soil erosion, etc.
7. The uptake from wet paddy soils of the nutrient elements by the rice plant at different stages of development and the effect of these elements on the metabolism of the plant.
8. Basic research on soil and plant physiological problems, studying such factors as the fixing capacity of the soil, crystal structure of clay minerals, factors affecting the utilization of different materials and biochemical changes in the plant.
9. Correlation between soil chemical analytical data and field responses to plant nutrients to enable advice to be given to individual farmers on the economics of the use of fertilizers.
10. Development of more suitable methods of sampling wet soils and, if necessary, of appropriate methods for analysis of such soils.
11. Perfection of techniques for the detection of nutrient deficiencies in the growing stage of the rice plant by foliar diagnosis and deficiency symptoms.
12. The influence of the water regime of the soil on the paddy plant, e.g.
 - (a) Water balance under various climatic and soil conditions.
 - (b) The effect of too much or too little water for the rice plant.
 - (c) Water management under different farming practice.

- (d) Design of irrigation and drainage systems.
- (e) Land preparation for irrigation.
- (f) Operation and maintenance of irrigation and drainage systems to effect greater irrigation efficiency.
- (g) Effects of temperature and quality of irrigation water on rice crop growth.

13. The function of water in relation to physiology and growth responses in the rice plant.

14. The effect of water on the chemical, physical and micro-biological changes including those undergone by added fertilizer materials in wet paddy soils and the plant toxicities that appear to be developed under prolonged flooded conditions.

15. The optimum physical conditions of rice soils:

- (a) Optimum soil moisture content for tillage operations;
- (b) Time, method and depth of tillage operations;
- (c) Optimum soil aggregation for rice production;
- (d) Drainage and aeration of rice soils.

16. Causes and remedies of the physiological diseases of paddy.

17. Development of an adequate system of classification for wet paddy soils.

18. The effect of micro-nutrients on rice, both from the point of view of availability from soil and their physiological effects in the plant.

19. Reclamation of soils containing large amounts of organic matter for rice cultivation.

APPENDIX V

FOOD AND AGRICULTURE ORGANIZATION OF THE UNITED NATIONS

The International Rice Commission (IRC)

WORKING PARTY ON RICE SOILS, WATER AND FERTILIZER PRACTICES

Eleventh Session

Kandy, Ceylon - 2-14 September 1968.

PROVISIONAL AGENDA

Procedural Matters

- Opening of Meeting
- Election of Chairman and Vice-Chairman
- Adoption of Agenda
- Election of Drafting Committee

Technical Matters

Water requirements and management as affected by:-

- (a) direct sowing vs. transplanting
- (b) temperature of soil and water
- (c) rotation with other crops
- (d) depth of water at various growth stages

Practical methods of increasing efficiency of irrigation.

- 1) Reclamation and water and soil management in acid, saline, alkaline and degraded soils.
- 2) Classification of rice soils

Water and fertilizer management for rice grown under upland conditions

Factors responsible for very high yields of rice.

The use of soil and plant analysis in determining the fertilizer requirements of rice.

Time and method of fertilizer application

Response of rice to micronutrients

Kinds of fertilizer materials

Discussion on hand book on water control and management

Discussion on bulletin on terminology.

APPENDIX VI

Outline of a project for FAO assistance in soil fertility improvement and fertilizer promotion work

The request for a project is usually prepared by the Member Government and include the following:

Background and origin, reason for the request, purpose of the project, description of the project, Government contribution, UN contribution, organization, sequence of operations and future of the project.

The reason for the request, and the purpose and description of the project may be indicated as below:

Reason for the Request

1. Although considerable improvement in the situation of fertilizer use has been achieved, it is urgently needed to expand fertilizer use in order to increase food production. This would not only save foreign exchange but help alleviate nutritional deficiencies that now exist.
2. The use of fertilizers should be combined with as many other production factors as possible, such as: improved cultivation methods, improved seeds, pest protection, irrigation, etc. The effect of fertilizer use on the still common practice of shifting cultivation should be investigated thoroughly with the final aim of eliminating the shifting cultivation.
3. The organization of fertilizer supply, Governmental and private, still needs intensification. The supply of other agricultural inputs should combine with it, also the improvement of marketing of agricultural products.

Purpose of the Project

1. To improve agricultural production by the establishment of a pilot development program in selected areas by the promotion of the rational use of fertilizers on a large scale. This program would also aim at the gradual replacement, where possible, of bush fallow by more permanent forms of agriculture through the efficient fertilizer use combined with appropriate soil management and through the introduction of better crops together with other improved practices.
2. To obtain more detailed information regarding fertilizer response under different conditions and its economic effect by an intensive trials program on the fields of the farmers.

To lay out a large number of fertilizer demonstrations to show farmers the use of, and the benefits to be obtained from, fertilizer use in combination with related improvements.

3. To prepare from the results available, a series of recommendations to farmers and cultivators on the most economic use of fertilizers and to advise the extension service on the suitable means of publicising these recommendations and supervising their application.
4. To assist the Government in improving the fertilizer distribution to farmers. For this purpose, the Government and UNDP will make available, during the period of the project, 3,000 tons of fertilizers to support action programs in the selected pilot areas. Careful attention would also be given to problems related to credit, subsidies, marketing of products and reduction of post harvest losses.
5. To combine the fertilizer use with better cultural practices, water control, improved seeds, plant protection measures and storage.
6. To establish a correlation between soil analysis and response of crops to fertilizers on different soil types and under different climatic conditions.
7. To provide the Government with realistic figures on the possibilities of increasing production in agriculture in view of saving foreign exchange through the rational use of fertilizers and additional improved farm practices.
8. To provide information needed related to the most suitable types of fertilizers as a basis for the planning of local fertilizer production.
9. To establish, within the five year period, a fully effective fertilizer branch in the Ministry of Agriculture.
10. To assist the Government in formulating a long term fertilizer policy.

11. Training of local personnel: in all fields of the project, personnel will be trained in such a way that the work started by the project may be continued and expanded to include other parts of the country after the completion of United Nations assistance in this field.

Description of the Project

1. The project will have a duration of five years. It will be carried out in co-operation with the extension service and in consultation with the local research organisations; it will operate mainly in contact and on the fields of the farmers. As the results obtained in the pilot areas should be used later on in other parts of the country, the economic soundness of the operations should be made certain from the beginning.
2. A number of areas will be selected for the project; each one representing typically the corresponding part of the country. There should be a project in:

3. The field program should include fertilizer trials and demonstrations in the fields of the farmers; not less than 500 trials and demonstrations per major season and area and not less than 250 trials and demonstrations during the minor season per area. The responses to N, P and K should be recorded in terms of yield increases and the economic effects. The efficiency of different forms of fertilizer materials should be compared. The best time and method of fertilizer application should be tried out.

Interaction of fertilizer with organic manuring, varieties, irrigation, cultural practices and plant protection measures should be investigated.

Relationship between soil type, soil conditions, drainage, aeration and fertilizer responses should be established through co-operation between soil fertility, soil correlation and soil analysis experts.

4. Pilot schemes for fertilizer distribution and for the distribution of other agricultural inputs should be organized in the pilot areas in order to encourage the Government and private commercial organizations to improve this field. The problems of credit and subsidy should be tackled at the same time.

With this the improvement of marketing of agricultural products should be combined as far as possible. According to the prevailing conditions the build-up or improvement of existing agricultural co-operative organizations should help to improve this, also on a long term basis.

The Government will ensure that necessary import licenses for fertilizers will be issued to meet the demand for this commodity in all parts of the country.

5. The existing fertilizer recommendations for the various crops should be reviewed from time to time in the light of experimental results obtained at the project. This could help the Government to establish a long term fertilizer policy.

6. During the course of the project, a study should be prepared on the possibilities for local fertilizer production.

7. Training of ----- counterpart personnel would be one of the most important aspects of the project.

The international staff would arrange training of personnel for field experiments, soil and plant analytical work, fertilizer extension and fertilizer supply. The training should consist of on the spot training, special training courses at different levels and fellowships.

APPENDIX VII

Summary results of FAO activities in the different projects

Under the Technical Assistance program 24 countries had been provided with 41 man-years of expert services by the end of 1966, to advise them regarding the production, distribution and use of fertilizers.

Special Fund projects had been carried out in 11 countries and provided with 33 man-years of experts by the end of 1966.

Since 1961, Freedom-from-Hunger Campaign projects have been carried out in 23 countries, viz., Turkey, Syria, Lebanon, Morocco, Ethiopia, Nigeria, Senegal, Togo, Ghana, Cameroon, Ivory Coast, Gambia, Sierra Leone, Senegal, Mali, El Salvador, Honduras, Nicaragua, Costa Rica, Panama, Columbia, Ceylon, India, and India. By the end of 1966, some 88,200 fertilizer demonstrations, 12,000 simple trials had been laid out in farmers' fields and the program is now proceeding at the rate of 20,000 demonstrations and trials a year.

One of the important findings of the FFHC Fertilizer Program has been that, even when used alone, without other improvements, by traditional farmers, fertilizers have almost everywhere given increased yields, on an average of 270 percent. Results of 23,446 demonstrations showed that in 92 percent of cases at least one fertilizer treatment was profitable--even on small, peasant farms at local prices--and that the average value/cost ratio of the best treatment was 3.7, i.e., 270 percent return on fertilizer cost.

On the other hand, in 3,128 simple trials where more efficient treatments were included, it was found that 96 percent showed a profitable return to at least one treatment, and the average value/cost ratio of the best treatment was 3.4.

The results varied from country to country, region to region, and crop to crop. Cereal crops on the whole showed the smallest profits from fertilizer use, while vegetable crops the largest profits, with cash and commercial crops like cotton and groundnuts in between. Even with cereal crops however, the use of fertilizers returned over 100 percent profit on the cost of the fertilizer in many countries.

In pilot schemes, fertilizers are distributed to the farmers for cash or credit under FAO supervision, from a fertilizer revolving fund with the objective of having a natural transition to the most suitable distribution, marketing and credit system under local conditions to serve the need of small farmers. An indication of the success of such programs is shown by the fact that the average rate of increase in fertilizer consumption has been only four times as fast in countries which participate in the Fertilizer Program, as in comparable countries not carrying out such a Program.

Detailed results obtained in these FFHC projects are being reported every year since 1961.

Simple fertilizer trials on farmers' fields have been conducted in most countries of South-east Asia as a result of the recommendation of the IRC, and also through technical assistance offered by FAO. Reports of the results obtained in Burma, Cambodia, Ceylon, Hongkong, India, Indonesia, Korea, Malaysia, Pakistan, Philippines, Thailand, and Vietnam, have been published either in the IRC Newsletter or in the proceedings of the IRC Working Party meetings. References about many of these are contained in the author's paper (1).

The Special Fund projects are more comprehensive as mentioned before, and the results obtained are regularly reported.

The Iran project worked from January 1961 to February 1966 and the final report has been published by FAO as FAO/SF: 20/IR. Excellent economic data on high monetary return rate and the maximum profit rate for fertilizer application has been obtained for wheat, rice, cotton, sugar-beet, tobacco, tea, grapes, potatoes, alfalfa and melons. In addition, investigations were conducted on residual effect of fertilizers, effect of trace elements, time of applying nitrogen, effect of planting time, response of improved varieties, and correlations of soil test data and crop response.

The Korea project started in 1963 and is still operational. In addition to the economic N,P,K, requirements of rice, wheat, barley, potatoes, soyabean, maize, radish, etc., investigations are being conducted on: cultural practices, time of fertilizer application, varieties, spacing, silica, lime, organic matter and micro-nutrient applications, improvement of low productive soils, prevention of physiological diseases, residual effects, soil test correlations, plant nutrition studies etc.,

The Philippine and Thailand projects are also working on the above lines, but the Ceylon FFHC project is mainly concentrating on the N,P,K, requirements under farmers' field conditions.

Apart from the specific plant nutrients and their rates, methods and times of application, interaction with varieties, irrigation, cultural practices, etc. under different soil-management conditions, work is being done to improve soils with different limitations and good results have been obtained.

In Korea, heavy clay soils, degraded sandy soils with or without an accumulated layer, sandy permeable soils, old polder soils with degraded heavy clay and an impermeable layer, soils with bad drainage, etc., are being improved with different treatments such as:- deep ploughing, compost, rice straw, paddy husk, lime, calcium silicate, Fe, Mg, Mn, red earth, high ridge cultivation, etc.,

Introduction of irrigation and multiple cropping to very poor soil in north-east Thailand, which tend to subside during ploughing and show salt concentrations in some areas, presented a number of problems. Heavy phosphorus applications are essential in addition to organic matter, while lime is beneficial in some cases. Rice has thus given yields of 6.6 tons per hectare and peanuts 2.5 t/ha, and very good results have been obtained with 8 kinds of vegetables. Maize, sorghum and cotton however still present problems of sudden failure in certain areas, due to P deficiency, salt, or bad physical conditions.

Detailed reports of the work done in the projects would be available during the conference.

A RAPID ACID DISSOLUTION METHOD FOR THE DETERMINATION
OF CATIONS IN PLANT MATERIALS USING ATOMIC ABSORPTION
AND EMISSION FLAME SPECTROPHOTOMETRY

By

Mohinder Singh and K. Ratnasingam

May, 1968

THE RUBBER RESEARCH INSTITUTE OF MALAYA

KUALA LUMPUR

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SUMMARY

A rapid method of determining potassium, calcium and magnesium in Hevea and Pueraria leaves, which consisted of extracting the elements by shaking 0.4g plant material overnight with 0.5 N hydrochloric acid solution at 30°C (room temperature) and analysing the extracts by atomic absorption and emission flame spectrophotometry using Unicam SP900A, is reported.

INTRODUCTION

Analysis of plant material in Malaysia is generally carried out by dry or wet ashing of the plant material (MIDDLETON, BISHOP, FALLOWS AND VARLEY 1964). These methods normally require 1-2g of the plant material for the ~~three~~ ^{of K, Ca, Mg.} determinations and several hours ignition at 500 to 550°C (for dry ashing) or digestion with concentrated acids (for wet ashing). These methods are tedious and time-consuming and in the case of the wet ashing procedure, large amounts of concentrated acid is used. The need to analyse large number of samples of small quantities of plant material from greenhouse cropping and the possible saving of time and chemicals led to a simple acid dissolution method, involving soaking of plant material with dilute hydrochloric acid, which has been successfully used elsewhere (TALIBUDEEN 1967) being examined.

PROCEDURE

50 ml of 0.5N HCl is added to 0.1 to 0.4g of oven-dry material (depending on availability of material) and the contents are shaken a few times over the day and left overnight (for convenience). The filtrate is analysed for cations with the Unicam 900A flame spectrophotometer which is calibrated to measure 0 to 1000 ppm. This normally requires a 100 to 500 fold dilution of the extract.

The appropriate strength of HCl is introduced into the standards to correct for its effect on the atomic absorption and emission flame characteristics of the elements. For Ca and Mg determination, 250 ppm La^{3+} and 500 ppm Sr^{2+} are added respectively to the diluted atomising solutions to overcome well-known interferences from phosphate, silicate, etc.

RESULTS AND CONCLUSIONS

4 leaf samples (two each of Pueraria and Hevea) were analysed for K, Ca and Mg contents, in order to test reproducibility and suitability. The results obtained by 6 replicated analysis were generally in close agreement with those obtained by the dry ashing procedure in current routine use in the R.R.I. Soils and Foliar Laboratory (MOHINDER SINGH AND KRISHNASINGAM 1966). High reproducibility was obtained, the coefficient of variation between the replicates being less than 5% for all the 3 elements K, Ca and Mg (Table 1).

31 leaf samples of Hevea brasiliensis were next analysed to cover a wide range of element concentrations, leaf age, clones and types of leaves (Table 2). The acid dissolution results agreed closely with the dry ashed results in all cases. The dry ashed solutions were analysed by the existing laboratory methods, flame photometer for determination of potassium and E.D.T.A. titration method for calcium and magnesium (MIDDLETON 1961). When

same dry ashed extracts were analysed by atomic absorption emission spectroscopy using the SP900A, similar results were obtained, confirming the analysis by E.D.T.A. titration method.

Recovery tests for potassium, calcium and magnesium were performed with the SP900A on 9 acid dissolution and dry ashing extracts of widely varying element compositions (Table 3). Recoveries were quantitative being in the range 95 to 107%, the average recovery of the 9 samples being $100 \pm 1\%$ with a maximum coefficient of variation of 4%. The method which involves a simple dissolution and dilution step before direct analysis by atomic absorption and emission flame spectrophotometry is therefore applicable to Pueraria and Hevea leaf materials and can be used with as little as 0.1g plant material. Dry ashing procedures however remain an advantage where P analysis is also required as P can be determined colorimetrically on the same dry ashing extract. Phosphorus is not easily extracted by the acid dissolution method and because this gives coloured solutions phosphorus cannot be determined by this simple extraction method.

ACKNOWLEDGEMENTS

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TABLE 2. Analysis of 31 *Hevea* Leaf Samples

Leaf concentrations as % Oven-dry material

Reference No.	Date leaves sampled	Notes on leaves	POTASSIUM						CALCIUM						MAGNESIUM								
			Dissolution*		Dry Ashing*				Dissolution		Dry Ashing				Dissolution		Dry Ashing						
			a*	b*	a	b	c*	a	b	a	b	c	a	b	a	b	c						
			SP 900A	SP900A	Eel SP900A	Eel	Eel	SP 900A	SP900A	EDTA SP900A	EDTA	EDTA	SP900A	SP900A	ETA SP900A	EDTA	EDTA						
299	25.1.64	Low leaves	.87	.81	.85	.89	.87	.89	.86	.99	1.03	1.05	1.02	1.02	1.03	1.00	.30	.30	.29	.28	.28	.28	.25
305	28.1.64	PB 5/63 1957 Low leaves	.65	.63	.64	.63	.66	.63	.61	1.95	1.95	2.05	2.06	2.01	2.06	2.02	.19	.19	.18	.17	.17	.18	.16
309	28.1.64	PB 5/51 1957 Low leaves	.75	.72	.73	.75	.74	.73	.70	1.59	1.73	1.70	1.74	1.68	1.73	1.72	.20	.21	.19	.19	.19	.19	.17
318	28.1.64	RRI 612 Low leaves	.73	.73	.69	.72	.69	.73	.68	1.24	1.34	1.41	1.35	1.46	1.36	1.33	.22	.23	.22	.21	.21	.21	.20
320	28.1.64	RRI 527 Low leaves	.70	.68	.67	.72	.68	.71	.68	.97	.99	1.02	1.00	.99	.99	1.00	.28	.29	.28	.27	.27	.27	.24
321	27.1.64		.76	.74	.74	.76	.74	.76	.74	1.69	1.82	1.82	1.81	1.77	1.81	1.83	.03	.04	.03	.04	.03	.03	.01
809	15.3.66		.67	n.d.	.66	.63	n.d.	n.d.	.61	.93	n.d.	.99	.94	n.d.	n.d.	1.00	.22	n.d.	.22	.23	n.d.	n.d.	.19
870	10.3.65	PB 5/63 Low leaves	.83	.83	.82	.79	.79	.79	.83	1.75	1.86	2.03	2.03	1.95	1.91	1.98	.30	.30	.28	.27	.27	.26	.23
898	5.2.64	RRI 623 Low leaves	.73	.71	.69	.73	.67	.72	.70	1.07	1.09	1.18	1.09	1.11	1.09	1.09	.35	.35	.35	.32	.35	.32	.30
1452	6.5.65	1334S Low leaves	.95	.99	.96	1.03	.95	1.00	1.02	.64	.66	.74	.62	.69	.64	.68	.15	.15	.15	.14	.15	.14	.11
2103	15.6.65		.97	.97	.99	1.04	.97	1.01	1.06	.18	.23	.24	.19	.22	.18	.20	.20	.22	.21	.22	.21	.21	.19
2661	4.6.64	PB 5/51 1961 Low leaves	1.03	1.03	1.01	1.11	1.02	1.10	1.03	1.02	1.06	1.10	1.06	1.10	1.05	1.06	.30	.30	.30	.28	.29	.28	.26
2664	4.6.64	GT 1 1963 2nd Whorl leaves	1.13	1.15	1.13	1.24	1.16	1.24	1.19	.59	.64	.66	.64	.66	.62	.65	.17	.17	.18	.18	.17	.17	.15
3254	27.6.64	PB 86 Low leaves	1.75	1.71	1.67	1.86	1.71	1.87	1.80	.22	.28	.28	.22	.28	.22	.25	.36	.36	.36	.36	.35	.36	.34
3256	27.6.64	PB 86 Low leaves	2.09	2.08	2.03	2.24	2.06	2.17	2.14	.51	.57	.57	.54	.60	.54	.56	.43	.43	.42	.42	.42	.41	.40
3261	27.6.64	GT 1 1938 Low leaves	2.14	2.15	2.11	2.24	2.13	2.25	2.19	.60	.63	.65	.62	.66	.62	.64	.43	.43	.42	.43	.42	.42	.40
3262	27.6.64	GL 1 1948 Low leaves	1.85	1.81	1.77	1.90	1.80	1.92	1.83	.68	.74	.74	.71	.75	.72	.71	.16	.17	.16	.16	.16	.15	.15
3268	3.7.64	RRI 513 Low leaves	.93	.92	.87	.95	.87	.95	.87	.72	.78	.78	.76	.77	.76	.76	.16	.17	.16	.16	.16	.15	.15
3378	26.7.65	RRI 623	.83	.83	.80	.86	n.d.	n.d.	.84	.32	.36	.38	.35	n.d.	n.d.	.35	.21	.22	.22	.21	n.d.	n.d.	.19
3629	1966	Low leaves	2.47	2.50	2.44	2.63	2.44	2.63	2.58	.80	.79	.81	.78	.80	.78	.79	.21	.22	.21	.21	.20	.21	.20
3896	23.7.64	Tj.1 1949 Low leaves	1.34	1.43	1.34	1.46	1.34	1.44	1.39	.62	.67	.68	.66	.66	.65	.66	.31	.32	.31	.29	.30	.29	.26
4427	24.8.65	RRI 513 Low leaves	0.88	.90	.89	.94	.87	.93	.95	1.29	1.40	1.46	1.47	1.40	1.43	1.49	.33	.33	.34	.31	.33	.32	.30
5017	9.9.64	PB 86 Low leaves	1.83	1.88	1.78	2.02	1.77	1.92	2.00	.54	.58	.59	.57	.60	.57	.68	.23	.24	.25	.24	.25	.24	.16
5780	4.10.65	RRI 623	0.78	.81	.75	.80	.75	.79	.79	.59	.64	.66	.62	.65	.62	1.00	.35	.36	.36	.33	.36	.33	.30
6384	15.10.64	1958 Low leaves	1.03	1.04	.99	1.06	1.00	1.06	1.00	.93	.98	1.00	.96	1.00	.97	1.00	.13	.14	.13	.13	.13	.14	.11
6417	15.10.64	2nd Whorl leaves	0.95	.99	.92	1.00	.95	1.00	.96	1.10	1.22	1.26	1.22	1.24	1.22	1.24	.21	.22	.22	.22	.20	.21	.18
6551	27.10.64	Tj.1 Low leaves	1.43	1.44	1.45	1.44	1.43	1.44	1.40	.81	.84	.85	.85	.86	.83	.81	.19	.19	.20	.19	.20	.20	.19
7162	14.12.65	RRI 623	0.64	.67	.66	.68	.66	.67	.64	.75	.79	.83	.79	.80	.79	.80	.36	.36	.36	.32	.35	.32	.35
7361	8.12.65	GL. 1 Low Leaves	0.71	.73	.69	.72	.69	.70	.69	2.27	2.42	2.44	2.50	2.41	2.52	2.46	.34	.35	.34	.32	.33	.32	.28
7814	21.12.64	PB 86 Low leaves	2.09	2.13	2.15	2.32	2.12	2.29	2.19	.43	.46	.47	.44	.46	.44	.46	.33	.35	.32	.32	.32	.32	.30
7851	23.12.64	RRI 501 Low leaves	1.23	1.20	1.23	1.15	1.16	1.14	1.04	.75	.76	.80	.75	.79	.75	.76	.33	.35	.32	.32	.32	.32	.30

* Dissolution : 0.2g plant material in 50 ml 0.5 N HCl

Dry Ashing : 5g plant material, dry ashed and dissolved in 250 ml 1.6% HNO₃

a, b : Duplicate extractions.

c : results when leaves freshly sampled (1964-1966).

n.d. : not determined.

TABLE 3 RECOVERY STUDIES OF 9 PLANT EXTRACTS WITH THE SP900A

Extract	Element	Leaf Conc. as % Oven-dry Material	Conc. of Extract p.p.m.	Amount Added for Test, ppm	Range of % Recovery of 9 samples	% Mean Recovery of 9 samples	Coeff. of Variance %
Acid Extract	K	0.6 - 1.0	25 - 40	30	94.7-107.3	101.4	3.9
	Ca	0.6 - 1.8	25 - 80	50	99.2-101.6	100.3	0.7
	Mg	0.03 - 0.35	2 - 14	10	95.0-102.0	99.4	1.8
Dry ashed Extract	K	0.6 - 1.0	125 - 200	100	99.0-102.0	101.0	0.9
	Ca	0.6 - 1.8	130 - 400	200	100.5-103.3	101.2	0.9
	Mg	0.03 - 0.35	10 - 70	30	96.7-103.3	100.2	2.3

A STUDY OF PHOSPHATIC FERTILIZER RESPONSES IN SARAWAK SOILS

BY

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Introduction

Fertilizer experiments by Bailey (1) and others, in pot trials with Bayam (Amaranthus gangeticus) maize and rice, together with field trials on the latter two crops in Sarawak have demonstrated the extreme state of phosphorus deficiency in Sarawak soils, particularly in upland residual soils. The inference has been that plant - available phosphorus is the dominating element in restricting crop growth.

The main object of the present study is to compare the growth and nutrient uptake status of Bayam on a range of Sarawak soils, and with particular emphasis on the growth responses to levels of two different phosphatic fertilizers. The series of Bayam pot experiments carried out during 1965, 1966 and 1967 has however some limitations in the comparison of soils. These factors are mainly:-

- a) Varying climatic conditions over the period of the experiments.
- b) The exclusion of trace elements from the study.
- c) The varying organic matter contents of the soils, - which can have considerable varying effects on a quick growing vegetable crop.
- d) The particular soil textural and structural differentiation of the soils when removed from field conditions and used in pot experiments.

However, in this study considerable differences in growth occurred on each soil for varying levels and kinds of phosphatic fertilizer application and the comparison of different soils it is hoped, will have application to the evaluation of the potential of Sarawak soils for other crops.

Experimental Details

The series of experiments were initiated in December 1965, terminating in December 1967, and carried out in a clear-polythene roof, open sided greenhouse.

The soils were collected from various soil series sites, (normally under roughage or jungle), using the top 0-9" only, on locations where no known fertilizing had ever been carried out. Then, the soil was dried, passed through a 1/4" mesh screen and hence all stones, large pieces of organic matter and roots etc., excluded. A bulk sample of the screened material was then taken for chemical analysis. Clay pots of 6 1/2" internal diameter were prepared with a complete internal and external bottom coating of bituminous paint, and then filled to hold approximately six pounds of soil. For most soils, the soil surface area in the pots after moderate compaction was approximately 30 square inches and this area was used for calculation of rates of fertilizer application, where 1 gramme of fertilizer per pot approximately equalled 4 cwts. of fertilizer per acre of pot soil surface.

Layout : Randomised block, eight replications for each of nine treatments for each soil.

Plot size : One pot, each pot 1/203,000 acre soil surface area, (approx.)
One Bayam plant per pot.

Treatments : For the first crop of Bayam (Amaranthus gangeticus).
All pots, basal dressing of:-

4 cwts. of Ammonium sulphate (21% N) per acre (1 gramme per pot).

2 cwts. of Muriate of Potash (60% K₂O) per acre (0.5 grammes per pot).

1 cwt. of Dolomitic limestone (16% MgO) per acre (0.25 grammes per pot).

Subsequently, total fertilizers applied prior to first crop, for the nine treatments.

Code	Treatments
P-0	Basal dressing only
C-1	Basal dressing + 1 cwt. of C.I.R.P. per acre (0.25 grammes per pot)
C-2	" " + 2 cwts. " " " " (0.5 ")
C-4	" " + 4 cwts. " " " " (1.0 ")
C-8	" " + 8 cwts. " " " " (2.0 ")
D-1	" " + 1 cwt. of D.S.P. per acre (0.25 ")
D-2	" " + 2 cwts. " " " " (0.50 ")
D-4	" " + 4 cwts. " " " " (1.0 ")
D-8	" " + 8 cwts. " " " " (2.0 ")

C.I.R.P. = Christmas Island Rock Phosphate (36% P₂O₅ - water insoluble).

D.S.P. = Double Superphosphate (40% P₂O₅ - water soluble)

For the second crop, the basal dressing (only) was again applied to pots.

The fertilizers were applied to the pots in solid form, and worked into the top 2 to 3 inches of the pot soil. The pots were then watered liberally, allowed to dry somewhat and then about 10 to 12 Bayam seeds sown in each pot.

