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THIRD MALAYSIAN
SOILS CONFERENCE

SARAWAK

1968

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The Proceedings of the Third Malaysian Soils Conference held in May 1968 Kuching - Sarawak East - Malaysia

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SPEECH OF THE HON. THE ACTING DEPUTY CHIEF MINISTER, DATO TEO KUI SENG FOR THE OPENING OF THE THIRD MALAYSIAN SOILS CONFERENCE ON 16TH MAY, 1968.

I was very pleased to learn some while ago that the Third Malaysian Soils Conference was to be held in Sarawak and I am happy to be able to welcome you all here today. I am glad that the Conference is being held here firstly because it enables the Sarawak delegation to reciprocate the hospitality they have received during the earlier conferences in Sabah and West Malaysia and secondly because I believe that by holding the Conference in different parts of Malaysia participants are able to familiarise themselves with the problems which face their fellows in the different States, some of which will be common to all but others will be peculiar to one area. It is only when all delegates are conversant with the conditions in every part of the Federation that the greatest benefit can accrue from this type of meeting. I also believe that it is a very good thing that this Conference is kept as informal as possible for this enables delegates to discuss all matters fully and frankly and this will lead to sound decisions being reached.

Most of you have spent the last few days on a field tour of parts of this State and will have thus learned something of the soils and agriculture of Sarawak. I think you will also have realised as I do the sound work achieved by the Soil Survey Division here. The conditions under which field surveys are carried out are frequently far from easy, but in spite of this a very high standard has been set and I am very glad that I have this opportunity to make public acknowledgement of this work and to record how valuable it has been.

The Division is comparatively young, having only been established approximately ten years ago, and devoted much of its original work to rapid reconnaissance surveys of large parts of the country to assist the Government in its road building programme. More than 30% of the State has now been covered by reconnaissance survey, and many of the areas of greater potential have been surveyed at a more detailed level. If we are to successfully implement our present Development Plan, one of the broad objects of which is to increase the per capita income and the employment opportunities of the population, it is essential that our planning is based on a thorough appreciation and knowledge of the areas where sound development can take place. For rural development this depends in no small measure on the basic information which you as Soil Scientists can provide. You will, I am sure, agree with me, that such knowledge is not an end in itself, but it forms an integral part of the many agronomic, social and economic factors which have to be taken into account by those responsible for planned development. I am happy to see that the Conference has recognised this, both in the nature of the Agenda and the tours that have been organised and by the different fields in which you as delegates or observers are engaged.

I hope you enjoy your visit to Sarawak. I am sure this Conference will be of great benefit both to us here and to Malaysia as a whole.

Gentlemen, I take pleasure in declaring the Third Malaysian Soils Conference open.

CONFERENCE PROGRAMME

Date	Event
8th - 12th May, 1968	Tours in Third Division, Sarawak.
13th - 15th May, 1968	Tours in First Division, Sarawak.
16th May, 1968	Official opening of the Conference by the Acting Deputy Chief Minister Dato Teo Kui Seng at the Kuching Rural District Council Building. Session I.
17th May, 1968	Session I. Session II.
18th May, 1968	Session III.
19th May, 1968	Session IV. Session on Correlation. Any other business.
20th - 22nd May, 1968	Tours in Fourth Division, Sarawak.

Sub-committee on Standardisation of Analytical Methods within Malaysia met on 12th May in Kuching.

Sub-committee on Correlation of Soils within Malaysia met on 19th May in Kuching.

Note from the Editor

Spelling and typing errors existing in the original cyclostyled papers have as far as possible been corrected. It is likely that some have remained, either because the right spelling, particularly of local topographic or soil names are unknown to me or they were overlooked. Pressure for other work makes it impossible for me to double check the manuscripts, for which I offer my apologies. No attempt has been made to edit the papers themselves, the scripts being the responsibility of the authors. For this reason, e.g., terms like podzol and podzolization are in some papers spelled with an 's' owing to the preference given by the authors. Maps and other enclosures in submitted papers which could not be duplicated have been omitted from the Proceedings. Where not yet mentioned as a footnote, those interested in obtaining these items may contact the authors of the papers concerned at the addresses given in the list of participants. Readers who would like to obtain copies of the articles may do this in a similar way. The Proceedings are circulated on a restricted basis and no copies of articles are available from the publishing source which is the Department of Agriculture, Sarawak.

J. P. Andriesse
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SESSIONS AND LIST OF PAPERS PRESENTED

SOME ASPECTS OF SOIL GENESIS IN SABAH

by

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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
Kambarangan	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 3,250 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 soil. In the cooler and probably drier zone above 9,500 ft., there is a rapid 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 to be 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 inorganic 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 and overlie country rock which is poorly resistant to marine erosion and their increasing incidence seems to be related to decreasing resistance to weathering and erosion (Panton, 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 impress 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 aeolian 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.

<u>Biological Action</u> 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., (Askew, 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 suites, and also in some estuarine areas.

<u>Mineral Metamorphism</u> 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.

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

Great Soil Group	Soil Family	Parent Material	Horizon Designation	Sample Number	% MINERAL CONTENT 2mm-50 µ															
					Feldspar	Quartz	Zircon	Garnet	Rutile	Kyanite	Silliminite	Epidote	Saussurite	Hornblende	Actinolite	Augite	Enstatite	Hypersthene	Rock	Ore
Lithosol	Tumunong	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 Podzolic Soil	Tengah Nipah	Sand-stone	A2	9329	-	83	-	-	-	-	-	-	-	-	-	-	-	-	17	
			B2	9330	-	80	-	-	-	-	-	-	-	-	-	-	-	tr	19	1
Ferral-sol	Ambun	Ultra-. basic rock	A2	6410	-	93	-	tr	-	-	-	-	-	-	-	-	-	-	tr	7
			B2	6411	tr	86	tr	-	-	-	-	-	-	-	-	-	-	-	1	13
Podzol	Serai	Raised marine alluvium	A2	3968	-	99	tr	-	-	-	-	-	-	-	-	-	-	-	-	1
			B2	3969	-	99	tr	-	tr	-	-	-	-	-	-	-	-	-	tr	1

<u>Note 1.</u> tr = traces.
<u>Note 2.</u> 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^{o}, 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^{o} or more and where weathering can not proceed far before soil material is removed by erosion. This effect is marked by the presence of rapidly weathered clay minerals such as biotite 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 (Panton, 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-oxide 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 endpoint 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 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 increase inversely with the size of the soil particles.

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

Great Soil Group	Soil Family	Parent Material	Sample Number	Horizon Designation	CLAY MINERAL SEQUENCE								
					Calcite	Biotite	Albite	Quartz	Illite	Montmorillonite	Kaolinite	Gibbsite	Haemarite
					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
			1972	R	-	pr	pr	pr	-	mod	pr	-	tr
* Lithosol	Bombalai	Basalt	1087	A	-	-	-	pr	-	-	dom	tr	pr
Active Riverine 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	-	-
Rendzina	Semporna	Coralline limestone	1714	A	-	-	-	pr	-	dom	pr	-	-
			1716	C	tr	-	-	pr	-	dom	mod	-	-
Red-Yellow Latosol	Beruang	Basic igneous intrusive rock	9753	A2	-	-	-	-	-	-	dom	-	-
Red-Yellow Podzolic soil	Tengah Nipah	Sandstone	9329	A2	-	-	-	tr	-	dom	pr	-	-
			9330	B2	-	-	-	tr	-	dom	pr	-	-
			9332	C	-	-	-	tr	-	dom	pr	-	-
Red Podzolic Soil	Edam	Basic colluvium	8722	A2	-	-	-	tr	dom	-	pr	-	-
			8723	B2	-	-	-	-	dom	-	pr	-	-
			8724	C	-	-	-	-	dom	-	tr	-	-
* Red-Brown Ferralsol	Table	Basalt	1667	AB	-	-	-	pr	-	-	dom	-	tr
			1668	AB	-	-	-	pr	-	-	dom	-	tr
Red-Brown Ferralsol	Bakapit	Basic ash	6711	AB	-	-	-	-	-	-	dom	-	-
			6712	AB	-	-	-	-	-	-	dom	-	-
			6713	AB	-	-	-	-	-	-	dom	-	-
Podzol	Serai	Raised marine alluvium	3968	A2	-	-	-	dom	-	-	dom	-	-
			3969	B2	-	-	-	dom	-	-	dom	-	-
			3970	C	-	-	-	dom	-	-	dom	-	-

Note 1. Group II Can also include glauconite and chlorite.
Group III Anorthite, microcline and stebnite.
Group IV Cristobalite.
Group V Muscovite, sericite, etc.
Group VI Beidellite.
Group VII Halloysite.
Group VIII Boehmite, and
Group IX Goethite and limonite.

Note 2. dom = dominant, mod = moderate, pr = present, tr = traces.

Note 3. 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.

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	Cristobalite	Illite	Montmorillonite	Kaolinite	2mm-200 μ	200 μ - 50 μ	50 μ - 2 μ	20 μ - 2 μ	< 2 μ
		II	IV	V	VI	VII					
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.

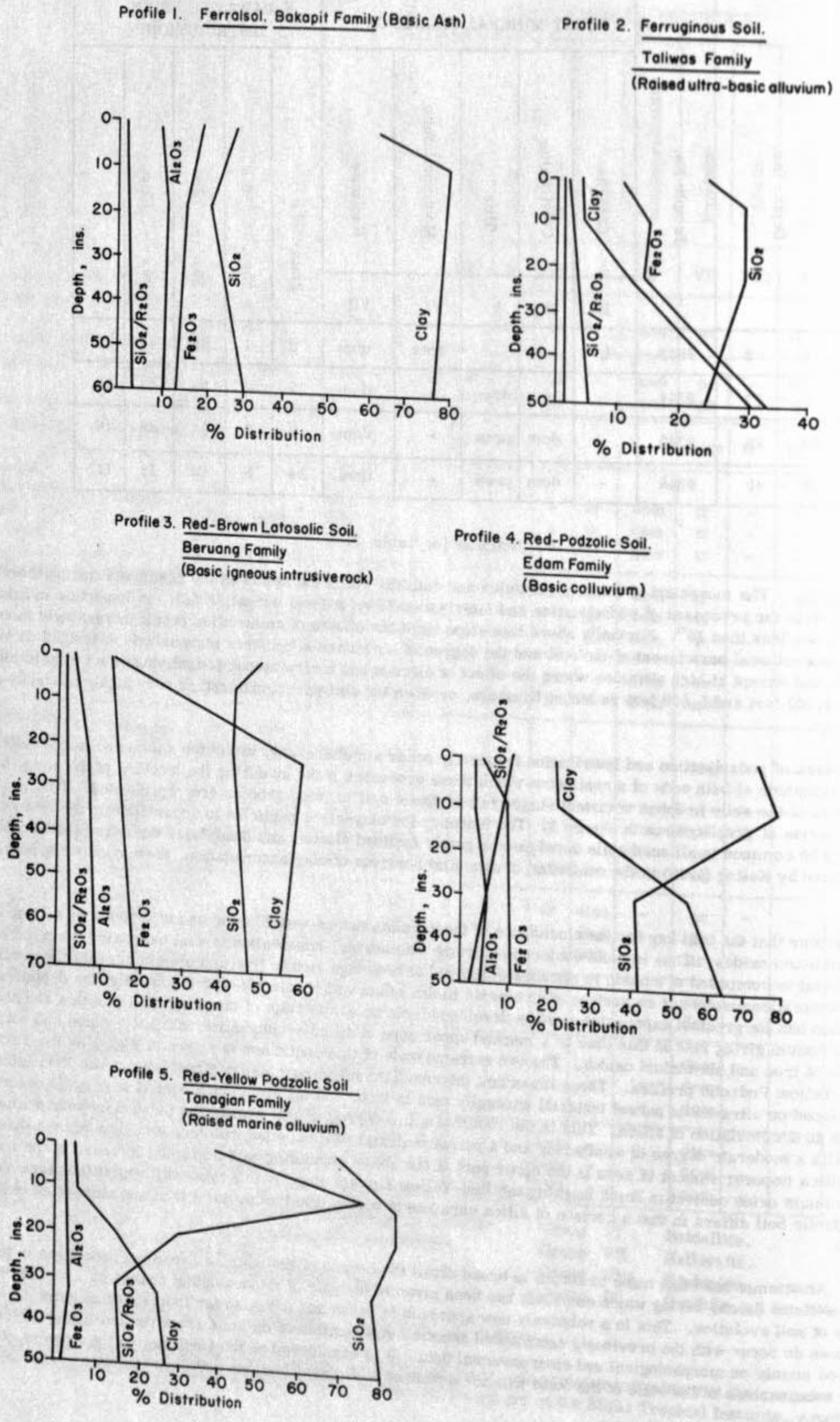
Mineral Movement. The movement of mineral particles and colloids within the solum as the result of leaching thereby giving expression to the processes of podzolization and laterisation (Twyford and Wright, 1966)., is important in Sabah generally on slopes less than 15°. Normally above this slope limit 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 feet and 5,500 feet 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 zone 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.

Conclusions. 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,

Figure 1. The Relationships between Clay, SiO_2, Fe_2O_3 and Al_2O_3 Distribution in the Profile and Soil Classification



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.

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Discussion

Moormann: Could you please give a definition of what you call Ferralsols. Are they the same as Reddish-Brown Lateritic Soils as we have seen them here in Sarawak?

Thomas: These are in fact the Red-Brown Ferralsols. They occur on ultra-basic to basic parent materials. There is normally a complete lack of horizonation, apart from a weakly developed AO or Al horizon. They are usually of a dark colour (dark reddish-brown). They are clayey and extremely well structured and the aggregation of the soil structure seems to be very stable. They are not the same as the Reddish-Brown Lateritic soils as found in Sarawak. They differ from the Reddish-Brown Lateritic soils in that one would not find any weatherable minerals at all nor any form of horizonation.

Moormann: Comment: They may be Dark Reddish-Brown Latosols according to Dudal and Moormann.

Joseph: Could you elaborate further on the relationship between the general plant nutrient status and the main great soil groups. Are you confident that the differences within the main great soil groups are not larger than between great soil groups?

Thomas: No; assuming that plant nutrient content in the soil is related to the content of weatherable minerals in the coarse fraction of the fine earth one would find that our more juvenile soils such as the Lithosols and the Active Riverine Alluvial Soils generally have a higher content of weatherable minerals than the more weathered soils. This was the relationship to which I briefly referred to in my paper.

Ng: In terms of soil pedogenesis it would probably be more valid to compare contents of certain constituents such as SiO_2, Al_2O_3 and Fe_2O_3 in the parent rocks with those in the soils developed on these rocks. Has such a study been made or are data not available?

Thomas: No data is available but it is realised that such a study would be valuable and necessary. The main difficulty is that it is frequently impossible to obtain unweathered parent rock material <u>in situ</u>.

CHARACTERISTICS OF A SANDY PODZOL IN MALAYA

by

K. T. Joseph and B. R. Hewitt.

Podzols 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 podzols from the Island of Bangka. The profile descriptions of Joachim (1935) and Hardon (1937) differ significantly in that Joachim's 'podzol' did not contain an A_2 horizon which is characteristic of the classical podzol whereas Hardon's description showed the sequence of an A_o 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 podzol profile to be typical must include the organic matter of an iron illuvial horizon. Zakharov (1910) cited by Muir (1961) discussed podzolization in the following stages. In the youngest (or cryptopodzolic) 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 podzolization 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 illuvial horizon. Muir considers that this subdivision indicates stages of podzolization and should be used as follows:

Slightly podzolic where $A_1 > 2\ A_2$; medium podzolic where $A_1 \cong A_2$;

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

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)
18½" - 20"	B_1	black sand with organic matter and iron (2.5Y 2/0) co-impregnated
20" - 30"	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 podzols 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 A_2 horizon (see table 1). When the A_2 and A_3 horizons are combined the conditions as laid down by Zakharov where $A_1 < \frac{1}{2}A_2$ for true podzols is approximated. The Dungun series can be regarded as a true podzol 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 1:5.02MKC1	Mixed Sesquioxides	Iron content % 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 0.2MKC1 were about 0.7 unit lower than in distilled water.

The pH values are lowest in the A_1 horizon, rising to a maximum in the A_3, falling in the B_1 and rising again in the B_3 horizon. The rise in the pH in the B_2 and B_3 horizons may be ascribed to the influence of the water table (note mottles in B_3 horizon) which is invariably characteristic of podzols which have an organic matter/iron illuvial horizon. The mixed sesquioxides drop steadily from the A_1 to the A_3 horizon and rise (tenfold increase) in the B_1 horizon. The iron content follows a similar trend and the increase of iron from the A_3 horizon to the B_1 is also approximately a tenfold increase. The iron content data confirms the field description of a truely 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 A_1 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) Humin & Ulmin	(2) Crenic and (3) Apocrenic Acid	Hymetomelanic Acid	Humic and Ulmic Acids
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

Humus fractions were carried out according to the scheme shown below.

Soil (extracted with 0.1N Na OH)

black solution — humin and ulmin (insoluble)

Action with HC1

precipitate — soluble fraction (crenic and apocrenic acids)

OH (alcohol)

hymatomelanic acid (soluble) — humic and ulmic acids (insoluble fraction)

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 the various horizons in the podzol profile. The four 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 summarises the distribution of these various humus fractions in the 3 horizons examined. As expected the total humus content is lowest in the A_2 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 A_1, A_2, and B_1 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 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 A_1 to the A_2 horizon and rises in the B_1 to an amount approximately equal to that in the A_1 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 HC1 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 B_1 (4 times as much as in the A_1) and lowest in the A_2 where the level is exceedingly low. The humic acid molecule has a complex structure consisting of an 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 podzol a striking mobility of the fulvic acid has been demonstrated (Kononova 1951 cited by Muir 1961). In the Dungun profile this is well examplified in table 2 (0.2% in the A_2 to 6.8% in the B_1). In more recent work by Kononova, it has been shown that stages in podzolization can be distinguished by the differences in the proportions of humic and fulvic acids. In the strongly podzolised or typical podzol 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 differing 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 cryptopodzolic whilst the Rudua and Jambu appear to represent more advanced stages in the podzolization process. Some chemical work on these soils should prove interesting.

The Dungun series can be regarded as a true podzol 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 A_2 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 A_1 as is typical of sandy podzols.

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Discussion

Moormann: The definition of podzol based on the depth of the A2 is not tenable, especially if thickness of the A2 is to be related to the degree of development of the podzol. Hence, the podzol should not be defined on thickness of A2 in relation to A1. The profile described in your paper is a podzol, regardless of the fact that it has a considerable A2. In the 7th Approximation this is realised even to the point where it is mentioned specifically that the A2 is not an absolute diagnostic characteristic of Spodosols.

Ysselmuiden: I have to support Dr. Moormann's view that the thickness of the A2 is not the only criteria for the classification of podzols. We have found in Brunei that cemented Bh horizons occur, this must in time result in a decrease of the thickness of the A2(Ae).

Andriesse: With reference to paper 4 in this session in which I specifically criticized the Russian approach in using the thickness of the A2 to indicate the intensity of the podzolization process I would like to comment here that the position of the Bh in tropical podzols as found in Sarawak is either dictated by the groundwater table or a texture change in the profile due to the bisequent nature of the parent material. Hence with homogeneous parent materials and low watertables the Bh may be found as deep as 12 feet while with a high watertable or a clay layer at shallow depth in an otherwise sand deposit the Bh would develop near the surface. Hence, the thickness of the A2 is not related to intensity of the podzol process but rather to factors dictating the position of the Bh.

Joseph: The depth of the A2 is one possible parameter for measuring the podzolization process and is not intended to define the podzol. I think that the Ae horizon is essential in any soil undergoing podzolization and that the depth of the Ae horizon should increase with the prolongation of the process. The fact that you have soils in Brunei and Sarawak where due to cementation of the coffee rock, the increase in the Bh horizon begins to mask the A2 is to my way of thinking a change in the process. In other words, the process goes so far and then changes. This change is obviously due to a new pedogenetic factor.

Law: Comment: The sequence of soils in coastal sands (East coast, West Malaysia) is as follows:

Baging series	-	Yellow brown sands with no profile development.
Rompin series	-	With faint differentiation of an Ae.
Rudua series (weakly developed phase)	-	With movement of humus down and redeposition at 12 to 18 inches depth.
Rudua series (on higher ridges)	-	(Possibly the same as your Dungun series) with a Bh and Bir at 2 - 3½ feet depth.
Jambu series	-	The giant podzol with a Bh and Bir at 6 to 12 feet depth.

It is suggested that in this sequence, considering the landforms, the watertable is responsible for the formation of the Bh.

Joseph: The Rudua series is similar but not identical to the Dungun series. My comments are based on Ives' description of these soils in his paper.

Guha: Have you studied relationships between soil organic acids (humic and fulvic acids) with the vegetation differences that exist between the sandy soils normally associated with podzols and the other heavier soils, particularly the upland soils in West Malaysia?

Joseph: The present study is the first of this kind we have done. We have not yet extended this to fractionation of humid acids in relation to vegetation.

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 stimulates 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 (1957) 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 surveyors 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 (1963) 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 (1964) 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 West Malaysia, mainly as a supplement to extensive ground surveys.

It must be well-known that all major organizations 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 (1963) 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 (in Vink 1963, 1 and 2) 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 airphotointerpretation 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 steepland in the interior. Access by boat is generally good although smaller rivers are obstructed by sawn 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 and 1967 plus some additional flights by Huntings for timber companies.

Quality as well as scale is variable and, in addition, some is still regarded as strategically important so 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 1:50,000 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 rentises 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 boatmen employed and familiarity with the area obtained.

Field work

Field work 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, but by 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 rentises 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 out the field work 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 a large numbers of men and assistants, so that he has little time to spead in the field himself. As a result the labourers and assistants cut and describe rentises 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 not wish to decree a method that has in 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 demands 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 porterage, 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. 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 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 approximately 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.

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Discussion

Law: What scale of survey and what mapping units are you using?

Acres: Mapping scale is 1:50,000 and the mapping units are associations of families and series.