One week to ten days after germination, the seedlings were thinned out, leaving one only to each pot. If no germination took place within three to four days of seed sowing, then the pots were resown, even a third time if necessary.

Throughout each experiment, the pots were rotated weekly for bench positions, to avoid possible uneven lighting.

Watering, using the domestic tap supply, was carried out one to three times daily, depending on climatic conditions and the porosity of individual soils. Any drainage water which entered the bottom trays was recirculated daily.

Harvesting took place individually for each pot when the single Bayam plant showed emergence of an apical flowering primordium. Thus, there was considerable variation in length of growing season for individual plants, but since plant analysis was required, it was desirable to harvest at a constant state of plant maturity.

Harvesting normally commenced at a plant age of 40 days, but variation was from 33 to 48 days. Harvesting normally finished at a plant age of approximately 52 days, but variation was from 43 to 61 days. The last ten to twenty plants in each experiment were normally harvested together, regardless of a range of maturation state.

Plant sections harvested, were the above ground portions only (stems and leaves), - these were weighed immediately on cutting for fresh weight, and then oven dried for dry weight recordings.

On completion of harvesting tops for all soils in the first crop in each experiment, the basal fertilizer dressing (Ammonium sulphate: 1.0 grammes, Potash: 0.5 grammes, and Dolomitic limestone: 0.25 grammes) only was again applied to every pot and then Bayam seeds sown for the second crop. Thus, the effect of P fertilizers for the second crop was residual for the fertilizers applied prior to sowing the first crop. The Bayam roots from the first crop were left in the soil, and incorporated together with the second basal fertilizer application for the second crop.

On completion of the second crop for each experiment, the pot soil from the eight replicates of each treatment was mixed together, and bulk samples taken for soil analysis. Plant roots were excluded from the soil analysis.

Total fertilizers applied expressed as N, P, K, Ca and Mg.

1. Christmas Island Rock Phosphate (36% P_2O_5 Water insol.)

Treatments

C - 1	=	0.039	gms. P/pot	=	17.6	lbs. P/acre
C - 2	=	0.079	" "	=	35.2	" "
C - 4	=	0.157	" "	=	70.3	" "
C - 8	=	0.314	" "	=	140.6	" "

2. Double Superphosphate (40% P₂O₅ Water sol.)

Treatments

- D - 1 = 0.044 gms. P/pot = 19.5 lbs. P/acre.
- D - 2 = 0.087 gms. P/pot = 39.1 lbs. P/acre.
- D - 4 = 0.175 gms. P/pot = 78.1 lbs. P/acre.
- D - 8 = 0.349 gms. P/pot = 156.2 lbs. P/acre.

3. All pots as total basal dressings for both crops.

- a. Ammonium sulphate (21% N)
= 0.420 gms. N/pot = 188.0 lbs. N/acre.
- b. Muriate of Potash (60% K₂O)
= 0.498 gms. K/pot = 222.9 lbs. K/acre.
- c. Dolomitic limestone (16% MgO and 30% CaO)
= 0.045 gms. Mg/pot = 10.1 lbs. Mg/acre.
and = 0.107 gms. Ca/pot = 50.0 lbs. Ca/acre.

4. Total Ca concentration in fertilizers.

C.I.R.P. + Dolomitic Limestone	D.S.P. + Dolomitic Limestone
C-1 = 79.6 lbs. Ca/acre	D-1 = 62.4 lbs. Ca/acre.
C-2 = 109.2 lbs. Ca/acre	D-2 = 74.8 " " "
C-4 = 168.3 " " "	D-4 = 99.6 " " "
C-8 = 286.7 " " "	D-8 = 149.2 " " "

Soils

Soils chosen for the series of experiments, are not comprehensive representatives of all Sarawak Great Soil Groups, but are for those which are commonly used for the cultivation of annual and perennial crops, particularly in this State's First Division.

The breakdown of Great Soil Groups, families and series included in the experiments is as follows:-

Great Soil Groups	Families	Series
Lateritic soils	Tarat	Tarat
Red - Yellow Podzolic soils	Nyalau	Nyalau
	Merit	Merit
		Semongok
	Malang	Malang
	Abok	Serin
Gley soils	Embang	Embang
Recent Alluvial soils	Ramun	Ramun
	Terbat	Terbat

Soil Survey Classification 1966 (10)

It was originally intended to include Semongok Series soil as a check series for each experiment, but this soil proved an unfortunate choice for the pot experiments, and no results were obtained for it in experiments 2 and 3. In experiment 5, Merit and Terbat series were used as checks for previous experiments.

The locations and derivations of soils used in the experiments are as follows:-

Experiment 1.

- a) Semongok Series (Semongok (1)) from Agricultural Research Centre, Semongok, site under secondary jungle. Soil derived from Sedimentary rocks - shale dominant. Residual. Previous land use - hill rice.
- b) Nyalau Series (Nyalau A) from Landeh Road Rubber Nursery, site newly cleared from secondary jungle. Soil derived from Sedimentary rocks - sandstone dominant. Residual. Previous land use - possibly hill rice.
- c) Malang Series (Malang A) from Landeh Road Rubber Nursery, site newly cleared from secondary jungle. Soil derived from sedimentary rocks, shale. and sandstone dominant. Alluvial. Previous land use - possibly hill rice.

Experiment 2.

- a) Tarat Series (Tarat A) from Simuja Rubber Planting Scheme 'B' area, site under primary jungle. Soil derived from altered basic igneous rock. Residual. Previous land use - nil. N.B. (This soil is noted as Tarat A for the purposes of this experiment - distinct in location, land use and vegetation cover from that noted as Tarat B in experiment 5.)

- b) Ramun Series (Ramun) from Simuja Rubber Planting Scheme 'B' area, site under primary jungle. Soil derived from basic igneous rocks. Recent alluvial. Previous land use - nil.

Experiment 3.

- a) Terbat Series (Terbat (1)) from Tarat Agricultural Station, site under tall grasses. Soil derived predominantly from basic igneous rock. Recent alluvial. Previous land use - nil.
- b) Malang Series (Malang B) from Mile 16 Penrissen Road, site under primary jungle. Soil derived from a mixture of basic igneous, shale, sandstone and limestone rock parent materials. Alluvial (seasonally flooded). Previous land use - nil.
- c) Embang Series (Embang) from Semongok Agricultural Station, buffalo grazing area, under mixed poor grass/scrub cover. Soil derived from recent riverine alluvium (in turn derived from a mixture of sedimentary rock parent materials) overlying old alluvial material. A gley soil. Previous land use - buffalo grazing on roughage.

Experiment 4.

- a) Serin Series (Serin) from Mile 29, Kuching-Serian Road, under secondary jungle. Soil derived from tuffaceous sandstone rock parent material. Residual. Previous land use - possibly hill rice.
- b) Semongok Series (Semongok (2)), Site uphill from Semongok series in experiment 1.
- c) Merit Series (Merit (1)) from Mile 15 Bau-Lundu Road, (oil palm experiment area) under secondary jungle. Soil derived from sedimentary rocks, shale dominant. Residual. Previous land use - hill rice.

Experiment 5.

- a) Nyalau Series (Nyalau B), from Mile 12 Oya (3D) Road, site under secondary jungle. Soil derived from sedimentary rocks - sandstone dominant. Residual. Previous land use - hill rice.
- b) Tarat Series (Tarat B), from Tarat Agricultural Station, under secondary jungle. Soil derived from altered basic igneous rocks. Residual. Previous land use - possibly hill rice.
- c) Terbat Series (Terbat (2)) from Tarat Agricultural Station, site identical with Terbat (1) used in Experiment 3.
- d) Merit Series (Merit (2)) from 15th Mile Bau-Lundu Road, site identical with Merit (1) in Experiment 4.

Plant and soil analysis methods.

A. Pre cropping soil analysis procedures.

A bulk soil sample of about two pounds weight is taken for each soil in each experiment, air dried, and ground to pass through a 2 m.m. sieve. pH (wet) 1:2.5 soil suspension in water is then determined. The soil is then sub sampled, ground to pass a 1 m.m. sieve, oven dried, and then subject to the following analyses:- Total % Nitrogen determined by the semi micro Kjeldahl method.

Reserve P, K, Ca and Mg:- One gram of soil is ignited at 800°C and then digested with conc. hydrochloric acid on a sand bath for half an hour. Phosphorus is determined by the molybdenum blue method using ascorbic acid as the reducing agent. Calcium and Magnesium are determined by the E.D.T.A. titration after removing the Fe and Al by precipitation as hydroxides. Group III oxides (iron and aluminium oxides mainly) are determined by weighing. Potassium is determined by Flame Photometer.

'Available' P:- Phosphorus is determined by extraction with 0.03 N NH_4F and 0.1 N HCL (Bray and Kurtz solution II).

Cation Exchange Capacity:- C.E.C. is determined using N. Ammonium Acetate for leaching the soil.

Phosphorus retention:- This is determined by end over end shaking for 24 hours of 5 gms. of the soil with 15.5 m.gms. of added soluble phosphate in an unbuffered solution. (Kurtz and Bray 1946).

(The results of the above determinations are shown in the base of tables 1/A to 1/O).

Post cropping soil analysis procedures.

A two pound weight sample is taken from a thoroughly mixed combination of all the soil from the eight pots of each replicated treatment, in each soil, after completion of cropping. The determinations for pH (H_2O), Reserve P, K, Ca and Mg, Available P and total % Nitrogen are carried out as in A. The results of the determinations are shown in the right hand body of tables 1/A to 1/O,

Plant analysis procedures.

Individual plants are harvested, weighed for fresh weight immediately, then oven dried at $60-70^{\circ}\text{C}$., and subsequently weighed individually again for dry weight. Then all the dried plants from the eight pots of each replicated treatment (for each crop separately) are bulked and the total plant portions (leaves and stems) milled. Nitrogen % in D.M. is determined by the usual semi micro Kjeldahl method. Plant samples are dry ashed at 500°C . for determination of % P, K, Ca and Mg in D.M. Phosphorus by the molybdenum blue method using stannous chloride as reducing agent, and Potassium by flame photometer on the plant ash solution. Calcium and Magnesium by E.D.T.A. titration after removing phosphate with zirconium nitrate.

The results of the determinations of elements as % in D.M. are shown as % P in Table 5, % N in Table 6, % K in Table 7, % Ca in Table 8, and % Mg in Table 9. Fresh tops, dry tops, and total recovery of P, N, K, Ca, and Mg (% in D.M. X D.M.) weight results are shown for each soil in Tables 1/A to 1/O. (N.B. All body of the table entries are the means of eight pot replicates records.)

Results

Yields in freshweight of Bayam tops for all five experiments are shown in Fig. 1. Individual pot records are not shown and the means of eight pot replicates for each treatment only are recorded. Fig. 2. shows the ratio of fresh weight to dry weight for Bayam top treatment means in all five experiments. It is apparent that there is a linear effect or rather two linear effects, with a critical point at a ratio of 10 gms. fresh weight to approximately 1.4 gms. dry weight. The ratio of dry weight over fresh weight varies from approximately 20% at lowest yield to 7% at the highest yield.

With total dry weight yields (and with fresh weight) there is a superiority of response to Double superphosphate (D.S.P.) treatments over Christmas Island Rock Phosphate (C.I.R.P.) treatments at equivalent rates of application for all soils, with the exception of Nyalau series. Figure 3 shows total comparative yields.

Yields from levels of C.I.R.P. treatments generally declined from first crop to second crop with the exception of some levels in Tarat B and Terbat (1) soils. The mean ratios of first crop over second crop yields (D.M.) for the C.I.R.P. levels for all soils are 2.5, 3.0, 2.1 and 1.6 for the C-1, C-2, C-4 and C-8. levels respectively. The mean dry matter yield for all soils for additions of the four levels of Christmas Island Rock Phosphate for two successive crops of Bayam are shown in Fig. 4., and for addition of levels of Double Superphosphate in Fig. 5.

Yields from levels of D.S.P. treatments generally decreased for the D-1 and D-2 levels, from first crop to second crop but the mean effect for the D-4 and D-8 levels was for little change in the magnitude of residual response. The mean ratios of first crop over second crop yields (D.M.) for the D.S.P. levels for all soils are 1.6, 1.3, 1.0 and 1.0 for the D-1, D-2, D-4 and D-8 levels respectively. However, the effect of D.S.P. treatments, residual for the second crop is quite variable in the range of soils studied, and it is suggestive that the group of soils derived from sedimentary rocks exhibit much less response to high levels of D.S.P. application than those soils derived from basic igneous rocks. The extreme state of deficiency of plant available phosphorus in the range of Sarawak soils studied is indicated by the negligible yields from the minus P (P-0) treatments for all soils with the exception of Semongok (1) Nyalau A and Malang A. It is possible that unbeknown to the author, some Phosphorus fertilizer contamination may have occurred with the latter three soils. Joseph (4) in a similar experiment in Malaya, but with a crop of *Pueraria phaseoloides*, has shown for three latosols (Malacca, Serdang and Rengam series) much less differentiation in response between nil and heavily P fertilized soils than that generally encountered in this study.

Phosphorus uptake.

The phosphorus concentration in Bayam tops (D.M.) for each treatment (mean of 8 replicates), crop and soil is shown in Table 5. This increased with most crops with increasing rates of both C.I.R.P. and D.S.P. Uptake appeared excessive in the soils derived from sedimentary rocks (particularly

FIGURE 1 MEAN YIELDS - FRESH BAYAM TOPS

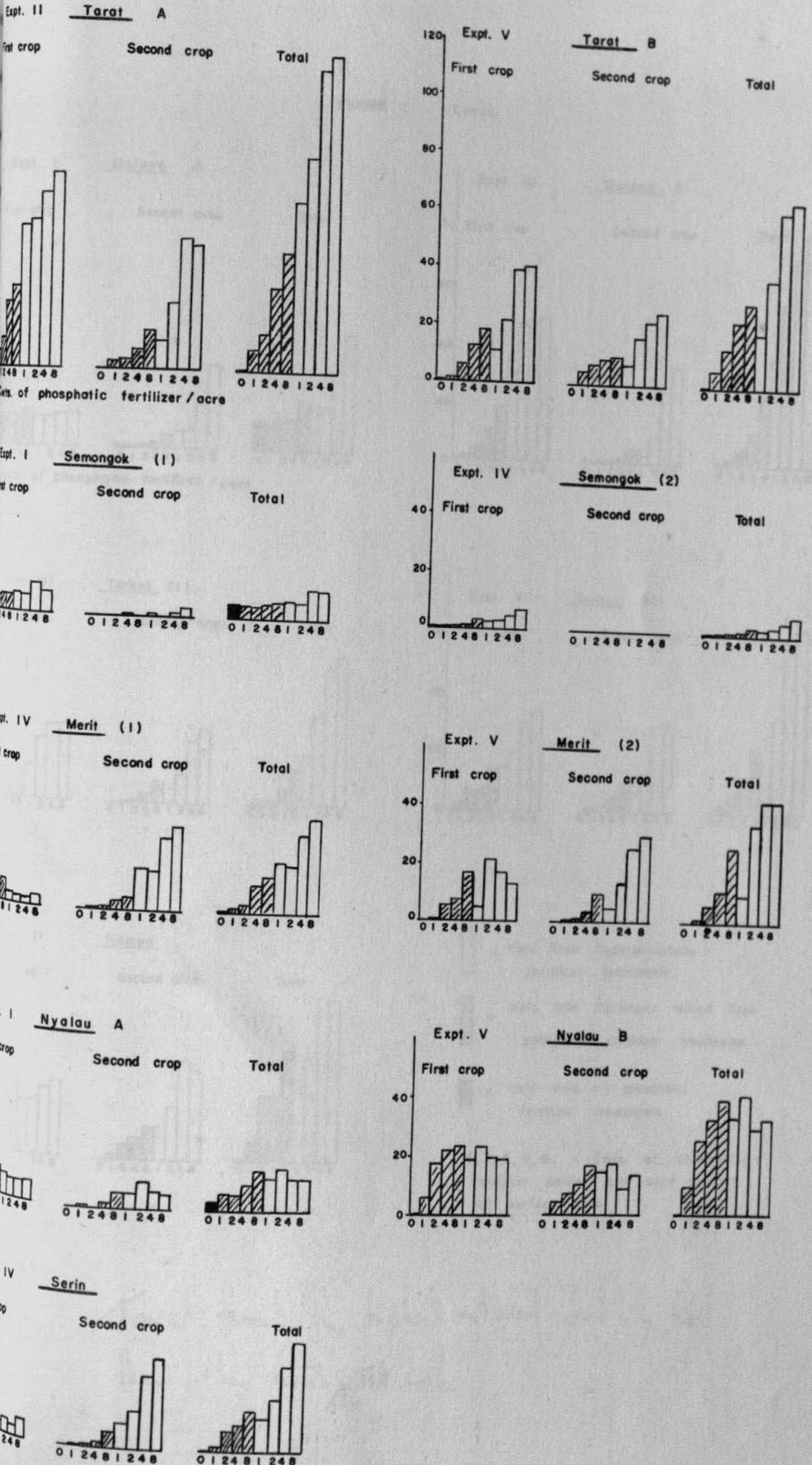
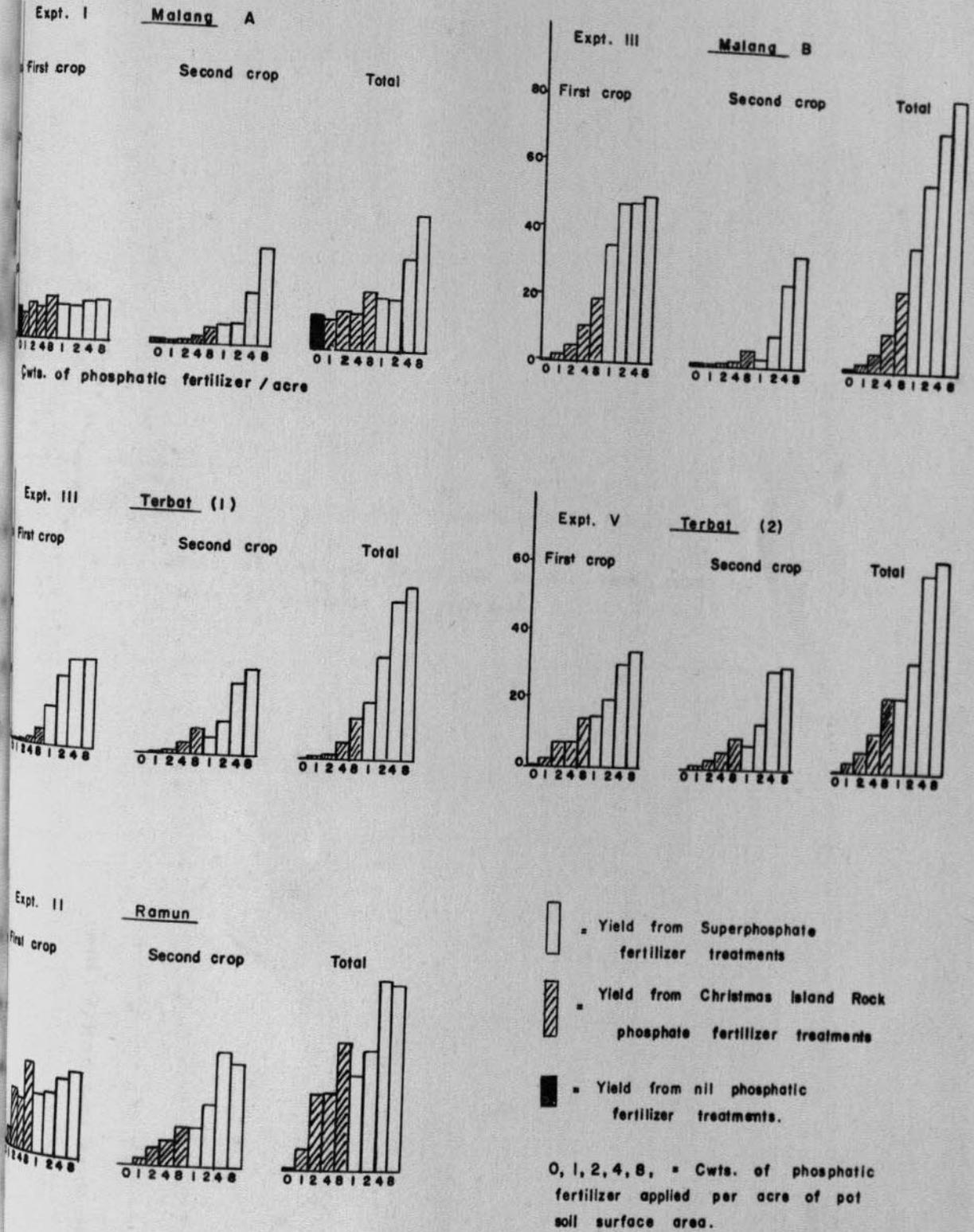


FIGURE 1 Contin.



Terbat family has higher natural fertility level than other investigated soils.

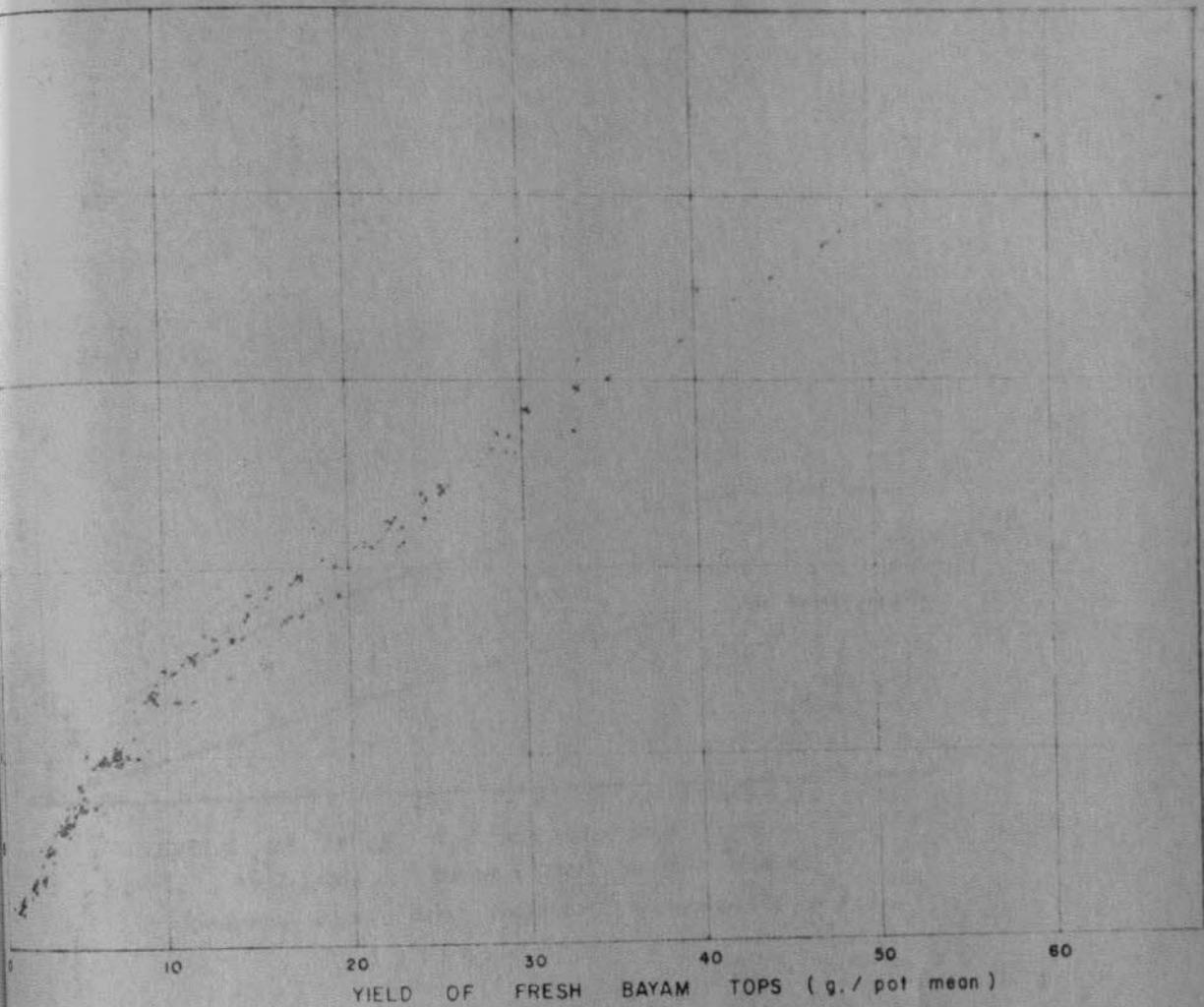


Fig. 2 - Yield of oven dry Bayam tops against fresh cut tops.
 Mean of recordings per treatment.

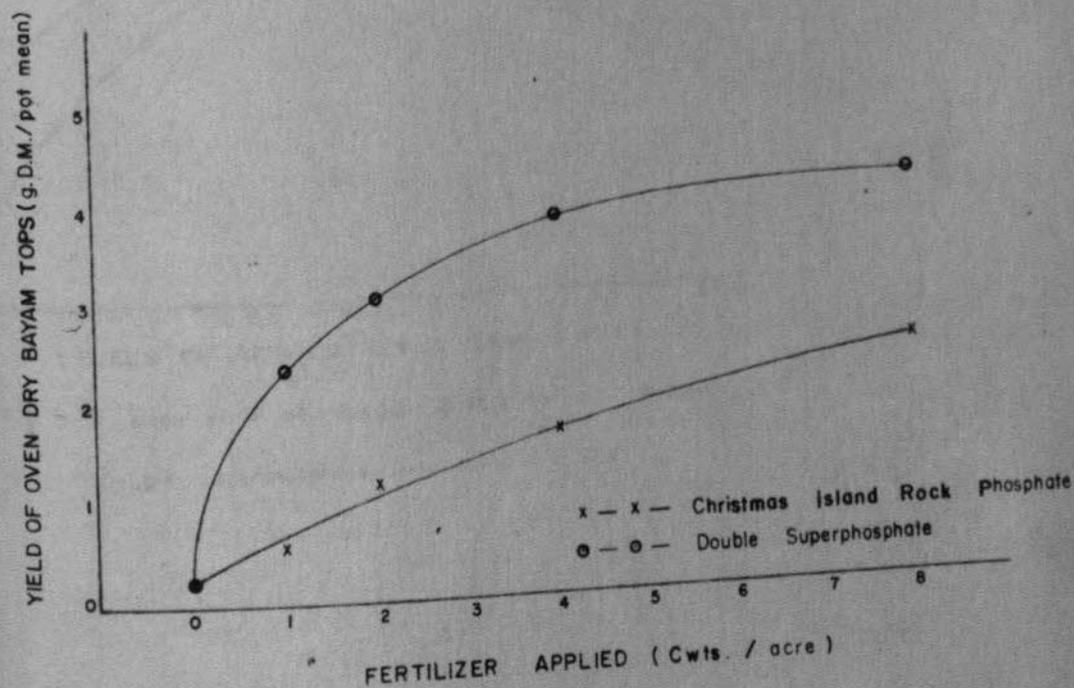


Fig 3 — Total yield of dry matter both crops
 mean of all soils combined

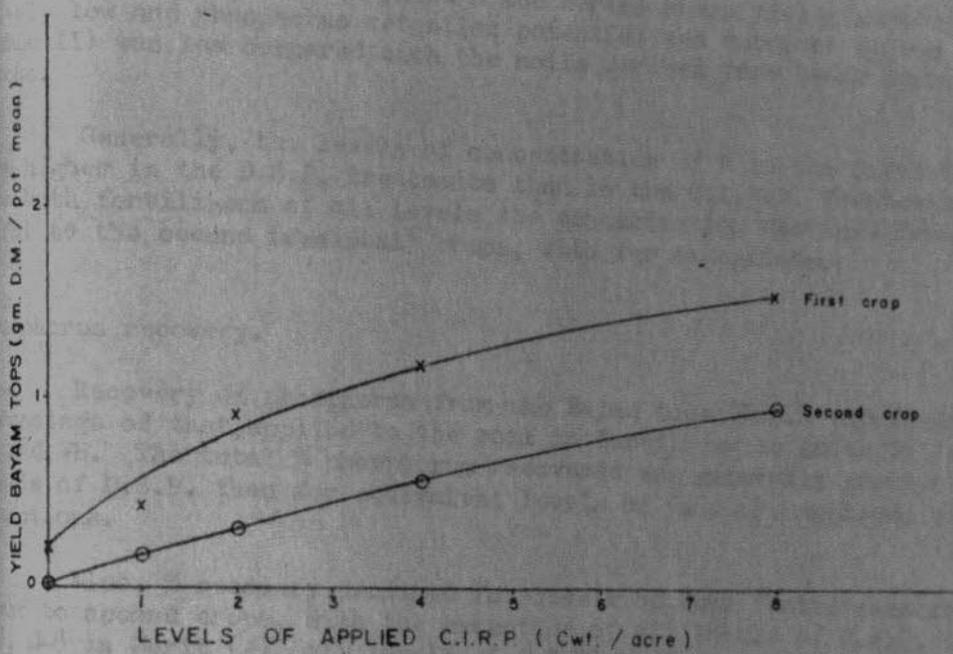


Fig. 4. Mean yield of Bayam (D.M.) for all 14 soils
Christmas Island Rock Phosphate treatments (C.I.R.P.)