Law: In West Malaysia it was found that for mapping at a series level air photographs were of little use. Good use could be made of air photographs to distinguish soils at a higher level of classification. Soils are related to terrain forms and when interpreting air photographs landforms are distinguished in which one is able to recognise associations of soils or possibly families. For more detailed work the classification of terrain forms should be also more detailed if the photographs are to be of any use and the mapping units should be set up in advance. For historical reasons series have been the mapping units until now in West Malaysia which is one of the reasons why we could not use air photographs to such a degree as we would wish to do. Another reason is the poor quality of the air photography which was available until recently.

Ashworth: I support Mr. Acre's view that air photographs are invaluable in reconnaissance surveys and agree that they cannot be used for delineating soil series or phases. I, however, disagree with the choice of 1:50,000 scale and would prefer 1:25,000. We have found that in our work a scale of 1:50,000 is inadequate and we needed the support of 1:25,000 and 1:8,000. I would say that a scale of 1:25,000 is the best scale for reconnaissance work. I agree that when working with a team, coordination of work and methods used is essential right from the start.

Acres: The 1:25,000 scale photographs you are using, are they recent photographs?

Ashworth: No, they were taken some time in 1947, but we think they can still be used for areas under virgin forest. I agree, however, that recent photography is important for survey work.

McEachern: Is the type and pattern of land use useful as an aid to delineating your soil unit boundaries?

Acres: Land Use is of very limited use for interpreting soil types as there is so little agriculture practised in this part of Sabah. Natural vegetation can be of great significance particularly in the areas of deposition such as deltas, flood plains and coasts.

McEachern: What about the identification of natural vegetation? To be useful must one become an expert forester to map soil units?

Acres: No. Having delineated on photos the main vegetation differences we would request the help of a forester to give further details.

Donaldson: I would like to substantiate the view that 1:25,000 scale photographs are better than 1:50,000 scale photographs because of cost and mechanics of organization. To give an example, West Malaysia was recently covered by 1:25,000 scale photography within 2 years. To do this at a scale of 1:50,000 would have taken longer because of clouds which prevail at the height from which photographs at that scale need to be taken. Also 1:25,000 photography can be used for other purposes and for the making of scaled 1:50,000 mosaics. There are also less restrictions on the choice of aircraft employed.

Ng: In the soil survey of the Jengka triangle in West Malaysia the consulting firm involved still found it necessary to traverse rentises at 1/3 mile interval to map soils at the series level, even with the availability of 1:25,000 photographs. Would the representative of the firm inform the conference to what extent they found aerial photography useful in soil mapping in Jengka?

Ysselmuiden: The aerial photography used was at a scale 1:25,000. The survey was at a semi-detailed level (mapping scale 1:25,000). The experience in this project was that help from aerial photographs was greatly reduced due to the masking of the topography by the jungle cover. The topographic map (scale 1:25,000) proved in the end to be more useful for drawing soil boundaries.

The International Training Centre for aerial surveys in Delft (Holland) also recognises the fact that the denser the number of field observations, the less support one gets from the air photographs. One would not cut out air photographs altogether but the support is greatly reduced at the more detailed mapping level. It should be mentioned that observations in the traverses were done where necessary which means that in actual fact the density of observations appeared to more than 1 per 1/3 mile.

Law: I agree that under virgin forest photographs become of less value as the degree of detail required increases. In developed areas photographs appear to be important for detailed soil surveys (apparently because the land-forms are easier to recognise) but this requires a more detailed classification of landforms.

Donaldson: You say that in the field the ground is steeper than it appears to be on air photographs. Yet, stereoscopic viewing exaggerates the three-dimensional effect. Possibly slopes appear less severe in valley bottoms because deeper soils tend to have a higher vegetation and would thus on photographs mask the difference in height which exists.

Lee: When using 1:25,000 photographs we sometimes find that changes in vegetation boundaries may be related to changes in geology.

Ashworth: I did not wish to infer that no vegetational changes can be detected on photographs. They can be seen and are often associated with soil changes but the changes are not necessarily at a family level. Again not all changes in soil are reflected in a change in vegetation.

A STUDY OF THE ENVIRONMENT AND CHARACTERISTICS OF PODZOLS OCCURRING IN THE TROPICAL LOWLAND OF SARAWAK (EAST MALAYSIA)*

by

J. P. Andriesse.

Summary

A study of the environment, profiles and analytical data of humus podzols 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 podzolization 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 podzols occur at low altitudes in the tropics is a well established fact. Following discoveries in the Indonesian 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 podzols 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 podzols in tropical areas.

This paper deals with studies which were particularly made to provide an overall picture of the environmental conditions and the characteristics of humus podzols (hereafter called podzols) 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 podzols 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 podzols do occur above an altitude of 1,000 m, in order to omit possible effects from climatic variations in the development of podzols at different altitudes only those occurring below 330 m 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 ca, therefore, be regarded as very similar to parent materials of sedentary origin, but even more impoverished.

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

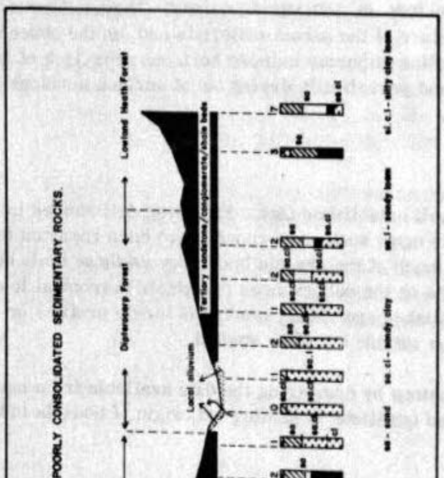


Fig. 1 CROSSECTION OF DIPSLOPE AREA UNDERLAIN BY TERTIARY, POORLY CONSOLIDATED SEDIMENTARY ROCKS.

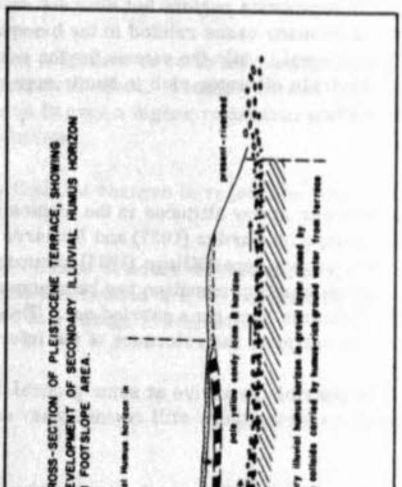


Fig. 2 CROSS-SECTION OF PLEISTOCENE TERRACE, SHOWING DEVELOPMENT OF SECONDARY ILLUVIAL HUMUS HORIZON IN FOOTSLOPE AREA.

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 podzols is distinctly different from those found in material on which iron podzols 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 podzol which presumably forms the source of the iron oxides which following weathering of the hornblende are released. Iron podzols 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 Podzolic soils and Podzols occur in association on these sandstones and deposits with and without orthoclase occur likewise, the fact whether the parent materials of the podzols 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.

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 podzols 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 podzols 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. Podzols 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 podzols 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 podzolization process and does not therefore reflect the drainage situation before the podzols 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 podzols 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 podzols 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

Eugeissonia insignis	-	on better drained places
Eugeissonia minor	-	throughout
Pinanga spp.	-	scattered, locally common
Licuala bidentata	-	" " "
Teysmanniana altifrons	-	on better drained sites.

Common other species are:- Tristanis spp., Whiteodendron moultonianum, Palaquium spp., Payena spp., Cratoxylon glaucum, Melanorrhoea spp., Ploiarium alternifolium, Calophyllum spp., Xylocarpus borneesis, 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 podzols 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.

Tha Al 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 cohesian 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 Al horizon. The lower boundary of the Al 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 uninterupted 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.

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 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 podzols 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 podzols 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 podzols in which the rock structure is still preserved in the illuvial humus horizon.

Detailed descriptions of a podzol with a soft humus pan on terrace material and of a podzol 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 Podzolic 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 podzols. The basic difference is texture, the podzolic soil having a much higher clay content than the podzols.

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 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 podzols under natural vegetation are morphologically similar to the turfy-strongly podzolic 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 podzols. (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 podzols' of central and western Europe (Kubiena, 1953) developed on quartz sands and have strong similarities with the Humic Podzols of Canada where they would possibly mainly belong to the hydromorphic type (Damman, 1962). They can further be compared with Australian Podzols and Groundwater Podzols (Stephens, 1956).

According to the U.S. 7th Approximation to a universal classification system all Sarawak podzols 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 podzols 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 podzols 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 podzolization 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 podzolic 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 podzolic 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 podzolization 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 podzols and the podzolic 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, 1961). 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 podzolization 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 podzols and podzolic soils is illustrated by Diagram 2 which shows the relation between C.E.C., % C and clay content. In the podzols, because of the high quartz content in the clay fraction, the exchange complex is mainly a function of the organic compounds while in the podzolic soils it is directly related to clay content.

Diagram I

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

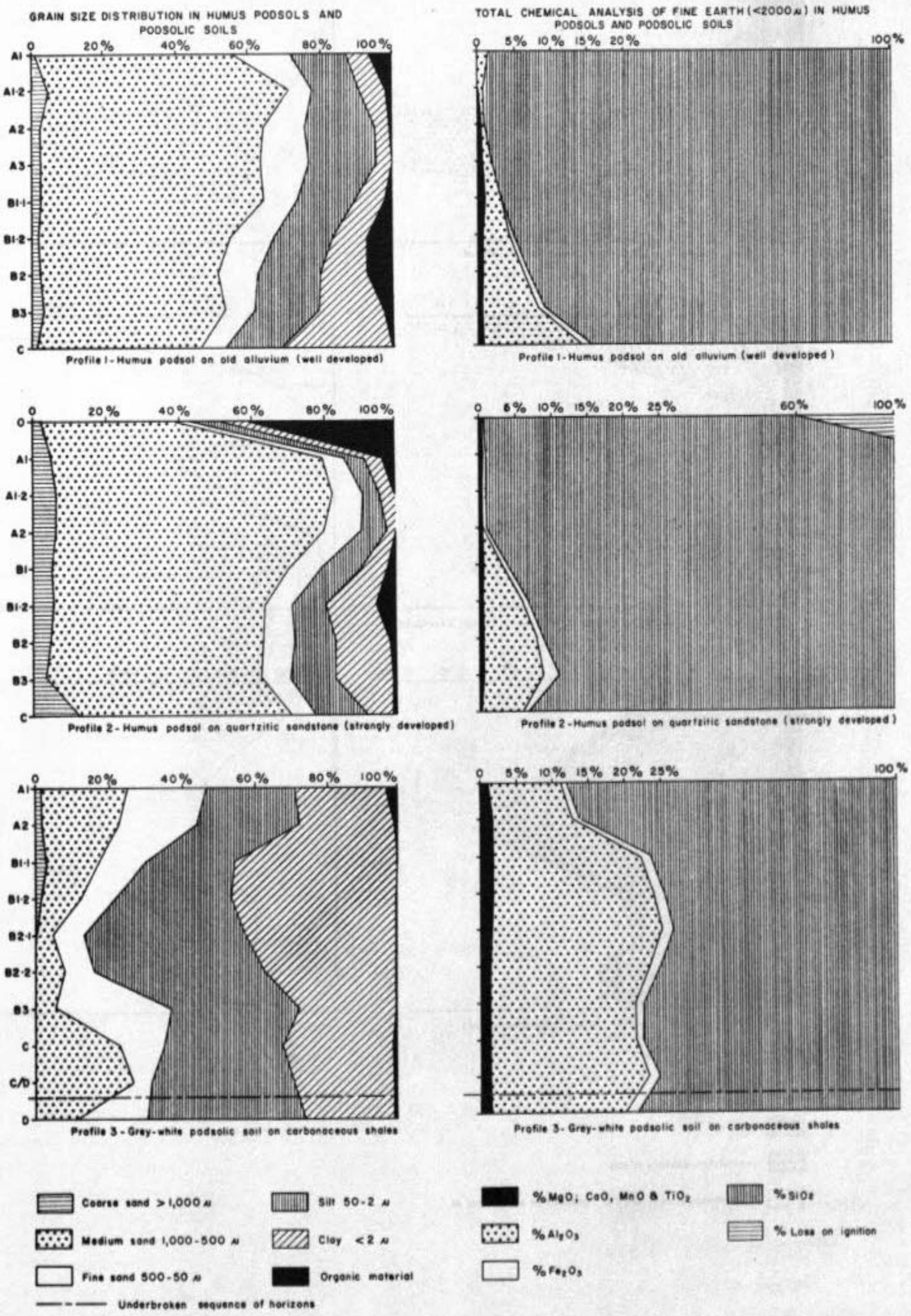


Diagram 2

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

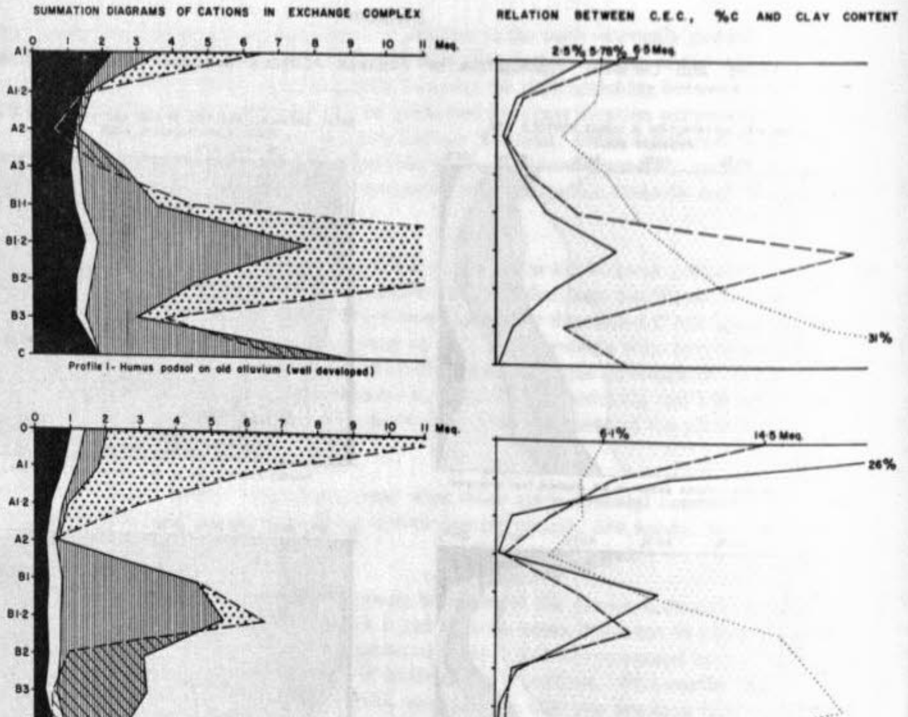
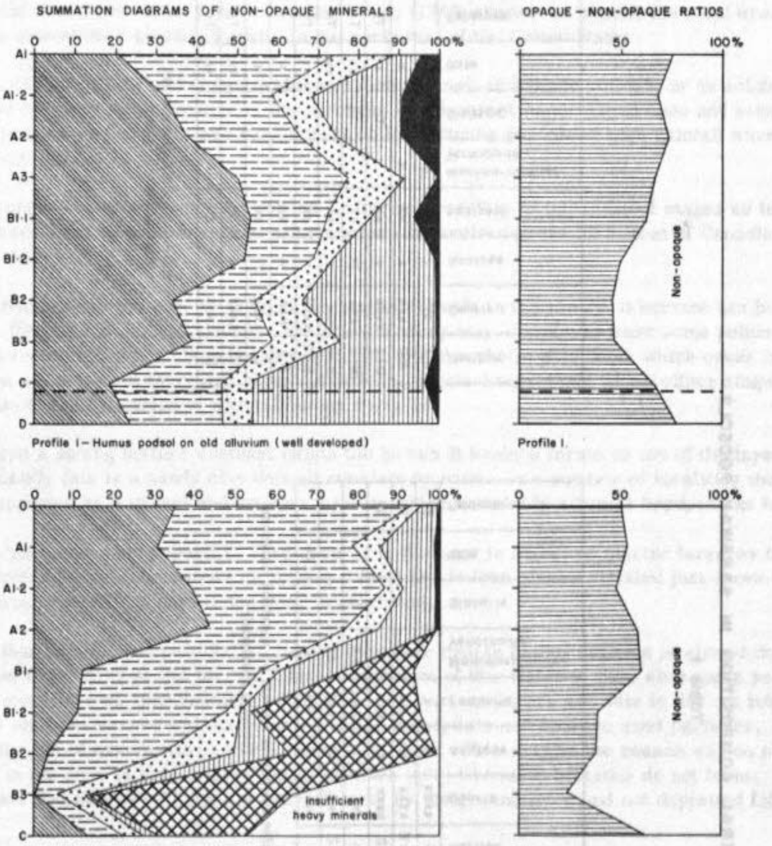


Diagram 3

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



CLAY MINERAL COMPOSITION IN SARAWAK PODSOLS

Table I

Horizon	Quartz	Anatase	Kaolinite	Montmorillonite/ Vermiculite	Gibbsite	Illite	Feldspar
A I	xxxx	x	x				
AI·2	xxxx	Tr					
A 2	xxxx	xx	x				Tr
A 3	xxxx	xx	Tr				Tr
BI.I	xxxx	xxx	xx				x
BI·2	xxxx	xx	x				Tr
B 2	xxx	xx	xx	x			
B 3	xx	xx	xx	Tr	x		
C	Tr	Tr	xx	Tr			

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

Horizon	Quartz	Anatase	Kaolinite	Montmorillonite/ Vermiculite	Gibbsite	Illite	Feldspar
A I	xxxx	x	x				Tr
AI·2	xxxx	xx	xx				Tr
A 2	xxxx	xx	xxx				Tr
B I	xx	x	xxx	xx			
B 2	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
A I	xx	x	xx	xx	Tr	Tr	
A 2	xxx	x	xx	x	Tr	x	
BI·I	xxxx	x	xx		Tr	x	Tr
BI·2	xxx	Tr	xx			xx	Tr
B2·I	xxx	x	xx			xx	Tr
B2·2	xxxx	x	xx			xx	Tr
B 3	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 podsolic soil on carbonaceous shale

A study of the heavy mineral association (Diagram 3) underlines the possibility that quite a number of podzols 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 podzols. 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 podzolic 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 podzols 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 base 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 podzols (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 the 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 podzolization 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 the pure sand this is almost nil and the humus B is formed almost directly above the ground watertable.

In otherwise uniform environmental conditions Podzols 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 podzols 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 podzol process.

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

Conclusions

Podzols occurring in the tropical lowlands of Sarawak are morphologically similar to most humus podzols 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 podzols. Impoverishment of soil material does not initiate the process of podzolization 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 dominant 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 podzol 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 podzolization 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 podzolization 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 podzolic 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 podzolic 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 podzols. 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 (1965, p.203). It is suggested that not only in Sarawak podzols but also in podzols 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 podzols in Sarawak are typically Intrazonal and it is perhaps ironical that the podzol profile originally taken as being a typical example of zonality in soils has proved to be as intrazonal as many other soils.

In fact, podzols 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 podzols while those occurring in temperate regions could be best regarded as climatic podzols.

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Profile descriptions

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

A1 0 - 7 inches
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

A1.2 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

A2 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

A3 12 - 15 "
7.5YR 5/2, dark brown, loamy fine to medium sand with 10YR 6/2, (light brownish grey) - 50/50%. Dark côlour 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

B1.1 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

B1.2 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

B2 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

B3 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

C 50 - 80 "
10YR 8/1, white, sandy clay loam, plastic, compact, moist. Gradual change to

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 bisequent.

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

O 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

A1 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

A1.2 5 - 9 "
5YR 5/2, reddish grey, medium sand (humus stained), with few roots, moist, single grain, firm clear but wavy change to

A2 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

B1 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

B1.2	**18 - 22 inches**	**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**
B2	**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**
B3	**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.**
C	**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 Podzolic Soil Derived from carbonaceous shales.

A1	**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**
A2	**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**
B1	**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.**
B1.2	**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**
B2	**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 quartz-grit. Moist. Abrupt but irregular boundary to**
B/C	**100 - 172 "**	**10YR 7/1, light grey, silty clay, massive and very compact. No cracks or roots, slightly moist, abrupt irregular boundary to**
D	**172 - ? "**	**Soft, easily cut black shale with quartz-strings. Inclusions of fossil roots and olive yellow coloured pyritic material particularly along fracture planes.**

Remark: B2 subsampled:

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

Discussion

Ng: Have you any analytical data to support your assertion that the humus removed from the surface horizon of your podsols is in the form of true humus colloids? If not, then your assertion is too categorical.

Andriesse: There is no analytical data available to prove this. An analogy was made with podsols showing an identical morphology and having similar environmental conditions as described for Canada by some Canadian research workers who made this observation. I agree that it would be more appropriate to stress the analogy rather than the actual process since the former is made by me while the latter is an observation made in Canada which not necessarily needs to coincide with the more obvious similarity in field characteristics.

Joseph: I would like to refer to your statement that humus colloids are distributed and deposited through purely physical processes. Are you implying that the humus does not break down at all? Our analyses of the A1 and B1 horizons of the Dungun profile show very clear differences.

Andriesse: When mentioning humus colloids I do not specify whether they are fulvic or humic acids. This is not of importance in this context. What I wanted to imply is that they are pure and not in the form of alluminium or humus iron compounds (possibly chelates) which may break down at a certain depth in the profile owing to a change in the chemical environment such as a difference in pH. I wanted to emphasize that not through such chemical means the humus is precipitated but mainly through a difference in moisture regime at a certain depth in the profile which I consider to be a physical factor.

Joseph: Don't you think that some soil organic matter fractionation carried out on the A1 and B2 horizons might prove or disapprove your beliefs?

Andriesse: I believe that such work is of interest but it would still leave open the question how humus compounds get arrested in the Bh. It may be of value to find out whether the humus compounds have any appreciable amounts of alluminium or iron in them but this is, as far as the problem of the development and position of the Bh is concerned, immaterial.

Watson: Are the Lowland Heath Forest Associations occurring on old alluvial or colluvial materials the same as those occurring on sedentary material such as sandstones?

Andriesse: Forest inventory reports observe that there is a wide range of species to be found in this forest type but there are local variations in which one or more species may become dominant. There are indications that a change in environment induces such a vegetational change such as the occurrence of a cemented Bh which influences soil drainage, but no prove has yet been found that a change in the parent materials within the range concerned causes a change in vegetation. This, apart from the fact that it is in most cases very difficult to find out whether the parent material is sedentary or alluvial.

Watson: Are the forest associations occurring on podsols developed in sedentary materials distinctly different from those found on say Red-Yellow Podsolics on shale?

Andriesse: Yes, and very much so. The sequence is as follows:

Dipterocarp forest on Red-Yellow Podsolics.

Poor Dipterocarp forest on Grey-White Podsolics and Podsols with incipient humus B horizons.

Lowland Heath Forest on Podsols with well developed humus B horizons.

The latter is extremely poor where podsols have cemented humus B horizons. Poor does not mean poor in species but refers to quantity of timber of commercial value.

Thomas: Have you any substantial evidence to prove the bisequent nature of podsols e.g. heavy mineral content?

Andriesse: Yes, to such an extent that a carefully selected profile which I thought was typically not bisequent proved to be bisequent when studying the heavy mineral association. I may refer to profile 2 in my paper which appeared to have shale derived material in the B horizon which could not be detected by field observations.

Chan: Mr. Andriesse's paper shows marked influence of environmental factors on podsol development. Mr. Joseph (paper 2 in this session) gave an account of characteristics of a true podsol. Would you say that, whilst Mr. Joseph's paper described a true podsol, yours describe a 'change' or modified podsol because of this marked influence of environment on the development of podsols?

Andriesse: The podsols concerned are of the same nature. There is not a thing like a true podsol and a podsol developed because of the influence of environment. In fact any soil is the result of the influence of environmental factors. The only example I would like to call a modified podsol is in the case where primary jungle on a podsol is removed. We than see that the Ao disappears through mineralization and oxidation of the organic matter. The A2 will become more pronounced because there is little humus moving down through it and humus staining is less. This, I would like to call a 'modified' podsol because of influence of man, but it is still a podsol, only the development has been halted through interference in the normal natural environment.

Chan: In the circumstances explained by you, do you consider a need to change the old definitions of podsols and introduce new definitions or would you agree to a certain extent that the old definitions of podsols are still adequate in describing our present-day podsols?

Andriesse: I would prefer to use at this stage, the term Spodosols rather than podsols since the latter have many definitions not covering the same meaning in all cases.

Moormann: The present definition of Spodosols is based on the Bh, formed by the podsolization process of humus colloids leaching down. Furthermore, the movement of ill-defined alluminium silicates (allophane) seems to be diagnostic of the group. The presence of a bleached A2 (albic horizon) is not diagnostic for the group, since such an A2 may or may not be present in Spodosols. Also, the movement and eventual concentration of Fe is not diagnostic of the group; Fe leaches and accumulates in other groups as well e.g. Alfisols, Ultisols.

Thomas: One of the characteristics of some podsols is the illuviation of amorphous clays such as allophane forming a B3. It has been stated (Andriesse) that where a coarse textured A2-A3 overlies a heavy B3/C the textural junction reflects the contact zone of the members of the bisequum. Could this not reflect normal eluviation and illuviation in a sequum?

Andriesse: The change is usually too abrupt to account for a normal textural B, also the increase in clay is frequently of such a magnitude that it is difficult to believe that just illuviation of clay is responsible. In fact both can happen and I think do happen. A slight difference in clay content between layers in a sediment induces changes in the moisture regime and if a podsol process is involved leached alluminium and SiO_2 may form new clay minerals in the horizon where stagnation of groundwater does occur. Also, eluviated clay may be arrested in such layers (lessivage). But one must not forget that the original difference in t xture has set the stage for the development of what is now a well developed textural B.

Joseph: If you think that an Ae horizon is unimportant in the podsol process, then how do you account for the iron in the B1 - where does it come from?

Andriesse: The Ae horizon may be important in the process but since the characteristics of this horizon vary so much, depending on other environmental conditions, the detailed characteristics cannot be used for classifying podsols. As for iron, is it necessary for iron to be there in a podsol? I do find very little iron in Sarawak podsols and its existence is immaterial. What counts is the relationship between the main elements in the podsols mainly, alluminium, quartz and humus.

The podzols concerned are in the [illegible]. There is not a thing like normal podzol and a [illegible] developed [illegible] of the [illegible] may still be the result of the [illegible] factors. The only [illegible] to call a modified podzol [illegible] is in the case where [illegible] but then see that the A2 develops through [illegible]. The A2 will become more pronounced [illegible]. This, I would [illegible] to call a "modified" podzol [illegible] to call it a podzol, only the development has been [illegible] as [illegible].

[illegible] in the [illegible] to change the old definitions of [illegible] and [illegible] to such extent that the old [illegible] of podzols [illegible] change the podzols?

I would prefer to use of this [illegible] rather than podzols since the latter have many definitions [illegible] in all cases.

The [illegible] of podzols [illegible]. Applying the [illegible] of [illegible] [illegible] ... A2 [illegible] is not diagnostic for the [illegible] ... the [illegible] and [illegible] accumulates in other groups [illegible].

One of the characteristics of some podzols is the [illegible] clays such as [illegible] forming a B3. It has been [illegible] a heavy B2/C [illegible] the [illegible] of the [illegible]. Could this not [illegible]?

The change [illegible] the [illegible] of such a [illegible] [illegible] in fact both can happen [illegible] ... [illegible] occurs. Also, [illegible] ... [illegible] that the [illegible] the stage for the [illegible] [illegible] or [illegible].

If you mean this as horizon [illegible] ... [illegible] from an [illegible]?

The A2 horizon may be [illegible] of the [illegible] of this horizon vary so much, depending [illegible] ... [illegible] podzol? I do [illegible] ... [illegible] comes in the relationship between the [illegible] ... quartz and humus.

CHARACTERISTICS OF SOME SOILS DERIVED FROM IGNEOUS ROCKS OF WEST MALAYSIA

by

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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 rhyollitic 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 occassionally 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 were 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
Intermediate	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-mfi	moderate	moderate	fairly distinct Ae/Bt
	Jerangau	Strong brown	fscl	mfr-mfi	moderately weak	moderate	fairly distinct Ae/Bt
	Kulai	Yellowish brown - yellow	c	mfi	moderate	moderate	fairly distinct Ae/Bt
	Rengam	Yellowish brown	cscl-scl	mfr-mfi	weak	moderate	fairly distinct Ae/Bt
	Kala	Brownish yellow - strong brown	cscl	mfi	weak	moderate	weakly distinct
	Tampin	Pale brown - olive yellow	sc	mfr-mfi	weak	moderate	fairly distinct Ae/Bt

B. LABORATORY DATA

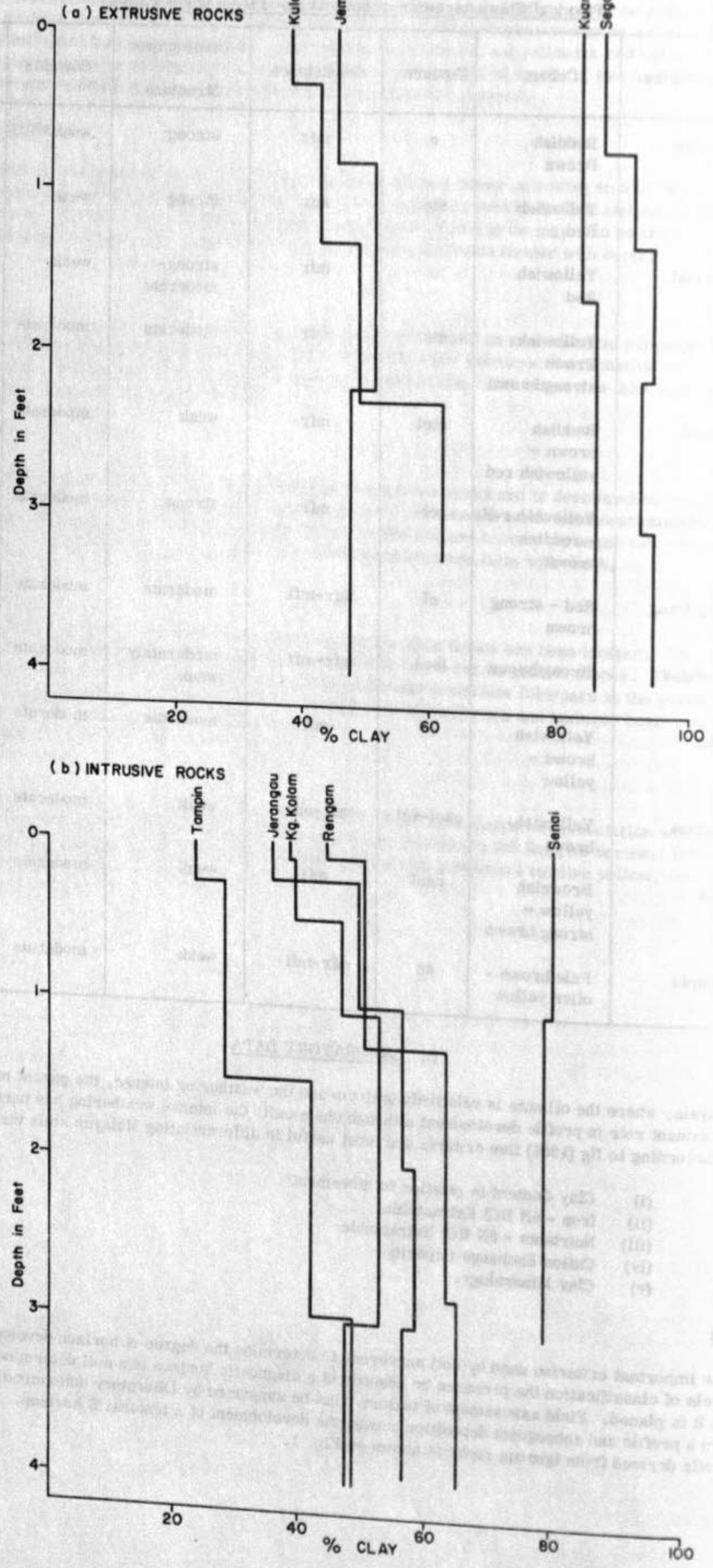
In West Malaysia, where the climate is relatively uniform and the weathering intense, the parent material has been found to play a dominant role in profile development although chemically the intense weathering has narrowed differences amongst them. According to Ng (1966) five criteria are most useful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

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



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 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 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 other 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.

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/Montmorillonite	Mixed Layer Micas	Vermiculite
Basic	Kuantan	dominant	-	-	-	-
Intermediate	Segamat	dominant	-	little	-	-
	Kpg. Kolam	dominant	little	little	little	-
Acid	Jerangau	dominant	-	little	-	-
	Rengam	dominant	-	little	-	-
	Kulai	dominant	much	some	some	-

FIG: 2 6N-HCL EXTRACTABLE Fe_2O_3 (Modified from S. K. Ng 1966)

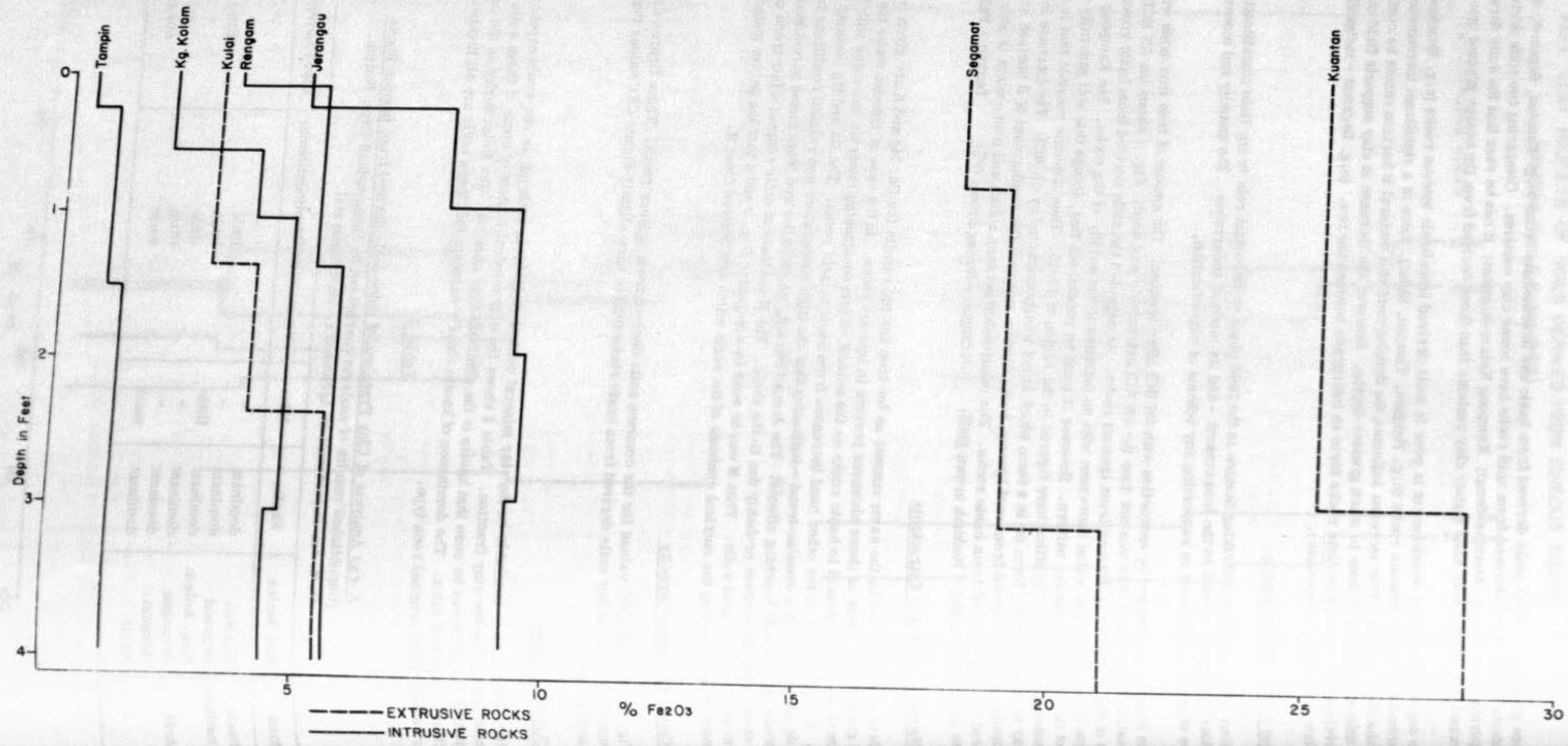


FIG. 3 TOTAL NUTRIENT CONTENTS IN SUBSOILS

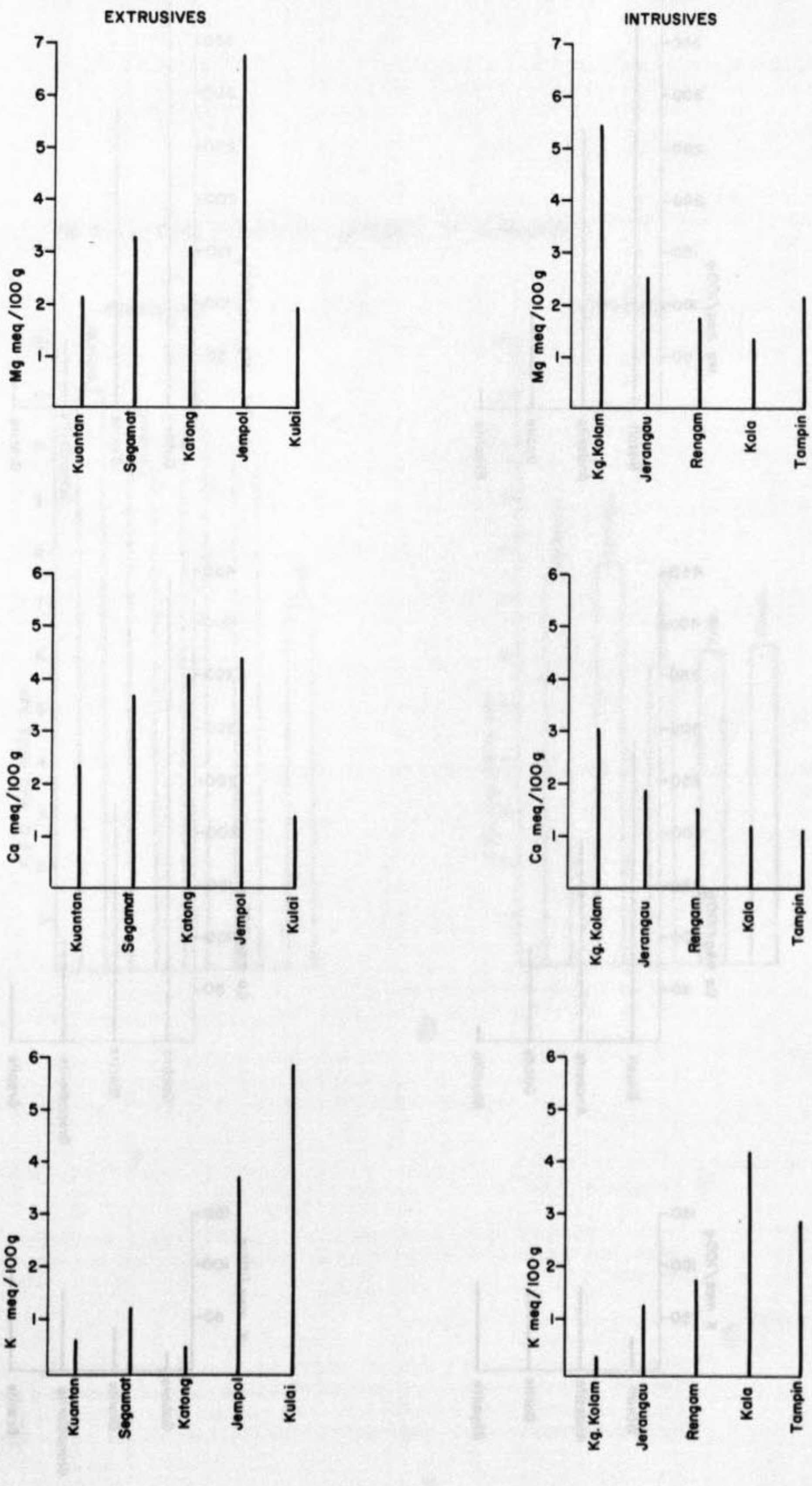


FIG. 4 MEAN ELEMENT CONTENTS OF SOME IGNEOUS ROCKS
(Based on Alexander et. al. 1964)

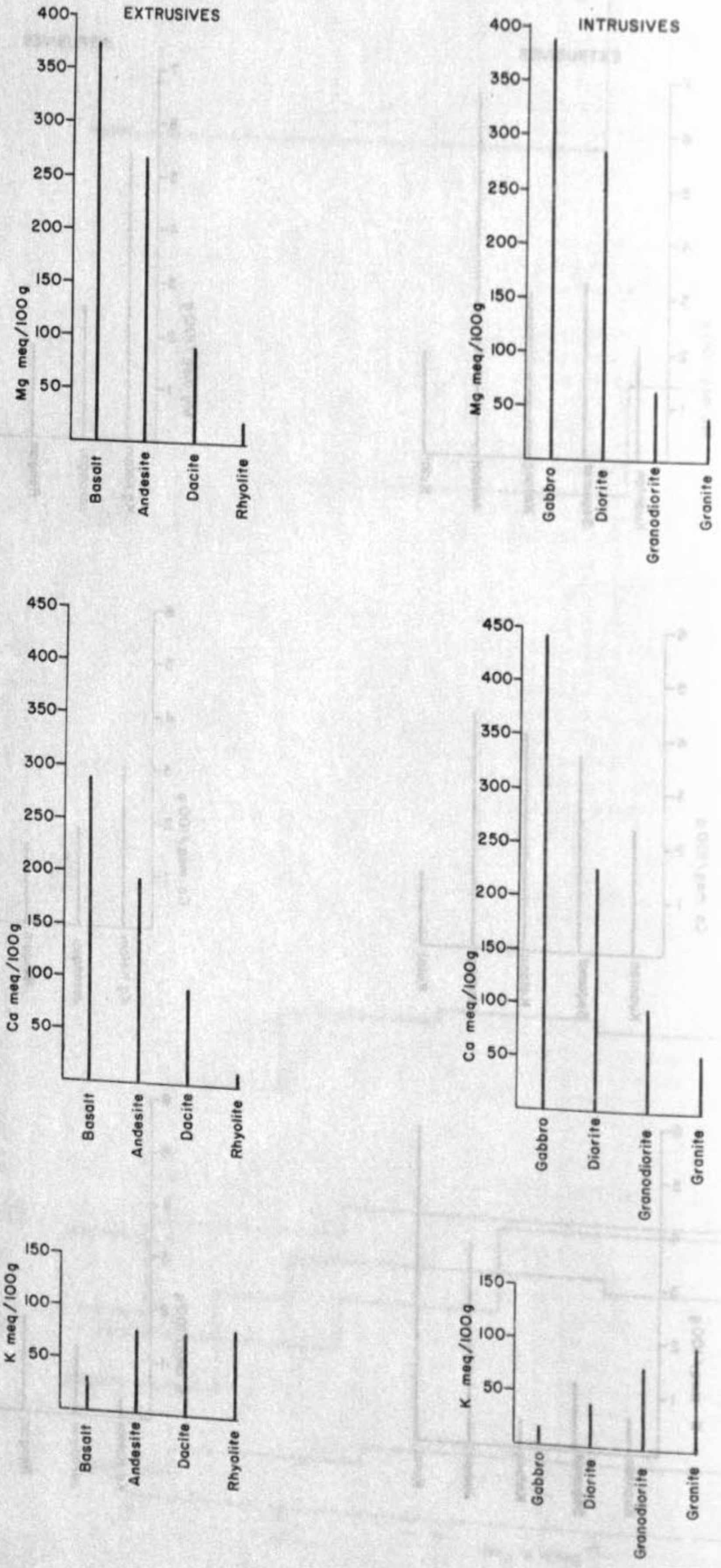
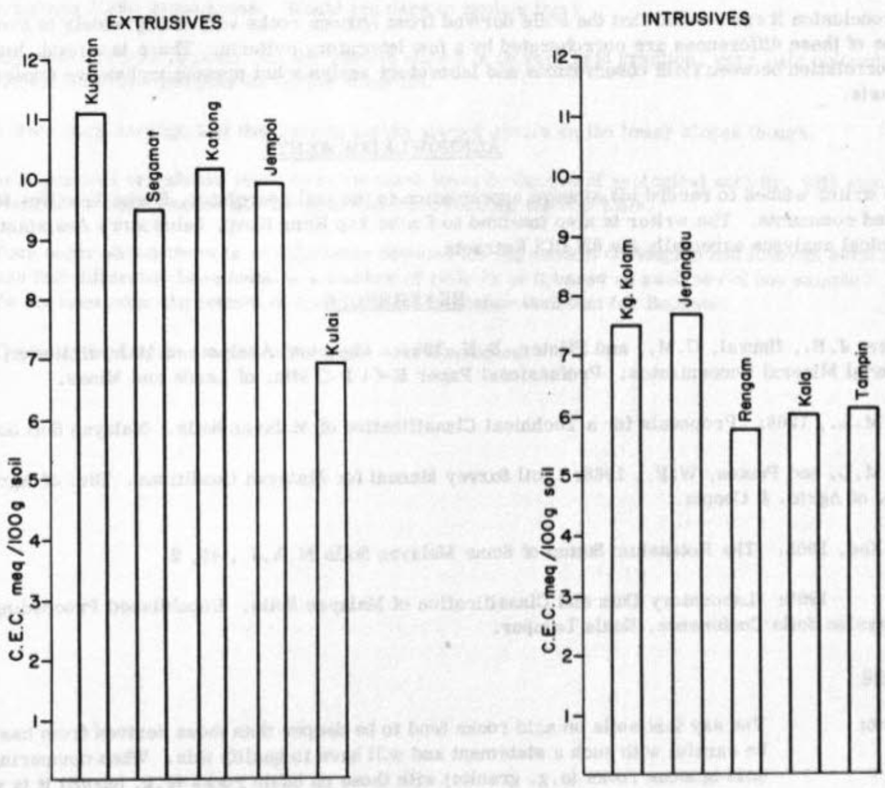


FIG: 5 CATION EXCHANGE CAPACITY OF SUBSOILS



DISCUSSION

The soils derived from igneous rocks vary prominantly 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. 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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Discussion

Moormann: You say that soils on acid rocks tend to be deeper than those derived from basic rocks. You must be careful with such a statement and will have to qualify this. When comparing soils developed on acid igneous rocks (e.g. granite) with those on basic rocks (e.g. basalt) it is very generally true that the Regolith (A+B+C) on acid rocks is deeper but it is certainly no rule that the Solum (A+B) is thicker. Very often the solum is thicker on basic igneous rocks, especially on basalt.