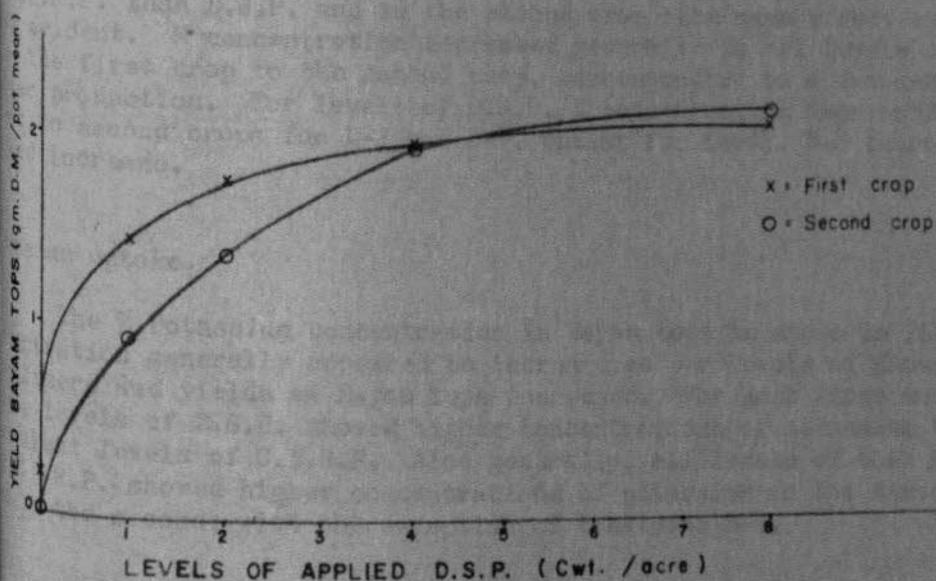


Fig. 5. Mean yield of Bayam (D.M.) for all 14 soils.

Double superphosphate treatments (D.S.P.)

with Merit (1), Nyalau A, Nyalau B and Serin) where yields were comparatively low and phosphorus retention potential and nutrient status (see Table II) was low compared with the soils derived from basic igneous rocks.

Generally, the levels of concentration of P in the Bayam tops were higher in the D.S.P. treatments than in the C.I.R.P. treatments, and for both fertilizers at all levels the concentration declined from the first to the second (residual) crops, with few exceptions.

Phosphorus recovery.

Recovery of phosphorus from the Bayam tops (D.M.) expressed as a percentage of that applied to the soil in fertilizer is shown in Tables 3A and 4B. The total % phosphorus recovered was generally greater for levels of D.S.P. than for equivalent levels of C.I.R.P. applied, with few exceptions.

Also, % recovery declined for levels of both fertilizers: from the first to second crops, with the exception of all levels of D.S.P. in Merit (1), D-8 in Merit (2), all levels of D.S.P. in Serin, D-8 in Malang A, and D-2, C-4, C-8 and D-8 in Terbat (1). Highest % recovery was obtained at the lowest levels of D.S.P. (D-1). Variation in % recovery of P between levels of C.I.R.P. and D.S.P. was greatest in the latter, and the % recovery at increasing levels of C.I.R.P. did not appreciably alter.

Nitrogen uptake.

The % Nitrogen concentration (uptake) in dry Bayam tops is shown in Table 6. Generally, nitrogen concentration in Bayam tops decreased with increasing yield, but this phenomenon was most evident on soils with high mean yields of tops, at a stage where Nitrogen is probably limiting for growth. In the first crop, N concentration was generally higher for levels of C.I.R.P. than D.S.P. and in the second crop the same effect was slightly more evident. N concentration increased generally in all levels of C.I.R.P. from the first crop to the second crop, corresponding to a decrease in dry matter production. For levels of D.S.P., N concentration decreased from first to second crops for D-2 and D-4, whilst for level D-8 there was a marked increase.

Potassium uptake.

The % Potassium concentration in Bayam tops is shown in Table 7. Concentration generally appeared to increase as per levels of phosphatic fertilizers and yields of Bayam tops increased. For both first and second crops, levels of D.S.P. showed higher concentrations of potassium than equivalent levels of C.I.R.P. Also generally, all levels of both D.S.P. and C.I.R.P. showed higher concentrations of potassium in the first crop than in the second, with the exception of treatment D-8.

Calcium uptake.

The % Calcium concentration in Bayam tops is shown in Table 8. The general pattern of concentration is not clear, but all levels of C.I.R.P. show a decrease in concentration from the first to second crops, whilst levels of D.S.P. remain relatively constant. With the exception of C.I.R.P. levels in the first crop, increasing levels of phosphatic fertilizers tend to show increasing concentrations of calcium.

TABLE 2A
Yield of Fresh Bayam Tops (gm./pot mean)

Tarat A.	Tarat B.	Semongok (1)	Semongok (2)	Merit (1)	Merit (2)	Nyalau A.	Nyalau B.	Serin	Melang A.	Melang B.	Terbat (1)	Terbat (2)	Regun	Means
FIRST CROP														
0.61	0.50	4.41	0.23	0.39	0.00	3.31	0.15	0.26	8.77	0.15	0.08	0.15	0.76	1.41
5.19	1.39	4.15	0.16	1.63	0.66	4.68	5.43	1.60	7.66	1.70	0.15	2.31	4.22	2.92
9.33	6.15	4.06	0.33	3.15	5.53	4.80	17.18	6.64	10.49	4.71	0.70	6.86	17.08	6.93
22.16	12.63	4.78	1.28	6.15	7.54	7.40	21.59	7.18	9.00	10.59	1.39	7.28	15.06	9.57
27.73	18.29	5.15	3.69	7.71*	16.96*	9.14*	23.10	7.61*	12.25*	18.94	4.24	13.79	25.67*	13.88
48.57	11.88	6.18	3.04	3.15	4.80	7.42	18.38	3.29	10.09	35.03	11.61	14.71	16.86	13.93
50.96	21.95	5.99	3.88	2.63	21.00	5.44	23.11*	4.66	9.31	47.55	20.30	19.46	17.45	18.12
59.90	39.43	9.59*	4.48	2.13	16.85	5.49	19.73	3.89	11.27	47.74	25.56	30.11	22.50	21.33
66.64*	40.24*	7.20	7.35*	3.15	12.60	6.70	18.73	5.80	11.89	49.50*	25.80*	33.44*	24.58	22.40*
32.34	16.94	5.72	2.72	3.34	9.55	6.04	16.38	4.55	10.08	23.99	9.98	14.23	16.02	12.28
SECOND CROP														
0.00	0.00	0.00	0.00	0.05	0.00	0.00	0.00	0.00	0.84	0.73	0.00	0.00	0.00	0.12
2.54	4.91	0.01	0.00	0.19	0.22	0.57	4.25	0.18	0.63	0.58	0.11	0.51	1.89	1.19
3.51	7.28	0.03	0.00	0.60	0.67	0.13	7.90	0.38	0.89	0.80	0.45	2.53	4.65	2.13
6.46	10.93	0.06	0.00	3.48	3.76	1.56	10.73	1.54	1.88	1.38	3.56	4.53	6.95	4.06
12.90	11.61	0.00	0.00	5.06	9.67	4.71	16.55	5.64	4.85	5.09	7.65	8.28	11.50	7.39
9.76	7.41	0.19	0.00	14.81	4.46	4.46	14.41	8.32	5.63	2.65	4.74	6.88	11.00	6.77
22.96	16.40	0.00	0.00	13.49	13.62	9.13*	17.50*	12.74	6.22	9.16	9.41	12.95	17.51	11.51
44.78*	22.46	1.04	0.00	25.44	25.22	6.04	8.90	24.43	15.76	24.76	20.57	28.93	33.05	20.10
42.65	25.14*	3.16*	0.00	29.19*	29.77*	4.97	13.62	30.53	28.47*	33.14*	24.79*	30.36*	29.48	23.23*
16.17	11.79	0.50	0.00	10.26	9.71	3.51	10.43	9.31	7.24	8.70	7.92	10.55	12.89	8.50
TOTAL BOTH CROPS														
0.61	0.50	4.41	0.23	0.44	0.00	3.31	0.15	0.26	9.61	0.88	0.08	0.15	0.76	1.53
7.73	6.30	4.16	0.16	1.82	0.88	5.25	9.68	1.78	8.29	2.28	0.26	2.82	6.11	4.11
12.84	13.43	4.09	0.33	3.75	6.20	4.93	25.08	7.02	11.38	5.51	1.15	9.39	21.73	9.06
28.62	23.56	4.84	1.28	9.63	11.30	8.96	32.32	8.72	10.88	11.97	4.95	11.81	22.01	13.63
40.63	29.90	5.15	3.69	12.77	26.63	13.85	39.65	13.25	17.10	24.03	11.89	22.07	37.17	21.27
58.33	19.29	6.37	3.04	17.96	9.26	11.88	32.79	11.61	15.72	37.68	16.35	21.59	27.86	20.70
73.92	38.35	5.99	3.88	16.12	34.62	14.57*	40.61*	17.40	15.53	56.71	29.71	32.41	34.96	29.63
94.68	61.89	10.63*	4.48	27.57	42.07	11.53	28.63	28.32	27.03	72.50	46.13	59.04	55.55	41.43
109.29*	65.38*	10.36	7.35*	32.34*	42.37*	11.67	32.35	36.33*	40.36*	82.64*	50.59*	63.80*	54.06	45.63*
48.52	28.73	6.22	2.72	13.60	19.26	9.55	26.81	13.85	17.32	32.69	17.90	24.79	28.91	20.78

N.B. * = Highest yield (Fresh tops) for each soil

Figs. in body of table are means of 8 pot replicates.

TABLE 2B.

Yield of Christmas Island Rock Phosphate (C.I.R.P) and Double Superphosphate (D.S.P.) treated Bayam (Fresh) and ratio of yield D.S.P. : C.I.R.P. treatments.

Tarat A.	Tarat B.	Semongok (1)	Semongok (2)	Merit (1)	Merit (2)	Nyalau A.	Nyalau B.	Serin.	Malang A.	Malang B.	Terbat (1)	Terbat (2)	Ramun	Means
FIRST CROP														
16.10	9.62	4.54	1.37	4.66	7.67	6.51	16.83	5.76	9.85	8.99	1.62	7.56	15.51	8.33
56.52	28.38	7.24	4.69	2.77	13.81	6.26	19.99	4.41	10.64	44.96	20.82	24.43	20.35	18.95
36.31	19.00	5.89	3.03	3.72	10.74	6.39	18.41	5.09	10.25	26.98	11.22	16.00	17.93	13.64
3.5	3.0	1.6	3.4	0.6	1.8	1.0	1.2	0.8	1.1	5.0	12.9	3.2	1.3	2.3
SECOND CROP														
6.35	8.68	0.03	0.00	2.33	3.58	1.74	9.86	1.94	2.06	1.96	2.94	3.96	6.25	3.69
30.04	17.85	1.10	0.00	20.73	18.27	6.15	13.61	19.01	14.02	17.43	14.88	19.78	22.76	15.40
18.20	13.27	0.57	0.00	11.53	10.93	3.95	11.74	10.48	8.04	9.70	8.91	11.87	14.51	9.55
4.7	2.1	36.7	0.0	8.9	5.1	3.5	1.4	9.8	6.8	8.9	5.1	5.0	3.6	4.2
TOTAL BOTH CROPS														
22.45	18.30	4.57	1.37	6.99	11.25	8.25	26.69	7.70	11.91	10.95	4.56	11.52	21.76	12.02
36.56	46.23	8.34	4.69	23.50	32.08	12.41	33.60	23.42	24.66	62.39	35.70	44.21	43.11	34.35
34.51	32.27	6.46	3.03	15.25	21.67	10.34	30.15	15.57	18.29	36.68	20.13	27.87	32.44	23.19
3.9	2.5	1.8	3.4	3.4	2.9	1.5	1.3	3.0	2.1	5.7	7.8	3.8	2.0	2.9
RATIO OF HIGHEST YIELD FOR D.S.P. TO HIGHEST YIELD FOR C.I.R.P. FOR EACH SOIL														
$\frac{D-8}{C-8}$	$\frac{D-4}{C-8}$	$\frac{D-8}{C-8}$	$\frac{D-8}{C-8}$	$\frac{D-8}{C-8}$	$\frac{D-2}{C-8}$	$\frac{D-2}{C-8}$	$\frac{D-8}{C-8}$	$\frac{D-8}{C-8}$	$\frac{D-8}{C-8}$	$\frac{D-8}{C-8}$	$\frac{D-8}{C-8}$	$\frac{D-8}{C-8}$	$\frac{D-4}{C-8}$	
2.2	2.1	2.0	2.5	1.6	1.1	1.0	2.7	2.4	3.4	4.3	2.9	1.5		

TABLE 3A
Yield of Dry Bayam Tops (O.D. gm./pot mean)

Tarat A.	Tarat B.	Semongok (1)	Semongok (2)	Merit (1)	Merit (2)	Nyalau A.	Nyalau B.	Serin	Malang A.	Malang B.	Terbat (1)	Terbat (2)	Ramun	Means
FIRST CROP														
0.06	0.09	0.65	0.04	0.06	0.00	0.50	0.04	0.04	1.26	0.01	0.01	0.03	0.08	0.21
0.78	0.21	0.63	0.03	0.25	0.11	0.70	0.76	0.26	1.10	0.24	0.02	0.33	0.62	0.43
1.33	0.87	0.61	0.05	0.39	0.80	0.70	1.94	0.99	1.45	0.68	0.08	0.95	1.92	0.91
2.25	1.58	0.67	0.19	0.78	0.97	1.08	2.11	1.00	1.30	1.46	0.20	0.96	1.80	1.17
2.55	2.24	0.77	0.54	0.94*	1.76*	1.33*	2.15	1.04*	1.62*	2.04	0.62	1.61	2.44*	1.55
3.80	1.50	0.93	0.52	0.39	0.60	1.05	1.89	0.48	1.48	3.03	1.53	1.74	1.90	1.49
3.95	2.17	1.04	0.55	0.30	2.17	0.77	2.21*	0.65	1.35	3.75	2.14	2.07	1.96	1.79
4.32	3.28	1.37*	0.62	0.29	1.74	0.82	1.89	0.51	1.53	3.77	2.44	2.87	2.26	1.98
4.55*	3.50*	1.05	1.01*	0.38	1.66	0.95	1.85	0.75	1.58	3.88*	2.45*	3.12*	2.37	2.08*
4.62	1.72	0.86	0.39	0.42	1.09	0.88	1.65	0.64	1.41	2.10	1.05	1.52	1.71	1.29
SECOND CROP														
0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.08	0.08	0.00	0.00	0.00	0.01
0.37	0.70	0.00	0.00	0.03	0.06	0.06	0.63	0.03	0.06	0.06	0.01	0.08	0.28	0.17
0.52	0.95	0.00	0.00	0.11	0.10	0.02	1.09	0.06	0.10	0.09	0.05	0.36	0.68	0.30
0.95	1.31	0.00	0.00	0.50	0.53	0.22	1.30	0.25	0.25	0.20	0.51	0.66	1.00	0.55
1.64	1.34	0.00	0.00	0.71	1.30	0.70	1.73	0.80	0.70	0.77	1.09	1.05	1.55	0.96
1.40	1.03	0.02	0.00	1.81	0.66	0.66	1.77	1.12	0.84	0.38	0.69	0.95	1.50	0.92
1.29	1.74	0.00	0.00	1.67	1.62	1.32*	1.79*	1.61	0.91	1.32	1.35	1.58	1.96	1.37
1.59	2.24	0.15	0.00	2.44	2.44	0.90	1.00	2.40	1.84	2.39	2.14	2.73	2.93*	1.94
1.46	2.31*	0.46*	0.00	2.62*	2.62*	0.73	1.42	2.81*	2.64*	2.93*	2.37*	2.76*	2.70	2.13*
1.58	1.29	0.07	0.00	1.10	1.04	0.51	1.19	1.01	0.82	0.91	0.91	1.13	1.40	0.93
TOTAL BOTH CROPS														
0.06	0.09	0.65	0.04	0.06	0.00	0.50	0.04	0.04	1.34	0.09	0.01	0.03	0.08	0.22
0.15	0.91	0.63	0.03	0.28	0.17	0.76	1.39	0.29	1.16	0.30	0.03	0.41	0.90	0.60
0.85	1.82	0.61	0.05	0.49	0.90	0.72	3.03	1.05	1.55	0.77	0.13	1.31	2.60	1.21
1.20	2.89	0.67	0.19	1.28	1.50	1.30	3.41	1.25	1.55	1.66	0.71	1.62	2.80	1.72
1.19	3.58	0.77	0.54	1.65	3.06	2.03	3.88	1.84	2.32	2.81	1.71	2.66	3.99	2.50
2.20	2.53	0.95	0.52	2.20	1.26	1.71	3.66	1.60	2.32	3.41	2.22	2.69	3.40	2.41
2.24	3.91	1.04	0.55	1.97	3.79	2.09*	4.00*	2.26	2.26	5.07	3.49	3.65	3.92	3.16
2.91	5.52	1.52*	0.62	2.73	4.18	1.72	2.89	2.91	3.37	6.16	4.58	5.60	5.19	3.92
2.91	5.81*	1.51	1.01*	3.00*	4.28*	1.68	3.27	3.56*	4.22*	6.81*	4.82*	5.88*	5.07	4.21*
2.20	3.00	0.93	0.39	1.52	2.13	1.39	2.84	1.64	2.23	3.01	1.97	2.65	3.11	2.22

N.B. * = highest yield (Dry tops) for each soil

TABLE 3B.

Yield of Christmas Island Rock Phosphate (C.I.R.P) and Double Superphosphate (D.S.P) treated Bayam (D.M.) and ratio of yield D.S.P. : C.I.R.P.

Tarat A.	Tarat B.	Semongok (1)	Semongok (2)	Merit (1)	Merit (2)	Nyalau A.	Nyalau B.	Serin	Malang A.	Malang B.	Terbat (1)	Terbat (2)	Ramun	Means
FIRST CROP														
1.73	1.23	0.67	0.20	0.59	0.91	0.95	1.74	0.82	1.37	1.10	0.23	0.96	1.70	1.01
4.15	2.61	1.10	0.68	0.34	1.54	0.90	1.96	0.60	1.48	3.61	2.14	2.45	2.12	1.83
2.94	1.92	0.89	0.44	0.47	1.23	0.93	1.85	0.71	1.43	2.36	1.19	1.71	1.91	1.43
2.4	2.1	1.6	3.4	0.6	1.7	0.9	1.1	0.7	1.1	3.3	9.3	2.6	1.2	1.8
SECOND CROP														
0.87	1.08	0.00	0.00	0.34	0.50	0.25	1.19	0.29	0.28	0.28	0.42	0.54	0.88	0.49
2.68	1.83	0.16	0.00	2.14	1.59	0.90	1.50	1.99	1.56	1.75	1.64	2.01	2.27	1.57
1.78	1.46	0.08	0.00	1.24	1.05	0.58	1.35	1.14	0.92	1.02	1.03	1.28	1.58	1.04
3.1	1.7	-	-	6.3	3.2	3.6	1.3	6.9	5.6	6.3	3.9	3.7	2.6	3.2
TOTAL BOTH CROPS														
2.60	2.30	0.67	0.20	0.93	1.41	1.20	2.93	1.11	1.64	1.38	0.65	1.50	2.57	1.51
6.84	4.44	1.26	0.68	2.48	3.38	1.80	3.46	2.58	3.04	5.36	3.78	4.46	4.40	3.35
4.72	3.27	0.97	0.44	1.71	2.40	1.50	3.20	1.85	2.34	3.37	2.22	2.98	3.49	2.46
2.6	1.9	1.9	3.4	2.7	2.4	1.5	1.2	2.3	1.9	3.9	5.8	3.0	1.7	2.2
RATIO OF HIGHEST YIELD FOR D.S.P TO HIGHEST YIELD FOR C.I.R.P FOR EACH SOIL														
D-8 C-8	D-4 C-8	D-8 C-8	D-8 C-8	D-8 C-8	D-8 C-8	D-2 C-8	D-2 C-8	D-8 C-8	D-8 C-8	D-8 C-8	D-8 C-8	D-8 C-8	D-4 C-8	
1.6	2.0	1.9	1.8	1.4	1.0	1.0	1.0	1.9	1.8	2.4	2.8	2.2	1.3	

TABLE 4A

Recovery of Applied Phosphorus in Bayam tops (% of P applied)

Tarat A.	Tarat B.	Semongok (1)	Semongok (2)	Merit (1)	Merit (2)	Nyalau A.	Nyalau B.	Serin	Malang A.	Malang B.	Terbat (1)	Terbat (2)	Ramun	Means
FIRST CROP														
3.6	1.0	4.6	-	2.3	0.5	6.9	7.7	1.0	9.5	1.3	-	1.6	4.4	3.2
3.0	2.4	2.6	0.3	2.1	2.2	3.5	8.9	4.0	5.6	1.8	0.3	3.1	8.8	3.5
3.5	3.0	1.2	0.4	2.2	2.4	2.5	6.3	2.8	2.8	2.7	0.3	1.8	3.8	2.6
2.4	2.2	0.8	0.6	1.3	2.1	1.8	3.9	1.6	2.0	2.1	0.5	1.5	3.2	1.9
24.3	8.3	5.5	2.3	4.8	5.1	10.6	18.1	4.4	15.4	23.6	10.6	11.3	17.0	11.5
14.0	8.7	4.0	2.2	2.0	9.2	5.3	13.4	3.8	6.7	16.8	9.9	7.8	10.6	8.2
11.4	9.0	2.9	1.8	1.3	5.0	3.2	7.1	2.3	4.4	11.7	5.8	7.2	7.1	5.7
5.6	5.0	1.5	2.3	1.1	2.6	2.1	3.8	1.8	2.9	6.5	3.9	4.2	4.6	3.4
SECOND CROP														
2.1	3.6	0.0	0.0	-	0.3	0.3	3.1	0.0	0.3	-	-	0.5	1.3	0.8
1.5	3.1	0.0	0.0	0.3	0.3	0.0	3.4	0.2	0.3	0.3	0.2	0.9	2.1	0.9
1.6	2.6	0.0	0.0	0.8	0.7	0.3	2.9	0.3	0.3	0.3	0.8	1.1	1.5	0.9
1.2	1.5	0.0	0.0	0.9	0.9	0.7	2.3	0.7	0.5	0.7	1.2	1.0	1.6	0.9
7.1	4.4	-	0.0	13.3	2.5	2.5	10.1	8.1	3.7	2.1	4.6	3.2	9.0	5.0
6.9	6.5	0.0	0.0	8.3	5.0	3.4	8.0	4.6	1.7	4.2	3.5	3.7	7.0	4.5
5.6	4.4	0.1	0.0	5.9	5.0	2.1	3.5	4.7	2.4	6.0	4.2	4.7	6.9	4.0
4.6	2.6	0.5	0.0	4.5	3.3	1.4	2.9	4.4	3.7	3.9	7.3	2.7	3.9	3.3
TOTAL BOTH CROPS														
5.6	4.6	4.6	-	2.3	0.8	7.2	10.7	1.0	9.7	1.3	-	2.0	5.6	4.0
4.5	5.5	2.6	0.3	2.3	2.4	3.5	12.3	4.1	5.9	2.1	0.4	4.0	10.8	4.3
5.1	5.5	1.2	0.4	3.0	3.1	2.8	9.2	3.1	3.1	3.0	1.0	2.9	5.2	3.5
3.6	3.7	0.8	0.6	2.2	3.0	2.5	6.2	2.3	2.5	2.8	1.6	2.5	4.8	2.8
14.4	12.6	5.5	2.3	18.1	7.6	13.1	28.2	12.4	19.1	25.7	15.2	14.4	25.9	16.5
10.9	15.2	4.0	2.2	10.2	14.2	8.7	21.4	8.4	8.4	20.9	13.3	11.5	17.6	12.6
10.0	13.3	3.1	1.8	7.2	10.0	5.3	10.5	7.0	6.8	17.7	10.9	11.9	14.0	9.8
7.2	7.6	1.9	2.3	5.6	5.9	3.4	6.7	6.1	6.6	10.3	7.6	6.9	8.4	6.4

N.B. Means are derived from totals of all 14 soils figures, non available figures being regarded as of negligible size.

TABLE 4B.

Recovery of Applied Phosphorus in Bayam tops (% of P applied).
 Means for Christmas Island Rock Phosphate, and Double
 Superphosphate treatments, and ratios of D.S.P.
 (P) recovery over C.I.R.P. (P) recovery.

	Tarat A.	Tarat B.	Semongok (1)	Semongok (2)	Merit (1)	Merit (2)	Nyalau A.	Nyalau B.	Serin	Malang A.	Malang B.	Terbat (1)	Terbat (2)	Ramun	Means
FIRST CROP															
C.I.R.P.	2.9	2.4	1.4	0.4	1.7	2.4	2.6	5.5	2.2	3.2	2.1	0.4	1.8	4.2	2.4
D.S.P.	12.0	6.7	2.5	2.2	1.6	6.7	3.4	6.9	2.3	4.6	10.4	5.6	6.0	6.9	5.6
Local	6.4	4.7	2.0	1.4	1.6	4.7	3.0	6.3	2.3	4.0	6.5	3.8	4.0	5.6	4.0
D.S.P. C.I.R.P.	4.1	2.8	1.8	5.5	0.9	2.8	1.3	1.3	1.0	1.4	5.0	14.0	3.3	1.6	2.3
SECOND CROP															
C.I.R.P.	1.4	2.2	-	-	0.7	0.7	0.5	2.6	0.3	0.4	0.5	0.9	1.0	1.7	0.9
D.S.P.	5.3	3.7	0.3	-	6.0	4.0	1.9	4.2	2.4	3.1	4.4	3.9	3.4	5.5	3.4
Local	3.5	3.0	0.2	-	3.5	2.4	1.2	3.5	2.7	1.8	2.5	2.5	2.3	3.7	2.3
D.S.P. C.I.R.P.	3.8	1.7	-	-	8.6	5.7	3.8	1.6	8.0	7.8	8.8	4.3	3.4	3.2	3.8
TOTAL BOTH CROPS															
C.I.R.P.	4.2	4.5	1.4	0.4	2.4	2.8	3.0	8.1	2.7	3.6	2.6	1.2	2.7	5.8	3.2
D.S.P.	14.8	10.4	2.8	2.2	7.5	8.2	5.3	11.1	7.1	7.7	14.8	8.0	9.3	12.3	8.7
Local	9.8	7.7	2.1	1.4	5.1	5.7	4.2	9.7	5.0	5.8	9.0	4.8	6.2	9.2	6.1
D.S.P. C.I.R.P.	3.5	2.3	2.0	5.5	3.1	2.9	1.8	1.4	2.6	2.1	5.7	6.7	3.4	2.1	2.7
1	5.6	2.7	1.2	-	7.9	9.5	1.8	2.6	12.4	2.0	19.8	-	7.2	4.6	6.4
2	4.6	2.8	1.5	7.3	4.4	5.9	2.5	1.7	2.0	1.4	10.0	33.3	2.9	1.6	5.9
4	3.3	2.4	2.6	4.5	2.4	3.2	1.9	1.1	2.3	2.2	5.9	10.9	4.1	2.7	3.5
8	2.8	2.1	2.4	3.8	2.5	2.0	1.4	1.1	2.7	2.6	3.7	4.8	2.8	1.8	2.5

(N.B. IN ALL ABOVE MEANS UNAVAILABLE DATA IS INCLUDED AS BEING NEGLIGIBLE)

N.B. Means of above ratios are of determinations available only.

TABLE 5.

Phosphorus concentration in Bayam tops (% in D.M.)