Thomas: You mention that because your normal maximum sampling depth was 48 inches, you had, in spite of a general increase in clay down the profile difficulty in determining whether a textural B horizon occurs. Do you think therefore that a decrease in clay at depth is necessary to designate this horizon?

Paramananthan: At least the Chemist insisted this was necessary for a good textural B but as soil surveyors we do not agree with that and find an increase only sufficient.

Andriesse: The base saturation figures in Malayan soils appear to be always about 10 fold those of genetically comparable soils in Sarawak. Is this an age factor or do you think leaching may be stronger in Sarawak?

Paramananthan: Possibly your rainfall is higher.

Law: Considering the landscape in Sarawak, this seems generally much older than the landscape in Malaya. You have generally very strongly dissected peneplains while our peneplained areas are normally only slightly dissected. This may indicate that your soils are older and hence more leached. Our Malayan figures may eventually reach the same low levels as you have in your Sarawak soils.

Shao: Referring to your figure 3, it is expected that Mg content for Kuantan soil should be higher. But on the contrary the Mg contents for Kuantan, Segamat, Katong and Kulai are more or less similar. The explanation given by you, that this could be due to leaching, is a very doubtful one. Your plot for K does very nicely show up the trend of increasing K from Kuantan to Kulai. If leaching was the reason for low values of Mg in your Kuantan and Segamat soils, I would expect K to be more easily leached than Mg. I consider that your 6N HCl extraction method may extract all your K but, however, fails to do so as far as Mg is concerned.

Paramananthan: The Kuantan series is derived from basalt and is a very senile profile. This may explain why all the figures are much lower than those for the Segamat series (on andesite but younger).

Shao: In your figure 4 you quoted Alexander's method. What extraction method did they use?

Paramananthan: I do not know.

Law: They are normal geological analyses in terms of oxides of all elements analysed by the fusion method.

Joseph: You have shown an interesting association of Tampin series with the Rengam series, the former occupying lower slope areas. Would you care to explain this?

Paramananthan: Analyses of rocks indicate that the Tampin series is on very acid granites, very pale coloured, rich in feldspars and poor in Fe/Mg minerals.

Joseph: It does seem strange that the Tampin series always occurs on the lower slopes though.

Law: Acid granites are always found to be intruded towards the end of geological activity, with mountains being of normal granites and the acid members forming the foot hills.

Singh: Your paper shows there is no difference between the Mg content of Rengam and Kuantan series. Has this difference been found in a number of soils or is it based on analyses of one sample? To my knowledge Mg content of Kuantan is much higher than that for Rengam.

Paramananthan: The analytical figures concern the mean over 5 samples.

TERRACE AND ALLUVIAL SOILS IN WEST MALAYSIA

by

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Introduction

Terraces occur adjacent to the coastal plains both in the East and West Coasts of West Malaysia. They also occur inland, flanking active flood plains of large rivers. At least three main terrace levels have been recognised. The high level terrace occurs at or about the 250 foot contour level with leached red yellow soils; the intermediate terrace is between the 50' and 150' contours with grey yellow soils; and the low level terrace occurs up to the 50' contour with grey clayey soils. These grade on to the coastal plains with clayey alluvials on the west coast and sandy beach ridges on the east coast. The soils developed on these terraces differ in the degree of development of the genetic horizons, morphological and chemical features.

Topography and Distribution

Terraces in different parts of West Malaysia and the soils developed on it are shown diagramatically in Fig. 1.

The terrain of the high level terrace, T_3, is dissected by streams and rivers with broad valley floors. The topography is undulating to rolling with rounded hills of concordant heights. In the Sungei Klau valley, in Pahang, the high level terrace is at a height of about 300' above sea level. It's topography, however, is flat to gently undulating. The high level terrace tends to occur inland, except in Johore where they occur immediately adjacent to the narrow coastal plain. They are widely distributed in the States of Perak, Pahang and Johore.

The intermediate terrace, T_2, is relatively less eroded. The terrain is weakly dissected and topography is flat with low dips, or gentle undulations. It is extensively developed in Perak and Pahang. Except for small pockets flanking the high level terrace in South Johore, the intermediate terraces have a very limited occurrence in the south western part of West Malaysia. In the Kahang area of North West Johore, it occurs in association with the high level terrace in the upper reaches of the Endau river. It is extensively developed in the northern States, particularly in Perak. In the east coast it occurs in Kelantan and Pahang. In Kelantan it occurs in 'the deficiency area' on the western edge of the Kelantan plain.

The low level terrace, T_1, has generally a level terrain occurring immediately adjacent to the coastal plains and flood plains of rivers. Like the intermediate terrace, it is almost absent in the Southern States. It is best developed in Perak and in Kelantan, where the Kelantan plain is a low level terrace. This terrace is subject to seasonal flooding.

Development of coastal and riverine flood plain, T_O, together with coastal swamps is most widespread in the west coast. This is a consequence of the quieter conditions prevalent in the sheltered Straits of Malacca, in contrast to the east coast which faces the open sea. The coastal plain here, is narrow and characterised by sandy beach ridges. In Kelantan, however, there is a wide riverine flood plain - the Kelantan plain. Occurrence of coastal swamps is limited in the east coast.

Peat deposits may be found in depressional areas T_O(d), within the coastal plain.

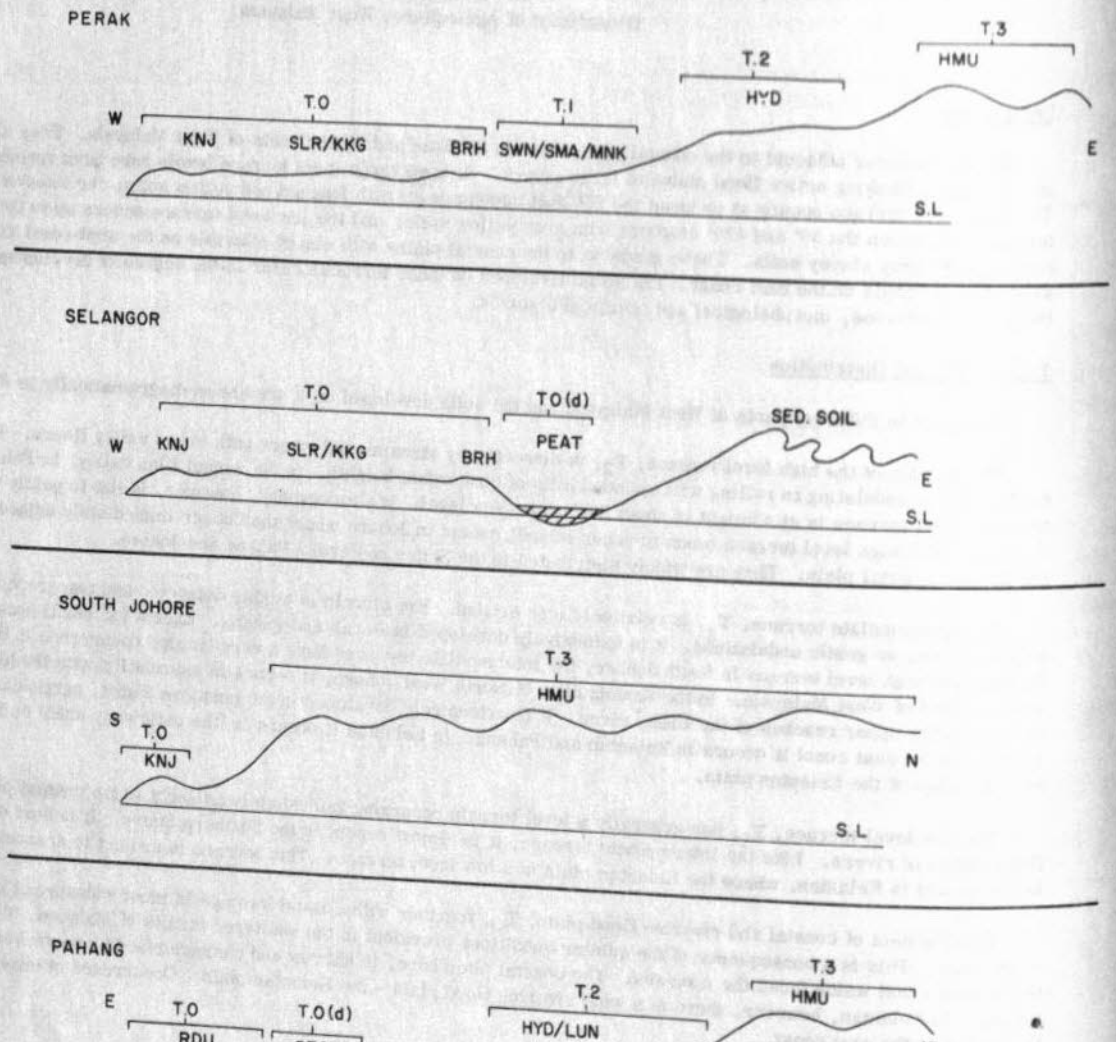
SOILS

(a) Soils on the High Level Terrace

The soils on this terrace display reddish yellow colours. The solum usually overlies bedded rounded pebbles and generally has a sandy to coarse sandy clay loam textures. Eluvial and argillic horizons are moderately developed, but often an intervening transitional horizon is observed. The general sequence of horizonation is Ah/Ae(j)/Bt/C. Occasionally diffuse bands of small lateritic concretions may occur in the sub-soil. There is incipient development of non-hardend plinthite overlying the pebbly parent materials. Structure usually varies from weak to moderately well developed subangular blocky. The soils are quite strongly leached and impoverished of weatherable minerals. Kaolin is the dominant clay mineral.

Ths soils on the high level terrace belong to the Harimau family. The members, include Harimau Series, Tampoi Series. Ulu Tiram, Klau and Tai Tak Series. The parent material is essentially granitic wash in the Harimau, Klau, Tak Tak and the Ulu Tiram. The Tai Tak has a finer texture while Ulu Tiram is distinctly coarse. The parent material of the Tampoi Series is made up largely of quartzite pebbles. The Klau Series departs from the general characteristics of the high level terrace soils in that it is relatively uneroded and occurs at higher elevation (350'). This may be expected in the upper reaches of rivers when alluvium is deposited within the confined area of a valley floor with steep sides, like the Klau valley.

FIG I DIAGRAMATIC REPRESENTATION OF TERRACES AND SOILS IN DIFFERENT PARTS OF MALAYA



N.B. Diagrams are not to scale

KNJ - Kranji Series
LUN - Lunas Series
BTU - Bukit Tuku Series
SLR - Selangor Series
SWN - Sitiawan Series
HMU - Harimau Series
KKG - Kankong Series
SMA - Sogomana Series
BRH - Briah Series
MNK - Manik Series
HYD - Holyrood Series
RDU - Rudun Series

(b) Soils on the Intermediate Terrace

Soils here have a weakly expressed illuvial B horizon. This is however detected only in soils with a relatively higher clay content. Horizonation is Ah/AB/C, Ah/Ae/AC or Ah/AB/Btj/BC. Horizon boundaries are usually diffuse. Textures are essentially sandy, ranging from sandy loam to sandy clay loam. Consistence is generally loose to friable and structures weakly developed. The colours of the soil are generally grey-yellow. The soils are quite strongly leached. Mottling in the heavier soils of this terrace is weak and diffuse.

Soils of the Holyrood and Bukit Tuku families occupy the intermediate terrace. The Holyrood and Lunas Series are members of the Holyrood family. The Holyrood Series is a yellowish brown friable weakly structured soil with rapid internal drainage. The Lunas Series is a grey coloured sandy clay loam occupying slightly lower lying areas than the Holyrood Series, and having higher clay content. Members of the Bukit Tuku family also occupy low lying areas in the intermediate terrace. Grey colours are predominant, and they are weakly mottled.

(c) Soils of the Low Terrace

Genetic horizons are absent in the soils of the low terrace. Textures are clayey and colours generally light grey. Structures are weak to moderately developed. Internal drainage is poor and consequently, the sub-soil is mottled and often gleyed. The soils too, are sometimes inundated although not as frequently as those in the flood plains. Horizon sequence is usually Ap/Bg/Cg.

The soils found in this terrace are the Manik, Sogomana and Sitiawan Series, all of them first recognized in lower Perak where they are found below the Holyrood Series of the intermediate terrace. Both the Manik and the Sogomana Series have poorly structured, light grey sub-soils of firm consistence. The Sitiawan Series occupies relatively higher levels, has better internal drainage and structures. The sub-soil is pale yellow and of firm consistence.

(d) Soils on the Coastal and Riverine Flood Plains

With the exception of the sandy soils of the beach ridges, horizons are very weakly expressed in the soils of coastal and riverine flood plains. Brown and grey colours are predominant in these soils. Members of the Selangor family are developed over bluish-green marine clay. In their natural condition they are poorly drained with gleying and mottling in the incipient B horizon. They are fine textured soils. On the levees of the rivers, soils of the Briah family are developed. Briah is broadly similar in morphology to Selangor Series, but differ in their clay mineralogy. Derived from marine clay, about 50% of the clay in the soils of the Selangor family is montmorillonite, while in Briah, which origin is mixed alluvia, the clay is a mixture of montmorillonite and Kaolin. Horizonation is Ap/ABg/BCg/Cr.

A loamy soil (Telamong Series) may be developed on the levee. This is commonly found in the east coast. The soils are weakly structured and genetic horizons are entirely lacking. Horizonation is Ah/AC/C. This soil is subject to seasonal flooding, and consequently may show stratification of different textural bands.

Genetic horizons are strongly expressed in the podzols found on the beach ridges. They have a clear albic horizon overlying a spodic horizon. The soil comprises essentially of quartz sand and is loose and friable, except in the spodic horizon which is relatively cemented. Colours in the Albic horizon varies from very pale brown to white and in the spodic horizon from black to very dusky red. General horizonation is Ah/Ae/Bh/C.

In the coastal swamps along the beach front, dark grey saline gley soils are actively accumulating. The soils include members of the Kranji family. Behind the Saline gley soils are the acid sulphate soils. These are characterized by an organic rich surface horizon overlying blue-green sulphurous clay. They have a very low pH.

Peat, organic clays and mucks are all characterized by high organic matter content. Depth of peat is variable varying from about 3 feet to more than 10 feet. These organic soils occur extensively in the depressional areas of alluvial flats in what were probably sites of former lagoons.

Discussion

The development of an argillic horizon is a distinctive feature in the soils of the high level terrace (Fig. 2). There is hardly any clay accumulation in the Holyroods of the intermediate terrace, although both the Harimau and the Holyrood are derived from a granitic wash. There has also been movement of iron in the Harimau besides that of clay. This is seen in the (i) development of unhardened plinthite which is a horizon where segregation iron has occurred, and (ii) iron enrichment in the 'Bt' horizon (Ng 1966 pp. 94). Clearly, horizon-forming soil processes have been operating in the soils of the high terrace to produce a more mature soil, relatively older than the soils of the lower lying terraces. This is also borne out by the geomorphology of the terrain and deficiency of weatherable minerals.

The soils in the high level terraces show podzolic or ultisol features (Leamy 1966) and simulate the morphological characteristics of sedentary soils, and have been grouped with the red yellow ultisols (Leamy 1966). The soils of the intermediate and low terraces in their poor or absent genetic horizonation, show entisol characteristics. A study of the mineralogical assemblage would no doubt provide more information on the relative immaturity of these soils. Cation exchange capacity values may also be used to differentiate the soils of the intermediate terraces, low terraces and the coastal plains (see Fig. 3). The soils of the low terrace have higher cation exchange capacity values than that of the more leached soils of the intermediate terrace. They are, however, distinctly lower than that of the coastal and riverine flood plains, except the podzols.

FIG: 2 CLAY PROFILES OF HOLYROOD AND HARIMAU SERIES. (after Ng. 1966)

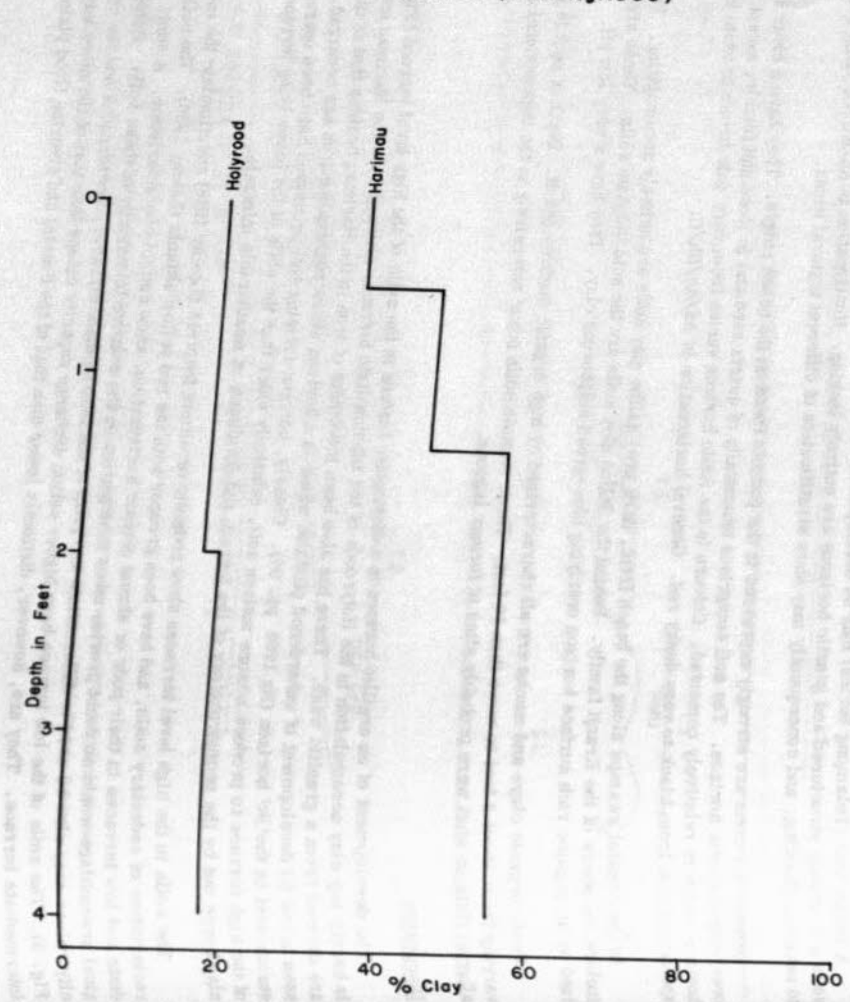
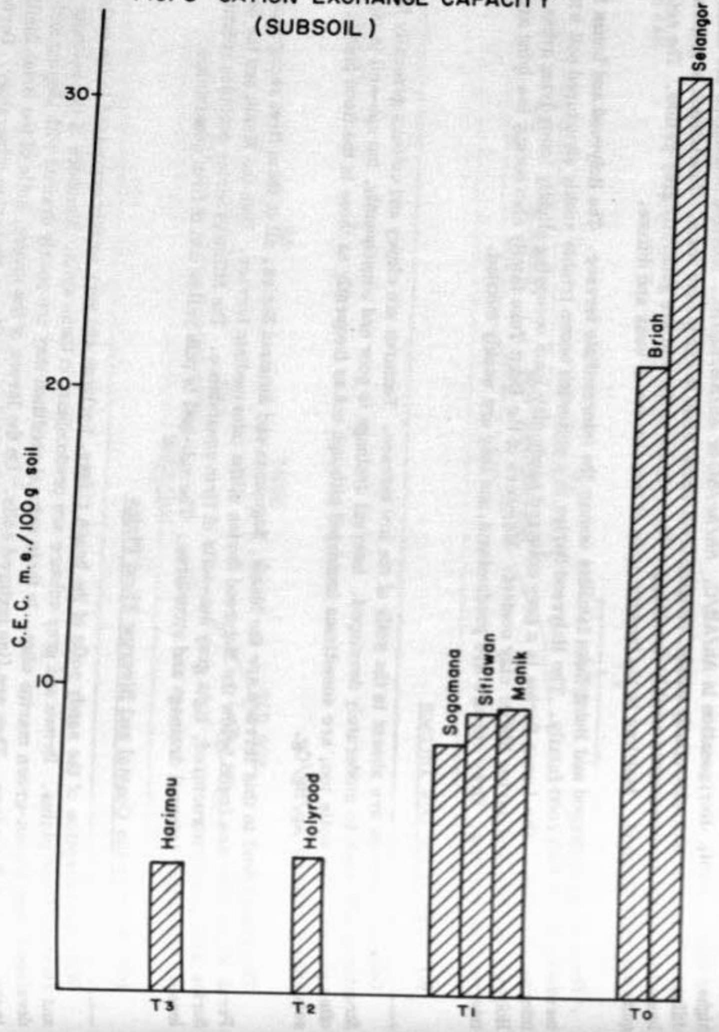


FIG: 3 CATION EXCHANGE CAPACITY (SUBSOIL)



The soils of coastal and riverine flood plains are somewhat variable in their morphological characteristics. In their natural state most of the soils have poor profile development, but cultivation, artificial drainage and various other soil amelioration practices have induced horizonations within the soil body. The soils developed over marine clay in the Kedah plain, north west Malaya, show marked horizon development. Here, where there is a distinct dry period for about three months of the year, climate, in addition to cultivation and artificial drainage has played a part in the development of the soil profile.