Tarat A.	Tarat B.	Semongok (1)	Semongok (2)	Merit (1)	Merit (2)	Nyalau A.	Nyalau B.	Serin.	Malang A.	Malang B.	Terbat (1)	Terbat (2)	Ramun	Means
FIRST CROP														
.14	-	.31	.40	.13	-	.35	-	.09	.31	-	-	-	.12	.23
.18	.19	.28	-	.34	.14	.39	.39	.17	.34	.22	-	.19	.27	.26
.17	.22	.33	.31	.40	.21	.39	.36	.31	.30	.21	.23	.25	.36	.29
.24	.29	.29	.31	.44	.38	.36	.47	.43	.34	.29	.18	.29	.33	.33
.30	.31	.30	.32	.44	.37	.43	.57	.48	.38	.32	.23	.28	.41	.37
.28	.24	.26	.20	.55	.36	.44	.42	.40	.45	.34	.30	.28	.39	.35
.31	.35	.34	.35	.57	.37	.60	.53	.50	.43	.39	.40	.33	.47	.42
.46	.48	.37	.50	.79	.50	.67	.65	.78	.50	.54	.41	.44	.55	.55
.43	.49	.48	.79	1.00	.54	.76	.71	.81	.63	.58	.56	.47	.67	.64
.28	.32	.33	.40	.52	.36	.49	.50	.50	.41	.36	.33	.32	.40	.39
SECOND CROP														
-	-	-	-	-	-	-	-	-	.18	-	-	-	-	-
.21	.20	-	-	-	.15	.15	.19	-	.17	-	-	.19	.17	.18
.24	.25	-	-	.16	.15	-	.25	.13	.15	.23	.21	.20	.24	.20
.26	.31	-	-	.24	.21	.19	.35	.18	.14	.25	.23	.25	.23	.24
.22	.35	-	-	.36	.22	.30	.41	.26	.22	.27	.34	.30	.32	.30
.22	.18	-	-	.32	.17	.17	.25	.31	.19	.23	.29	.15	.26	.23
.26	.33	-	-	.43	.27	.23	.39	.25	.16	.27	.22	.20	.31	.28
.27	.34	.16	-	.42	.36	.41	.61	.34	.23	.44	.34	.30	.41	.36
.46	.40	.36	-	.60	.44	.65	.71	.54	.49	.46	.54	.34	.50	.50
.27	.30	-	-	.36	.25	.30	.40	.29	.21	.31	.31	.24	.31	.30
FIRST CROP														
.22	.25	.30	.31	.41	.28	.39	.45	.35	.34	.26	.21	.25	.34	.31
.37	.39	.36	.46	.73	.44	.62	.58	.62	.50	.46	.42	.38	.52	.49
SECOND CROP														
.23	.28	-	-	.25	.18	.21	.30	.19	.17	.25	.26	.24	.24	.23
.30	.31	-	-	.44	.31	.37	.49	.36	.27	.35	.35	.25	.37	.35

N.B. Mean values are those of determinations available only.

TABLE 6.

Nitrogen concentration in Bayam tops (% in D.M.)

Terbat A.	Tarat B.	Semongok (1)	Semongok (2)	Merit (1)	Merit (2)	Nyalau A.	Nyalau B.	Serin	Malang A.	Malang B.	Terbat (1)	Terbat (2)	Ramun	
FIRST CROP														Means
4.61	-	3.54	4.32	4.64	-	4.39	-	5.06	4.46	6.45	5.42	-	5.84	4.87
4.46	4.48	4.06	4.65	4.77	4.76	4.33	5.20	3.93	4.43	5.74	5.21	4.47	5.01	4.68
4.40	4.52	4.30	4.95	5.18	4.88	4.37	3.34	4.55	4.17	5.58	5.62	4.75	4.87	4.68
4.97	4.29	4.19	4.64	5.10	4.72	4.38	5.04	5.20	4.37	6.10	5.54	4.74	5.51	4.91
4.33	4.00	4.22	4.36	5.57	4.68	4.61	4.78	4.83	4.98	5.18	5.59	4.88	4.03	4.79
3.69	3.90	4.16	3.65	5.50	4.94	4.70	4.56	5.25	4.42	5.21	5.56	5.05	4.47	4.65
3.41	4.43	4.54	5.55	5.67	4.87	4.94	5.27	5.45	4.54	5.03	5.77	5.01	5.10	4.97
3.50	4.71	4.90	4.56	4.91	5.32	5.00	5.08	5.07	4.87	5.13	5.40	5.03	5.25	4.91
3.62	4.82	5.14	4.80	5.18	2.14	4.97	3.79	5.12	5.04	4.79	5.99	4.72	4.50	4.54
4.00	4.39	4.34	4.61	5.17	4.54	4.63	4.63	4.94	4.59	5.47	5.57	4.83	4.95	4.76
SECOND CROP														
-	-	-	-	-	-	-	-	-	5.52	-	-	-	-	-
4.94	4.10	-	-	5.54	4.99	5.57	5.19	5.43	5.16	-	-	4.46	5.19	5.06
4.90	4.26	-	-	4.90	4.60	-	4.90	5.64	4.80	5.95	5.54	4.29	5.51	5.03
5.32	4.64	-	-	5.96	4.86	5.10	5.10	5.47	4.89	5.90	5.60	4.89	5.28	5.25
4.95	4.99	-	-	5.48	4.58	5.20	5.30	5.10	5.13	6.16	5.68	4.80	3.50	5.07
4.57	4.24	-	-	4.90	4.91	3.71	4.33	6.13	4.52	5.83	5.41	4.24	5.21	4.83
4.65	4.05	-	-	6.33	4.07	4.25	4.79	4.95	3.88	5.77	5.05	4.50	4.96	4.77
4.94	4.43	3.94	-	5.10	4.85	4.82	5.59	5.05	4.57	6.16	5.91	4.60	5.02	4.84
4.44	4.42	4.75	-	5.57	3.93	5.43	4.88	5.10	5.59	5.54	5.78	5.04	5.30	5.06
4.59	4.39	-	-	5.47	4.60	4.87	5.01	5.36	4.90	5.90	5.57	4.60	5.00	5.02
FIRST CROP														
4.54	4.32	4.14	4.65	5.13	4.76	4.42	4.59	4.63	4.49	5.65	5.49	4.71	4.86	4.77
4.31	4.47	4.69	4.64	5.32	4.32	4.90	4.68	5.22	4.72	5.04	5.68	4.95	4.83	4.77
SECOND CROP														
4.03	4.50	-	-	5.47	4.76	5.29	5.12	5.41	5.00	6.00	5.61	4.61	4.87	5.14
4.15	4.29	-	-	5.48	4.44	4.55	4.90	5.41	4.64	5.83	5.54	4.60	5.12	4.91

N.B. Mean values are those of determinations available only.

TABLE 7.

Potassium concentration in Bayam tops (% in D.M.)

Tarat A.	Tarat B.	Semongok (1)	Semongok (2)	Merit (1)	Merit (2)	Nyalau A.	Nyalau B.	Serin	Malang A.	Malang B.	Terbat (1)	Terbat (2)	Ramun	Means
FIRST CROP														
4.41	-	5.59	4.17	3.41	-	7.05	-	2.76	6.85	-	-	-	2.50	4.59
5.67	4.15	5.25	-	4.89	3.51	6.85	4.81	4.95	6.46	4.65	-	4.27	5.93	5.12
5.86	4.76	5.57	5.56	5.68	4.21	7.10	6.38	5.26	5.88	5.06	5.81	4.62	6.00	5.55
5.30	5.76	5.30	5.78	6.48	5.33	6.34	7.62	6.13	6.40	5.11	3.38	4.81	6.13	5.71
5.07	5.66	5.52	5.71	7.21	6.52	7.31	8.19	6.42	6.24	6.64	4.30	5.93	7.28	6.29
6.69	6.26	5.60	4.09	6.76	6.38	7.58	7.57	5.40	5.90	5.70	4.06	4.92	6.08	5.93
7.10	8.05	5.85	5.98	6.51	6.35	7.73	8.01	6.33	7.38	6.08	4.47	5.76	7.03	6.62
7.04	8.76	4.98	6.07	7.29	6.33	9.23	8.98	6.53	7.57	5.96	4.91	5.71	7.13	6.89
6.24	7.44	6.26	6.66	7.25	4.96	7.92	7.74	6.70	7.66	6.42	3.17	5.76	7.01	6.51
5.94	6.35	5.53	5.48	6.15	5.44	7.35	7.35	5.63	6.65	6.74	4.34	5.24	6.13	6.04
SECOND CROP														
-	-	-	-	-	-	-	-	-	3.61	-	-	-	-	-
5.74	4.27	-	-	-	3.25	4.08	4.56	-	3.27	-	-	4.64	4.76	4.32
3.20	4.80	-	-	3.31	4.03	-	5.18	3.10	3.39	6.10	5.92	4.65	6.64	4.57
6.35	6.13	-	-	5.20	4.76	3.98	6.41	4.12	4.12	6.26	5.90	4.80	6.31	5.36
6.53	5.13	-	-	5.31	6.03	4.96	6.66	5.42	4.80	6.34	6.15	5.83	6.81	5.83
6.62	4.68	-	-	5.61	4.52	3.79	5.60	3.97	3.39	6.48	5.65	5.08	6.64	5.17
6.78	5.82	-	-	5.31	6.01	5.46	7.65	4.45	3.77	6.59	5.74	6.13	7.65	5.95
4.51	6.21	3.40	-	7.80	7.44	7.13	7.98	5.51	4.84	6.35	5.68	5.67	7.40	6.15
6.09	6.29	5.16	-	7.35	8.19	7.26	8.15	7.94	6.02	5.99	6.80	6.32	7.74	6.87
5.73	5.42	-	-	5.70	5.53	5.24	6.52	4.93	4.13	6.30	6.00	5.39	6.74	5.64
FIRST CROP														
5.48	5.08	5.41	5.68	6.07	4.89	6.90	6.75	5.69	6.25	5.37	4.50	4.91	6.34	5.67
6.76	7.63	5.67	5.70	6.95	6.01	8.12	8.08	6.24	7.13	6.04	4.15	5.54	6.81	6.49
SECOND CROP														
5.46	5.08	-	-	4.61	4.52	4.34	5.70	4.21	3.90	6.23	5.99	4.98	6.13	5.10
6.00	5.75	-	-	6.52	6.54	5.91	7.35	5.47	4.51	6.35	5.97	5.80	7.36	6.13

N.B. Mean values are those of determinations available only.

TABLE 8.

Calcium concentration in Bayam tops (% in D.M.)

Tarat A.	Tarat B.	Semongok (1)	Semongok (2)	Merit (1)	Merit (2)	Nyalau A.	Nyalau B.	Serin	Malang A.	Malang B.	Terbat (1)	Terbat (2)	Raman	Means
FIRST CROP														
1.46	-	1.22	0.28	0.55	-	0.85	-	0.33	0.82	-	-	-	0.84	0.79
1.58	1.79	1.10	-	1.10	1.59	0.79	1.39	0.75	0.92	1.07	-	1.52	1.07	1.22
1.47	1.70	1.22	0.44	1.14	0.79	0.78	0.80	0.43	0.71	1.25	1.27	1.79	0.89	1.05
1.53	1.80	1.50	0.86	0.63	0.92	0.65	0.60	0.72	0.81	1.30	1.25	1.91	0.94	1.10
2.12	1.77	1.48	0.70	0.51	0.68	0.87	0.57	0.61	1.01	1.23	1.36	1.56	0.61	1.08
1.46	1.28	1.20	0.50	0.41	0.64	0.69	0.49	0.49	0.83	1.24	1.21	1.67	0.64	0.91
1.29	1.26	1.15	0.61	0.40	0.93	0.77	0.47	0.48	0.79	1.39	1.27	1.49	0.55	0.92
1.37	1.44	1.42	0.58	0.43	0.69	0.82	0.49	0.45	0.68	1.31	1.06	1.76	0.60	0.94
1.02	1.55	1.13	0.47	0.39	0.94	0.72	0.44	0.47	0.91	1.26	1.32	1.94	0.57	0.94
1.48	1.57	1.27	0.56	0.62	0.90	0.77	0.65	0.53	0.83	1.26	1.25	1.71	0.75	1.01
SECOND CROP														
-	-	-	-	-	-	-	-	-	0.24	-	-	-	-	-
1.48	2.02	-	-	-	0.38	0.06	0.77	-	0.25	-	-	0.91	0.44	0.79
1.20	2.02	-	-	0.52	0.22	-	0.87	0.18	0.91	1.22	1.32	1.36	0.46	0.93
1.23	2.16	-	-	0.59	0.22	0.39	0.61	0.53	0.75	1.32	1.27	1.78	0.46	0.94
1.78	2.27	-	-	0.50	0.82	0.46	0.64	0.65	0.26	1.54	1.63	1.65	1.03	1.10
1.31	1.42	-	-	0.54	0.54	0.37	0.60	0.63	0.67	1.23	1.33	1.41	0.73	0.90
1.54	1.60	-	-	0.44	0.65	0.42	0.61	0.46	0.58	1.64	1.19	1.28	0.76	0.93
1.28	1.83	0.39	-	0.48	0.78	0.80	0.72	0.58	0.51	1.47	1.61	1.42	0.96	0.99
1.73	1.87	0.82	-	0.62	1.09	0.36	0.66	0.71	0.74	1.53	1.52	1.52	1.12	1.10
1.44	1.90	-	-	0.53	0.59	0.41	0.69	0.53	0.55	1.42	1.41	1.42	0.75	0.97
FIRST CROP														
1.68	1.77	1.33	0.67	0.85	1.00	0.77	0.84	0.63	0.86	1.21	1.29	1.70	0.88	1.11
1.29	1.38	1.23	0.54	0.41	0.80	0.75	0.47	0.47	0.80	1.30	1.22	1.72	0.59	0.93
SECOND CROP														
1.42	2.12	-	-	0.54	0.41	0.30	0.72	0.45	0.54	1.36	1.41	1.43	0.60	0.94
1.47	1.68	-	-	0.52	0.77	0.49	0.65	0.60	0.63	1.47	1.41	1.41	0.89	1.00

N.B. Mean values are those of determinations available only.

TABLE 9

Magnesium concentration in Bayam tops (% In D.M.)

Tarat A.	Tarat B.	Semongok (1)	Semongok (2)	Merit (1)	Merit (2)	Nyalau A.	Nyalau B.	Serin	Malang A.	Malang B.	Terbat (1)	Terbat (2)	Ramun	Means
FIRST CROP														
0.98	-	1.32	0.57	0.31	-	0.39	-	0.30	0.49	-	-	-	0.80	0.64
1.04	1.19	0.69	-	0.62	0.50	0.19	0.83	0.41	0.62	0.70	-	1.13	0.81	0.73
0.97	1.40	0.77	0.64	0.48	0.46	0.61	0.51	0.58	0.40	0.58	1.07	1.28	0.66	0.74
1.11	1.34	0.72	0.57	0.41	0.47	0.76	0.44	0.33	0.54	0.65	0.96	1.47	0.39	0.73
1.23	1.19	0.77	0.37	0.36	0.46	0.55	0.43	0.35	0.55	0.50	0.76	1.23	0.47	0.66
0.76	1.23	0.63	0.21	0.24	0.36	0.53	0.39	0.29	0.46	0.52	0.92	1.35	0.51	0.60
0.73	1.07	0.77	0.23	0.28	0.28	0.57	0.42	0.26	0.49	0.55	0.96	1.21	0.47	0.59
0.68	1.04	0.87	0.25	0.25	0.55	0.52	0.39	0.23	0.48	0.49	0.92	1.43	0.48	0.61
0.56	1.07	0.76	0.23	0.29	0.39	0.66	0.28	0.24	0.34	0.48	1.04	1.54	0.49	0.60
0.90	1.19	0.81	0.38	0.36	0.43	0.53	0.46	0.33	0.49	0.56	0.95	1.33	0.56	0.66
SECOND CROP														
-	-	-	-	-	-	-	-	-	0.67	-	-	-	-	
0.97	1.23	-	-	-	0.51	0.49	0.61	-	0.74	-	-	1.20	0.85	0.83
0.90	1.53	-	-	0.41	0.49	-	0.55	0.56	0.77	0.73	1.27	1.02	0.89	0.83
1.16	1.39	-	-	0.49	0.71	0.46	0.47	0.42	0.59	0.68	1.24	1.23	0.86	0.81
1.04	1.56	-	-	0.43	0.26	0.50	0.61	0.47	0.86	0.76	1.29	1.26	0.77	0.82
1.02	1.35	-	-	0.36	0.33	0.32	0.49	0.55	0.44	0.68	1.10	0.98	0.63	0.69
0.77	1.19	-	-	0.48	0.34	0.21	0.47	0.41	0.34	0.65	1.03	1.02	0.57	0.62
0.65	1.31	0.60	-	0.37	0.40	0.37	0.51	0.36	0.42	0.67	1.30	1.15	0.61	0.67
0.79	1.31	0.45	-	0.48	0.45	0.30	0.41	0.43	0.49	0.65	1.12	1.28	0.73	0.68
0.91	1.36	-	-	0.43	0.44	0.38	0.52	0.46	0.59	0.69	1.19	1.14	0.74	0.74
FIRST CROP														
1.09	1.28	0.74	0.53	0.47	0.47	0.53	0.55	0.42	0.53	0.61	0.93	1.28	0.58	0.72
0.68	1.10	0.76	0.23	0.27	0.40	0.57	0.37	0.26	0.44	0.51	0.96	1.38	0.49	0.60
SECOND CROP														
1.02	1.43	-	-	0.44	0.49	0.48	0.56	0.48	0.74	0.72	1.23	1.18	0.84	0.80
0.81	1.29	-	-	0.42	0.38	0.30	0.47	0.44	0.42	0.66	1.14	1.11	0.64	0.67

N.B. Mean values are those of the determinations available only.

The soils derived predominantly from basic igneous rocks (Tarat A & B, Malang B, Terbat (1) and (2) and Ramun) exhibit much higher concentrations of Ca in Bayam tops than do the soils derived from sedimentary rocks, (Semongok, Merit (1) and (2), Nyalau A and B, Serin and Malang A). However Ramun and Semongok (1) appear to be exceptions.

Magnesium uptake.

The % Magnesium concentration in Bayam tops is shown in Table 9. The general pattern of Mg. content is for a decline in concentration as the yield of dry matter from treatment levels of both fertilizers increases. However, within levels of either phosphatic fertilizer for each crop, there is very little variation in Mg. concentration despite a large variation in yield of dry matter from different levels. Concentration of Mg. is higher in dry matter at all levels of C.I.R.P. than at equivalent levels of D.S.P. for both crops. However, when considering each soil in turn, the above relationships do not always apply. As with Calcium content, the Magnesium content in dry matter in tops harvested from soils derived from basic igneous rocks is greater than that from soils derived from sedimentary rocks, despite higher yields from the former group.

The mean total dry matter yields, and percentage concentration of Nitrogen, Phosphorus, Potassium, Calcium and Magnesium, for all levels of application of both Christmas Island Rock Phosphate and Double Superphosphate on all soils is shown in figures 6A to 6C.

Discussion

A statistical appreciation of the plant analytical data is not undertaken in this study and it is intended to compare mainly the highest yielding phosphatic fertilizer treatments for each soil as a basis for determining the limiting factors for growth for the range of soils. This method as used by Rosenquist (8) and others in oil palm foliar analysis studies has however reservations as cited by Ng (7) where high yielding palms can have sub optimal leaf nutrient contents.

Table 10/A shows the D.M. yield and % concentration of N, P, K, Ca and Mg. in Bayam leaves for the highest yielding P fertilizer treatment for each soil for both crops. Table 10/B shows the subsequent total recovery of (D.M.) N, P, K, Ca and Mg from the Bayam tops in the highest yielding treatments, expressed as figures relative to the recovery of the Tarat A highest yielding treatment:- The soils are arranged from left to right in order of decreasing yield for the two groups:-

- (a) Soils derived principally from basic igneous rocks.
- (b) Soils derived principally from sedimentary rocks.

Nitrogen uptake appears to depend on supply, and the figures for concentration in Bayam tops from soil Tarat A (in Table 10/A) are low compared with other soils despite high yield of D.M. in the former. For soil Merit (2) N appears deficient at highest yield, and the general pattern of N uptake suggests that at the level of N applied as fertilizer, N is limiting only for Tarat A and Merit (2) soils.

Mean Bayam Yields (D.M.) and % Concentration of N, P, K, Ca, and Mg in Bayam Tops for all soils

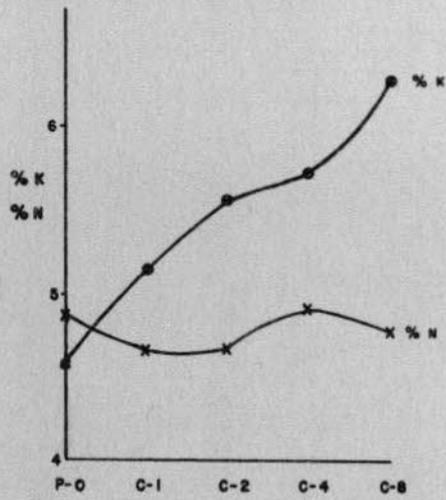
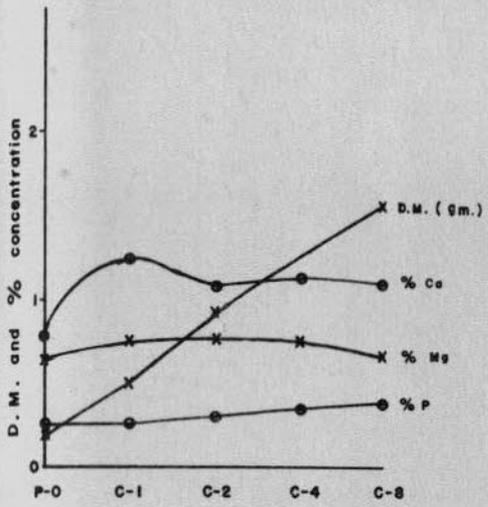


Fig. 6A First crop levels of C.I.R.P. effects

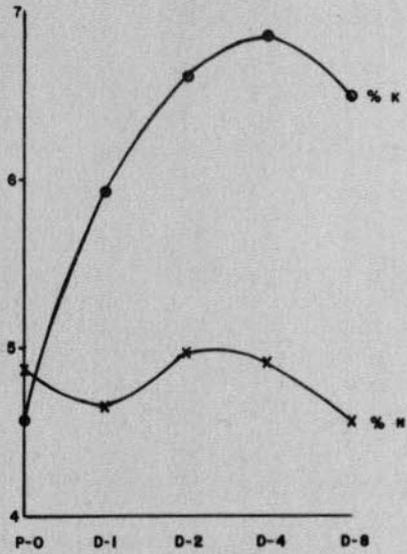
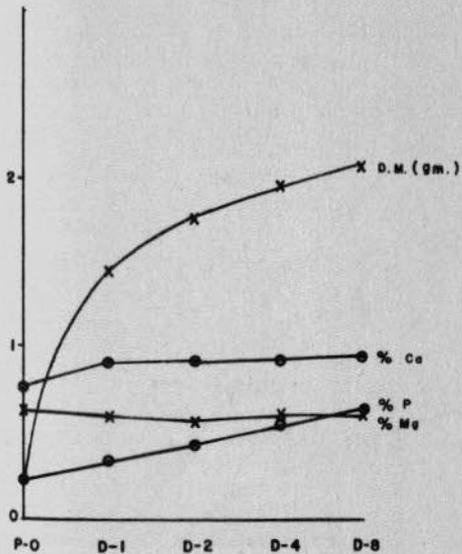


Fig. 6B First crop levels of D.S.P. effects

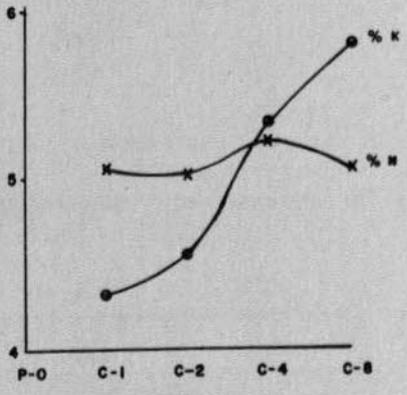
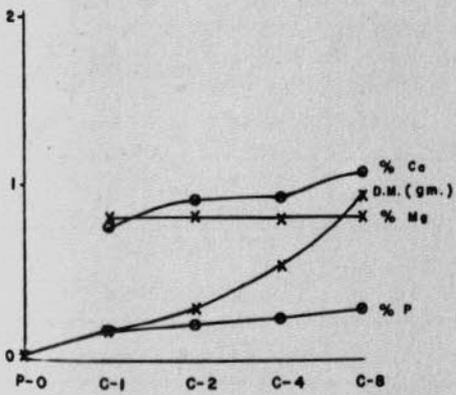


Fig. 6C Second crop levels of C.I.R.P. effects

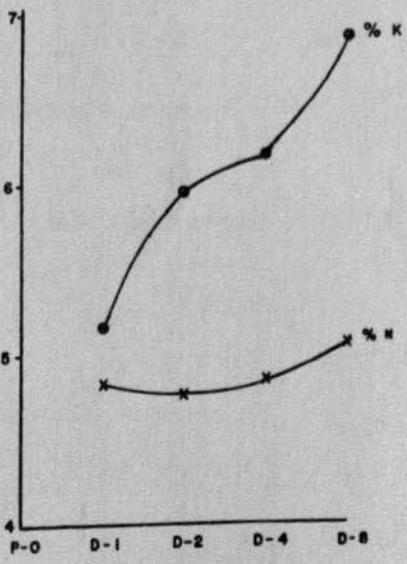
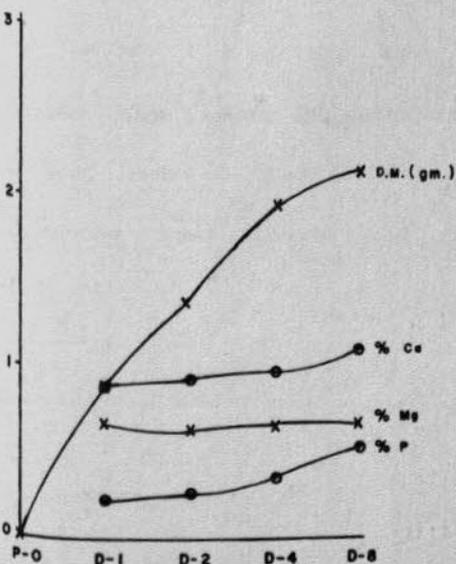


Fig. 6D Second crop levels of D.S.P. effects

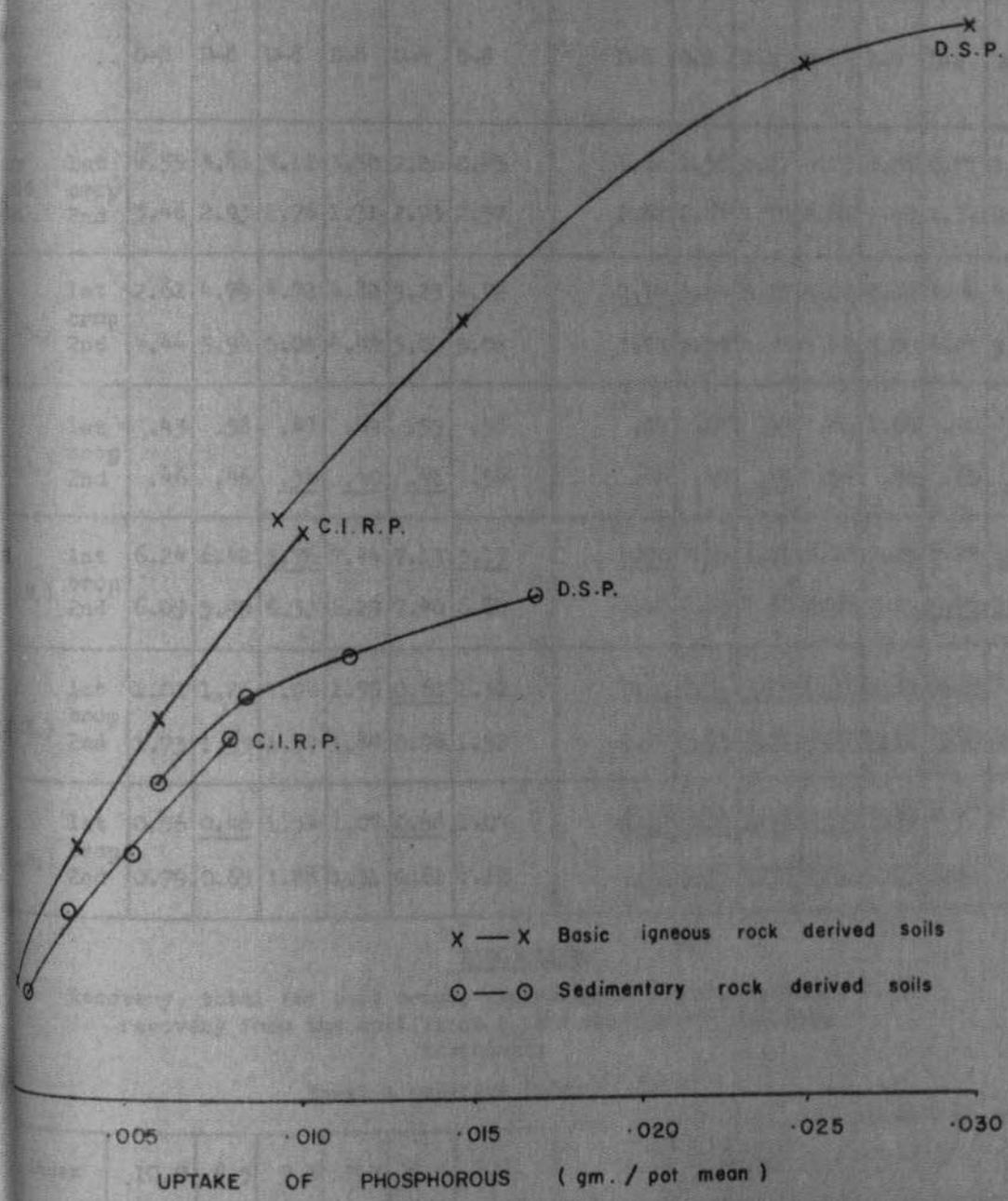


Fig. 7. Total mean yields of Bayam tops (D.M.) for both crops against mean uptake of phosphorous from two phosphatic fertilizers (C.I.R.P. and D.S.P.) at four levels of application. Comparing Basic igneous rock derived soils with Sedimentary rock derived soils.