The strongly developed horizonation in the podzols formed on the sandy beach ridges is no doubt due to their susceptibility to rapid leaching which allows podzolization to occur very much more easily than in the other heavier soils.

Conclusion

Three main terrace levels each within a certain range of elevations and having a characteristic land form, may be distinguished. The soils developed on each of the terrace have a characteristic profile morphology. These features, including cation exchange capacity values can be used to correlate the terrace soils in Malaya.

The soils of the coastal swamp, peat and the sandy podzols are easily located through their characteristic profile morphology and chemistry.

Acknowledgement

The writer wishes to record his sincere appreciation to the soil correlator, Enche Law Wei Min for his valuable advice and comments.

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Discussion

Moormann: Good correlation exists between the soils of the different terrace levels in West Malaysia and Southern Thailand. Many of the high terrace soils in Thailand, though having an A1 and A2 appear to have an oxic B, rather than an argillic B. This may be a variant to the Red-Yellow Podzolic soils you find on your high terrace soils.

For the middle level terraces Holyrood in West Malaysia and Kohong in Thailand appear to be very similar, these soils show weak horizonation, there is a clay accumulation at great depth (60 cm) and the clay content shows a slight bulge at this depth. These seem to be typical characteristics of what we consider to be Paleudult (Grey-Podzolic soils).

Soils on the lower terraces do, in Thailand, include so called 'paddy-soils' which are Low Humic Gley soils with usually a distinct B tg horizon (Aquults).

Law: Paddy soils in West Malaysia will have to be included in the general classification scheme but I feel it is only right to point out that these soils will further be classified in the padi soils scheme. They are, however, essentially Low Humic Gley soils.

Moormann: Paddy soils should not be considered as a separate group on a very high level. Depending on the amount of change due to the growing of submerged rice, they could be distinguished from the adjacent non-paddy soils on a great group, little group or even another lower categorical level, e.g. wet alluvial soils, whether under paddy or not hardly show different characteristics. On the other hand, a Latosol, used for paddy may change considerably and may warrant a distinction at a high categorical level.

Allbrook: Would Dr. Moormann ignore the features associated with paddy cultivation such as mottles and manganese accumulation?

Moormann: The general accepted definition of 'paddy soils' is: soils on which rice is grown under submerged conditions. This is a very general name and not fit for soil classification purposes. If you say: paddy soils are soils which have already changed considerably then I would agree but as the definition stands at present I maintain that it cannot be used for soil classification purposes. Furthermore, one should be very careful to associate mottles and manganese accumulation and such with paddy cultivation. In many soils of a hydromorphic nature, such features are present even if the soil is not used for submerged rice (e.g. in Low Humic Gley soils).

Chan: Referring to figure 3 on C.E.C., there appears to be a considerable gap (difference of about 10 meq. C.E.C.) between the Selangor and Briah series. At the same time in your high level terrace soils, C.E.C. is quite the same for the three soils on these terraces. As Selangor and Briah have been grouped together and you mention that these soils are morphologically the same, why is there a comparatively significant difference in the C.E.C. of these two soils? Would a difference in clay mineralogy account for this difference?

Gopinathan: Yes, Selangor and Briah have higher C.E.C. values because of the montmorillonitic nature of the clays. Selangor has a higher content of montmorillonite while Briah has a mixture of kaolinite and montmorillonite.

Holyrood and Harimau series on the middle level terraces have kaolinite as the predominant clay mineral which accounts for the low C.E.C.

A PRELIMINARY STUDY OF ACID SULPHATE SOILS IN WEST MALAYSIA

by

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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):

$$Fe_2(SO_4)_3 + 2H_2O \longrightarrow H_2SO_4 + Fe_2(SO_4)_2(OH)_2$$

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 general 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 description 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 fertilisation. 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 PYE 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 shakened 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 topsoil (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 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.

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.

Table 1

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

		pH				Sulphur Contents in % of Dry Soil					
Soils	Depth (ins)	Wet		Dry		H_2O-Soluble SO_4-S		2N HCl Sol. 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

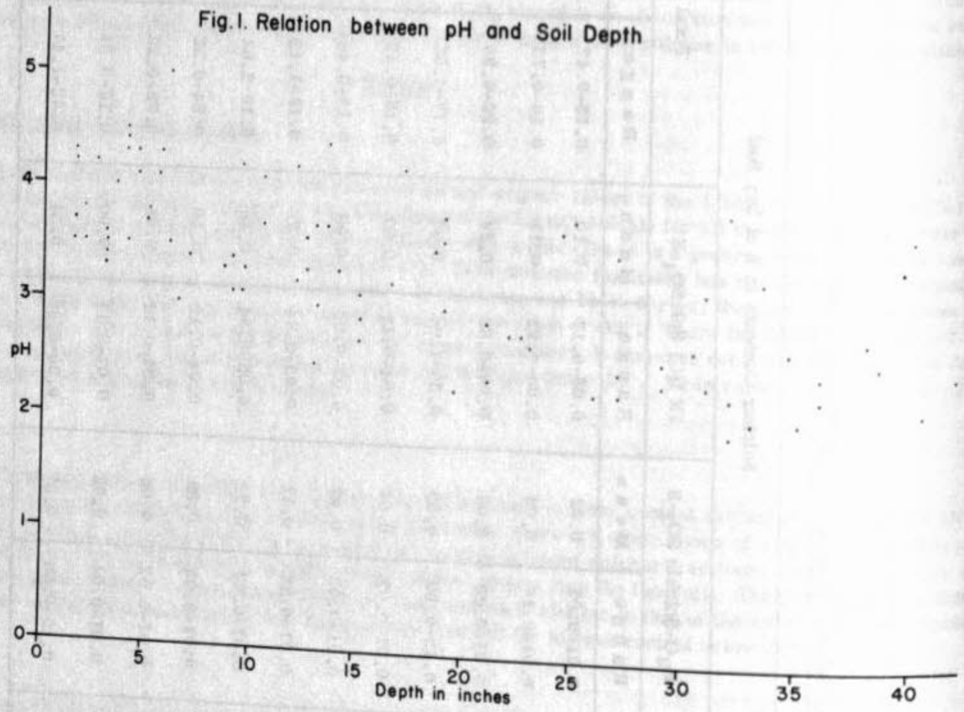

Fig. 1. Relation between pH and Soil Depth

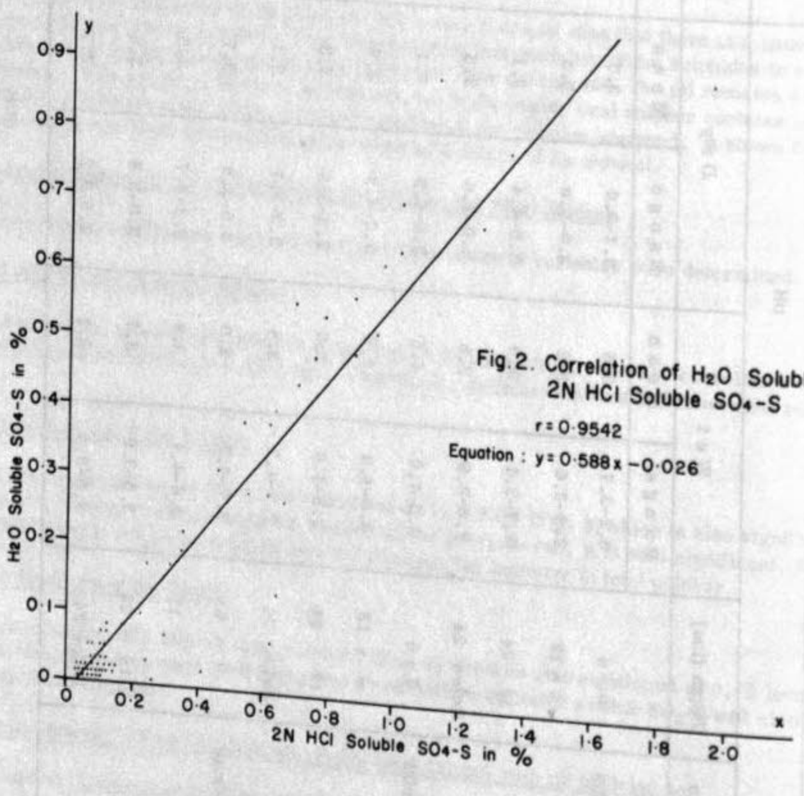

Fig. 2. Correlation of H_2O Soluble with 2N HCl Soluble SO_4-S

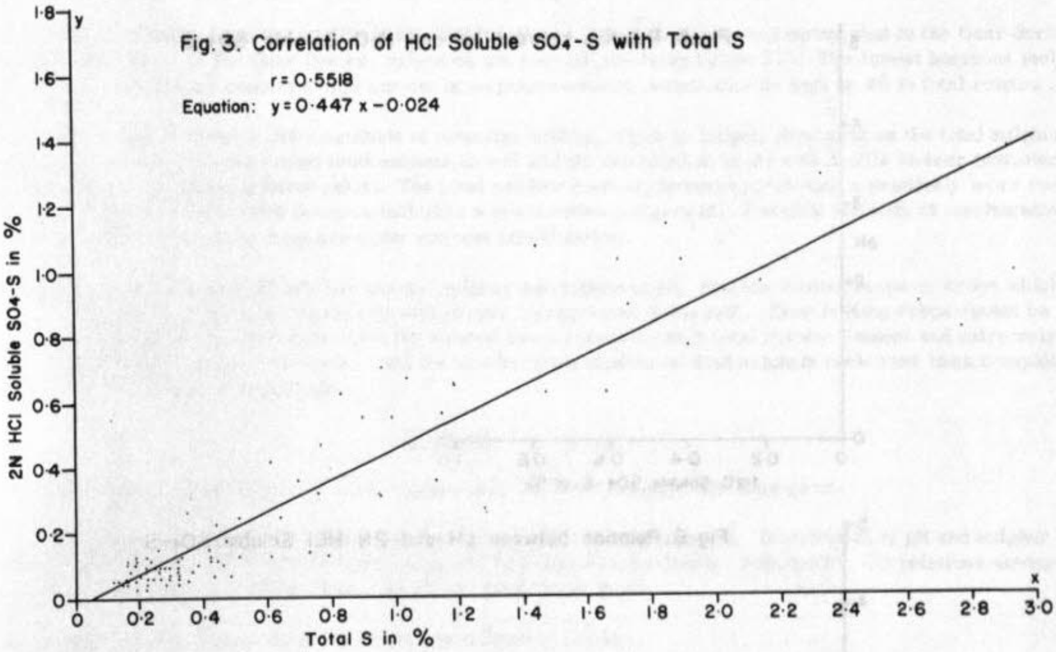

Fig. 3. Correlation of HCl Soluble SO4-S with Total S
r = 0·5518
Equation: y = 0·447 x − 0·024
2N HCl Soluble SO4-S in %
Total S in %
y
x
0
0·2
0·4
0·6
0·8
1·0
1·2
1·4
1·6
1·8
2·0
2·2
2·4
2·6
2·8
3·0

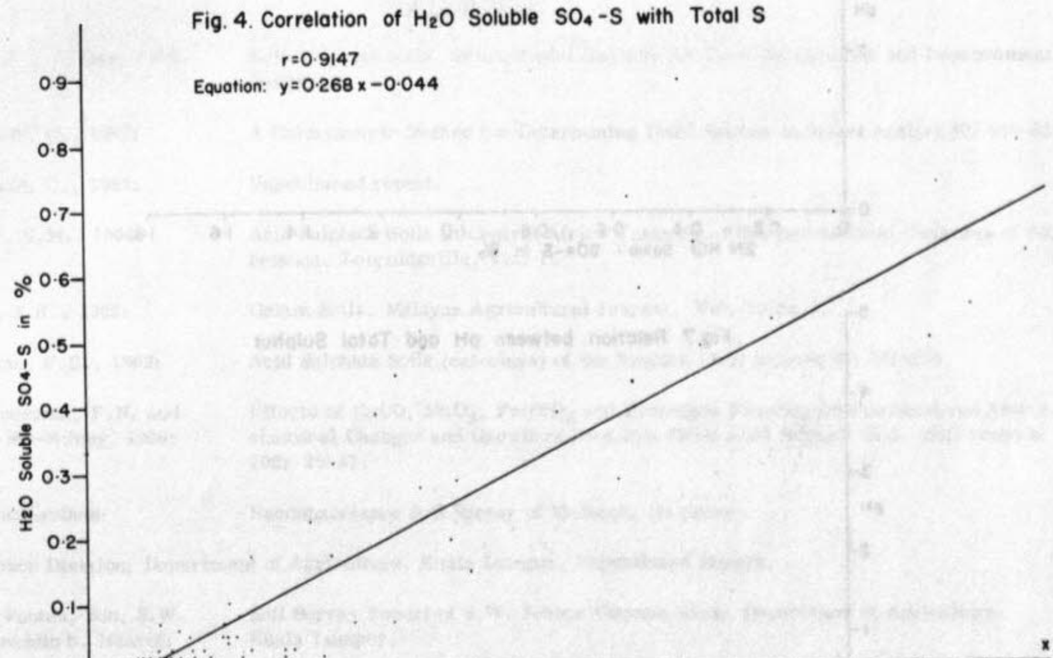

Fig. 4. Correlation of H2O Soluble SO4-S with Total S
r = 0·9147
Equation: y = 0·268 x − 0·044
H2O Soluble SO4-S in %
Total S in %
x
0
0·1
0·2
0·3
0·4
0·5
0·6
0·7
0·8
0·9
0·2
0·4
0·6
0·8
1·0
1·2
1·4
1·6
1·8
2·0
2·2
2·4
2·6
2·8
3·0

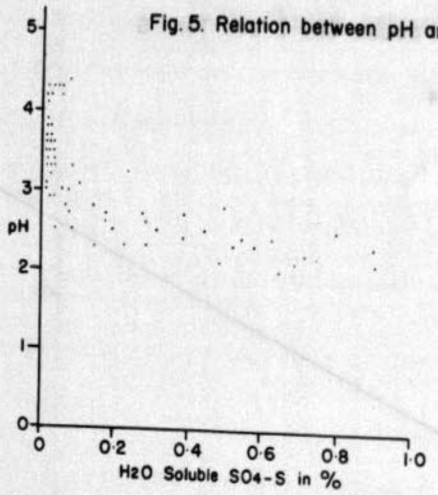

Fig. 5. Relation between pH and H_2O Soluble SO_4-S

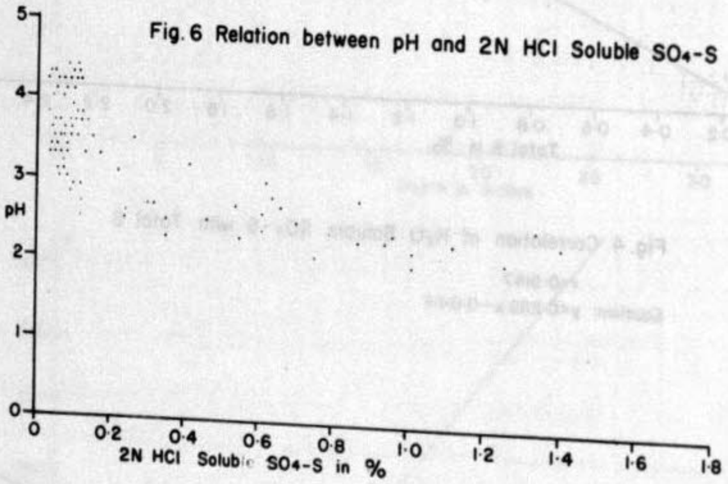

Fig. 6 Relation between pH and 2N HCl Soluble SO_4-S

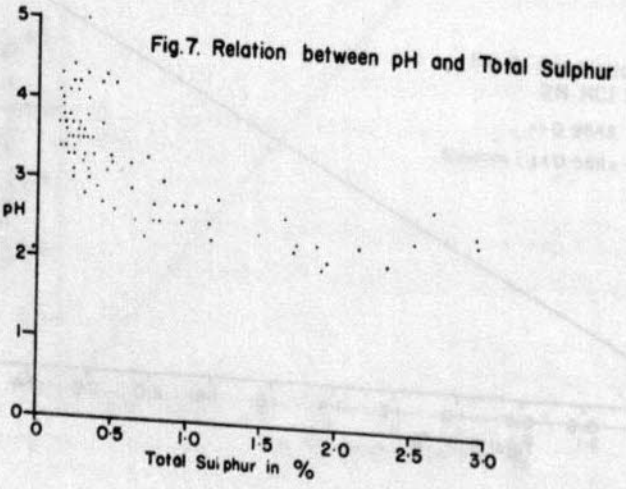

Fig. 7. Relation between pH and Total Sulphur

Discussion

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

Water soluble SO_4-S   2N HCl Soluble SO_4-S   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.

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Discussion

Ashworth: Since your pH was measured on wet samples in the laboratory would it not be possible that the low figures you obtained are caused by oxidation which may have taken place during transport of the samples?

Chow: The samples were taken by the Soil Surveyor and analysed in the laboratory. I am unable to say whether they were still in the field condition.

Ashworth: I suggest that in future air-tight tins or so should be used in order to preserve the field condition.

Andriesse: Potential catclay samples from the Santubong Scheme in Sarawak were brought to the laboratory in sealed plastic bags. Wet pH was on average 6 while after drying for a month the drop in certain samples was on average 1.5 units. The difference is significant.

Watson: Why does the water soluble sulphate increase with depth in the profile? Would the soils you investigated not be from well drained areas in which the topsoils were oxidised or were the samples from undrained areas?

Chow: Most of the soils collected were from drained areas, some were undrained.

Watson: Why would the soluble sulphate then increase with depth? Is this a chemical process?

Chow: I think so. There is generally a higher sulphur content in the subsoil than in the topsoil.

Watson: Do you relate this to a process after drainage or does this happen as part of the normal soil forming process?

Ng: The increase in water soluble sulphate contents with depth is due to the oxidation of sulphur compounds in the soil samples before analysis and as total sulphur content increases with depth, so does the content of water soluble sulphate. On the question of pH determination on fresh samples, while this has intrinsic value, in our experience we have found that it is of more practical value to do the pH determination on the air-dried sample as this can indicate whether we are likely to have an acid sulphate condition.

Moormann: Acid-Sulphate soils in mangrove swamps are usually completely reduced, hence show a high field pH (6-7). Acid-Sulphate soils of the 'older' areas inland which usually have been drained to some extend may be already acid to a considerable depth and show the typical straw-yellow mottling of $FeSO_4(OH)_2$.

For mangrove soils it is more difficult to recognise whether they are going to be catclays or not. Were your samples taken from the coast or from the older areas?

Chow: They were taken from the coast but not from mangrove areas and from land which was already partly drained and developed.

Chan: The results of increasing sulphur content and decreasing pH with depth are interesting and I think have a bearing on agricultural practise of draining these soils. For rubber, a deep rooting crop, we advocate that drains should be dug and lowered gradually with time (say 6 inches per 6 months of a year) so that the rubber would not be subject to a sudden drop in pH and therefore a sudden increase in acidity. Could you, therefore, give some information on what possible methods of amelioration you have in mind to counter this effect of drainage on acid sulphate soils.

Chow: We have as yet not conducted any amelioration studies.

Poon: Our experience is that extensive drainage of such areas has increased the problem. In one of our experiments of intensive drainage over a period of 9 years where we drained to a depth of 5 feet, this was clearly shown. From pH and water soluble sulphate measurements, there was no decrease in acidity to notice. Added to this the soils had become irreversibly dried.

Andriesse: I notice that you distinguish three series in your Acid Sulphate Soil Group. What are the distinct features of these three series?

Law: Linau series found near the beach with catclay right beneath the topsoil, the soil at a depth of 6 to 12 inches turns black on exposure after a day or so.

The Telok series has a watertable at lower depth and has a mottled zone below the A humus horizon. This mottled zone overlies the acid sulphate horizon at 12 inches or so. The Telok soil turns yellow after exposure indicating that oxidation has already taken place in field condition due to the lower watertable.

The Guar series has been cultivated for a long time. This has induced further development of the acid sulphate condition.

Andriesse: In Sarawak, Acid-Sulphate soils comparable to your Linau series (they turn black on exposure) were found as far inland as 50 miles but invariably occur there were the alluvial material had as its source basalt on which we find the Reddish-Brown Lateritic soils. Would you think that the original iron content of these alluvial deposits has something to do with the arresting of the sulphur in the form of pyrites so that the sulphur could not leach out. In that case alluvial deposits with low iron contents would not form catclay.

Law: The catclay 50 miles away from the present coast may mark the old sea coast and this would then be an old catclay. Presence of iron may not be necessary for catclay formation.

Moormann: For formation of acid sulphate soils the <u>sulphate</u> from the sea water is the prime requirement.

KAOLINITIC CLAY IN THE BALAI RINGIN-ABOK AREA, WEST SARAWAK

by

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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 cut 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 consequence 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. Gunong Buri, 2,442 feet); these hills are formed of volcanic, metamorphic and sedimentary 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. 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 podsolic 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 quart 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 63½ 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 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 podsolic soils of the Saratok family and red-yellow podsolic 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 (from 7 to 10 feet and 30 to 36 feet respectively) 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.

TABLE 1. ANALYSES OF KAOLINITIC CLAY FROM BALAI RINGIN - ABOK AREA, WEST SARAWAK.

Sample No.	Locality	Chemical Analyses (percent)											
		Moisture	Loss on Ignition	SiO_2	Al_2O_3	TiO_2	Fe_2O_3	CaO	MgO	K_2O	Na_2O	Whiteness (percent)	pH
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
Chemical composition	**percent**
SiO_2	63.94
TiO_2	0.20
Al_2O_3	24.23
Fe_2O_3 and FeO	0.68
MgO	0.16
CaO	nil
Na_2O and K_2O	1.28
SO_3	0.09
Inferred mineralogical composition	**percent**
Quartz	36
Mica	9
Kaolinite	52
Size analyses	**percent**
+ 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

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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Discussion

Andriesse: Based on evidence in the field I am opposed to the idea that these white clays are mainly of igneous origin, particularly in the Telagus area. The occurrences are wide-spread and are not confined to certain lines which should be the case if dykes of igneous intrusions are concerned. Also, the analytical evidence is not conclusive and in fact rather suggest that the clays are of sedimentary origin. The same heavy mineral association is found in most of our older alluvials. High Na_2O content also shows possible influence of marine deposition.

Kho: I agree to some extent but in certain places we do find contact zones of the igneous intrusions and shale. The clays are quite different in texture from those developing on the black shales.

I think that the Japanese (who did most of the preliminary investigations) are right in a way. Our studies have not been finalised yet and we are unable at this stage to say whether they were right or not.

Andriesse: Could you explain the high sodium content of your clay?

Kho: I am afraid I cannot but on the whole the sodium and potassium contents are comparable to kaolinitic clays found elsewhere.

Andriesse: This may be so, but it does not mean that all these clays are therefore derived from acid igneous rocks.

Paramananthan: In the Telagus section the description given seems to indicate that the clay is of igneous origin because of: (a) The abrupt change from clay to black shale.
(b) The occurrence of xenoliths of black shale in the clay. This seems to indicate that the dykes were intruded into the shale and then by erosion were exposed and then covered by older alluvium. The dykes would thus form a 'catchment' where weathering can take place to give the clay deposit. If the clay was formerly a sedimentary rock there would not be an abrupt change from clay to shale.

Andriesse: With reference to the Kerait profile developed over the black shale under discussion, the change from black shale into dirty white clay is very abrupt in a geological sence. The transition takes place within a band of 1 to 2 inches. The geological observations if made by auger may disturb this transition. Possibly the form of the sand particles in the clay deposits would be more conclusive as to their origin than the mineral association itself.

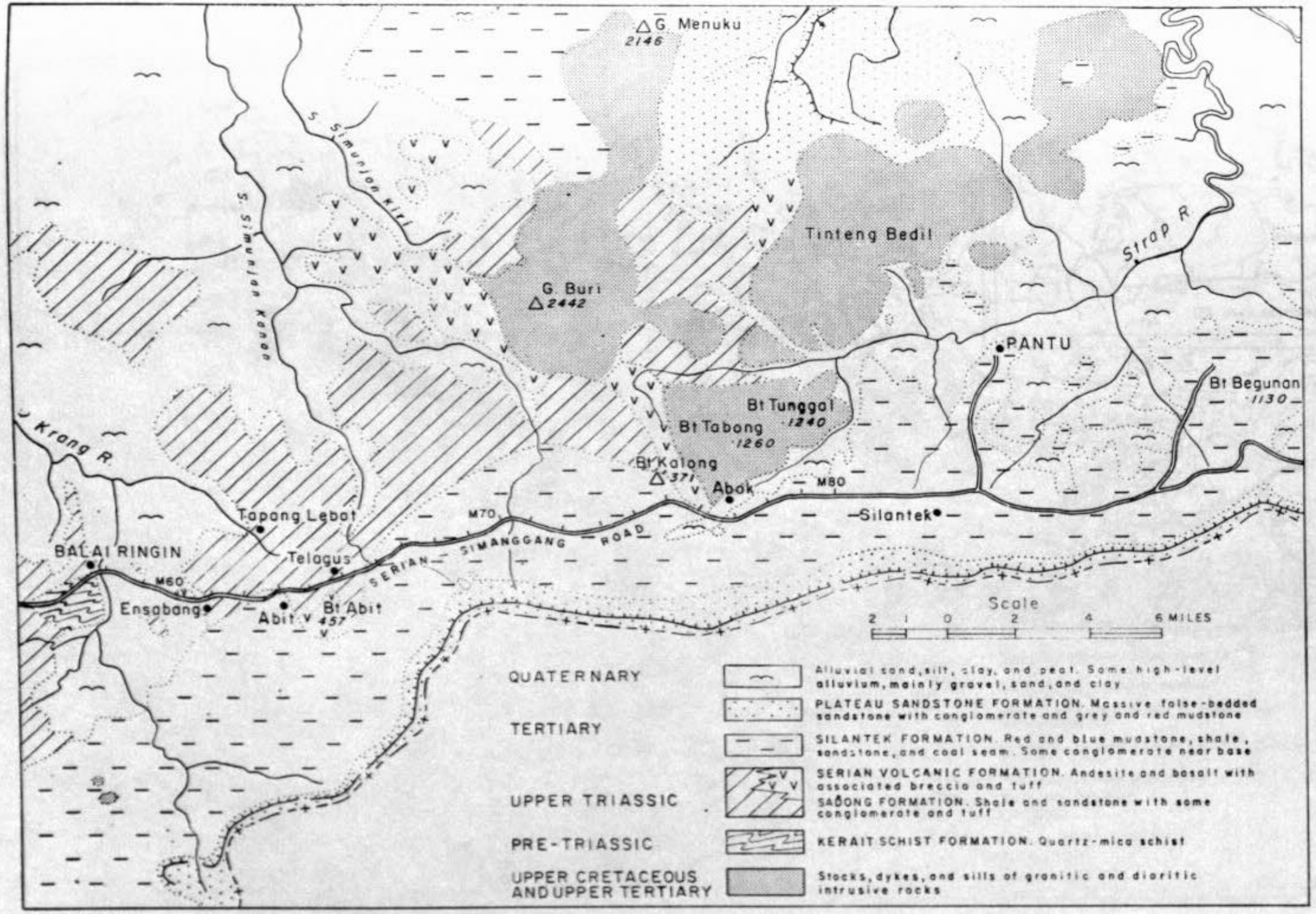

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FIGURE 1. Simplified geology between Balai Ringin and Silantek, west Sarawak

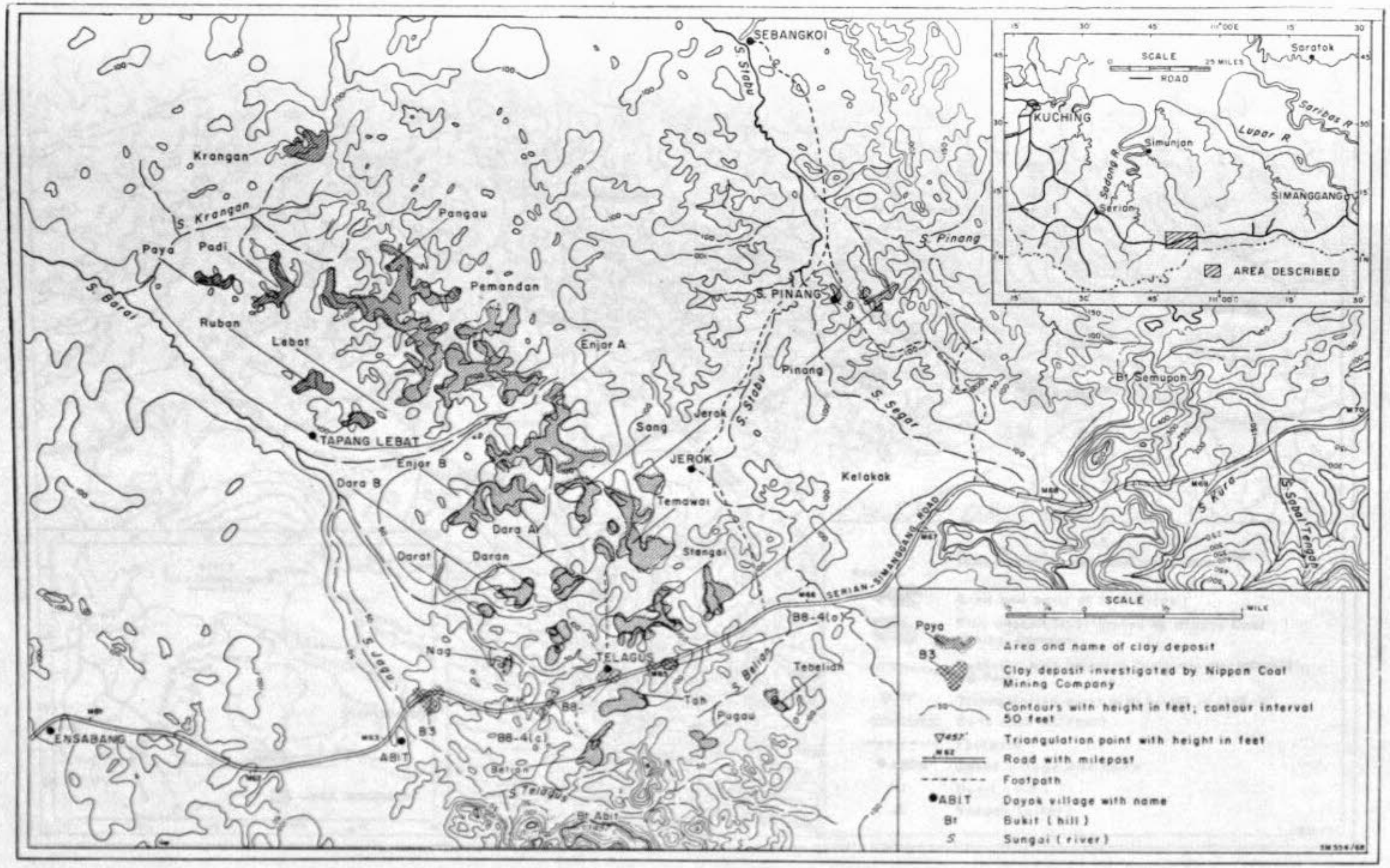

FIGURE 2. Kaolinitic clay deposits in the Telagus area, west Sarawak

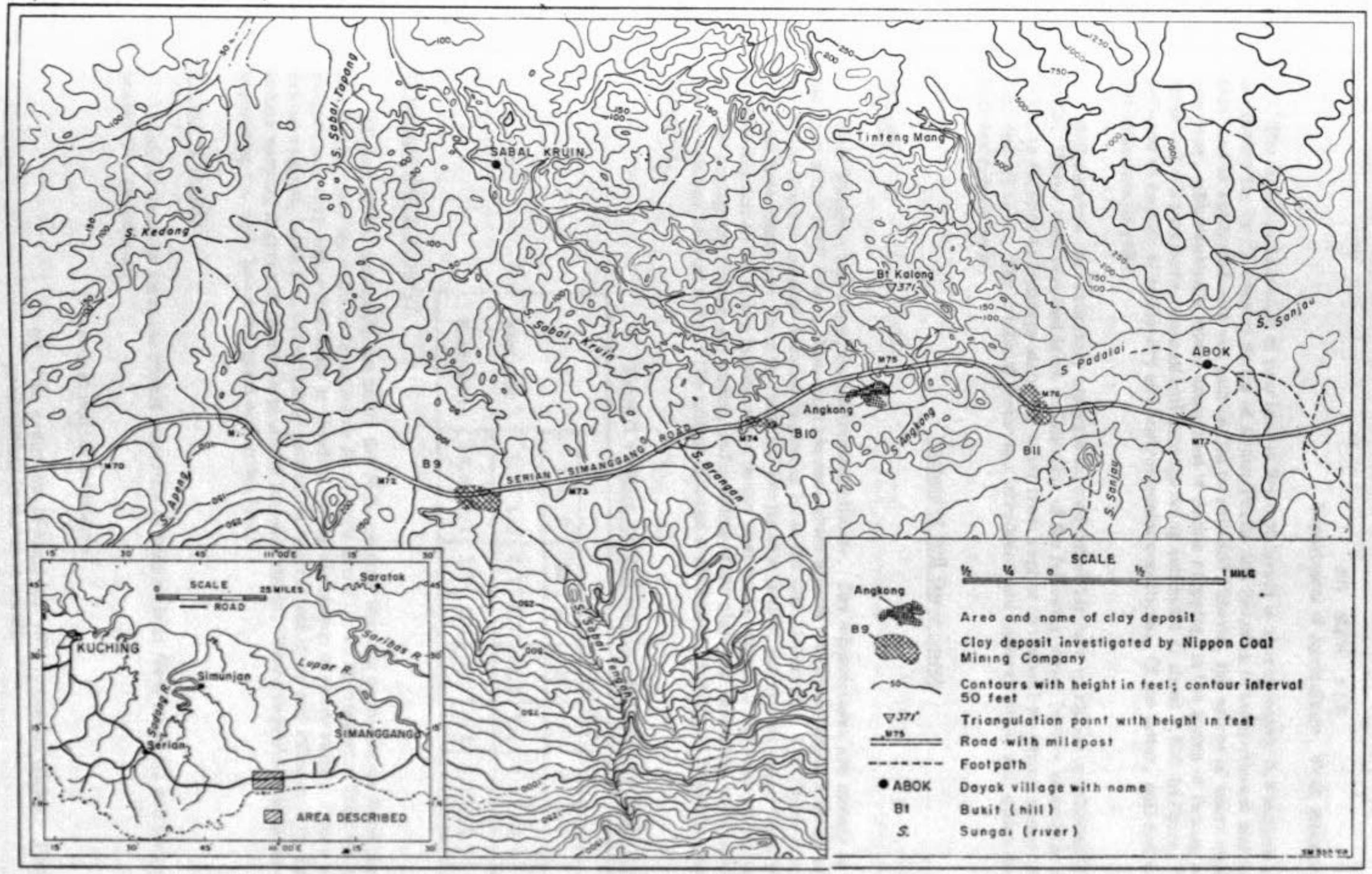

FIGURE 3. Kaolinitic clay deposits in the Abok area, west Sarawak

PADI SOILS OF WEST MALAYSIA

by

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The estimated acreage of padi land in West Malaysia is approximately 0.9 million acres, of which about half is accounted for by the coastal plains of Kedah/Perlis and Kelantan in the northwest and northeast respectively. All this land is cultivated with wet padi on flat terrain and hitherto, the nature of water availability permits only one crop per year, with relatively minor exceptions of double cropping, in the States of Penang and Selangor. Padi 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 husbandry 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 from regime in the soil (c) parent material (d) effect of cultivation by man and (e) time. The artificial factor has introduced new features in the soil which distinguish them from natural, hydromorphous soils.

Factors of Soil Development

Climate

West Malaysia has a hot, humid tropical climate. Day temperatures are mostly in the eighties (°F) while at night, they are about 15°F lower. The main element which affects the development of these soils is the distinct dry period of about two to three months' duration beginning from the time of harvest. For illustration, the rainfall figures for Alor Star and Kota Bahru are given in Table 1. During this period, the ground water-table is well below four feet and wide cracks develop en the heavy marine clays on the west coast, except in the very poorly drained localities. This pronounced drying 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 drying effect.

Table 1 : Main Rainfall Data for Alor Star and Kota Bahru (Ins)

	MONTH												
	J	F	M	A	M	J	J	A	S	O	N	D	Total
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 Bahru	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

Relief and Drainage Status

Almost all the padi soils are below the 50 ft. contour line and on the major 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 the padi soils are subject to a very high water-table or flooding during the season of heavy rains. Under this alternate waterlogging and drying regime, reduction and oxidation processes operate and these are influenced by differences of micro-relief which induce varying degrees of hydromorphism in the padi plains. These degrees of wetness constitute the major criteria of 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 commonly occur as narrow strips 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 integrades 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 the 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 hydromorphic soils.

Time

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 more oxidised parts of the profile. Reactions are thus largely governed by redox 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.

1. 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 horizonation is thus: ApgG - AsG - (AG) - G where s denotes ploughsole. A typical example is the Telok' Series, found mainly in Kedah, Perlis and Perak.

2. 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, pedogenesis 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 horizonation is ApgG - AsG - (AgG) - BgG - G. These soils are mainly derived from marine and river alluvium. Examples are Kuala Kedah and Jelawat (tentative).

3. 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. Slickenslides can occur in the BgG horizon and occasionally, blotches of soft iron concretions may be found. The common horizonation 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 west coast.

4. Well drained soils

These soils are either situated in relatively higher elevations or have lighter textures. They are characterised by a prominent B horizon which generally dominates the soil profile and the G horizon is commonly below 3 feet. The B horizon is not only profusely mottled but abundant concretions of iron and manganese are also distributed in this horizon. Structures are typically of fine to medium sub-angular blocky with friable to firm consistence. The common horizonation is ApG - AsgG - (AgG) - Bg(ir-mn) - BgG.

These soils are largely found on river, terrace or mixed alluvium. Examples are Kangar, Sembrim and Sedaka.

5. 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. Textures are relatively more sandy and structures finer. The horizonation is commonly:

Apg - AsgG - 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 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
No. 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
Clay Mineralogy					
(a) Kaolin %	25-35	70-90	90	60	45-55
(b) Illite %	5-10	5-10	5	5	5-10
(c) Montmorillonite - Vermiarlite %	50-70	5-20	5	35	40-50
C.E.C. (NH_4Ac) m.e.%	15-29	2.4-7.0	2.4	2.0	8-16
Exch. Mg m.e.%	8-20	1-3	1.0	0.4	1-5
" Ca "	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
C%	1.6-9.5	1.1-3.5	2.2	0.6	1-7.5
N%	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
Soluble P (ppm) (Bray No. 2.)	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 heavy textured and that clay mineralogy, cation exchange capacity and organic matter content provide the most useful bases for differentiating padi soils. Montmorillonite-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 mineral in soils occupying intermediate positions between the true marine alluvium and river or terrace alluvium indicates a mixing of these alluvia. 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 soluble phosphate contents are higher and more variable in marine clays and mixed sediments than in the others although all indicate a low phosphate status.

Pedogenetic 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 classed as Humic gleys or Low Humic gleys in the Hydromorphous Sub-order of Intrazonal soils. By the 7th Approximation of the U.S. Department of Agriculture (1960), they would probably be under the Inceptisol and Entisol Orders, Sub-orders being Aquept or Aquent. However, present field and laboratory data are not comprehensive enough to justiful 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 differentiae. Twelve genera are proposed to accommodate the various soils and these are shown as follows:

Family	Genus
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 in future 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 species 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. In general, 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 in yield are the very well drained soils where low nitrogen and phosphate status, and too rapid drainage are the major limitations. Where irrigation is provided, better yields are obtained. Soils of the remaining three drainage Families on the whole comprise the best padi soils but differences in yield within each Family can be generally greater than those between Families. These differences are mainly due to various factors of nutrient status, chiefly nitrogen and phosphate, pH 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 alluvium.

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

Soil Genus Represented	Padi Yields lbs./acre
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; 1665 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

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3. Thorp, J. and Smith, G.D. 1949: Higher categories of soil classification - Order, Suborder and Great Soil Groups. Soil Sci. 67, 117.
4. United States Department of Agriculture 1960: Soil classification - A Comprehensive System 7th Approximation.

Discussion

Mukerjee: I think we have touched already on the name of Padi soils before (ref. see discussion Paper 6 in this session) but I would like to emphasize that when manmade soils are studied the changes induced in the profile due to manmade conditions should be specified in detail. These can be of different nature such as management practises, multiple cropping which may totally change the redox conditions in soils due to irrigation, and fertilization. The latter results in a great increase in yield and with that the organic materials in the form of straw and roots added to the topsoils are also greatly increased.

Ng: I agree on theterminology. I have been persuaded by the Soil Surveyors not to use Padi soils and Padi-growing soils would be more appropriate.

I also do not quite agree with Kanno who separates the Padi soils from the rest at a high level. The Padi soils do not quite fit and it would be better to place them into e.g. Inceptisols or Ultisols. We do envisage changes in the profile due to padi growing practises but these changes occur over a long period and their study is necessarily of long duration.

Guha: What are the soil requirements for hill padi in Malaya and the yields expected and what are cultivation methods with particular reference to water requirements?

Ng: Hill padi growing is not extensive at all in West Malaysia. Usually the rice is planted after clearing jungle and the crop is entirely depended on rainfall only and we have not studied these areas because of the very small acreage.

Law: Yields to be expected from hill padi in Malaya are:

300 gantangs for the first crop. If a second crop is planted than yields drop considerably and well below 200 gantangs per acre. Usually the first crop is planted immediately after the burning of the felled jungle.

Guha: Are there any specific soil requirements?

Law:	I would say that all you require is one foot of soil, slightly more than that required for wet padi.
Chan:	Has any work been carried out to find out whether we have to discriminate between different soils as far as fertilizer requirements are concerned? This with specific reference to N and P which as you stated are very important.
Ng:	Yes, we have carried out fertilizer trials over the last two years on different series (N.P.K. factorial).
Chan:	Did you get any particular results on these soils in general?
Ng:	We find that our local varieties are very susceptible to lodging with high N applications. If you give more than 60 lbs per acre of N, lodging is a serious problem. We, therefore, recommend 45 lbs per acre in general. Where padi Ria (IR/8) is introduced then the level of N can go up to 90 lbs per acre, but the acreage planted up with this variety is still very small.
Chan:	So, this is still the general recommendation for all padi soils, 45 lbs per acre. Since I see that your C.E.C. value seems to change from your marine sediments to the mixed sediments, I thought that there should be some discriminatory fertilizer recommendation.
Ng:	I referred to the Muda area where 45 lbs of N per acre is usually recommended but when we go to Kelantan for instance this may go up to 60 lbs and beyond. As I said, this is mainly related to the problem of lodging.