TABLE 10/A.

Dry matter yields and leaf analytical data for the highest yielding treatment for each soil

A. Igneous rock derived soils							B. Sedimentary rock derived soils.								
	Tarat A.	Malang B.	Terbat (2)	Tarat B.	Remun	Terbat (1)		Merit (2)	Malang A.	Nyalau B.	Serin	Merit (1)	Nyalau A.	Semongok (1)	Semongok (2)
Planting treatments	D-8	D-8	D-8	D-8	D-4	D-8		D-8	D-8	D-2	D-8	D-8	D-2	D-4	D-8
Dry yield (t/ha)	4.55	3.88	3.12	3.50	2.26	2.45		1.66	1.58	2.21	0.75	0.38	0.77	1.37	1.01
	3.46	2.93	2.76	2.31	2.93	2.37		2.62	2.64	1.79	2.81	2.62	1.32	0.15	0.00
N. D.M.)	2.62	4.79	4.72	4.82	5.25	4.72		2.14	5.04	5.27	5.12	5.18	4.94	4.90	4.80
	4.44	5.54	5.04	4.42	5.02	5.04		3.93	5.59	4.79	5.10	5.57	4.25	3.94	-
P. D.M.)	.43	.58	.47	.49	.55	.56		.54	.63	.53	.81	1.00	.76	.37	.79
	.46	.46	.34	.40	.41	.54		.44	.49	.39	.54	.60	.65	.16	-
M. D.M.)	6.24	6.42	5.76	7.44	7.13	3.17		4.96	7.66	8.01	6.70	7.25	7.73	4.98	6.66
	6.09	5.99	6.32	6.29	7.40	6.80		8.19	6.02	7.65	7.94	7.35	5.46	3.40	-
Sa. D.M.)	1.02	1.26	1.94	1.55	0.60	1.32		0.94	0.91	0.47	0.47	0.39	0.77	1.42	0.47
	1.73	1.53	1.52	1.87	0.96	1.52		1.09	0.74	0.61	0.71	0.62	0.42	0.39	-
Ng. D.M.)	0.56	0.48	1.54	1.07	0.48	1.04		0.39	0.34	0.42	0.24	0.29	0.57	0.87	0.23
	0.79	0.65	1.28	1.31	0.61	1.12		0.45	0.49	0.47	0.43	0.48	0.21	0.60	-

TABLE 10/B.

Recovery, total for both crops, expressed as figures relative to the recovery from the soil Tarat A, for the highest yielding treatments

Tarat A relative index = 10.0

Index	10.0	8.5	7.3	7.3	6.5	6.0		5.3	5.3	5.0	4.4	3.7	2.6	1.9	1.3
	10.0	12.7*	7.8	9.9*	9.7*	10.4*		5.1	8.4*	7.5*	6.6*	6.1*	3.4*	2.7*	1.8*
	10.0	10.1	6.8	7.4	6.9	7.5		5.8	6.5	5.3	6.0*	5.5*	4.1*	1.5	2.3*
	10.0	8.6	7.2	8.2	7.6	4.8		6.0	5.7	6.3	5.5	4.5	2.7	1.5	1.4
	10.0	8.8	9.6*	9.2*	3.9	6.4		4.2	3.2	2.0	2.2	1.7	1.1	1.9	0.4
	10.0	7.1	15.8*	12.8*	5.4	9.8*		3.5	3.5	3.4	2.6	2.6	1.4	2.4	0.4

* = recovery at least 30% greater than the dry wt. yield index.
Underlined values are those less than the Tarat A. figs. (10/A) and less than dry wt. index (10/B).

Phosphorus uptake also appears to depend on supply, with luxury uptake occurring on soils of low P retention status (see Table 11), - namely, Nyalau, Merit (1) and Semongok (2) series. Why Merit (1) differs from Merit (2) and Semongok (1) from Semongok (2) in this respect is not fully understood by the author. Figure 7 shows the broad comparison of uptake of phosphorus against dry matter yields for all levels of P application of D.S.P. and C.I.R.P. for the two groups of soils.

Luxury uptake of P is most evident with the sedimentary rock derived soils for the highest levels of D.S.P. application. Russell (9) indicates that over-supply of phosphate causes depression in crop yield more particularly on light soils, which applies to most of the latter group.

The lowest % concentration of P in Bayam leaves occurs on the basic igneous rock derived soils where yields were high generally, but the soils have a high P retention status and Group III oxide content evident. Of the latter group, Terbat series has the highest P retention status and 'Reserve' P analysis figures, but the lowest 'Available' P in the unfertilized state, and consequently a low P % concentration in leaf material, which supports Bailey's (2) and (3) findings of high anion exchange capacity in soils high in iron and aluminium. Of interest is the fact that for Ramun, Merit (1) & (2), Serin, Malang A and Nyalau B soils for the highest yielding P fertilizer treatments, yields (tops) increased from crop 1 to crop 2 (unlike other soils) when P % leaf concentration declined, suggestive that P is depressive in the first crop. Both Malang A and Nyalau A soils were studied by Watson (11) for growth of seedling (nursery) rubber, and both soils, and more particularly the latter showed no significant benefit in terms of growth for high (normal recommendation) phosphate applications over low applications. Also, D.S.P. for seedling rubber was suggestively more superior to C.I.R.P. only on the Malang A Series Soil.

Nyalau A soil in the present study appears to show similar characteristics to Serdang series with which Middleton (5) and Middleton and Chin (6) for seedling rubber showed that at low rates of application double superphosphate was superior to Christmas Island Rock Phosphate in effect in the presence of ammonium sulphate, but that at high rates there was no significant difference. Joseph (4) however, showed the converse relationship with Pueraria phaseoloides using single superphosphate and C.I.R.P. up to 4 and 8 cwts. per acre respectively, in the absence of ammonium sulphate.

Joseph (4) also in the same experiment showed that both superphosphate and C.I.R.P. treatments produced higher leaf P % concentration in the residual second crop than in the first on Malacca, Serdang and Rengam soils, despite decreasing yields. The Sarawak soils with Bayam show the opposite effect at all levels of P fertilizer application with few exceptions. Whilst in temperate climates P availability from various phosphatic fertilizers may be relatively constant over a long period of time (Widdowson (12) and Widdowson & Rothbaum (13)), under Sarawak conditions the present study indicates a rapid state of availability of plant available P from both D.S.P. and C.I.R.P. fertilizers, and a subsequent rapid decline in a short space of time, irrespective of a wide range of soil P retention status. The residual soil P fractions as determined in 'Reserve' and 'Available' form (post cropping) in Tables 1/A to 1/O, generally reflect the magnitude of the pre fertilizer application determinations and P fertilizers added. However, the residual (post cropping) fractions of 'available' P are higher for C.I.R.P. than for D.S.P. at all levels in Tarat A, Tarat B, Terbat (1) and (2), Malang B and Serin Soils, which suggests that 'available' P is not a reliable measurement of plant available P, especially in basic igneous rock derived soils. But, Bailey (14) in work on the Semongok series soils with rice and maize crops found that 'available' P obtained with the Bray & Kurtz's extraction method follows

Soil Series	Highest yielding treatments. Yields (D.M. gm./pot mean)	Total % N	p. p. m. O.D.					pH (H ₂ O)	C.E.C. m. equ. % O.D.	Group III oxides % O.D.	P retention % O.D.
			P 'Av.'	P 'Res.'	K 'Res.'	Ca 'Res.'	Mg 'Res.'				
Tarat A.	D - 8 8.01	0.244	9	464	3843	776	2129	4.6	10.1	17.9	47.0
Tarat B.	D - 8 5.81	0.358	4	723	1336	1763	2115	5.8	15.2	35.2	59.0
Malang B.	D - 8 6.81	0.297	7	451	1266	778	2069	4.5	11.7	15.0	48.1
Terbat (2).	D - 8 5.88	0.278	4	801	1901	1536	4409	5.0	17.8	26.8	69.4
Terbat (1).	D - 8 4.82	0.338	1	992	1265	1124	2146	4.8	17.3	26.6	71.3
Ramun	D - 4 5.19	0.427	13	226	2729	788	1661	4.0	14.6	15.7	64.7
Merit (2)	D - 8 4.28	0.107	4	72	1032	156	685	5.0	5.7	4.3	60.5
Merit (1)	D - 8 3.00	0.115	7	83	881	411	677	5.1	6.0	14.4	30.1
Malang A.	D - 8 4.22	0.180	4	216	3435	194	1432	4.0	11.2	5.6	49.1
Nyalau B.	D - 2 4.00	0.103	5	66	510	391	136	4.6	5.4	1.3	12.3
Nyalau A.	D - 2 2.09	0.080	3	93	2056	249	536	4.4	10.4	18.8	33.5
Serin	D - 8 3.56	0.207	3	152	1517	111	935	5.3	7.2	21.5	45.0
Semongok (1)	D - 4 1.52	0.270	4	222	2894	441	1853	4.4	22.2	7.6	75.1
Semongok (2)	D - 8 1.01	0.249	7	160	2616	348	1342	4.6	15.8	9.3	32.6
Embang	C - 8 0.04	0.125	11	66	'Trace'	409	368	4.0	4.9	0.6	10.7

very closely the soil aluminium bound phosphate which in turn is correlated with the Group III oxide soil content. He found considerable differences in yields from replicates of the fertilizer experiments on Semongok series which paralleled differences in Group III oxide content. Variation in soil analytical data and Bayam yields on Semongok series soils in the present study is also diverse. Bailey quotes in addition, "that the percentage of non-occluded soil phosphates (Ca-Al-Fe and organic - P compounds) of the total phosphate was positively correlated with maize growth would agree with the findings of A.M. Baeba and R.H. Bray (cited by Russell (9)), namely that the phosphate held on the sesquioxide surfaces may be taken up by the crop more easily than the calcium phosphates. This means that superphosphate would be more effective even on this 'acid soil' than rock phosphate which has much of its phosphate in calcium phosphate." These deductions would support the results of the present study where D.S.P. is much more effective on the basic igneous rock derived soils (generally high sesquioxide content) than on the sedimentary rock derived soils (generally low to medium sesquioxide content).

Potassium, Calcium and Magnesium

Tables 10/A and 10/B show that in comparison with the highest yielding treatment for Tarat A, Potassium uptake is possibly deficient in Terbat (1) and Semongok (1) soils only, whereas Calcium and Magnesium uptake for both soils is probably sufficient or in excess of requirements.

However, all the sedimentary rock derived soils with the exception of Semongok (1), and in addition - Ramun and Malang B (the latter for Mg only) indicate possible Calcium and Magnesium deficiencies, but sufficient, or excess Potassium uptake. The Calcium and Magnesium uptake for the P fertilizer treatments in Tables 10/A and 10/B is generally paralleled in magnitude by the pre-fertilizer soil analysis data shown in Table 11, and Tables 1/A to 1/O. Such evidence would denote care required in providing the correct K / Ca + Mg balance for crops particularly on the low Calcium and Magnesium status sedimentary soils. Bailey (3) in experiments with hill rice in pot trials with residual soils found that excessive added Calcium and Magnesium had a depressive effect on leaf Potassium and subsequent yield (and vice versa) for a similar range of Sarawak Soils as in this study.

SUMMARY

Considerable differences in yield have been obtained from the addition of Christmas Island Rock Phosphate (C.I.R.P.) and Double Superphosphate (D.S.P.) fertilizers separately, and for each at levels of 1, 2, 4 and 8 cwts. per acre to a wide range of Sarawak soil series for two successive crops of Amaranthus gangeticus (Bayam) grown in pots. Christmas Island Rock Phosphate was inferior to Double Superphosphate in terms of both fresh and dry matter produced. At the 1, 2, 4 and 8 cwt. rates, C.I.R.P. treated Bayam produced 20%, 31%, 33%, 47% of the fresh matter, and 25%, 38%, 44% and 59% of the dry matter obtained from D.S.P., as a mean for all soils. Yields generally decreased from first to second crops as a consequence of lowered phosphate status in the soils. Of the phosphorus content in the C.I.R.P. applied, 3.2% was recovered in the Bayam tops over the period of both crops compared with 8.7% from D.S.P. for all soils. Recovery of phosphorus from the D.S.P. source was much higher (16.5%) for the 1 cwt. rate of application than other rates, but recovery of phosphorus from the C.I.R.P. was greatest from the 2 cwt. rate.

The soils derived principally from basic igneous rock parent material yielded higher generally, and with greater magnitude for the S.P. treatments than did the soils derived from sedimentary rocks.

From these results it is concluded that Christmas Island Rock Phosphate would have no advantages over Double Superphosphate as a fertilizer for a short term vegetable crop for the majority of Sarawak Soils.

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Table 1/A

Experiment 2. Soil - Tarat A

Treatments (T-Tarat)	First Crop gm.				Second Crop gm.				Total both crops (recovery)							pH (H ₂ O)	Soil analysis post creeping						Total % N
	Wt./pot (mean)		Oven dry basis		Wt./pot (mean)		Oven dry basis		Wt./pot (mean) gm.								p.p.m.						
	Fresh tops	Dry tops	%P	P Total	Fresh tops	Dry tops	%P	P Total	Fresh tops	Dry tops	P	N	K	Ca	Mg		P	Av.	K	Ca	Mg		
(T) P-0	0.61	0.06	0.14	.0001	0.00	0.00	-	-	0.61	0.06	.0001	.003	.003	.001	.001	4.4	300	13	2862	1469	1574	0.330	
(T) C-1	5.19	0.78	0.18	.0014	2.54	0.37	0.21	.0008	7.73	1.15	.0022	.053	.065	.017	.012	4.5	329	33	2738	1136	1302	0.333	
(T) C-2	9.33	1.33	0.17	.0023	3.51	0.52	0.24	.0012	12.84	1.85	.0035	.084	.095	.021	.013	4.4	248	31	2451	928	929	0.289	
(T) C-4	22.16	2.25	0.24	.0054	6.46	0.95	0.26	.0025	28.62	3.20	.0079	.163	.179	.036	.036	4.3	339	38	3654	929	1240	0.285	
(T) C-8	27.73	2.55	0.30	.0076	12.90	1.64	0.22	.0036	40.63	4.19	.0112	.191	.236	.083	.048	4.5	142	91	3406	1428	1775	0.310	
Mean C.I.R.P	16.10	1.73	0.22	.0042	6.35	0.87	0.23	.0020	22.45	2.60	.0062	.123	.144	.039	.027	4.4	264	48	3062	1105	1311	0.317	
(T) D-1	48.57	3.80	0.28	.0106	9.76	1.40	0.22	.0031	58.33	5.20	.0137	.204	.347	.073	.043	4.7	323	12	3280	1781	880	0.317	
(T) D-2	50.96	3.95	0.31	.0122	22.96	2.29	0.26	.0060	73.92	6.24	.0182	.241	.435	.086	.047	5.2	306	11	3449	1655	1427	0.282	
(T) D-4	59.90	4.32	0.46	.0199	44.78	3.59	0.27	.0097	104.68	7.91	.0296	.257	.466	.105	.052	5.2	320	19	3616	1803	1307	0.313	
(T) D-8	66.64	4.55	0.43	.0196	42.65	3.46	0.46	.0159	109.29	8.01	.0355	.273	.495	.106	.052	4.6	450	84	3548	1258	1258	0.300	
Mean D.S.P	56.52	4.15	0.37	.0156	30.04	2.68	0.30	.0087	86.55	6.84	.0242	.244	.436	.092	.048	4.9	350	31	3473	1624	1218	0.303	
Mean total(9)	32.34	2.62	0.28	.0088	16.17	1.58	-	.0054	48.52	4.20	.0135	.163	.258	.059	.034	4.6	306	37	3223	1376	1299	0.309	

Soil analysis pre creeping:-

4.6	464	9	3843	776	2129	0.244
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TABLE 1/C

Experiment 1. Soil - Semongok (1)

Treatments (S=Semongok)	First Crop Wt./pot (mean) gm.				Second Crop Wt./pot (mean) gm.				Total both crops (recovery) Wt./pot (mean) gm.							pH (H ₂ O)	Soil analysis post cropping Oven dry basis							Total % N
	Fresh tops	Oven dry basis			Fresh tops	Oven dry basis			Oven dry basis								P Res.	P Av.	K Res.	Ca Res.	Mg Res.			
		Dry tops	% P	P Total		Dry tops	% P	P Total	P	N	K	Ca	Mg	P	K							Ca	Mg	
(S) P-0	4.41	0.65	0.31	.0020	0.00	0.00	-	-	4.41	0.65	.0020	.023	.036	.008	.009	4.0	190	16	1700	328	1507	0.273		
(S) C-1	4.15	0.63	0.28	.0018	0.01	0.00	-	-	4.16	0.63	.0018	.026	.033	.007	.004	3.9	235	21	1900	329	1712	0.187		
(S) C-2	4.06	0.61	0.33	.0020	0.03	0.00	-	-	4.09	0.61	.0020	.027	.034	.007	.005	4.0	235	20	1700	288	1752	0.274		
(S) C-4	4.78	0.67	0.29	.0019	0.06	0.00	-	-	4.84	0.67	.0019	.028	.036	.010	.005	4.1	285	61	1900	463	1838	0.279		
(S) C-8	5.15	0.77	0.30	.0023	0.00	0.00	-	-	5.15	0.77	.0023	.032	.043	.011	.005	4.0	370	78	1700	659	1449	0.278		
Mean C.I.R.P	4.54	0.67	0.30	.0020	0.03	0.00	-	-	4.56	0.67	.0020	.028	.037	.009	.005	4.0	281	45	1800	435	1688	0.255		
(S) D-1	6.18	0.93	0.26	.0024	0.19	0.02	-	-	6.37	0.95	.0024	.039	.052	.011	.006	3.9	235	19	1600	331	1853	0.282		
(S) D-2	5.99	1.04	0.34	.0035	0.00	0.00	-	-	5.99	1.04	.0035	.047	.061	.012	.008	4.0	245	22	1600	441	2019	0.282		
(S) D-4	9.59	1.37	0.37	.0051	1.04	0.15	0.16	.0002	10.63	1.52	.0053	.073	.073	.020	.013	4.0	250	58	1600	332	1727	0.329		
(S) D-8	7.20	1.05	0.48	.0050	3.16	0.46	0.36	.0017	10.36	1.51	.0067	.076	.090	.016	.010	3.9	370	141	1600	441	2223	0.323		
Mean D.S.P	7.24	1.10	0.36	.0040	1.10	0.16	-	.0005	8.34	1.26	.0045	.059	.069	.015	.009	4.0	275	60	1600	386	1956	0.304		
Total mean (9)	5.72	0.86	0.33	.0029	0.50	0.07	-	.0002	6.22	0.93	.0031	.041	.051	.011	.007	4.0	268	48	1700	401	1787	0.279		

Soil analysis pre cropping:-

4.4	222	4	2894	441	1853	0.270
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Table 1/D

Experiment 4. Soil - Semongok (2)

Treatments (S-Semongok)	First Crop Wt./pot (mean) gm.		Second Crop Wt./pot (mean) gm.			Total both crops (recovery) Wt./pot (mean) gm.						Soil analysis post cropping Oven dry basis						Total %N						
	Fresh tops	Oven dry basis		Fresh tops	Oven dry basis		Fresh tops	Oven dry basis			pH (H ₂ O)	p.p.m.												
		Dry tops	%P		P total	Dry tops		%P	P total	Dry tops		N	K	Ca	Mg	P 'Res.'	P 'Av.'		K 'Res.'	Ca 'Res.'	Mg 'Res.'			
																						P 'Res.'	P 'Av.'	K 'Res.'	Ca 'Res.'	Mg 'Res.'
(s) P-0	0.23	0.04	0.0002	0.00	-	-	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	130	14	1792	370	1056	0.29
(s) C-1	0.16	0.03	-	0.00	-	-	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	125	26	1716	493	1500	0.29
(s) C-2	0.33	0.05	0.0002	0.00	-	-	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	213	44	1659	505	1464	0.30
(s) C-4	1.28	0.19	0.0006	0.00	-	-	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	229	71	1933	318	1848	0.29
(s) C-8	3.69	0.54	0.0017	0.00	-	-	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	167	86	1840	403	1176	0.28
Mean C.I.R.P.	1.37	0.20	0.0006	0.00	-	-	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	184	57	1787	430	1497	0.29
(s) D-1	3.04	0.52	0.0010	0.00	-	-	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	131	27	2129	465	1464	0.28
(s) D-2	3.88	0.55	0.0019	0.00	-	-	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	166	41	1605	465	1356	0.28
(s) D-4	4.48	0.62	0.0031	0.00	-	-	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	232	50	1307	510	1560	0.29
(s) D-8	7.35	1.01	0.0080	0.00	-	-	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	182	121	2262	668	1692	0.30
Mean D.S.P.	4.69	0.68	0.0035	0.00	-	-	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	178	60	1826	527	1518	0.29
Mean total (9)	2.72	0.39	0.0018	0.00	-	-	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	175	53	1805	466	1457	0.29

Soil analysis pre cropping:-

4.6

160

7

2616

348

1342

0.24

Table 1/E

Experiment 4. Soil - Merit (1)

Treatments (Mt.=Merit)	First Crop Wt./pot (mean) gm.			Second Crop Wt./pot (mean) gm.			Total Both Crops (recovery) Wt./pot (mean) gm.						Soil analysis post cropping Oven dry basis						Total %N		
	Oven dry basis		P total	Oven dry basis		P total	Oven dry basis			pH (H ₂ O)	p.p.m.										
	Fresh tops	Dry tops		%P	Fresh tops		Dry tops	%P	P		N	K	Ca	Mg	P 'Res.'	P 'Av.'	K 'Res.'	Ca 'Res.'		Mg 'Res.'	
(Mt) P-0	0.39	0.06	0.13	0.0001	0.05	0.00	-	0.44	0.06	0.0001	0.003	0.002	0.000	0.000	4.5	21	8	938	422	1032	0.121
(Mt) O-1	1.63	0.25	0.34	0.0009	0.19	0.03	-	1.82	0.28	0.0009	0.014	0.012	0.003	0.002	4.5	44	15	815	485	1008	0.110
(Mt) G-2	3.15	0.39	0.40	0.0016	0.60	0.11	0.16	0.0002	3.65	0.49	0.018	0.026	0.004	0.002	4.4	61	22	970	525	720	0.123
(Mt) G-4	6.15	0.78	0.44	0.0034	3.48	0.50	0.24	0.0012	9.63	1.28	0.046	0.077	0.008	0.005	4.4	80	47	918	475	1116	0.122
(Mt) G-8	7.71	0.94	0.44	0.0041	5.06	0.71	0.36	0.0026	12.77	1.65	0.067	0.091	0.106	0.009	4.4	115	82	818	540	900	0.132
Mean C.I.R.P.	4.66	0.59	0.41	0.0025	2.33	0.34	-	6.97	0.93	0.0035	0.050	0.054	0.006	0.004	4.4	75	42	880	506	936	0.122
(Mt) D-1	3.15	0.39	0.55	0.0021	14.81	1.81	0.32	0.0058	7.96	2.20	0.079	0.110	0.128	0.008	4.4	56	21	870	468	936	0.132
(Mt) D-2	2.63	0.30	0.57	0.0017	13.49	1.67	0.43	0.0072	16.12	1.97	0.089	0.123	0.109	0.009	4.5	44	23	670	438	732	0.129
(Mt) D-4	2.13	0.29	0.79	0.0023	25.44	2.44	0.42	0.0102	27.57	2.73	0.125	0.138	0.211	0.013	4.5	170	37	723	538	780	0.117
(Mt) D-8	3.15	0.38	1.00	0.0038	29.19	2.62	0.60	0.0157	32.34	3.00	0.195	0.166	0.221	0.017	4.6	149	95	718	518	852	0.123
Mean D.S.P.	2.77	0.34	0.73	0.0025	20.73	2.14	0.44	0.0097	23.50	2.48	0.122	0.134	0.167	0.013	4.5	105	44	745	491	825	0.125
Total mean (9)	3.34	0.42	0.52	0.0022	10.26	1.10	-	0.0048	13.59	1.52	0.070	0.082	0.099	0.008	4.5	82	39	827	490	897	0.123

Soil analysis pre cropping:-

5.1	83	7	881	411	677	0.115
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Treatments (N = Nyaleu)	First Crop Wt./pot (mean) gm.				Second Crop Wt./pot (mean) gm.				Total both crops (Recovery) Wt./pot (mean) gm.								Soil analysis post cropping Oven dry basis						Total % N
	Fresh tops		Oven dry basis		Fresh tops		Oven dry basis		Fresh tops		Oven dry basis		P		K		Ca		Mg				
	Wt.	% P	P	Total	Wt.	% P	P	Total	Wt.	% P	P	N	K	Ca	Mg	pH (H ₂ O)	'Res.'	'AV.'	'Res.'	'Ca Res.'	'Mg Res.'		
(N) P-0	3.31	0.50	0.35	.0018	0.00	0.00	-	-	3.31	0.50	.0018	.022	.035	.004	.002	4.1	100	6	3000	352	534	0.089	
(N) C-1	4.68	0.70	0.39	.0027	0.57	0.06	0.15	.0001	5.25	0.76	.0028	.033	.050	.001	.001	3.9	230	14	1600	528	1332	0.206	
(N) C-2	4.80	0.70	0.39	.0027	0.13	0.02	-	-	4.93	0.72	.0027	.031	.050	.005	.004	4.1	130	11	1600	208	623	0.112	
(N) C-4	7.40	1.08	0.36	.0039	1.56	0.22	0.19	.0004	8.96	1.30	.0043	.058	.077	.008	.009	4.1	165	13	1400	416	648	0.138	
(N) C-8	9.14	1.33	0.43	.0057	4.71	0.70	0.30	.0021	13.85	2.03	.0078	.097	.132	.015	.011	4.0	250	14	1200	541	487	0.164	
Mean C.I.R.P	6.15	0.95	0.39	.0038	1.74	0.25	-	.0007	8.25	1.20	.0044	.055	.077	.009	.006	4.0	194	13	1450	423	773	0.155	
(N) D-1	7.42	1.05	0.44	.0046	4.46	0.66	0.17	.0011	11.88	1.71	.0057	.073	.105	.009	.008	4.1	155	13	1900	415	622	0.128	
(N) D-2	5.44	0.77	0.60	.0046	9.13	1.32	0.23	.0030	14.57	2.09	.0076	.094	.132	.007	.007	4.1	160	14	1900	249	599	0.128	
(N) D-4	5.49	0.82	0.67	.0055	6.04	0.90	0.41	.0037	11.53	1.72	.0092	.084	.140	.014	.007	4.0	195	12	1300	311	684	0.115	
(N) D-8	6.70	0.95	0.76	.0072	4.97	0.73	0.65	.0047	11.67	1.68	.0119	.096	.140	.010	.009	4.0	245	14	1600	145	636	0.106	
Mean D.S.P	6.26	0.90	0.62	.0055	6.15	0.90	0.37	.0031	12.41	1.80	.0086	.087	.129	.011	.008	4.1	189	13	1675	280	635	0.119	
Mean total (9)	6.04	0.88	0.49	.0043	3.51	0.51	-	.0017	9.55	1.39	.0060	.065	.096	.009	.006	4.0	188	12	1722	352	685	0.132	

Soil analysis pre cropping:-

4.4	93	3	2056	249	536	0.080
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Treatments (N = Nyalau)	First Crop Wt./pot (mean) gm.				Second Crop Wt./pot (mean) gm.				Total both crops (recovery) Wt./pot (mean) gm.							Soil analysis post cropping Oven dry basis					Total % N					
	Fresh tops		Oven dry basis		Fresh tops		Oven dry basis		Fresh tops	Dry tops	Oven dry basis				pH (H ₂ O)	P. P. m.										
	Dry tops	% P	Dry tops	% P	Dry tops	% P	Dry tops	% P			P	N	K	Ca		Mg	P 'Res.'	P 'Av.'	K 'Res.'	Ca 'Res.'		Mg 'Res.'				
	Total	Total	Total	Total	Total	Total	Total	Total	Total	Total	Total	Total	Total	Total	Total	Total	Total	Total	Total							
(N) P-0	0.15	0.04	-	-	0.00	0.00	-	0.0000	0.15	0.04	0.0000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	4.4	44	7	355	513	197	0.089
(N) C-1	5.43	0.76	0.39	0.030	4.25	0.63	0.19	0.0012	9.68	1.39	0.0042	0.066	0.016	0.010	0.010	0.010	0.016	0.016	0.016	4.5	69	20	355	245	343	0.089
(N) C-2	17.18	1.94	0.36	0.070	7.90	1.09	0.25	0.0027	25.08	3.03	0.0097	0.180	0.025	0.016	0.016	0.016	0.025	0.016	0.016	4.4	74	27	507	511	61	0.086
(N) C-4	21.59	2.11	0.47	0.099	10.73	1.30	0.35	0.0046	32.32	3.41	0.0145	0.172	0.021	0.015	0.015	0.015	0.021	0.015	0.015	4.4	121	56	304	532	86	0.089
(N) C-8	23.10	2.15	0.57	0.123	16.55	1.73	0.41	0.0071	39.65	3.88	0.0194	0.195	0.023	0.020	0.020	0.020	0.023	0.020	0.020	4.4	222	112	408	864	222	0.102
Mean C.I.R.P	16.83	1.74	0.45	0.081	9.86	1.19	0.30	0.0039	26.69	2.93	0.0120	0.140	0.021	0.015	0.015	0.015	0.021	0.015	0.015	4.4	122	54	394	538	178	0.092
(N) D-1	18.38	1.89	0.42	0.079	14.41	1.77	0.25	0.0044	32.79	3.66	0.0123	0.163	0.020	0.016	0.016	0.016	0.020	0.016	0.016	4.6	69	17	407	411	185	0.099
(N) D-2	23.11	2.21	0.53	0.117	17.50	1.79	0.39	0.0070	40.61	4.00	0.0187	0.202	0.021	0.017	0.017	0.017	0.021	0.017	0.017	4.4	74	38	356	411	197	0.102
(N) D-4	19.73	1.89	0.65	0.123	8.90	1.00	0.61	0.0061	28.63	2.89	0.0184	0.152	0.016	0.012	0.012	0.012	0.016	0.012	0.012	4.5	127	71	407	349	246	0.093
(N) D-8	18.73	1.85	0.71	0.131	13.62	1.42	0.71	0.0101	32.35	3.27	0.0232	0.171	0.017	0.011	0.011	0.011	0.017	0.011	0.011	4.4	222	137	356	411	123	0.101
Mean D.S.P	19.99	1.96	0.58	0.113	13.61	1.50	0.49	0.0069	33.60	3.46	0.0182	0.172	0.019	0.014	0.014	0.014	0.019	0.014	0.014	4.5	123	66	382	396	188	0.099
Mean total (9)	16.38	1.65	-	0.086	10.43	1.19	-	0.0048	26.81	2.84	0.0134	0.138	0.018	0.013	0.013	0.013	0.018	0.013	0.013	4.4	114	54	384	472	184	0.094
	4.6	66	5	510	391	136	0.103																			

TABLE 1/1

Experiment 1. Soil - Malang A

Treatments (M = Malang)	First Crop Wt./pot (mean) gm.				Second Crop Wt./pot (mean) gm.				Total both crops (recovery) Wt./pot (mean) gm.							Soil analysis post cropping Oven dry basis						Total % N
	Fresh tops	Oven dry basis			Fresh tops	Oven dry basis			Oven dry basis							p. p. m.						
		Dry tops	% P	P Total		Dry tops	% P	P Total	Fresh tops	Dry tops	P	N	K	Ca	Mg	pH (H ₂ O)	P 'Res.'	P 'Av.'	K 'Res.'	Ca 'Res.'	Mg 'Res.'	
(M) P-0	8.77	1.26	0.31	.0039	0.84	0.08	0.18	.0001	9.61	1.34	.0040	.060	.089	.010	.007	4.0	210	8	2700	465	1497	0.186
(M) C-1	7.66	1.10	0.34	.0037	0.63	0.06	0.17	.0001	8.29	1.16	.0038	.052	.073	.010	.007	4.1	120	12	1600	311	1586	0.106
(M) C-2	10.49	1.45	0.30	.0044	0.89	0.10	0.15	.0002	11.38	1.55	.0046	.075	.088	.011	.007	4.0	245	13	3000	317	1521	0.196
(M) C-4	9.00	1.30	0.34	.0044	1.88	0.25	0.14	.0004	10.88	1.55	.0048	.069	.093	.013	.008	4.0	275	12	3100	550	1460	0.236
(M) C-8	12.25	1.62	0.38	.0062	4.85	0.70	0.22	.0015	17.10	2.32	.0077	.117	.135	.018	.015	4.0	315	17	3400	639	1663	0.175
Mean C.I.R.P	9.85	1.37	0.34	.0047	2.06	0.28	0.17	.0005	11.91	1.64	.0052	.078	.097	.013	.009	4.0	239	13	2775	454	1558	0.178
(M) D-1	10.09	1.48	0.45	.0067	5.63	0.84	0.19	.0016	16.72	2.32	.0083	.113	.115	.018	.011	4.0	230	12	2900	317	1650	0.176
(M) D-2	9.31	1.35	0.43	.0058	6.22	0.91	0.16	.0015	15.53	2.26	.0073	.096	.134	.016	.010	4.0	240	13	3300	529	1522	0.183
(M) D-4	11.27	1.53	0.50	.0077	15.76	1.84	0.23	.0042	27.03	3.37	.0119	.159	.205	.019	.015	4.1	295	17	3000	527	1669	0.209
(M) D-8	11.89	1.58	0.63	.0100	28.47	2.64	0.49	.0129	38.36	4.22	.0229	.228	.280	.034	.018	3.9	400	15	1400	569	1557	0.183
Mean D.S.P	10.64	1.48	0.50	.0075	14.02	1.56	0.27	.0050	24.41	3.04	.0126	.149	.183	.022	.013	4.0	291	14	2650	486	1600	0.188
Mean total (9)	10.08	1.41	0.41	.0059	7.24	0.82	0.21	.0025	17.21	2.23	.0084	.108	.135	.017	.011	4.0	259	13	2711	469	1569	0.183

TABLE 1/J

Experiment 3. Soil - Malang B

Treatments (M = Malang)	First Crop Wt./pot (mean) gm.			Second Crop Wt./pot (mean) gm.			Total both crops (recovery) Wt./pot (mean) gm.							Soil analysis post cropping Oven dry basis						
	Fresh tops	Oven dry basis		Fresh tops	Oven dry basis		Fresh tops	Dry tops	P	N	K	Ca	Mg	pH (H ₂ O)	P 'Res.'	P 'Av.'	K 'Res.'	Ca 'Res.'	Mg 'Res.'	Total % N
		Dry tops	% P		Dry tops	% P															Dry tops	Total
			P Total			P Total														
(M) P-0	0.15	0.01	-	0.73	0.08	-	0.88	0.09	-	.001	-	-	-	4.0	522	29	1530	1499	1982	0.406
(M) C-1	1.70	0.24	0.005	0.58	0.06	-	2.28	0.30	0.005	0.14	0.11	0.03	0.02	4.0	533	70	1702	1182	1289	0.410
(M) C-2	4.71	0.68	0.014	0.80	0.09	0.23	5.51	0.77	0.016	0.43	0.39	0.10	0.05	3.9	572	44	1647	1109	1996	0.401
(M) C-4	10.59	1.46	0.029	1.38	0.20	0.25	11.97	1.66	0.047	1.01	0.88	0.22	0.10	4.0	648	86	1701	1503	1933	0.384
(M) C-8	18.94	2.04	0.065	5.09	0.77	0.27	24.03	2.81	0.086	1.53	1.84	0.37	0.16	3.9	702	114	1648	1396	1868	0.384
Mean C.I.R.P	8.98	1.10	0.031	1.96	0.28	-	10.95	1.38	0.038	0.78	0.80	0.18	0.08	3.9	614	78	1674	1297	1771	0.395
(M) D-1	35.03	3.03	0.34	2.65	0.38	0.23	37.68	3.41	0.112	1.80	1.98	0.43	0.19	4.0	515	11	1884	1384	1592	0.382
(M) D-2	47.55	3.75	0.39	9.16	1.32	0.27	56.71	5.07	0.182	2.65	3.25	0.74	0.30	3.9	572	26	1485	923	1384	0.412
(M) D-4	47.74	3.77	0.54	24.76	2.39	0.44	72.50	6.16	0.309	3.40	3.77	0.84	0.34	4.0	575	38	1384	1230	2080	0.365
(M) D-8	49.50	3.88	0.58	33.14	2.93	0.46	82.64	6.81	0.360	3.48	4.24	0.94	0.38	4.0	647	55	1522	1097	2108	0.375
Mean D.S.P	44.95	3.61	0.46	17.43	1.75	0.35	62.38	5.36	0.241	2.83	3.31	0.74	0.30	4.0	577	32	1569	1158	1791	0.383
Mean total (9)	23.99	2.10	-	8.70	0.91	-	32.69	3.01	0.124	1.61	1.83	0.41	0.17	4.0	587	53	1611	1258	1804	0.391

Soil analysis pre cropping:-

4.5	451	7	1266	778	2069	0.297
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TABLE 1/K
Experiment 4. Soil - Serlin

Treatments (Sn = Serlin)	First Crop Wt./pot (mean) gm.				Second Crop Wt./pot (mean) gm.				Total both crops (recovery) Wt./pot (mean) gm.							Soil analysis post cropping Oven dry basis					
	Fresh tops	Oven dry basis		P Total	Fresh tops	Oven dry basis		P Total	Fresh tops	Oven dry basis						pH (H ₂ O)	P. P. m.					Total % N
	Dry tops	% P		Dry tops	% P			Dry tops	P	N	K	Ca	Mg		P 'Res.'		P 'Av.'	K 'Res.'	Ca 'Res.'	Mg 'Res.'	
(Sn) P-0	0.26	0.04	0.09	0.0000	0.00	0.00	-	0.26	0.04	0.0000	0.002	0.001	0.000	0.000	4.4	127	6	1800	385	1140	0.226
(Sn) C-1	1.60	0.26	0.17	0.0004	0.18	0.03	-	1.78	0.29	0.0004	0.012	0.013	0.002	0.001	4.6	58	14	1562	353	684	0.240
(Sn) C-2	6.64	0.99	0.31	0.0031	0.38	0.06	0.13	7.02	1.05	0.0032	0.048	0.054	0.004	0.006	4.6	172	23	1581	405	720	0.234
(Sn) C-4	7.18	1.00	0.43	0.0043	1.54	0.25	0.18	8.72	1.25	0.0048	0.066	0.071	0.008	0.004	4.5	106	30	1702	355	816	0.214
(Sn) C-8	7.61	1.04	0.48	0.0050	5.64	0.80	0.26	13.25	1.84	0.0071	0.091	0.110	0.008	0.008	4.6	220	73	1690	383	852	0.215
Mean C.I.R.P	5.76	0.82	0.35	0.0032	1.94	0.29	-	7.69	1.11	0.0039	0.054	0.062	0.006	0.005	4.6	139	35	1634	374	768	0.226
(Sn) D-1	3.29	0.48	0.40	0.0019	8.32	1.12	0.31	11.61	1.60	0.0054	0.094	0.070	0.009	0.007	4.3	142	10	1569	243	816	0.223
(Sn) D-2	4.66	0.65	0.50	0.0033	12.74	1.61	0.25	17.40	2.26	0.0073	0.115	0.113	0.010	0.009	4.6	142	13	1518	360	984	0.234
(Sn) D-4	3.89	0.51	0.78	0.0040	24.43	2.40	0.34	28.32	2.91	0.0122	0.147	0.165	0.016	0.010	4.6	104	18	1455	405	792	0.233
(Sn) D-8	5.80	0.75	0.81	0.0061	30.53	2.81	0.54	36.33	3.56	0.0213	0.181	0.273	0.024	0.014	4.7	188	65	1496	460	924	0.210
Mean D.S.P	4.41	0.60	0.62	0.0038	19.01	1.99	0.36	23.42	2.58	0.0116	0.134	0.155	0.015	0.010	4.6	144	27	1510	367	879	0.225
Mean total (9)	4.55	0.64	0.44	0.0031	9.31	1.01	-	13.85	1.64	0.0069	0.084	0.097	0.009	0.007	4.5	140	28	1597	372	859	0.225

Soil analysis pre cropping...

Table 1/M

Experiment 3. Soil - Terbat (1)

Treatments (Te=Terbat)	First Crop Wt./pot (mean) gm.				Second Crop Wt./pot (mean) gm.				Total both crops (recovery) Wt./pot (mean) gm.							Soil analysis post cropping Oven dry basis							
	Fresh tops		Oven dry basis		Fresh tops		Oven dry basis		Fresh tops		Oven dry basis					pH (H ₂ O)	p.p.m.						Total %N
	Wt.	%P	P total	Wt.	%P	P total	Wt.	%P	P	N	K	Ca	Mg	P	P. Av.		K	Ca	Mg				
(Te) P-0	0.08	0.01	-	0.00	0.00	-	0.08	0.01	-	0.001	-	-	-	3.8	1099	11	2116	752	1933	0.331			
(Te) C-1	0.15	0.02	-	0.11	0.01	-	0.26	0.03	-	0.001	-	-	-	4.0	1218	14	1949	536	3217	0.636			
(Te) C-2	0.70	0.08	0.23	0.45	0.05	0.21	1.15	0.13	0.003	0.007	0.008	0.002	0.002	4.3	1101	22	2174	1183	2712	0.288			
(Te) C-4	1.39	0.20	0.18	3.56	0.51	0.23	4.95	0.71	0.016	0.040	0.057	0.009	0.008	4.0	1117	24	1930	983	3604	0.310			
(Te) C-8	4.24	0.62	0.23	7.65	1.09	0.34	11.89	1.71	0.051	0.097	0.094	0.026	0.019	4.0	1280	65	1994	960	3330	0.307			
Mean G.I.R.F.	1.37	0.23	-	2.94	0.42	-	4.56	0.65	0.018	0.036	0.035	0.009	0.007	4.1	1179	31	2012	913	3217	0.385			
(Te) D-1	11.61	1.53	0.30	4.74	0.69	0.29	16.35	2.22	0.066	0.122	0.111	0.028	0.021	4.0	813	9	1811	738	3304	0.638			
(Te) D-2	20.30	2.14	0.40	9.41	1.35	0.22	29.71	3.49	0.116	0.191	0.173	0.043	0.035	3.9	730	12	1894	964	2036	0.306			
(Te) D-4	25.56	2.44	0.41	20.57	2.14	0.34	46.13	4.58	0.173	0.145	0.242	0.060	0.050	4.1	1084	16	1714	742	3856	0.205			
(Te) D-8	25.80	2.45	0.56	24.79	2.37	0.54	50.59	4.82	0.265	0.284	0.239	0.068	0.051	4.2	1163	20	1948	1178	3277	0.294			
Mean D.S.P.	20.82	2.14	0.42	14.88	1.64	0.35	35.70	3.78	0.130	0.186	0.191	0.041	0.039	4.1	948	14	1842	906	3186	0.361			
Mean total (9)	9.98	1.05	-	7.92	0.91	-	17.90	1.97	0.0076	0.099	0.100	0.026	0.021	4.0	1067	21	1948	893	3030	0.369			

Soil analysis pre cropping:-

4.8	992	1	1265	1124	2146	0.336
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Treatments (R = Ramun)	First Crop Wt./pot (mean) gm.					Second Crop Wt./pot (mean) gm.					Total both crops (recovery) Wt./pot (mean) gm.							Soil analysis post cropping Oven dry basis						
	Fresh tops	Oven dry basis			Fresh tops	Oven dry basis			Fresh tops	Oven dry basis			pH (H ₂ O)	P. P. m.						Total % N				
		Dry tops	% P	P Total		Dry tops	% P	P Total		Dry tops	P	N		K	Ca	Mg	'Res.'	'AV.'	'Res.'		'Res.'	'Res.'		
(R) P-0	0.76	0.08	0.12	0.0001	0.00	0.00	-	0.76	0.08	0.0001	0.005	0.002	0.001	0.001	3.9	670	11	2894	314	1592	0.346			
(R) C-1	4.22	0.62	0.27	0.0017	1.89	0.28	0.17	6.11	0.90	0.0022	0.046	0.050	0.008	0.007	4.0	591	26	2730	624	1122	0.322			
(R) C-2	17.08	1.92	0.36	0.0069	4.65	0.68	0.24	21.73	2.60	0.0085	0.130	0.160	0.020	0.019	3.6	669	23	2892	848	764	0.331			
(R) C-4	15.06	1.80	0.33	0.0059	6.95	1.00	0.23	22.01	2.80	0.0082	0.152	0.173	0.022	0.016	4.0	718	40	2660	737	1264	0.335			
(R) C-8	25.67	2.44	0.41	0.0100	11.50	1.55	0.32	37.17	3.99	0.0150	0.152	0.284	0.031	0.023	4.1	958	82	2926	843	1453	0.324			
Mean C.I.R.P	15.51	1.70	0.34	0.0061	6.25	0.88	0.24	21.76	2.57	0.0085	0.120	0.167	0.020	0.016	3.9	734	43	2802	763	1151	0.328			
(R) D-1	16.86	1.90	0.39	0.0074	11.00	1.50	0.26	27.86	3.40	0.0113	0.163	0.216	0.023	0.019	4.2	590	18	2727	935	1994	0.322			
(R) D-2	17.45	1.96	0.47	0.0092	17.51	1.96	0.31	34.96	3.92	0.0153	0.197	0.288	0.036	0.020	4.0	656	18	2937	307	1496	0.308			
(R) D-4	22.50	2.26	0.55	0.0124	33.05	2.93	0.41	55.55	5.19	0.0244	0.266	0.378	0.042	0.029	3.9	660	20	2693	418	1882	0.160			
(R) D-8	24.58	2.37	0.67	0.0159	29.48	2.70	0.50	54.06	5.07	0.0294	0.250	0.375	0.044	0.032	4.2	901	107	2597	944	1448	0.339			
Mean D.S.P.	20.35	2.12	0.52	0.0112	22.76	2.27	0.37	43.11	4.40	0.0201	0.219	0.314	0.036	0.025	4.1	702	41	2739	651	1705	0.282			
Mean total (9)	16.02	1.71	0.40	0.0077	12.89	1.40	-	28.91	3.11	0.0127	0.151	0.214	0.025	0.018	4.0	713	38	2784	663	1446	0.310			

Soil analysis pre cropping:-

4.0	226	13	2729	788	1661	0.427
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THE 1968 RECONNAISSANCE SOIL MAP OF MALAYA

by

LAW WEI MIN & K. SELVADURAI
Department of Agriculture,
West Malaysia.

Session 4/2

INTRODUCTION

Prior to the mid-nineteen fifties, soil surveys were carried out on an ad hoc basis, for specific purposes only. The systematic reconnaissance soil survey of the whole country was only started in 1957 and in 1963 a target date was set for the completion of this ambitious project. With a tremendous burst of combined effort from personnel under the Colombo Plan from Canada and New Zealand, the U.S. Peace Corps and the present soil survey staff during the last four years, the whole country topographically suitable for agricultural development was traversed by 1967. Reports of some of these survey areas have been published either as Bulletins of the Department of Agriculture or as the Malayan Soil Survey Report Series. The reports of the remaining areas are in various stages of being published.

This paper represents the compilation of the efforts of each and every member of the survey teams connected with this national project. This is a very much needed revision of the 1962 soil map of Malaya, especially so since agricultural development in this country has progressed at such a tremendous rate.

Some of the information inferred using the air reconnaissance maps which show only form lines were not as accurate as to be desired. Where such air reconnaissance maps have been replaced by the New Series topographical maps, these areas have been revised and brought up to date. Hence the accompanying map of a scale of 1:500,000 (7.89 miles to 1 inch) is as accurate as the scale of the soil surveys allows for.

Field mapping consisted of the examination of the soils along roads, tracks, and paths in the developed areas and along timber tracks, paths and river banks in the undeveloped areas. Where the undeveloped areas are not served by timber tracks or paths, a network of rentis² was cut through such forested areas with the rentis normally in an east-west direction so as to cut across the normally NNW-SSE trending geological formations. These rentis² were spaced at 2 to 2½ miles apart, and were either traversed and the soils examined and identified using a 2 inch screw auger mounted on a 3 feet 6 inches long shaft at regular intervals of 10 chains or less, or the samples were collected at 20 chain intervals using a 6 inch post hole auger at 0-6, 6-12, 12-24 & 24-36 inches depths and these samples were examined and identified.

The soils were identified as series in the field, as defined in Leamy & Panton, 1966 p. 64, but because of the scale of survey it has not been possible to show the series in all cases. The main mapping unit is the soil association, where two or more soil series occurring in a definite geographical pattern were combined to form a mapping unit. Other mapping units of convenience were also employed, often on a geomorphological or physiographical entity. These included steep land, urban and mining land local alluvial soils, etc.

It has been decided after much thought to produce the soil map showing the mapping units rather than any form of groupings on a higher classification category. The main users of this map being the Soil Scientists, Land Development Planners other Research Workers, Agricultural Extension Officers etc., a map showing the mapping units would in this case be of more practical use. Before this map goes into final printing, the major changes envisaged at this moment are (i) breakdown the steep land

Rentis² - Malay word for a trace cut on a set compass bearing.

unit into the various hill soils related to the more mature soils formed on similar rock types over easier terrain; (ii) amendments to the soil boundaries after field checking especially in the Kelantan, Trengganu and Kedah surveys.

A generalised soil map showing the great soil groups will be produced in the near future. This map is presented to this 3rd Malaysian Soil Conference to evoke comments and discussion which may be of help in preparing the final report on the soils of Malaya, which will be a much more comprehensive attempt than what is being presented now.

SOILS

The terms 'sedentary' and 'alluvial' soils are familiar to soil workers in West Malaysia and the following brief descriptions of the soils are given under these two headings. Further sub-divisions are based on the influence of the parent rocks/material on the formation of the soils. Only those series listed in the legend are described, but it must be pointed out that the mapping units here do include to a minor extent other soils mapped in the field but excluded in the mapping units because of the large scale of the map.

I - SEDENTARY SOILS ON

1. Igneous Rocks

KUANTAN SERIES

The soil is developed on basaltic flows on rolling to hilly terrain in the vicinity of Kuantan, the capital of Pahang. This is a reddish brown very friable and uniform clay to heavy clay. The profile shows almost a total lack of horizon differentiation. Structures are moderately to strongly developed medium granular and subangular blocky throughout. Laterite may be present but at depths of more than 5 feet and also mainly massive. Although having a high P content (conc. HCl extract ranges from 400 - 600 ppm), the bases are low and base saturations are less than 5%. Total Fe_2O_3 is more than 20%. This is a Class I soil highly suitable for a very wide range of tree crops. On flat terrain, short term crops are also suitable. Establishment of crops, however, is difficult during the drier months, due to the porous nature of the soil.

SEGAMAT SERIES

The parent material is derived from andesite or andesitic tuffs, and the soil is found on rolling to hilly terrain in central Pahang extending north into Trengganu and south into Johore. The yellowish red to red, very friable clay to heavy clay with a strong medium subangular blocky structure is not likely to be confused with any other soil in Malaya. Horizon differentiation is very indistinct. Laterite when present occurs as a distinct band of nodules at depths of 4 feet or more. Both the soluble and total P are lower than that of the Kuantan Series, but the bases are higher giving it a higher base saturation. This is a Class I soil and crop establishment again should be timed for the rainy seasons.

KATONG SERIES

The soil is found on quartz andesite over rolling and hilly terrain in central Pahang. It is yellower and siltier than the Segamat, and easily mistaken for the Munchong Series, but shows a more distinct Ae/Bt horizonation than the Munchong does. Structures are moderate medium subangular and clayskins moderate. This is mainly a Class I soil, well suited to diversified cropping except when the slopes are steep.

JEMPOL SERIES

This soil is found on rolling to hilly terrain and occasionally on steep terrain. It is formed on volcanic agglomerate or ferruginous shales in central Pahang mainly. The colour is reddish brown to yellowish red, with clay loam or sandy clay textures and moderate medium subangular blocky structures. Although having a reddish brown colour the total Fe_2O_3 is below 4%. Laterite nodules or laterised parent material are common as a band at auger depth. This is a Class I soil on the easier terrain and Class III on the steeper slopes.

KAMPONG KOLAM SERIES

The parent rock is dioritic in composition or its equivalents and the soil developed on these rocks are found in central Pahang and Trengganu over rolling and hilly terrain. The soil is yellowish red to red in colour, clay loam to clay texture with moderate to strong medium subangular blocky structures. Consistence is friable in the top and increases in firmness with depth. Horizonation is relatively distinct with a weak eluvial A on the textural B. Exchangeable magnesium is greater than other cations although the profile is well leached. This is a Class I soil, except where the terrain tends to be on the steep side.

JERANGAU SERIES

This is a fine sandy clay loam to fine sandy clay on undulating to hilly terrain in Trengganu, Pahang and Johore closely associated with the Rengam Series. The parent rock is granodioritic in composition and finer in texture than the granites. The colour of the top four feet is strong brown but at depths it is yellowish red. Consistence is friable at the top and firm at depth. Structures are moderate to strong fine and medium subangular blocky. Horizonation is moderately distinct with Ae/Bt and the clayskins are moderate. The profile is well leached of nutrients. This is a Class I soil, well suited to oil palm except at the steep slopes.

RENGAM SERIES

This soil is formed on granites over undulating and rolling terrain, but when associated with the Bukit Temiang Series can be found on steep terrain. The soil is very widespread, especially in Johore and Pahang. There is normally about 5 feet or more of brownish yellow or yellowish brown coarse sandy clay loam to coarse sandy clay overlying light red coarse sandy to gravelly clay. It is friable throughout with weak to moderate medium subangular blocky structures. Horizonation is distinctly Ae/Bt. Easily soluble P is normally below 60 ppm and K below 30 ppm. Bases are low. This is a Class I soil well suited to most tree crops, but conservation measures are essential on the steeper slopes as it is easily eroded.

KALA SERIES

This soil formed on the porphyritic granites in the north of Perak on hilly to steep terrain. The solum is brownish yellow to strong brown overlying a coarsely mottled parent material, due mainly to the persistence of the partly weathered phenocrysts of microcline or orthoclase feldspar in a matrix of yellowish red coarse to gravelly clay. Consistence is friable at the top and firm at depth, while the structures are moderately developed medium subangular blocky. The P content is comparable to that of the Rengam Series, but the K is much higher due to the presence of the orthoclase feldspars in the parent rock. This is essentially a Class III soil because of terrain, and erosion is particularly severe when the soil is exposed.

TAMPIN SERIES

This soil is developed on highly siliceous and coarse grained granites over undulating terrain closely associated with the Rengam Series in parts of Negeri Sembilan, Trengganu, Pahang and Malacca. The top 12-18" is friable to loose gravelly clay loam, very pale brown to light grey in colour with weak subangular blocky structures. There is a very abrupt change to the weak textural B, pale brown or yellow firm gravelly clay, with weak medium angular blocky structures. The easily soluble P is very low but the K is slightly higher which could be due to the presence of the potassic feldspars in the very acid granites. This is a Class III soil offering poor conditions for tilth and therefore more suited to tree crops.

KULAI SERIES

Kulai Series is formed on rhyolitic tuffs or rhyolites over rolling and hilly terrain in Johore and Pahang. Colour is pale yellowish brown to strong brown at depth, texture ranges from loam to silty clay while the firm weak angular blocky subsoil will distinguish it from the Batu Anam Series in which the subsoil tends to be prismatic and compacted. Horizonation is distinctly eluvial A overlying the textural B. This is a Class III soil because of terrain but with good management, oil palm has been grown successfully in parts of Johore.

YONG PENG SERIES

The soil is formed on dacite on undulating to steep terrain in parts of Johore. This is normally a shallow soil with only about 2 feet of strong brown friable clay loam to clay overlying the firm yellowish red clay with a laterite layer varying in thickness from a couple of inches thick to 12 inches lying on top of this horizon. The structure is moderate medium subangular blocky in the top and medium to strong angular blocky in the subsoil. This is a Class III soil but with judicious management oil palm has been planted successfully on this soil.

2. Metamorphic Rocks

FRANG SERIES

The parent material is derived from the more basic schists in parts of Selangor, Pahang and Kelantan. The terrain ranges from rolling to steep, and the soil becomes shallower with steepness of slopes. Horizonation is weak, with a very friable yellowish red heavy clay overlying a friable yellowish red heavy clay, the structures are moderate to strong fine and medium subangular blocky. Clayskin is weak. Laterite may be present, but usually at depths. This is a Class I soil.

BATANG MERBAU SERIES

The soil is formed on schists over undulating to hilly terrain in parts on Kelantan, Central Pahang and Johore. Horizonation is distinct with a friable yellowish brown silty clay loam overlying a firm fine clay loam to silty clay. The structures are weak subangular blocky and the profile is often micaceous. This is a Class II soil on the easier terrain and steepness of slope limits the development of this soil.

SEREMBAN SERIES

The soil formed on quartz-mica schists intermixed with phyllites and vein quartz, over undulating to hilly terrain in parts of Selangor and Pahang, generally where the contact between the sediments and the granitic intrusion is reached. The A horizons are greyish brown to yellowish brown friable to firm fine sandy clay loam overlying the reddish yellow to yellowish red firm fine sandy clay. Structures are moderate medium subangular blocky. Quartz gravels and angular pebbles together with laterized pieces of schists or phyllites are characteristic of this soil. This is a Class III soil.

3. Argillaceous Sedimentary Rocks

MUNCHONG SERIES

This is a wide spread soil found on shales or mildly metamorphosed shales over rolling to undulating terrain in Perak, Selangor, Negeri Sembilan, Johore and Pahang. This is a silty clay loam to silty clay, yellowish brown to strong brown or redder but colour is normally uniform to more than 4 feet depth. Structures are moderate to strong fine and medium subangular blocky with moderate clay skins. Consistence is friable

at the top but increases in firmness with depth. Normally free of laterite, but thin bands of nodules are found well below 4 feet depth. A Class I soil well suited to diversified cropping.