Development Planning and Land Analysis Techniques with special reference to Sarawak

by

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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 night 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.*

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* 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.

It has now 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 inventries 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 subjective, and that the data which is collected be recorded in absolute terms rather than in 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 products valueless. It will be seen from this that survey and record should be kept entirely separate from 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 miner 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:-

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* (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 decenial 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.

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 100) by the resource survey departments 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 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 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 basic topographic survey. It has been widely used; both in its own right, and in the preparation of 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.

Second Level Analysis

A second level analysis may be defined as one which is concern 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 are 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.

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* The Land Capability Classification is a simple third level analysis. It is also being adopted by the State of Sabah.

** For a summary of the development of the Land Suitability Classification in Sarawak see Appendix III.

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 factors. 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 factors into the analysis, and suggests that studies of climate 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 Sebangan-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;

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* 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.

(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.

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 United Nations Special Fund 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 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 transport 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 judgements. In this way the basic data, which changes but slowly, is always available for re-analysis in the light of new conditions.

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* See Appendix VII for the classification used.

** A Classification of Sarawak Soils, Technical Paper No.2 by the Soil Survey Staff, Research Branch, Department of Agriculture, Sarawak.

*** RPS Bonney B. SC., Proceedings of the Town & Country Planning Summer School, Overseas Section 1963.

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 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.

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.

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* Even the best documented economic projection is unreliable enough. In the words of the Statistician M.J. Moroney:- "Economic forecasting, like weather forecasting in England, is only valid for the next six hours or so. Beyond that it is sheer guesswork." (Facts from Figures, revised 1965).

APPENDIX I

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 and 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 and Survey Department. In addition the Soil Survey Division has produced a generalised Soil Survey Map of Sarawak on the same base map, and the Geological Survey has in hand the compilation of the 1:250,000 Geological Map.

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* 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.

APPENDIX II

First Level Analyses: West Malaysia

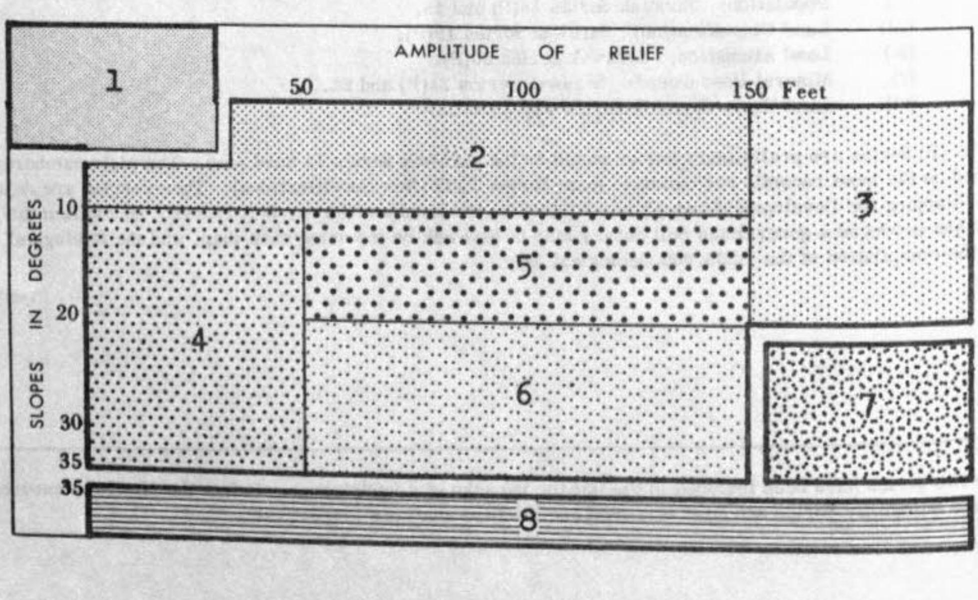
(i) Soil suitability classified as follows:-
(1) Soils with no limitations to agricultural development.
(2) Soils with few minor limitations to agricultural development.
(3) Soils with at least one serious limitation to agricultural development.
(4) Soils with more than one serious limitation to agricultural 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:-

KEY OF TERRAIN UNITS



(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 watertable	> 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

* Soil Suitability for oil palm in West Malaysia by Ng Siew Kee; Proceedings of the First Malaysia Oil Palm Conference 1968.

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.

APPENDIX IV

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	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

Terrain Categorise / soil family/series	1 Flat Land. No appreciable amplitude of relief	2 Land with slope not 10^o amplitude of relief up to 150'	3 Land with slope not 20^o amplitude of relief 150'	4 Land with slopes of $10-35^o$ amplitude of relief 50'	5 Land with slopes of $10-20^o$ amplitude of relief 50-150'	6 Land with slopes of $20-35^o$ amplitude of relief 50-150'	7 Land with slopes of $20-35^o$ amplitude of relief 150'	8 Land with slopes of 35^o
ABOK	-	II	II	II/IV	II	IV	IV	VI
ANDERSON 1	IIIa	-	-	-	-	-	-	-
ANDERSON 2	V	-	-	-	-	-	-	-
ANDERSON 3	V	-	-	-	-	-	-	-
ANTAYAN	-	II	II	II/IV	II	IV	IV	VI
BAKO	-	VI	VI	VI	VI	-	-	-
BEKENU	-	II	II	II/IV	II	IV	IV	VI
BELAT	V	-	-	-	-	-	-	-
BENTANG	I	II	-	-	-	-	-	-
BIJAT	I	I	-	-	-	-	-	-
BOKAH(S)	IIIa							
BUSO	V	VI	VI	VI	VI	-	-	-
DARO(S)	IIIa	-	-	-	-	-	-	-
EMBANG(S)	IIIa	III	-	-	-	-	-	-
BAYA	V	VI	-	-	-	-	-	-
GERAWAT	IIIa							
GONG(S)	IIIa	III	-	-	-	-	-	-
IGAN	IIIa	-	-	-	-	-	-	-
JERIJEH	IIIa	-	-	-	-	-	-	-
JOL	I							
KABONG	IIIa	-	-	-	-	-	-	-
KABALOH	I	II	II	II	II	IV	IV	VI
KAPIT	-	IIIb	IIIb	IIIb	IIIb	VI	VI	VI
KAYAN	IIIa	-	-	-	-	-	-	-
KEDODUN								
KERAIT	-	IIIb	IIIb	IIIb	IIIb	VI	VI	-
KELUPU	IIIa							
LIMBANG	IIIa	-	-	-	-	-	-	-
LUBAI	IIIa	IIIb	IIIb	IIIb	IIIb	-	-	-
LUIS(S)	V	-	-	-	-	-	-	-
LUPAR	I	II	II	II/IV	-	-	-	-
MALANG	I	II	-	-	-	-	-	-
MATANG	-	II	II	IIIb	IIIb	VI	VI	VI
MATU	IIIa	-	-	-	-	-	-	-
MELUAN	-	VI	VI	VI	VI	VI	VI	VI
MERIT	-	II	II	II/IV	II	IV	IV	VI
MIRI	V	VI	VI	VI	VI	-	-	-
MUKAH	I/IIIa	-	-	-	-	-	-	-
MULU	V	VI	VI	-	-	-	-	-
NONOK	IIIa	-	-	-	-	-	-	-
NYALAU	-	II	II	II/IV	II	IV	IV	VI
PENDAM	I	-	-	-	-	-	-	-
PLAN(S)	IIIa	-	-	-	-	-	-	-
RAJANG	V	-	-	-	-	-	-	-
RAMUN	I	I	-	-	-	-	-	-
RAPAK	-	III	III	III	-	-	-	-
SABANGANG	I	II	II	II/IV	II	-	-	-
SARATOK	-	III	III	III/VI	III	VI	VI	-
SEBANDI	I	I	-	-	-	-	-	-
SEDONG	-	II	II	II/IV	II	IV	IV	VI
SEDUAU	I	-	-	-	-	-	-	-
SEMADOH	IIIa	IIIb	IIIb	IIIb	IIIb	-	-	-
SEMATAN	IIIa	-	-	-	-	-	-	-
SEMILAJAU	I	II	-	-	-	-	-	-
SILANTEK	-	VI	VI	VI	VI	-	-	-
TARAT	-	II	II	II	II	IV	IV	VI
TATAU	IIIa	-	-	-	-	-	-	-
TERBAT	I	-	-	-	-	-	-	-
TRIBOH	IIIa	IIIb	IIIb	IIIb	IIIb			

APPENDIX V

Special Purpose second level analysis of land suitability for agriculture in Sarawak.

(i) Land Rating (Andriesse 1966)**

Categories	Sub-categories* (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.

(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.

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 REQUIRED

CLASS 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.

* Combinations of sub-categories for land with more than one main limitation are possible.
** Soil Survey Report No. 94, "The Sebangan, Simunjan, Batang Krang Area" by J. P. Andriesse 1966.
*** Soil Survey Report No. 113, "The Tanjong Jol Area" by I. M. Scott 1967.

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 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 underlaid 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 VI

Third 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 VII

Third Level Analyses - Sarawak

Sarawak Land Potential

Study 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 18(P)

On the basis of this study eleven tentative Development Blocks have been identified for further study (see Map).

Study III: Permanent Forest Estate

This study relates primary forest to land suitability classes:

Kerangas Forest	- light brown
Mangrove Forest	- blue
Other Primary Forest Land Suitability Classes I and II	- yellow
Land Suitability Classes III and IV	- light green
Land Suitability Classes V and VI	- dark green
Forest Reserves	- red border

All Kerangas* forest is on Class VI land. As a result of the new drainage requirement and development potential classification some of the land under mangrove forest formerly in Class V will be upgraded to Class IIIa. This study will therefore be modified as follows:-

Mangrove Forest
Land Suitability Class IIIa - light blue
Land Suitability Class V - dark blue

This study will be used in conjunction with the forest inventories to be made by the U.N.S.F./F.A.O. team to produce recommendations for the future permanent forest estate.

* Kerangas forest is forest of simple botanical structure found on infertile soils, with some commercial species e.g Kapor; but a low tonnage yield per acre.

Study IV: Permanent Forest Estate

This study identifies land of agricultural potential with existing forest reserves, and relates this to existing and proposed roads to establish priorities for soil surveys.

Forest Reserves	- green border
Land Suitability Classes I, II & III	- yellow
Land Suitability Classes IV, V & VI	- blue
Existing roads	- thick red
Roads under construction	- thick broken red.

Discussion

Ashworth: I would like to reinforce your argument in favour of not to introduce too many factors into a Land Capability Classification. However, I am a bit worried about you introducing the transport factor in such a classification.

To introduce location and economics into a capability classification is in my opinion prejudging the issue. Land capability is an inherent characteristic and does not depend on its location. I think the economic evaluation comes after the land capability classification.

Gwilliam: I would entirely agree with your last remark. It does come after the land capability classification and that is why we introduce it at the fourth level of analysis.

Nevertheless, I am sure that in considering land potential, "where it is" is as important, or nearly so, as "what it is", and this fact must be brought out in the evaluation. At any point in time transport costs can be obtained and their effect assessed. I take your point that if factors are variable the situation must be re-assessed continuously.

Ashworh: To introduce economics into a classification confuses the issue and eliminates choice.

Moormann: Evaluation of land after soil surveying can be done in three phases:

a) determination of the 'stable ' land characteristics e.g. soils, mining, forest, etc. (Inventory).

b) land capability classification indicating the quality of the land for any or all purposes (Soil Survey interpretation).

c) land use planning e.g. proposing the best land use under the present (or future) economics and social conditions.

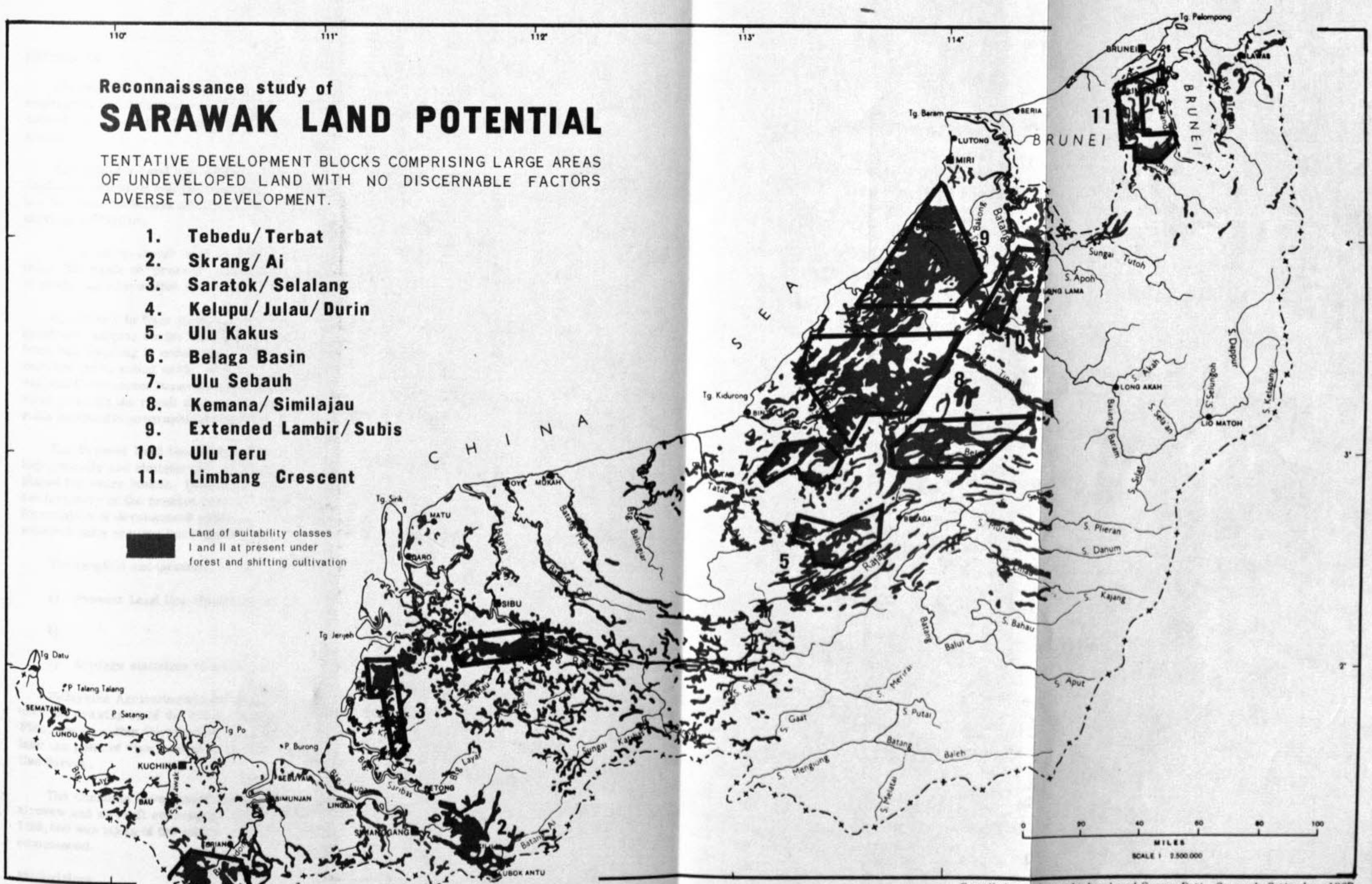
Gwilliam: We recognise these three phases in Sarawak and are using them. The point I would like to emphasise is that the analysis should not replace the scientific record but should be supplementary to it.

Andriesse: These arguments are not from this day. As I see it they mainly arise from the fact that there is a lot of confusion on how to differentiate between types of classification and how to name them. According to the original definition of Land Capability Classification, and I think the U.S. were the first to use this term, it should not be based on economic factors and should be of use for long term planning. Any such classification considering present economic conditions and crops should not be termed as such but rather perhaps: Suggested Land Use or land use planning, which is done on values of the present day.

Gwilliam: The point I would like to make is that it is not possible to have a capability classification which is of value now and which would be equally valid in, say, 25 years. As an example, I may quote the West Malaysian land capability classification which is very much based on present day economic values (e.g. mining land).

Ashworth: Your reply to Mr. Andriesse's point proves that the West Malaysian land capability classification is not a capability classification. I think that capability classifications must be based on measureable factors which are basically unchanged in time.

Roberts: I would like to stress that the mapping of resources should remain strictly of that resource and that where e.g. a soil surveyor proceeds to interpret his data in terms of suitability for a crop, or group of crops, this should be recognized as an analysis and treated as such. Thus any report might contain two maps - one mapping the resource, and the other stating the present-time interpretation of the resource data. All interpretations and capability classifications are analytical, and eventually must change in the light of new factors. Hence the need for scientific rigourousness in the initial resource mapping; without this, many present day resource inventories will need to be repeated in six - ten years time.



Compiled and drawn by Land and Survey Dept., Sarawak, September, 1968.

METHODOLOGY OF THE PRESENT LAND USE SURVEY OF WEST MALAYSIA

by

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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 and 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 can thus be 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 Colombo 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 Toronto to conduct this Survey and Canadian aircrew and aircraft commenced the aerial photographic phase in early 1966. Aerial photography at the scale of 1:25,000 was taken of the entire area of West Malaysia by early 1967 and the Present Land Use Survey could then commenced.

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 and 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.

It is important to remember that the complete picture of land use acreage is presented. The "whole" has been obtained by inspection and classification of the entirety. Regardless of the limitations imposed by the aerial photographic method, it can categorically be stated that an accurate universal picture is obtained and that, as far as the major crops are concerned, the results can be considered as those of an accurate crop survey.

Fairdrawing:

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.

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 recognised 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 interupt 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 interupts 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.

. 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, pineapples, 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" (4C) 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:

3. 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 looses 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 recognised 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 it 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.

7. 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.

Normal 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 recognised not only by a very "clean" appearance, but also by the presence of felled trees and traces of burning.

8. Swamp, Marshland and Wetland Forests

This category includes Mangrove, Nipah, Gelam and other Wetland Forest Associations.

9. Unproductive Lands

All areas, which, by present practices, are unproductive. e.g. sand dune areas and exposed rock.

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
1F	:	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

PRESENT LAND USE SURVEY — 1966
STATE LAND USE SUMMARY — MALACCA

AREAS 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 POPULATION	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
IU: Urban	4,591	1,590	765	6,946	1.70	URBAN AND ASSOCIATED AREAS			
IE: Estate Buildings	121	456	558	1,135	0.28				
IT: Tin Mining	1	153	271	425	0.10				
IX: Other Mining,Quarrying	80	96	182	358	0.09	9,404	2.31		
IP: Transmission Line	87	237	216	540	0.13				
2H: Mixed Horticulture	5,062	6,750	4,953	16,765	4.12	HORTICULTURAL			5.38
2M: Market Gardening	736	601	151	1,488	0.36	18,381	4.51	5.90	0.48
2E: Agriculture Stations	59	63	6	128	0.03				0.04
3G: Rubber	30,850	115,519	100,385	246,754	60.58	TREE, PALM AND PERMANENT CROPS			79.14
3O: Oil Palm		240	587	827	0.20				0.30
3C: Coconuts	3,502	2,705	5,242	11,449	2.81				3.64
3N: Pineapple									
3K: Coffee									
3T: Tea									
3A: Cocoa									
3P: Pepper		15		15	0.00				0.00
3S: Sago	120	642	242	1,004	0.25	261,031	64.08	83.72	0.32
3B: Bananas		28		28	0.01				0.01
3F: Fibre Crops									
3H: Fish & Hyacinth Ponds	186			186	0.04				0.06
3X: Orchards	159	166	443	768	0.19				0.25
4P: Padi	13,805	11,593	6,461	31,859	7.82	CROPLAND			10.22
4C: Diversified Crops	68	133	310	511	0.12	32,370	7.95	10.38	0.16
4X: Shifting Cultivation									
5: Improved Permanent Pasture									
6: Scrub Grassland	1,195	2,770	4,061	8,026	1.97	8,026	1.97		
7F: Forest	4,579	12,391	31,074	48,044	11.80	Forest and Scrub			
7S: Scrub	939	3,463	4,003	8,405	2.06	56,449	13.86	100%	100%
7C: Newly Cleared Land	338	749	1,569	2,656	0.65	2,656	0.65	Total Acreage Under Agricultural Use: 311,782	
8: Swamp	6,335	3,877	4,745	14,957	3.67	14,957	3.67		
9: 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.

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, Gelam and other Wetland Forest Associations

9. Unused Land

Discussion

Gwilliam: I would like to put the Conference into the picture on what we are doing about land use mapping in Sarawak. We commenced in 1965 as part of our mapping programme for planned development. Our aim was to cover the whole of the State as quickly as possible and hence we adopted a scale of 1:250,000. The majority of the photography used is at a scale of 1:25,000. Because of the small scale of the final maps land use units of less than half an inch square on the photographs are not normally delineated. However in the case of crops of high value, such as pepper and high yielding rubber, more detailed interpretation is undertaken, even though this cannot be carried through to the printed map. The interpreted land use data is compiled on 1:50,000 base maps, and then reduced to 1:250,000. A preliminary hand coloured edition of the map has been prepared on the old Sarawak Series 14 base map. As the latest Series T.503 base maps become available, land use is being brought up to date from the latest photography, and sheets scribed for printing. About 85% of the State has been mapped so far, and the first printed sheets will be available shortly. The photographs which have been interpreted are retained for reference purposes and are always available for further examination.

The classification is based on the World Land Use Classification and was drawn up in close collaboration with West Malaysia. Nevertheless there are some differences between the classifications used in the two territories. Scrub forest in Sarawak is linked with shifting cultivation and areas under scrub have been mapped as shifting cultivation. Shifting cultivation in West Malaysia is totally different from shifting cultivation in Sarawak, where it is essentially a land rotation system. Lallang has not been mapped as such but has been included in shifting cultivation from which, on air photographs, it is difficult to distinguish. Sheet lallang will be distinguished in more detailed mapping. A major difference in the legend is that we have split 'Forest' into seven classes. This was originally done on the 1956 Land Use Map of Sarawak and has proved to be useful it is not strictly a difference in Land Use.