CHENIAN SERIES

These soils have been mapped only in North Perak on rolling to undulating terrain. The parent material is mixed shale and quartz porphyry. The soil is easily recognized by the highly mottled yellow to yellowish brown silty clay to clay loam subsoil, with very well developed angular blocky structures and well developed clay skins. A stoneline of angular vein quartz is normal at 3 feet depth. Only tapioca has been planted on this soil to date, but oil palm should do reasonably well on this soil.

JERAM SERIES

This has been mapped only in Pahang over rolling and hilly terrain on reddish or ferruginous shales. It is easily recognized by the firm and very well developed blocky subsoil and the reddish brown to yellowish red colours. Textures are normally silty clay loam. Depth to the parent rock varies from 30 inches to less than 24 inches depending on the steepness of the slopes. So far this soil is not developed as yet for agriculture but the physical properties will tend to limit it to more tolerant tree crops.

DURIAN SERIES

This is a very widespread soil formed on shales and phyllites on rolling to hilly terrain stretching from Kelantan through central Pahang to Negeri Sembilan and also small patches in Johore. It varies in depth according to the steepness of the terrain. The A horizons are friable brownish yellow silty clay overlying the firm to very firm strong brown to yellowish red clay. The subsoil structures are moderate angular blocky to prismatic. The underlying parent material is a variegated red and pale yellow clay, with weak to massive structures. A band of laterite some 6 - 9 inches thick is common on top of the variegated horizon. It is low in P but is above average in K and very high in K when formed on phyllite. This is a Class III marginal to oil palm and more demanding crops.

BATU ANAM SERIES

The Batu Anam Series stretches from the west and west-central Johore to Negeri Sembilan into central Pahang, formed on shales (pale coloured) over undulating terrain. This is a pale coloured clay with a firm and very firm and compacted subsoil. Structures are strong medium subangular in the A's and medium to coarse angular to prisms in the B's. The underlying parent material is a very variegated massive heavy clay, with colours including red, yellowish red and yellow and pale grey. Laterite occurs as a thin band overlying the parent material. Rubber has been grown in wide acreages and although oil palm has been grown the yields are low. The soil is very low in P but has reasonable K values.

MARANG SERIES

First mapped in Trengganu, this is now found in parts of central Pahang and Negeri Sembilan on rolling and hilly terrain over shales interbedded with sandy lenses and vein quartz or siltstones. It occurs in close association with the Apek Series, and generally occupying the upper slopes. The friable A horizons of fine sandy loam are pale brown to light grey in colour overlying the firm and compacted subsoil of fine sandy clay loam, yellow to brownish yellow with mottles. The parent material is light grey with reddish mottles, massive and sticky. This soil is very low in P & K and is a Class III soil.

APEK SERIES

This is located in Johore and Trengganu, on greysilty shales over undulating and rolling terrain. It occurs in close association with the Marang Series, often being found on lower slopes to the Marang. The topsoil is a grey loose weakly crumbed fine sandy to silt loam overlying the rather compact light grey fine sandy clay loam with weak structures. The underlying parent rock is present within 3 feet depth. This is a Class III soil.

KUALA BRANG SERIES

The soil is formed on silty shales or shales interbedded with quartzites over rolling to steep terrain consisting of long ridges running NNW-SSE in Trengganu and Kelantan. The horizonation is a weak Ae/Bt, with a yellowish brown to brownish yellow fine sandy loam overlying the fine sandy clay loam. Consistence is friable in the A's but becomes firm with depth. Structures are weak to moderate medium subangular with moderate clayskins. The parent material with shale fragments and vein quartz is reached within 3 feet on easy terrain but becomes very shallow on the steep slopes. The soil is Class II on rolling terrain and Class V on the steep terrain. Rubber is successfully grown on this soil, but oil palm will require proper techniques of management.

POHOI SERIES

The brown or olive brown colour is peculiar to this soil formed on the carbonaceous shales over the low hills in East Pahang and Johore. Texture varied from clay loam to fine sandy clay, with moderate medium subangular blocky structures which becomes coarse with depth. The consistence is friable in the upper portions of the profile and becomes firmer with depth. On steeper slopes a laterite band with shale pieces may be present. On the easy terrain this is a Class II soil, while the steep terrain will lower the suitability Class to V.

KEMUNING SERIES

The soil is formed on very dark carbonaceous shales and silt stones over rolling to hilly terrain in Kelantan and east Johore. It is characterized by a greyish brown uniform clay loam to clay with firm consistence and moderate medium subangular blocky structures. Depth of soil varies with steepness of slope, being less than 3 feet even on easy terrain, sometimes with hard, almost black silt stones and shales scattered in the profile. This is a Class II soil on the easier terrain, but is not suitable for agriculture on the steep terrain.

PADANG BESAR SERIES

This is located in south Kedah, derived from silt stones on flat to undulating terrain. It is characterized by a very high proportion of silt, with less than a foot of yellowish brown silt loam with weak medium subangular blocky structure overlying the yellowish red pisolitic laterite concretions in a yellowish brown silt loam matrix. The parent material is pale coloured with red mottles. This is a Class III soil.

GAJAH MATI SERIES

The soil is easily recognized by the presence of the dense laterite layer of pisolitic nodules occurring at an average of 18 inches from the surface, and on nearly flat to undulating terrain. It is formed on shales mainly in Kedah. The eluvial A overlying the dense laterite nodules is a strong brown very friable clay loam. The laterite nodules increase in abundance and compactness with depth. This is a Class III soil, suitable for the more tolerant crops only.

TAVY SERIES

This soil consists of some 12 - 18" of laterite-free friable sandy clay loam with weak to moderate subangular blocky structures and yellowish or strong brown colours. The laterite band consists of well rounded nodules in the upper portion and subangular to angular fragments in the lower portion, embeded in a yellowish red to red fine sandy clay or silty clay matrix, with moderate medium subangular blocky structures. The laterite layer is normally less than 2 feet thick and overlies the variegated parent material of massive clay. This soil is formed on shales over undulating to hilly terrain in Pahang, Johore and parts of Kedah. This is a Class III soil, well suited for rubber but marginal to oil palm.

MALACCA SERIES

This is a well known laterite soil in Johore, Pahang, Negeri Sembilan and Malacca. It either occurs on flat to undulating terrain as in Temerloh, or forms cappings on low hills of shales. Laterite boulders may litter the surface, but more commonly the laterite which occurs in the form of well rounded nodules in the top portion rapidly increases in size and becomes very irregularly shaped at depth. Laterite boulders of varying sizes may be scattered throughout the profile. Overlying the laterite is the brownish yellow or redder clay loam or fine sandy clay with strong fine and medium subangular blocky and granular structures. Underlying the laterite is the "mottled zone" clay, massive with reddish yellow and light grey streaks. Depending on the thickness of the laterite-free horizon above and the degree of laterization, Malacca has been classed as III or.V.

BUNGOR SERIES

This soil is common in Pahang and Negeri Sembilan, over undulating to steep terrain and is formed on shales interbedded with sandstones. It is characterised by yellowish brown or brownish fine sandy clay loam to fine sandy clay, and strong medium subangular blocky structures and strong clayskins, in the subsoil. The profile is strongly podzolic. On easier terrain it is at least a Class II soil, but is Class V on the steep terrain.

4. Arenaceous Sedimentary Rocks

SERDANG SERIES

This soil is widespread throughout Malaya on undulating to hilly terrain formed on sandstones, quartzites or conglomerates, and thus the texture is commonly coarse sandy loam to sandy clay loam or even sandy clay depending on whether the parent material is mixed with shales or not. The colour is commonly strong brown but may be yellowish brown or brownish yellow. The structures are weak to moderate fine and medium subangular blocky. Clayskins are weak and the profile is friable throughout. Horizonation is distinctly podzolic. This is a Class I soil, but even then care should be exercised because it is easily eroded. On steeper slopes, especially when associated with the shallow Kedah Series, the soil is Class III.

KEDAH SERIES

The Kedah Series is limited to the quartzite or conglomerate ridges which form such an outstanding feature of the arenaceous countryside. The slopes are in excess of 20° and the soil formed on these ridges are shallow profiles, but are still reasonably developed to be considered as a shallow relative of the mature Serdang Series, except on the very steep slopes where the proper lithosols are to be found. Depending on the cementing matrix of the parent rock, which may be sands to silts or even clays, the texture ranges from sandy loam to sandy clay. The colour is strong brown and structures are weak to moderate except on the lithosols

which is structureless. Laterite concretions and laterised shale pieces may be present when interbedded with shales. This soil is not suitable for agriculture because of the steepness and shallowness.

POKOK SENGA SERIES

This is mapped in Kedah and Johore, formed on quartzite/sandstones over flat to undulating terrain. The A horizon is a brown fine sandy loam overlying the yellowish brown loam with fine weak to moderate subangular blocky structures overlying the laterite layer of loosely packed pisolitic concretions in which the matrix is of the same colour and texture as the A horizon above. The underlying pale coloured clay with red streaks is the parent material with weathered sand stones/quartzites beneath. This is a Class III soil.

II - ALLUVIAL SOIL ON

1. Older Alluvium

HARIMAU SERIES

The soil is developed on older alluvium over undulating to rolling terrain, in Johore and parts of Pahang and Perak. The yellowish brown to brownish yellow sandy clay loam to sandy clay with weak to moderate medium subangular blocky structures and weak clayskins is easily mistaken for the Rengam Series. So far they have not been found above the 300 feet contour. Because of the sedimentary nature of the parent material, the quartz grits present throughout the profile have been partly sorted, which is not the case with the Rengam Series. Although classed as a Class II soil, due to the deficiency of manganese in the rubber, the correct fertiliser application on the oil palm has given most encouraging yields of around 8 tons of f.f.b. per acre per annum.

ULU TIRAM SERIES

The soil is developed on coarsely textured older alluvium over mildly dissected topography at elevations of up to 150 feet in Johore, and parts of central Pahang. The profile consists of about 2 feet of yellowish brown friable sandy loam to sandy clay loam with weak structures overlying the firm and compact coarse sandy loam or gravelly loam. This is a Class III soil.

TAMPOI SERIES

This is also formed on the older alluvium over undulating terrain in Johore at elevations of between 50 - 150 feet but at higher elevations in the Tasek Bera region of Pahang. The redder colours and heavier texture with the coarse blocky structures which break into weak crumbs and firm consistence distinguishes this from the Harimau. When associated with the Harimau Series, it always occupies the lower and more moist positions. This is a Class III soil, but with proper management oil palms have yielded reasonable as well as the Harimau.

KAWANG SERIES

This is mapped in the recent surveys of central Pahang located on highly dissected high terraces of the Sungai Pahang and tributaries. The surface soil is friable, yellowish brown sandy loam to sandy clay loam with weak to moderate fine subangular blocky structures which overlies the brownish yellow to reddish yellow, friable clay loam to gravelly clay with moderate medium and fine subangular blocky structures. Quartz grits occur as thin bands. Beneath is the thick layer of very well rounded quartz pebbles in a matrix of quartz grits and clay. The deposits sit on the moderately dissected old surface with a thin band of iron-rich hardpan at the contact. This is a Class III soil suitable for a more tolerant crop.

KLAU SERIES

This is located at elevations of about 300 feet above sea level on mildly dissected high terrace of the major rivers in central Pahang and Province. The main diagnostic feature is the presence of well sorted quartz gravels which increase in abundance and size with depth. The profile is reasonably developed with a weak Ae. It consists of friable yellowish brown to brownish yellow sandy clay loam with moderate fine and medium subangular blocky structures overlying a firm brownish yellow to strong brown coarse sandy clay with weak to moderate medium and coarse subangular blocky structures. The clayskins are weak to moderate. The parent material is a mottled, very gravelly coarse sandy clay and sits on the dissected old surface. Rubber has done very well on this soil, and oil palm is expected to do well too.

2. Sub-recent Alluvium

HOLYROOD SERIES

The Holyrood Series is formed on sandy lowlying terrace alluvium bordering the coasts in Perak and Pahang, and the old beaches in Johore. It is a very friable, yellowish brown weakly developed sandy loam to sandy clay loam. Nutrients are variable, being slightly higher in the heavier textured soils, but are very low by Malayan standards. This is a Class III soil for tree crops, but should be a good medium for tapioca, ground-nuts, maize and sugarcane.

LUNAS SERIES

Closely associated with the Holyrood Series, this is located in depressions where the watertable is high. This gives rise to the pale grey colours and the weak structures. Textures vary from sandy loam to sandy clay loam, although clay phase of this Series has been mapped in Pahang. This soil offers very poor tilth and is a Class III soil.

RASAU SERIES

This has been mapped in east Pahang at elevations of about 100 feet a.s.l., occupying the slightly higher and more dissected surface than the Holyrood Series with which it is closely associated. The texture of sandy clay loam at the top and sandy clay at depth distinguished this from the Holyrood, at the same time the consistence is firmer. It is reasonable to expect that this soil would be slightly higher in nutrients than the sandy Holyrood. At present it is put into a Class III soil.

SOGOMANA SERIES

This soil has only been mapped along the coast in Perak on the low lying flat terrace at elevations of less than 50 feet above sea level. The subsoil is light grey to white silty clay to clay with weak coarse prismatic structures which break down to angular blocks. The consistence is firm and moderately compact. Reddish yellow mottling is normal, occupying about 10% of the soil volume. Below is the white stiff compacted massive clay. When adequately drained this soil has proved suitable for rubber. This is a Class III soil.

SITIAWAN SERIES

This is found in close association with the Sogomana Series but occupies the higher areas which may be about 5 feet above only. The soil is characterised by a highly mottled pale yellow or yellow clay, with the mottles increasing both in size, abundance and distinctness with depth. Structures are moderate coarse angular blocky and consistence is always firm. Rubber does well in this soil and oil palm has been established successfully. This is a Class II soil.

MANIK SERIES

This soil has been mapped in Perak on the subrecent alluvial, and normally occurs as narrow stretches rising above the generally flat terrace. It is characterised by a grey top of mottled clay loam to clay with weak subangular blocky structures. The subsoil is a light grey sparsely mottled clay with quartz gravels and moderate coarse subangular blocky structures. The parent material is a white mottled coarse gravelly clay, compact and firm with weak coarse angular blocky structures. This soil offers a very poor tilth and is a Class III soil.

3. Recent Riverine Alluvium

TELEMONG SERIES

The soil is formed on the levees of the larger rivers throughout Malaya and is generally a weakly structured friable loamy sand or sandy loam with colours varying from brown to brownish yellow to strong brown. This is essentially an AC profile, and because of its youthfulness is relatively high in nutrients. This soil is well suited for annual crops like tobacco, maize, groundnuts tapioca and sweet potatoes. This has been placed as a Class II soil because of susceptibility to flooding.

AKOB SERIES

The soil is formed on the riverine alluvium on the flood plain of the larger rivers throughout Malaya. This being so, the texture varies considerably, depending on the parent material. The soil is characterised by weak horizon development, colours range from yellowish brown to paler colours, with mottles becoming more pronounced in the horizon underlying the weak eluvial A. Dark soft concretions (manganese?) are common at the top of the mottled horizon. Structures are weak medium subangular blocky. With good water control, this soil is suitable for a wide range of annual crops including maize, tobacco, etc. and with irrigation suited for wet padi. This has been placed as a Class II soil because of susceptibility to annual flooding.

LOCAL ALLUVIUM

This mapping unit includes all soils formed on the alluvia of the smaller rivers and streams and invariably shows a certain degree of gleying. The texture is variable but normally heavy. Structure is poor and consistency is firm at depth. The water table is usually high.

4. Marine Alluvium

BRIAH SERIES

The Briah Series is commonly formed on a mixture of recent riverine and recent marine alluvium, especially so when the soils are located along the levees of the rivers passing through the marine coastal plain. The soil is characterised by a dark brown silty clay top with strong medium crumbs and granules, with distinct mottles along root channels. The underlying subsoil is light brown or brownish grey silty clay loam or silty clay with pronounced mottles along pores and channels with strong or moderate medium subangular blocky structures. The parent material is a brownish grey silty clay with little mottles, weakly structured and rests on a bluish grey sticky clay often with slight sulphurous smell. The clay minerals show a mixture of vermiculite with montmorillonite and kaolinite. With adequate drainage this soil will support a very good stand of oil palm.

SELANGOR SERIES

The Selangor Series is formed on the flat coastal alluvial of the West Coast. Under natural conditions, the high water table has resulted in the depth of the clay parent material to be at depths of less than two feet. Most of these areas however have been well developed and the improved drainage has resulted in a well developed soil in a very short space of time. The topsoil is dark brown silty clay loam with moderate medium and fine crumbs overlying the dark greyish brown or greyish brown friable silty clay with weak to moderate coarse prisms, and structural faces stained with reddish mottles. The subsoil proper is dark greyish brown to greyish brown with weak to moderate coarse prisms or angular blocks again with stains along the structural faces. Beneath is the bluish grey structureless clay, often with a faint sulphurous smell. This is the most fertile soil in Malaya with high reserves of nutrients and clay minerals dominated with montmorillonite. Rubber has been known to maintain a good yield with minimum fertilizer application.

KANGKONG SERIES

The Kangkong Series is formed on the more recent marine clay deposits of the west coast, especially Kedah and Selangor. It is characterised by grey, light grey or greenish grey clay subsoil, with moderate coarse prisms or angular blocky structures and strong brown or reddish brown mottles. Soft concretions of various colours are common in this horizon. The parent material is a massive bluish grey clay. It is also one of the most fertile soils in Malaya.

TELOK SERIES

This occurs in close associations with the Selangor Series, occupying the low lying depressions of the coastal alluvial plain. The topsoil is generally organic while the subsurface horizon is greyish brown or dark greyish brown with abundant yellowish red mottles along the structural faces and root channels. The structures are moderate coarse blocky. The underlying parent material is a greenish grey massive clay with distinct sulphurous smell, and undecomposed plant roots. The pH is generally below 4 and drops down to below 2 in the parent material. This is an acid sulphate soil, and yellow jarosite may be present in the subsoil. This is a Class IV soil, and will require special techniques to bring this under proper cultivation.

LINAU SERIES

This is found in brackish water environment along the west coasts of Johore, Selangor, Malacca etc. with a very dark greyish brown organic clay topsoil, overlying the dark brown muck with some decayed plant remains, and slight sulphurous smell, with the bluish structureless clay beneath, with strong sulphurous smell and abundant plant remains. Occasionally yellow deposit can be seen along root channels throughout the profile. This acid sulphate clay is a Class IV soil, and will require a lot of amelioration before cultivation can be contemplated.

KRANJI SERIES

This is located as a narrow fringe along the west coasts on the marine clays under swamp conditions. The profile consists of a thin topsoil of dark greyish brown organic clay, with friable weak structures overlying the permanently waterlogged greenish grey sticky and structureless clay with sulphurous smell at depths and plant remains. These are very saline soils, and with bunding and drainage has supported some coconuts and padi.

RUDUA SERIES

This is formed on old beach ridges which run parallel to the coast along the east coast from Kelantan down to Johore and also along a short stretch in Perak. The topsoil is loose sand stained with humus and overlying a light grey to white eluvial A. Beneath is the slightly compacted and cemented iron-humus horizon located at depths varying from 2½ feet to four feet. The soil is very low in nutrients and poses a special problem in development.

RUSILA SERIES

This soil is closely related to the Rudua Series and occupies the lower slopes of the old beach ridges and gradually merges with the old lagoon back waters with peat of varying depths at the lowest waterlogged portions. The dark grey topsoil of loose sand overlies the light grey to sand or clayey sand. Beneath is the iron stained horizon generally above the water table, which is generally very high. Padi has been planted on this but with low yields.

JAMBU SERIES

This series is essentially similar to the Rudua Series, with the iron-humus layer being located at depth varying from below 4 feet to more than 10 feet depth. They seem to be located on very high beach ridges, in Perak and Pahang and as small patches in Johore and Selangor. The eluvial A of almost white sand is almost devoid of nutrients. Coconuts grown on this soil are very poor.

5. Organic Soils

ORGANIC CLAYS AND MUCKS

These are generally found surrounding the peat proper, with the former having loss of ignition of up to 25% and the latter of 25 - 65%. The overlying organic layer varies from 12 inches to more than 2 feet. The underlying material is usually clay on the west coast but is sandy along the east coast. On the west coast, with adequate drainage, oil palm has been yield above average.

PEAT

Peat is material with loss of ignition of above 65%. The peat has not been differentiated at all but only depth has been recorded. Peat has been formed on the former lagoons behind the forebeach, along both east and west coasts. The underlying material is clay on the west and sandy clay on the east. Pineapple has been doing well on drained peat, otherwise peat of more than 5 feet depth poses special problems to agricultural, chief among which are deficiency in micronutrients and acidity.

6. Miscellaneous Mapping Units

URBAN AND MINED LANDS

These consist of land disturbed by urban development or mining activities. The former are the townships, while the latter consists of tin tailings mainly which are nothing but sands washed clean of nutrients, or spoils on the iron mines. Mined lands will take a long time and effort to develop into soils suitable for agriculture.

STEEPLAND

These include all land with average slopes of more than 20° slope, and are considered not suitable for normal agriculture. The soils in most cases have shallow immature profiles, and are related to the mature

soils developed on similar parent materials/rocks on easier terrain.

PADI SOILS

The main padi plains of the north western corner(Kedah/Perlis) has been mapped on a semi-detailed scale and the map produced, while the other main padi plain in the north east Kelantan is being resurveyed. Indication at present have indicated that the Kedah plain is mainly mixed riverine/marine and marine parent material while the Kelantan plain is mainly subrecent alluvial or riverine alluvial in origin. This being so, the Kedah plain soils are higher in nutrient reserves that of the Kelantan plain.

SOIL ASSOCIATIONS

Class J	JOHORE	KEDAH	KELANTAN	MALACCA	NEGERI SEMBILAN	PAHANG	PROVINCE & PENANG	PERAK	PERLIS	SELANGOR	TRENGGANU	TOTAL	% MALAYSIA
Class I													
Kuantan	-	-	-	-	-	30700	-	-	-	-	8000	30700	0.12
Segamat-Katong-Jempol	65400	-	-	-	-	183700	-	-	-	-	5600	254700	0.78
Rengam-Jerangau-Kg. Kolan-Tampin	1175000	33500	195700	143500	291700	605000	39900	298900	-	118000	488600	3389800	10.42
Prang	12000	-	-	2800	-	16300	-	-	-	6000	-	37100	0.11
Munchong-Bungor-Serdang	26300	46200	-	-	-	344000	-	135500	-	-	-	552000	1.70
Serdang-Munchong-Jeram	187300	223200	-	3600	9600	520500	-	237500	13600	168200	-	1363500	4.20
Selangor-Briah-Kangkong	-	10000	-	-	-	-	800	246300	-	319200	-	576300	1.71
Briah-Akob	130300	-	-	15900	6000	127500	-	18700	-	27100	-	325500	1.00
	1596300	312900	195700	165800	307300	1827700	40700	936900	13600	638500	502200	6537600	20.10
Class II													
Kia-Rengam	-	-	-	-	-	-	-	36700	-	-	-	36700	0.11
Serdang-Munchong-Seremban	-	27900	-	2800	58200	11200	-	2400	-	118400	-	220900	0.68
Munchong-Malacca-Serdang	-	-	-	42200	24300	6000	-	-	-	2000	-	74500	0.23
Bungor-Serdang-Malacca	-	-	-	-	32300	-	-	-	-	17100	-	49400	0.15
Bungor-Durian-Tavy	24700	-	-	-	2000	147900	-	-	-	-	-	174600	0.54
Serdang-Kedai	7600	-	5600	-	18300	81300	-	48600	-	21500	-	182900	0.56
Durian-Munchong-Serdang	-	-	53300	-	42200	43300	-	-	-	-	-	618800	1.90
Batang Merbau-Munchong	-	-	78100	-	-	4800	-	-	-	-	-	82900	0.25
Batang Merbau-Durian	41800	-	-	-	-	-	-	-	-	-	-	41800	0.13
Chenian	-	-	-	-	-	-	-	52200	-	-	-	52200	0.16
Pohoi-Batang Merbau-Serdang	27900	-	-	-	-	-	-	-	-	-	-	27900	0.09
Hariatau-Tampoi-Llu Tiram	199700	-	-	-	-	-	-	-	-	-	-	280200	0.86
Telemong-Akob-Local Alluvium	311700	95700	22700	15100	70100	80500	-	232000	-	35100	112400	1231600	3.79
Selangor-Organic Clays & Mucks	123600	-	-	-	-	334800	2000	-	-	40700	-	156300	0.48
Selangor-Telok	-	-	-	-	-	-	32700	-	-	-	-	40700	0.12
	737000	123600	639700	60100	247400	709800	34700	371900	-	234800	112400	3271400	10.05
Class III													
Batu Anam-Pungor-Malacca	4800	-	-	-	18700	2800	-	-	-	-	-	26300	0.08
Batu Anam-Durian	99200	-	-	-	12000	138300	-	-	-	44600	-	294100	0.90
Batu Anam-Durian-Malacca	144300	-	-	-	67800	92500	-	-	-	3600	-	308200	0.95
Durian-Malacca-Tavy	68600	-	-	32300	126300	392200	-	-	-	-	-	619400	1.90
Kulai-Young Peng	67400	-	-	-	49000	-	-	-	-	-	-	67400	0.21
Batu Anam-Malacca-Tavy	232800	-	-	-	-	60100	-	-	-	-	-	361900	1.11
Kuala Brang-Serdang-Munchong	-	-	-	-	-	45400	-	-	-	-	-	45400	0.14
Marang-Bat. Anam-Bungor	8000	-	-	-	108400	23900	-	-	-	-	-	140300	0.43
Durian-Kuala Brang	-	-	-	-	-	98800	-	-	-	-	-	98800	0.30
Pohoi-Durian Tavy	133100	-	-	-	-	13600	-	-	-	-	-	146700	0.45
Kawang-Klau	-	-	-	-	-	48200	-	-	-	-	-	48200	0.15
Holyrood-Lunas-Rasau	43000	8400	61400	-	4800	141100	47000	199300	71741	-	-	576900	1.77
Sogomana-Sitiawan	-	-	-	-	-	=	-	113600	-	-	-	113600	0.35
Organic Clays & Mucks	110800	-	-	-	-	-	-	128300	-	-	-	239100	0.73
Batu Anam-Marang-Apek	-	-	-	-	-	8000	-	-	-	-	-	8000	0.02
Kuala Brang-Serdang-Marang Apek	-	-	-	-	-	62200	-	-	-	-	686300	748500	2.30
Gajah Mati-Malacca	-	387400	-	-	-	-	-	-	-	-	-	387400	1.19
Kemuning-munchong	6400	-	-	-	-	-	-	-	-	-	-	6400	0.02
Malacca-Munchong-Tavy	5200	-	24000	85300	149900	2000	-	-	-	-	-	266400	0.82
Pokok Sena-Padang Besar	-	119600	-	-	-	-	-	-	-	-	-	119600	0.37
Manik-Sogomana	-	-	-	-	-	-	-	43800	-	-	-	43800	0.13
	923600	515400	85400	117600	530900	1149100	47000	405000	71200	48200	686300	4666200	14.34
Class IV													
Marang-Apek	75700	-	-	-	-	-	-	-	-	-	-	75700	0.23
Malacca-Tavy	54200	4000	-	-	8800	106400	-	-	-	3200	-	172600	0.53
Puducheri-Ta-Jamba	34300	9200	49400	-	14700	127700	32700	13200	-	140300	153800	381400	1.17
Kranji-Linab-Latok	249400	-	-	51000	-	33100	-	176200	-	-	12800	719400	2.21
Peat	452200	-	39100	-	-	601800	-	259000	-	444000	98400	1897500	5.83
	868800	13200	88500	51000	23500	868000	32700	448400	-	587500	265000	3246600	9.97
Class V													
Urban & Mixed Landis	-	-	-	-	13600	17500	13600	222800	-	139500	-	407000	1.25
Steepland	585000	1616800	2391100	15000	528900	4336700	34800	2644200	22200	367600	1575900	518200	41.55
	585000	1016800	2391100	15000	542500	4354200	48400	2867000	22200	507100	1575900	13925200	42.80
Padi Soils	-	360700	298900	-	-	-	52600	29900	90900	-	58200	891200	2.74
	4710700	2342600	3699300	409500	1657600	8908800	256100	5139100	198400	2016100	3200000	32538200	100

SOIL SUITABILITY AND AGRICULTURAL POTENTIAL

Based on the suitability classification outlined in Leamy & Panton, 1966 and modified by Wong, 1966 the soils are grouped under the five suitability classes. The table below shows the distribution of these five classes in the States.

The agricultural potential of the whole country could only be properly evaluated when the land use information is combined with the soil suitability. Although the present land use information is not available for the whole country, we are still able to point out that there are nearly 9.8 million acres of Class I & II soils which are more suitable for crops other than rubber. There are still 4.7 millions acres of Class III soils which are suitable for the more tolerant crops. The above figures cover both cultivated and forest lands. The Class IV soils form 3.2 million acres of which 1.9 million acres are peat. Steep-land with average slopes of greater than 20 degree slopes form the biggest unit, 14.0 million acres and are centred in the mountainous regions of the country. This still leaves 900,000 acres of land cultivated with padi(wet) mainly in the flat coastal plains of both the east and west coasts of west Malaysia.

-ooOoo-

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Grossing 4/3

MALAYAN SOILS CLASSIFIED ACCORDING TO THE 7TH APPROXIMATION

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I suppose no system of soil classification has made so much impact, at any rate in the English-speaking countries, as that which is generally known as the 7th Approximation, put out by the American Soil Survey Staff in 1960.

In it the soils of the tropics fare rather badly as, and I quote, "there are few oxisols in the United States" and, as they only once go outside the United States, to the Congo, to find examples of tropical soils. Tropical experience is therefore limited to Hawaii and Puerto Rico neither of which have the high rainfall and high temperature of Malaysia, both factors which contribute to the intense weathering and leaching which goes to form a well-developed tropical soil.

When the Supplement was issued in March last year it was natural therefore to turn first to the sections which dealt with tropical soils, the ultisols, and oxisols. This paper is a discussion of the developments of the 7th Approx. as it affects Malayan soils.

The first point that I want to raise is the factor of the argillic horizon. Since 1960 the Americans have put this in a more important position. In 1960, an oxisol could have an argillic horizon whereas now this is not so. The presence of an argillic horizon automatically puts a soil, as far as Malaysia is concerned, in the ultisol order. This therefore makes the mechanical analysis figures of great importance as a diagnostic feature. The second feature of an argillic horizon, the presence of (orientated) clay skins can only be determined with certainty by thin section technique due to the weak nature of much of tropical soil structure and owing to possible confusion with pressure coatings.

Having then divided our upland soils with developed profiles into oxisols and ultisols, (there are I know the spodsols and as well but I do not suppose anyone here would confuse them with either of the two other orders), we can move to the suborder level.

The ultisols are first divided between gleyed and non-gleyed soils, the gleyed soils are the aquults of which Manik series (Leamy 1966) and Lubok Kiat (2nd Malayan Soil Conference 1966) are examples. No change here from 1960, the rest of the suborders are different: climate divides up the old ochrult suborder and the umbrults are renamed humult with a different definition. The well-drained ultisols now, are further divided into ustults and xerults which are soils occurring under a climate having a three month dry season which may or may not be continuous, and humults that have a humic top to the argillic horizon. None of these soils are found under lowland Malaysian conditions since climatic conditions cause

a rapid breakdown of organic matter and, of course, we do not have any really dry season. I would suspect however, that humults could occur above the 3,000 ft. contour and below 4,000 ft. contour (Beckett & Hopkinson 1961), (Maruyama, K. et al. 1965).

Malayan soils with an argillic horizon are thus mostly in the udult suborder. At this point I would like you to see the soil map of the United States and you can see from this that the ultisols occupy that area in the United States that was previously shown as having red-yellow podsollic soils and the udult suborder accounts for nearly all of this area except for a strip down the coast where aquults are found. Now this area is very different climatically from Malaysia. However, the Americans have only emphasised the humidity and not the warmth so for the time being we are stuck with the udults where I should have liked tropults.

The factor of temperature is thus passed on to the Great Soil Group level but unfortunately, at this level, two other additional factors are introduced of diagnostic importance, both of which take precedence over the tropic factor. These two are the paleudults and plinthudults. The formative words being paleos, old and plinthos brick. Both of these factors, age and the presence of plinthite, are closely related to the tropical conditions and both seem to be well represented in Malaya.

Plinthite has had a change in definition which says that it restricts the meaning to nonindurated materials which change irreversibly to ironstone hardpans on exposure to repeated wetting and drying cycles. A plinthudult has plinthite forming a continuous phase or constituting more than 50% of the matrix in some horizon above 50 inches.

Paleudults are defined as follows: in the upper 40 inches of the argillic horizon there are less than 10% weatherable minerals in the fine sand fraction, a clay distribution such that the % clay does not decrease from its maximum by more than 20% of that maximum within 60 inches of the soil surface or the layer in which the % clay decreases, shows signs of eluviation, there is no fragipan, no plinthite forming 50% of the matrix within 50 inches of the surface.

Finally, we have the tropudults which are soils excluding the definitions of the paleudults and plinthudults which have no fragipan, no fluctuations in soil temperature of more than 5 degrees Centigrade in different seasons, an epipedon with a moist colour value of 4 or more or an argillic horizon that has a dry colour value of 5 or more or a moist colour value of 4 or more.

The subgroups of the paleudults are straightforward, the typic is a well-drained soil with a texture finer than loamy fine sand with no more than 5% plinthite in the top 60 inches and an Ah horizon less than 6 inches thick. If these characters are altered then the required adjective is substituted for typic, viz., aquic, arenic, (psammentic if the argillic horizon is sandy), plinthic, humic or a combination of them.

No subgroups are as yet developed for the plinthudults.

The subgroups of the tropudult are similar to the paleudult, a typic is well drained, has a texture finer than loamy fine sand, has an argillic horizon thicker than 10 inches, no horizon has more than 5% plinthite and also, has more than 24 m.e.q./100 gms. clay C.E.C. and has a cation retention from NH_4 Cl of more than 12 m.e.q./100 gms. clay in the major part of the argillic horizon, and lacks the following: cracks at some period in most years that are 1 cm. or more wide at 50 cm. depth and that are 30 cm. long in some part and that extend upwards to the surface or Ap horizon, expands and contracts on wetting and drying and has more than 35% clay in horizons that total 20 inches thick.

The subgroups that do not have one or more of these characteristics are called aquic, arenic, dystropeptic, plinthic, oxic, and vertic.

Some of these criteria are quite simple but perhaps we should first take a look at plinthite which in Malaya seems to be confined mainly to shale-derived soils, Malacca, Batu Anam, Apek, Durian, and Tavy series, although not to Munchong or Jeram series at least in the profile descriptions I have seen. This may be due to the plinthite being at a greater depth than the pit is dug. The definition goes to 50 inches so there may be a need here for deeper pits. In addition to the shale-derived soils I have seen plinthite on a profile over granite in Penang (see Appendix) the soil was very deep, 15 ft. and the plinthite came in at 60 - 70 inches which is below the critical level. So it would seem that plinthite is not restricted to shale soils. It is strongly related to laterite but the American Soil Survey do not consider that laterite can be hardened unless it has been exposed and then subjected to soil forming processes as a kind of parent material and thus not used at a high level of classification, (G. Smith, priv. comm.). Mostly, they reckon the laterite has been moved and concentrated by past erosion cycles. I would suggest that there is good evidence for this in some lateritic soils (see Appendix soil from Gemas) where a sharp break in the profile occurs at the base of the lateritic band but there are others that do not show this as in the Penang soil and in the deep shale soils. For this reason I would be in favour of retaining Haantjens' petric horizon particularly as now plinthite does not cover hardened material.

The adjective petric may thus be used as a subgroup where concretions occur as in the Malacca, Durian, Kodiang, and Chungloon series, but not the Batu Anam or Segamat where insufficient laterite occurs.

The second feature to consider is the introduction of the paleudults which, together with the tropic constitutes the main suborder to which Malaysian soils are likely to belong. Since the paleudults occur before the tropudults in the key most Malayan soils with an argillic horizon are going to come in it which hardly seems logical for soils developed in the tropics when a tropic great soils group is present. The separation of these two great soil groups is on the basis of maturity, thus a less mature soil will have more weatherable minerals, and clay eluviation will not have continued for long enough that no bulge in the textural profile occurs, i.e. clay content increases to a maximum without a decrease to any extent in the top 60 inches. Of these two criteria the latter is easily recognised but what of the former, it seems to infer that fine sand will have to be separated out and examined under the microscope for weatherable minerals.

Now what of the oxisols. These are certainly more restricted under the new classification. The suborders have been developed and are readily understood, the wet soils or soils over plinthite - aquox, soils developed in regions with a dry season - torrox and ustox, soils with a humic top - humox, and the rest orthox. It is therefore the last group that concerns us. The great soil groups are also easy to follow with chemistry the dominant criteria, less than 1 m.e.q. extractable bases plus aluminium per 100 gm. clay are acroorthox (the cation retention capacity is an alternative): more than 35% base saturation are the eutroorthox: more than 1% carbon in all horizons above 30 inches are the umbriorthox: 30% or more gibbsite in sheets or gravel sized aggregates are the gibbsiorthox and the rest haploorthox.

The acrothox are thus the soils with extreme weathering with no discernible structure in the oxic horizon or only a weak blocky or prismatic one, no sheets or aggregates of gibbsite above 30% in the top 50 inches and have in some sub horizon of the oxic horizon this low extractable base content. I have tried the cation retention concept in my laboratory and on Segamat soils and get too high a result for it to be in the acrothox group but in view of its low total exchangeable bases I have ignored this. The typical acroorthox has then, no plinthite, an oxic horizon 80 or more inches deep and a texture of sandy loam or finer to 40 inches. All of these criteria would seem to be had by Kuantan and Kampong Kolam series, the Segamat has a less deep oxic horizon and is classed therefore, as a tropeptic acroorthox due to the presence of concretions at 60 inches.

The eutroorthox is a similar sort of soil to the acroorthox except for its high base saturation, 35% and higher total bases. Only the Langkawi series developed over limestones fits this group (Joseph 1965).

The haploorthox are again similar to the eutroorthox but have less than 35% base saturation. Examples of these are possibly Munchong, Seremban, Senai and Chungloon series. The subdivisions of this group are aquic - with mottles above 50 inches, plinthic - with plinthite above 50 inches, psammentic - sandier than sandy clay loam above 50 inches, tropeptic - with an oxic horizon thinner than 50 inches or well structured or both. Pits in this group must therefore go to 50 inches.

Now what of other soil orders found in Malaysia, the **spodosol**, entisol and inceptisol. The two former mentioned by Leamy (1966) included the latter in the entisol group, incorrectly, I think.

Spodosols occur in two very different areas in West Malaysia, one on the Bris soils on the East Coast, the Rudua series and the other at high altitude in Trengganu, the Cameron Highlands and on Ulu Kali near to Kuala Lumpur, the Gunong Padang series (Panton 1958, Wagner, T., /). This therefore, gives us an example of two sub-orders, the aquod and humod.

The classification, as far as the Gunong Padang series is concerned, has only developed slightly. The soils with a thin iron pan are the placaquods and if it has a histic epipedon then it is a histic plafaquod.

The humod classification has been changed mainly to give more emphasis to climate, so the soils here go into the tropohumod great soil group. In the case of the Rudua series the thickness of the albic horizon and the sandiness of the profile suggests the subgroup grossarenic.

Now the entisols, these again fall into two types depending on the topographical position these are the lithosols, Bukit Temiang (Panton 1958), and Bukit Lanchu (Null, Acton and Wong, 1965), and the soils developed over recent alluvium, Penor, Kranji, Telemong, Linau, Holyrood Baging and Jambu series. These latter are developed in low-lying areas and are either regosols or low humic gley soils.

The entisols are first divided into whether or not they are water affected. If they are, then they are aquents. In the case of the very sandy entisols, this is not always an easy division particularly if one is working from field description sheets since a sandy soil does not reflect the hydrology of the profile very well so the Jambu and Holyrood series may or may not be in the aquents. Field soil surveyors should therefore, make this clear from their reports.

The hydraquents are the first subgroup which has a temperature above freezing, has an N value above 0.5, and at least 8% clay and 3% organic matter down to 12 inches, has a finer texture than loamy fine sand. This fits the Linau and possibly the Kranji series.

The second group is the tropaquent. These differ from the hydraquent by not being organic and are developed under tropic conditions; Penor seems to fit in here.

Next, we have a new suborder, the fluvents, which are not sandy but have a fairly high organic status, more than 2% carbon in the top 50 inches and are not waterlogged. The Telemong series would appear to fit this description. Due to climate, it is in the tropofluent great group.

The next is another new suborder: the orthents. These are similar to the fluvents but with a lower carbon content reaching to 0.2% in the top 50 inches. Into this goes the mixed assortment of Holyrood and lithosolic soils. Again, due to climatic conditions, the great group is the troportents. The subgroups separate the typic, Holyrood series, from the lithic Bukit Temiang and Bukit Lanchu series.

Lastly, there are the sandy entisols, the psamments, of which Jambu and Baging are examples. Due to the leached nature of the Jambu series and the high watertable, it goes into the aquodic quartzipsamments, the Baging series again due to climate goes, I think, into the ustipsamments, as it is not mottled, has no clay, no lithic content within 20 inches and has no durinodes. Also, being on the East Coast, I think it may well be a bit dry and anyhow, there is not a better Great Group available.

The last order we have to deal with is the inceptisols, these do not appear in Leamy (1966) or Leamy and Panton (1966) so perhaps, this may lead to some disagreement. The soils we are concerned with are those previously classified in the entisol order: the Selangor, Briah and Telok series. In the case of the Selangor series, it has an umbric epipedon, an underlying cambic horizon, a mean summer and winter temperature differing by less than 5 degrees Centigrade and 35% or more of the clay with montmorillonite mineralogy (Ng 1966), but low in calcium carbonate. In the Briah and Telok series, both have an cambic horizon, are moist between 7 and 20 inches, and have a low conductivity of the saturation extract. These three series are all, therefore, aquepts due to their geographical position and tropaquepts due to the climate. The subgroup are rather more difficult as the criteria sometimes cut across series boundaries. The Briah in Selangor (Wong 1966) is a typic and the Selangor series in the same report is vertic, the Briah in the Pahang correlation trip was histic due to its histic epipedon. The Telok series would seem to be a typic tropaquept.

Since the possession of a cambic horizon is a key factor in the inceptisols perhaps I should anticipate a question on it. The cambic horizon is an altered horizon with a texture finer than loamy fine sand. No fine stratification should be apparent and oxidation reduction and segregation can be seen with aggregation of the soil into peds. It normally lies in the B horizon position. It does not lie below an argillic or spodic horizon. Thus position and non-illuviation are characteristic.

Cambic horizons may form in the presence of a fluctuating ground watertable. Mottling alone is not evidence of sufficient alteration, the process of reduction must be intense enough to give a low chroma matrix of 2 or less if there are mottles or 1 or less if there are not. Weathering may have affected the easily weathered minerals but has not progressed to the point where only kaolinites and sesquioxides remain with quartz.

I have already mentioned one soil series that goes into two subgroups and no doubt there are many such examples. By using tight definitions such as are used in this classification this sort of thing can be avoided even though it may mean an increase in the number of soil series. Ideally, at every fork in the classification, one criteria should be considered even though other criteria are linked to it, viz., for Serdang series:

1. Are there diagnostic horizons - Yes, (vertisol, aridosol, alfisol, oxisol, ultisol, inceptisol).
2. Is there an argillic horizon - Yes, (alfisol, ultisol).
3. Is the base saturation less than 35% - Yes, (ultisol)
4. Does it have feature of wetness- No, (not an aqult).
5. Is it found in a wet humid climate - Yes, (udult).
6. Does it have plinthite above 50 inches - No, (not a plinthudult).
7. Does it have a fragipan - No, (not a fragiudult).

8. Does it have less than 10% weatherable minerals in the fine sand fraction - Yes, (a guess) paleudult.
9. Does it have mottles with chromas of 2 or less in the top 30 inches - No, (not an aquic paleudult).
10. Does it have a texture coarser than loamy fine sand in the top 20 inches - No, (not arenic).
11. Does it have an argillic horizon thinner than 10 inches - No, (not dystropeptic).
12. Does it have less than 24 m.e.q. C.E.C./100 gms. clay in any major part of the argillic horizon - Yes, (oxic).
13. Does it have any horizon above 60 inches with more than 5% plinthite - No, (not plinthic).
14. Does it lack the following combination of characters:
 - a) cracks at some period of most years
 - b) have a coefficient of linear extensability (COLE) of 0.09 or more in some horizon at least 20 inches thick
 - c) have more than 35% clay in horizons totalling 20 inches thick- No, (not vertic).
15. Does it have a texture coarser than loamy fine sand and in some part of the argillic horizon and have lamellae - No, (not psammentic).
16. Does it have an Ap horizon with a moist colour value of 4 or more or an A horizon more than 6 inches thick if it has a moist colour value lower than 3.5 - No, (not humic).
17. Does it have any lithic contact within 20 inches of the surface - No, (not lithic).

The Serdang series is therefore oxic paleudult.

In the tropudults I have classified the Batu Anam as plinthic tropudult. This series and its relations, Durian and Apek cause much trouble (Law Wei Min & Leamy 1966); perhaps if these series were broken up more the difficulty might disappear. Batu Anam, for instance, has been classified as an aquic plinthudult (Leamy 1966); now, no description I have seen has mottles with chromas of 2 or less which is required for an aquic subgroup.

The Batu Anam from South Johore (Null, Acton and Wong, 1965), has a Bt horizon of 10 YR 8/1 and hence, can be classed as an aquult, the other examples from the 2nd Malaysian Soils Conference, Temerloh-Gemas and Selangor Reports, reach this colour range only in the C horizon which is not the control horizon for this criteria. Again, these latter three except the Selangor Survey are on strongly sloping topography unlikely to be waterlogged. The colour of the parent material must not be allowed to put a soil in the wrong group. As to whether the Batu Anam series has more than 5% plin- thite, this seems to vary, the one in South Johore and Selangor may have, but not the Temerloh-Gemas or the 2nd Malaysian Soils Conference.

Again, with the Malacca, Tavy, Tandak, and Durian series, the criteria of depth and percentage plinthite can be used, followed by petric or plinthic as applicable.

To sum up, how can this class classification help us in Malaysia? Primarily, I think, by helping us to keep a clear head when discussing soil features by calling soils by meaningful names, secondly, by directing the creation and tighter definition of more soil series, and lastly, by directing the laboratory side of soil survey to do the sort of determinations that help in soil classi- fication.

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Soil Series Classified According to the 7th Approximation

ORDER	SUB ORDER	GREAT SOIL GROUP	SUB GROUP	S E R I E S
Entisol	Aquent	Hydraquent	-	Kranji Linau
	Orthent	Tropaquent	Typic	Penor
		Troporthent	Typic	Holyrood
			Lithic	Bukit Lunchau Bukit Temiang
	Psamment	Quartzipsamment	Aquodic	Jambu
		Ustipsamment	Typic	Baging
	Fluvent	Tropofluvent	Typic	Telemong
Spodosol	Aquod	Placaquod	Histic	Gunong Padang
	Humod	Tropohumod	Grossarenic	Rudua
Ultisol	Aquult	Tropaquult	Typic	Manik Lubbock Kiat
	Humult	-	-	?
	Udult	Paleudult	Typic	Harimau
			Oxic	Serdang Jempol
			Plinthic	Malacca
		Plinthudult	Petric	Durian
		Tropudult	Aquic	Bukit Tuku
			Oxic	Rengam
Plinthic			Batu Anam	
Dystropeptic	Kamang			
Oxisol	Orthox	Acrorthox	Typic	Kuantan, Kg. Kolam
			Tropeptic	Segamat
		Eutrorthox	Typic	Langkawi
		Haplothox	Typic	Munchong, Seremban
		Petric	Kodiang, Chungloon	
Inceptisol	Aquept	Tropaquept	Typic	Telok
			Histic	Briah
			Vertic	Selangor

APPENDIX

Soil from Penang

- 0" - 6" 2.5Y 5/2, greyish brown, sandy clay loam.
- 6" - 30" 10 YR 5/6, yellowish brown, clay loam, friable, merging.
- 30" - 40" 10 YR 6/8, brownish yellow, slightly mottled.
5 YR 5/8, yellowish red, clay, gravelly, merging.
- 40" - 60" (as above), but more compact, merging.
- 60" - 70" variegated 5 YR 5/8, 10 YR 6/6, mottled 2.5 YR 4/8
clay, very gravelly, firm, merging.
- 70" - 120" variegated 10 YR 7/4, 2.5 YR 4/4 clay, frequent
concretions angular small and soft, merging.
- 120" - 200" 10 YR 8/3 - 7/4 angular concretions (10 YR 4/2) large
soft merging.
- 200"+ 5 Y 8/1 large diffuse mottles 10 R 4/2.

Soil from roadside cutting near Gemas, N. Johore.

- 0" - 3" 5 YR 5/6, yellowish red, sandy clay loam, abundant
roots, abundant gravel sized concretions round and
hard, clear.
- 3" - 30" 2.5 YR 5/8, red, clay, few roots, abundant concretions
but less than in horizon 1. Also with some subangular
soft ones, sharp to
- 30" - 33" A stone layer of tabular laterite.
- 33" - 54" 2.5 YR 5/8, red, frequent motts 10 YR 7/6, clay hard
consistence, few angular laterite gravel soft, merging
to
- 54" - 150" variegated 10 YR 7/6, 10 R 5/4, the red colour being
the incipient concretions which get progressively
harder as one moves up the profile. The percentage
of red and yellow changes so that at greater depths
there is more red with a decrease in value. This is
a very merging boundary over several feet and marks
the division between the 'pallid zone' and the less
weathered underlying shale.

METHODS OF DETAIL SOIL CLASSIFICATION AND MAPPING
FOR RUBBER GROWING SOILS IN MALAYA

by

M.M. Guha

May 1968

SOILS DIVISION
THE RUBBER RESEARCH INSTITUTE OF MALAYA
KUALA LUMPUR

METHODS OF DETAIL SOIL CLASSIFICATION AND MAPPING
FOR RUBBER GROWING SOILS IN ~~MALAYA~~

W. Malaysia.

by

M.M. Guha

(The Rubber Research Institute of Malaya)

Following provisional classification of Malayan soils at series level by OWEN (1951), only some ad hoc soil surveys in selected areas were carried out (COULTER, 1956, PANTON, 1954, 1957, etc) during the period - 1951 to 1962, when it was decided to carry out a systematic reconnaissance soil survey for the whole of West Malaysia. The reconnaissance soil survey showed associations of soil series in the scale of 2 to 4 miles to an inch or 1 : 126,000 or 250,000. Field work for such survey for all states in West Malaysia has now been completed. Reports on many of the states are already available and only a few are still awaiting publication (NG, 1968).

While this systematic reconnaissance soil survey provides first national inventory of soil resources in West Malaysia, a more detailed soil map not only in a larger scale but also providing further detail of the soil characteristics for each mapping unit is necessary in areas where the land has already been brought to intensive agricultural use. Such a classification to suit the practical need of soil management for rubber cultivation in Malaya was developed and used. The classification developed, the mapping procedures followed, and the progress to-date are discussed below.

CLASSIFICATION

In order to develop a method of classification which would be useful from the practical point of view of rubber cultivation, it is first necessary:

- (a) to determine soil factors that are important for rubber cultivation,
- and (b) to determine the scale of mapping

The soil factors that are important for cultivation of rubber need be sub-divided on the basis of their effect on the growth and yield of rubber trees. The factors that were considered to be relevant from this point of view, but are not included in the basic criteria for defining a soil series, are as follows:-

- (a) Texture of surface soil
- (b) Depth of soil up to parent material
- (c) Slope of the land
- (d) Drainage
- (e) Occurrence of hard-pan or lateritic layer within

the soil profile which is not easily penetratable by rubber roots.

While the factor (a) - variation in texture of surface soil - is taken into consideration for sub-dividing a soil series at type levels, all the other factors (b) to (e) are considered for sub-dividing a soil type at phase level. For soil type classification, the normal textural class names with their meanings as defined in the U.S.D.A. Soil Survey Manual No.18 (1962) are used. For phase classification, the sub-divisions of drainage and slope factors are similar to those given in the U.S. Department of Agriculture Soil Survey Manual, while the sub-divisions of depth of soil to parent material and depth of hard-pan or lateritic layer within solum are devised in accordance with the rooting system of rubber trees. The sub-divisions that were finally accepted for the above factors are shown below.

*hardened
plinthite*

Phase differentiation based on Depth of Soil up to parent material.

Class A	Very shallow	less than 10"
Class B	Shallow	between 10" - 20"
Class C	Moderately shallow	between 20" - 30"
Class D	Moderately deep	between 30" - 40"
Class E	Deep	between 40" - 50"
Class F	Very deep	more than 50"

Phase differentiation based on slope of land

Class A	level to nearly level terrain	0 - 3% slope
Class B	gently sloping to undulating terrain	3 - 8% "
Class C	sloping to rolling terrain	8 - 16% "
Class D	moderately steep to hilly terrain	16 - 30% "
Class E	steep terrain	30 - 65% "
Class F	very steep terrain	above 65% "

Phase differentiation based on drainage conditions of soil

Class A	Poorly drained	
Class B	Imperfectly or somewhat poorly drained) as defined in Soil Survey Manual, USDA.
Class C	Moderately well drained	
Class D	Well drained	
Class E	Somewhat excessively drained	
Class F	Excessively drained	

Phase differentiation based on occurrence of hard-pan or lateritic layer within the solum which is not easily penetrable by rubber roots

High laterite phase	0" - 20"
Medium laterite phase	20" - 50"
Low laterite phase	More than 50"

Sub-division of soil series to type and then to phase levels were then made by combination of the above classes of factors to obtain a soil mapping unit. A particular soil series may be uniform with respect to any of the above factors for type or phase level consideration. Combination by groupings of that factor in obtaining a soil mapping unit then becomes unnecessary. For example, Selangor series soil, which always occurs within 0 to 3

degrees slope class but have variable drainage and depth of solum up to parent material, has to be classified into phase level according to soil depth and drainage only, but not according to slope. For Kuantan and Segamat series, on the other hand, depth of soil is almost always more than 50 inches and drainage is uniform, being "well-drained", but slope is variable between the four slope classes covering from 0 to 30 percent slope. Phase classification of these soils therefore should be on the basis of slope of soil only; no phase classification on the basis of drainage or depth of soil is required.

No phase classification on the basis of degree of erosion has yet been worked out, although it is recognised that in some soil areas, like Serdang and Malacca series, considerable amount of sheet erosion has taken place. This is mainly because of the difficulty in measuring the degree of sheet erosion accurately. However, this is being looked into; and when a satisfactory system of measurement of the degree of erosion at least for the more erodible soils are worked out, phase classification on the basis of degree of erosion will be introduced.

In obtaining the name of the soil mapping unit, the series name is given first, followed by type (giving the textural class name for the surface soil), and then the class of factor or factors for the phase differentiation. For example, "Rengam sandy clay, 20 to 50 inches deep, 8 to 16 percent slope" is a complete name of a soil mapping unit.

For the above classification to be practically workable, it is important that the series description is rigidly defined. For this purpose, the limits of the range of morphological characteristics of a soil profile below the plough depth that is

allowed within a series is to be so defined as to relate with the crop performance. Variations that are likely to affect the growth of rubber trees cannot be put under the same series name, as these will not differentiate soils which have different agronomic values. The variations that would not affect the growth of trees may however remain separated under different series names, if this is required from the pedogenic point of view.

In West Malaysia, soil depth has sometimes been taken as a criterion to differentiate soils at series level, although the profile characteristics other than depth of soil were similar. For example, the shallow phase of Serdang series soil has been named as Kedah series (OWEN, 1951). In view of the above phase classification on the basis of depth of soil, the Kedah series should now be classified as shallow phase of Serdang series.

MAPPING

The scale used for mapping the soils at phase level was 5 inches to a mile or 1: 12,500. On this scale, 1 sq. inch of the map represents about 25 acres. This scale was considered suitable in view of the size of the fields or the units of management which normally vary between 20 and 40 acres.

Field mapping is carried out using enlarged topographical sheets published by the Survey Department as base maps. Only the areas under rubber within a toposheet are mapped as shown by a completed sheet No. 94(a) (Kepong) in Selangor (only one copy presented at the Conference).

Soil profiles up to a depth of about 5 feet are examined at the rate of one profile for every 100 acres, to ensure the classification at soil series level. Determination of boundary

at type level is carried out by auger examination for the texture of surface soil up to plough depth or 0 - 9 inches. Phase differentiation with respect to depth of soil, drainage condition and occurrence of hard-pan or lateritic layer is carried out by a combination of profile examination up to 5 feet depth as described above, by occasionally digging shallow profiles up to 2 feet depth or by using auger. For phase differentiation with respect to slope of land, the contour lines in the toposheets and stereo interpretation of aerial topographs are used.

PROGRESS

It is estimated that about 80 toposheets (1: 25,000 toposheets published by the Survey Department) will cover almost 90 percent of the total acreage of 4.3 million acres of rubber in West Malaysia. The index to soil maps of the rubber growing areas of Johore (only one copy presented at the Conference) shows that about 20 toposheets cover most of the rubber growing areas in Johore. So far, detail soil survey to cover the rubber growing areas of 6 toposheets in Johore and 3 toposheets in Selangor, or about 200,000 acres in all has been completed.

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AREA COVERED ON
PART D TOUR

Scale 1 : 250,000

S
E
A

C
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N
A

BRUNEI

DISTRICT

MIRI

SHEET

SUAI - NIAH - SIBUTI SUB-DISTRICT



VISION

50°

BINTULU 113°

DISTRICT

10°

113

SHEET

E A

SUAI - NIAH - SIBUTI SUB-DISTRICT

FOREST DEPARTMENT
EXPERIMENTAL PLANTATION AREA

SEBIEU R. P. S. A. AREA

BARAM DISTRICT

10°

3°

50°

40°