After the completion of this series we will start producing 1:25,000 scale maps for the agriculturally more important areas.

Donaldson: For statistical and mapping purposes we have only subdivided 'Forest' into two classes. Apart from the fact that we did not have a Forester in our team for interpreting Forest types, the Forest Department in West Malaysia contemplates the preparation of their own forest inventory in the near future.

Moormann: What is approximately the ratio of time spent for office interpretation against time for field checking?

Donaldson: In the beginning we used a lot of time in the field for initial familiarisation. I would say approximately 5-10% of our time is spent in the field. On average four interpretors have a field trip of about three days per month. No systematic field checks are carried out. With continuing experience in interpretation, associated with ground checking, it is found that the time required for field checking becomes progressively less.

Allbrook: How long can the maps produced by the Land Use Programme be considered accurate in view of the rapid changes in land use, viz rubber to oilpalm?

Donaldson: This question should in fact better be answered by the planners. We are carrying out our investigations as requested but as a personal opinion I might say that although we realise that land use might change rapidly, at least we have for once a benchmark of land use statistics which can be used as a working base. Possibly the statistical value is higher than the mapping value.

Andriesse: What is the cost of Land Use Mapping at a scale 1:25,000 in West Malaysia?

Donaldson: Since we are intergrated in a Government Department, actual costs are difficult to give. As a guess, I would say that US$150,000 for the whole exercise might be a fair bet.

Andriesse: Would working on a smaller scale mean that the value of the work would be much less in relation to the costs?

Donaldson: From a statistical point of view the value would certainly be much less.

Ng: For the completion of the present Land Use Survey in West Malaysia, we now estimate the costs, excluding the cost of air-photography and senior technical staff to be in the region of M$150,000 (this does not cover recurrent expenditure.)

THE LAND CAPABILITY CLASSIFICATION OF WEST MALAYSIA*

by

Lee Peng Choong.

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 becoming 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 gazettement 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 swamp land, worked out mining land and steep land with a slope of greater than 18° 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.

* Copies of the Explanatory Handbook and supplements are available from the Economic Planning Unit, Prime Minister's Department, Malaysia.

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 gazettement 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 machanically. 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 gazettement 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 back-ground 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.

Discussion

Gwilliam: This paper has provided a very interesting explanation of the West Malaysian Land Capability Classification and I am glad to be brought up to date on the current situation.

I must emphasise, however, that the Land Capability Classification as described is not permanent. It is a rather general high level land analysis technique. The classification has already been modified and no longer follows the original classification as set down. There has been a movement in emphasis from dry land crops to padi because of falling price of rubber and increase in the price of rice.

I am very interested to note that in West Malaysia you are moving towards a system of mechanical analysis which could eventually progress to a fully computerised system. There is no doubt that in the future analysis should be speeded up by replacing mechanical analysis by a computer. For this reason, I refer back to a point made earlier in this session (see paper 1) that there is a need in resource data surveys for precise scientific descriptions of the kind that can be put into a computer. I was unaware until this conference that there exists a system of coding soils by using factors such as permeability, depth, etc., which goes beyond a family or series classification. It is essential, if land analysis is to keep up with rapidly changing physical and economic circumstances, that all resource and geographical data be recorded in a way that will permit a computer to be used. I am glad to see that steps in this direction have been taken in West Malaysia.

Lee: There is a plan to use a computer. As factors become more and more complicated and the number of factors increase this is essential. As far as the permanency of the classification is concerned: we have been limited in our objectives in the past by too much emphasis on the major crops. And we need now more information in order to be able to deal with diversification of crops - but the main issues will not changes significantly, that is the division of land use between forestry, agriculture and mining.

Roberts: When using punch cards have you sufficient and proper scientific description on various soils, forests types etc. to put on the punch cards or do you have to make a lot of value judgement yourself to be able to code the information? If that is the case, could this not be done much better by the experts concerned if they knew that you wanted the information that way.

Lee: The information is coded according to set classifications of the different resources. These classifications have been drawn up by experts in the respective fields.

Clarke: Mr. Gwilliam spoke of the permanency of the Land Capability Classification. From a forestry point of view, permanency of land tenure is essential. I liked his phrase "Permanent Forest Estate" which is a much better term than "Forest Reserve". The latter term is often taken to mean land reserved for some future use and not necessarily for forestry purposes.

The forest estate can take two forms:-

1) natural virgin forest which involves little or no financial investment by the State.
2) exploited, silviculturally treated forest or plantations involving considerable investment extending over a long period of time which may be 20 - 30 years for plantations and up to 80 years for naturally regenerated forest. The importance of permanency for these types of forest cannot be overstressed.

Lee: The basic aim of the land capability classification is to locate the land to be used for agriculture or forestry. This will be more or less permanent. In fact forest will be mainly on land unsuitable for agriculture because of steepness of slope. Even though agriculture could be done on steep land with proper conservation measures, it is considered to be uneconomic on a large scale. Therefore, forest land as assessed at present is more or less a permanent allocation.

Andriesse: In your supplement to the Land Capability Classification you are using the range of crops as a measuring stick for indicating suitability of land for agriculture. In your Soil Resources Map you are using a different approach, namely the number of limitations to agriculture. I would like to ask how you relate the former with the latter?

Lee: There has been some confusion in terminology in the past, due to the fact that we were trying to relate our classification according to the U.S.D.A. system of land capability classification. In actual fact, when we speak of limitations to agriculture, we mean limitations to the range of agricultural crops which may be grown, and the assumption is that the range of crops which may grown is directly related to the number and severity of these limitations.

Ashworth: You distinguish five classes of which Class I is a mineral class. I agree that if this land is exploited, it will bring in more than agriculture would do. However, the impression I get is that you put a piece of land in Class I and it gives no idea what the agricultural potential is. Most countries keep mineral deposits in reserve because you cannot mine all mineral deposits at one time. A situation could be visualised where you have:

Class I	-	Agriculture
Class I	-	Mineral
Class I	-	Forestry. That would be Class I land.

Also you can visualise another situation in which:

Class I	-	Mineral
Class II	-	Agriculture
Class III	-	Forestry. Is this still Class I land?

Lee: Yes, we map it as Class I land but we still provide in the report information on the agricultural and forestry potential so that alternative uses are indicated.

Gwilliam: I would again like to question the so-called "permanent classification". Surely permanency must be read in the context of other things being equal. What would happen if the world decided that it needed tin no longer. Your classification will only remain "permanent" as long as circumstances do not change and we all know that conditions do not remain unchanged for long.

Lee: We are planning for the foreseeable future. We try to apply our resource data to development planning.

Gwilliam: That is the point. The land capability classification is not permanent but the resource data is.

Moormann: I suggest that what you call land capability classification is better termed land use planning classification for the present day economic situation in Malaysia.

Lee: I agree that you may have a point there. But it must be remembered that we are classifying land according to its capability for development. The U.S.D.A. Land Capability Classification is essentially a classification according to crop suitability, whereas land is certainly capable of being used for more purposes than just the growing of crops. We are trying to take this into consideration.

Recter: The land capability classification program consists of two distinct phases:

a) the collection of physical resources data, in the form of soil suitability, forest productivity and mineral potentiality maps.

b) to use this information as a guide for sound land use planning.

A land capability classification has been introduced to be used as a preliminary guide for future land allocation. However, it should be fully realised that additional information is required before any planning let stand implementation can take place.

The economic parameters used in a program like this do fluctuate, however, the program is flexible enough to allow for such changes to be incorporated at any stage, as has been done in the past.

It should be clearly understood that the program in West Malaysia has two objectives: a) to provide state governments with an appreciation of their physical resources and rough guide lines how they should be used and allocated. b) to obtain a nation wide appreciation of West Malaysia's physical resources, before the Second Malaysian Plan is drafted.

LAND CAPABILITY CLASSIFICATION IN SABAH

by

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Introduction. The need for a land capability classification was long 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 liasion 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.

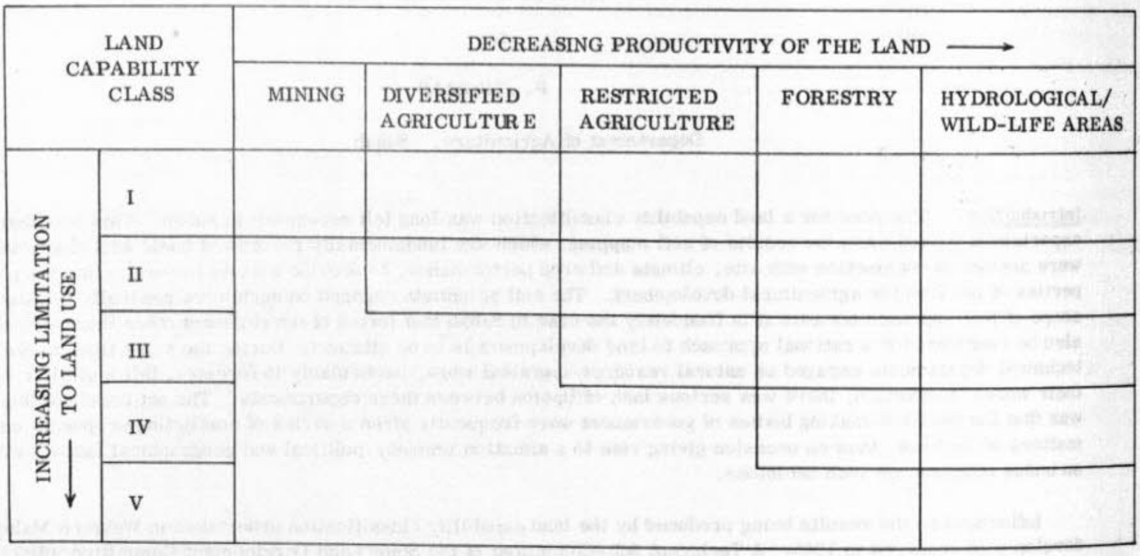
Influenced by the results being produced by the land capability classification undertaken in Western Malaysia a new development occurred in 1966. A Technical Sub-Committee of the State Land Development Committee was charged with undertaking a schematic land capability classification of the State. The 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 maps being published for the State.

The General Approach to Land Capability Classification. There are a number of Land Capability Classifications in use elsewhere almost 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. (Klingebiel and Montgomery, 1961). It grades land according to its potentialities and the severity of its limitations for crop growth 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 for the Land Capability Classification of Western Malaysia. This classification gives the relative economic capability of the land for 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 (Hockensmith, 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.

The Principles of the Land Capability Classification. The groupings 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 on 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 as accessibility and the pattern of land ownership and current land 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 and 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.



The Land Capability Classification.

Land Capability Classes. The various natural resource groups are interpretated into five Land Capability Classes, and these are set up so that land having the greatest theoretical alternative uses but always giving the highest return on development is in 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 mineral 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.

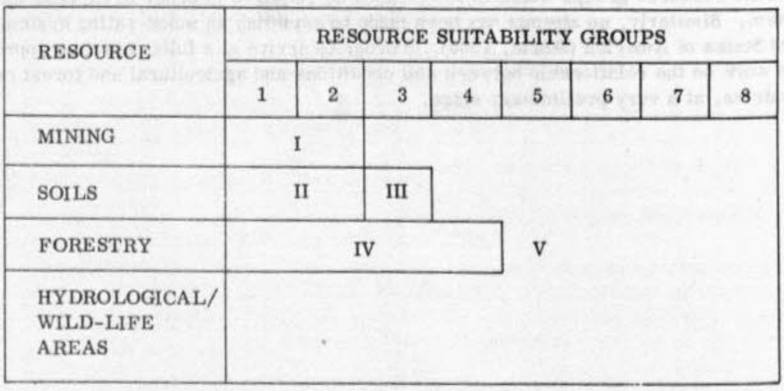
Land Capability Class III, which has a moderate potential for agriculture with a restricted range of crops and therefore best suited for a limited variety of crops with a high level of soil tolerance.

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 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 each resource is defined into Resource Suitability Groups as follows.

A. Mining. The Mining Suitability Groups refer to mineral deposits workable 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 a 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.

B. Soils. The Soil Suitability Groups are based on a series of limitations inherent to the soil and a moderately high degree 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 limit is never in excess of 5°. Having no limitations to 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 for 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 20 inches and 48 inches of the surface, a slightly unfavourable soil structure which is usually moderately developed only, extreme coarse textures, or moderate slopes generally falling within the 5 to 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 i.e., within 20 inches of the soil surface, or soils showing acute 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 suited 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 shallow 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 strong 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 steeplands in which slopes greater than 25° predominate, extremely stony, rocky and boulder strewn soils or bare rock, soils with toxic 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.

C. Forestry. The rating employed relates essentially to timber production and emphasis is given to the forest potential inherent to 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 imminent 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.

Group 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 foreseable future.

Group 8. Non-forested land subject to shifting cultivation, or savannah, in which the forest potential is limited to reforestation with plantations of exotic tree species such as various pines.

D. Hydrological and Wild-Life resources are not rated into suitability groups, mainly because they are frequently difficult to define on a quantative 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 CLASSES	LAND EXPLOITATION UNIT	RESOURCE SUITABILITY GROUPS		
		MINING	SOILS	FORESTRY
I	IA	1-2	4-5	5-8
II	IIA	4	1-2	5-8
	IIB	4	1-2	1-2
	IIC	3	1-2	5-8
	IID	3	1-2	1-2
III	IIIA	4	3	5-8
	IIIB	4	3	1-2
	IIIC	3	3	5-8
	IIID	3	3	1-2
IV	IVA	4	4-5	1-3
	IVB	3	4-5	1-3
	IVC	4	4-5	4
V	VA	4	4-5	5-8
	VB	3	4-5	5-8

Land 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 occur each having similar qualities and uses in having the same kinds 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 assigned Unit. The following fourteen Land Exploitation Units are at present recognised.

IA. Land possessing a high potential for mineral development.

IIA. Land with a high potential for agriculture only.

IIB. Land with a high potential for both agriculture and timber exploitation.

IIC. Land with a high potential for agriculture and also a possible mining potential.

IID. Land with a high potential for agriculture and timber exploitation and also a possible mining potential.

IIIA. Land with a moderate potential for agriculture only.

IIIB. Land with a moderate potential for agriculture and also a high potential for timber exploitation.

IIIC. Land with a moderate potential for agriculture and a possible mining potential.

IIID. Land with a moderate potential for agriculture, a high potential for timber exploitation and a possible mining potential.

IVA. Land with commercially exploitable timber resources only.

IVB. Land with commercially exploitable timber resources and also a possible mining potential.

IVC. Land with potentially productive mangrove resources only.

VA. Land having no potential for agriculture, or timber and mineral exploitation.

VB. 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, 1960).

Table 2. The classification of the alienation and gazettement detail.

LAND CATEGORY	ALIENATION AND GAZETTEMENT 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 communial 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 underway, and it is expected to be completed by 1971.

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Discussion

Recter: I see you introduced in Sabah the system of land exploitation units into the Land Capability Classification. Would it be possible to have all the 14 exploitation units in your Class I and land according to the Land Capability Classification?

Thomas: No, in Class I land we only have one exploitation unit, that is land only suitable for mining and no potential for agriculture or forestry. This is our experience up to date and I do not think that we are going to have more units in this class. But when we go to the lower classes e.g. Class II we have 4 exploitation units (suffices A, B, C, D.)

Roberts: How do you classify land with existing settled cultivation?

Thomas: The legal aspect of the land does not come into our Classification, and does not affect this grading; although the pattern of land ownership and current land use will of course influence decisions on development.

Roberts: It has to come in somehow. Would you say that land under settled cultivation is suitable for agriculture?

Thomas: Frequently it is not. For example rubber is sometimes grown on extremely steep slopes or on deep peat, and as such does not give an economic return.

Clarke: In Sabah, do you consider that peat deeper than 48 inches has no agriculture potential whatsoever?

Thomas: In Sabah, yes.

Recter: Is there any current mining in Sabah?

Thomas: No, furthermore, there are no proven mineral resources. There are prospects which are to be investigated. The distribution of Class I land is, therefore, very limited.

Gwilliam: As a general point, is the prospect of increased timber yield following forest exploitation and using proper silvicultural methods taken into account in rating the capability of land for forestry purposes. In Sarawak it appears that e.g. swamp forest can give increased production if modern silvicultural practises are followed.

Thomas: In Sabah for the Land Capability Classification sustained timber yields, i.e. the same yields as experienced today have been taken as our basic consideration. No increase in yield has been envisaged.

Ashworth: Are you not trying to encompass too many factors in a single classification? American experience has been that the more simple the classification the better it would be.

Thomas: Our experience to-date is that now we have got down to our Land Exploitation Units, of which there are 14 (and we do not think that there will be more in future), we can quite easily cope with the present degree of complexity. I submit that this compares favourably in simplicity with the U.S.D.A. system which employs 8 Capability Classes (compared to our 5 Land Capability Classes), and theoritically an almost infinite number of Capability Units which are restricted to agricultural criteria only.

Recter: I would like to suggest you modify the wording of your Land Capability Classification classes from "therefore best suited" to "possible", thereby reducing the emphasis inherent in the classification. Experience in West Malaysia has shown this modification to be necessary and more in keeping with the intended use of the Land Capability Classification as aid to planning rather than as proposals in their own right.

Thomas: Local economic conditions have strongly influenced us. It has been tentatively assessed that the one present prospect, being investigated for copper porphory, is $1,000 million over 100 acres of open cast mining.

LAND USE IN MALACCA AND SOME AGRICULTURAL DEVELOPMENT POSSIBILITIES

by

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Introduction

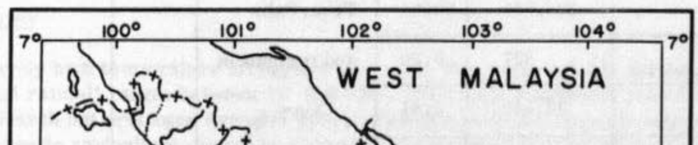
A survey of the present land use pattern of West Malaysia is currently being carried out by interpreting aerial photographs of scale 1:25,000 taken during 1966 and using a modified International Land Use Legend to suit Malaysian conditions. Land use maps of 1:25,000 scale and acreage statistics are being 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. I

Map showing location of the State of Malacca



Malacca's history of interesting agricultural development is based upon its initially strategic position, favourable climate, good soils and suitable topography. The result is that 76% of the State is under cultivation.

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.

Land Use Category	Acreages	%	Major land use categories in Acres	%	Land under Agricultural use in %: Major categories	Land under Agricultural use in %: Sub-categories
1U: Urban	6,946	1.70	Urban and			
1E: Estate Buildings	1,135	0.28	Associated			
1T: Tin Mining	425	0.10	Areas			
1X: Other Mining Quarrying	358	0.09	9,404	2.31		
1P: Transmission Line	540	0.13				
2H: Mixed Horticulture	16,765	4.12	Horticultural			5.38
2M: Market Gardening	1,488	0.36				0.48
2E: Agriculture Stations	128	0.03	18,381	4.51	5.90	0.04
3G: Rubber	246,754	60.58	Tree, Palm			79.14
3O: Oil Palm	827	0.20	and permanent			0.30
3C: Coconuts	11,449	2.81	Crops			3.64
3P: Pepper	15	0.00				0.00
3S: Sago	1,004	0.25				0.32
3B: Bananas	28	0.01				0.01
3H: Fish & Hyacinth Ponds	186	0.04	261,031	64.08	83.72	0.06
3X: Orchards	768	0.19				0.25
4P: Padi	31,859	7.82	Cropland			10.22
4C: Diversified Crops	511	0.12	32,370	7.95	10.38	0.16
6: Scrub Grassland	8,026	1.97	8,026	1.97		
7F: Forest	48,044	11.80	Forest and Scrub			
7S: Scrub	8,405	2.06	56,449	13.86	100%	100%
7C: Newly Cleared Land	2,656	0.65	2,656	0.65	Total acreage under	
8: Swamp	14,957	3.67	14,957	3.67	Agricultural use:	
9: Unused land	203	0.05	203	0.05	311,782	
Unclassified	3,838	0.94	3,838	0.94	Percentage of State area under agricultural use:	
Total	407,315	100%	407,315	100%	76.54%	

The Agricultural Land Use

About three-quarters of the land in Malacca is under cultivation embracing 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. (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 gantangs (Statistical Digest 1966).

Mixed horticulture or dusun, makes up 5% of the cultivated land. It is only associated with smallholdings and is found in association with dwellings along the roads and river-banks.

Coconut occupies less than 4% of the land under cultivation and is only 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. fruit trees in orchards, sago, market gardening and diversified crops comprising 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 exists 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 to offset the dependence on rubber and utilize scarce soil resources to better advantage.

ii) Increase the production of the basic food crops, especially padi.

a) Climate and Topography

Malacca has a uniformly high temperature throughout the year. The mean monthly temperature ranges between 78° and 82°F. The annual rainfall ranges between 75" and 100". Generally a period of relatively lower rainfall occurs from January to March but prolonged droughts affecting plant growth are virtually unknown. On the other hand, widespread flooding adverse to agriculture caused by excessive precipitation is very uncommon.

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.

b) Soil Suitability and its relationship to Present Land Use

By super-imposing a land use transparency over a soil suitability map (Paramananthan 1967) on a scale of 1:63,360, the acreage of each class of soil under the different land use categories can be area-measured using a dot-grid. The results is summarized in Table 2.

TABLE 2

LAND USE IN RELATION TO SOIL SUITABILITY

(Areas in acres)

Soil Suitability Class	Total Acreage	Urban	AGRICULTURAL		Cleared Land	Scrub & Forest land	Swamp	Total
			Rubber	Others				
I	130,275	3,079	106,104	6,130	1,487	13,475	-	13,639
II	133,906	2,186	91,299	15,025	717	20,656	4,025	24,679
III	70,411	275	37,753	16,361	358	14,497	1,167	15,664
IV	47,651	1,250	9,130	25,496	93	2,294	9,408	11,702
V	19,252	2,094	2,468	944	-	13,552	194	13,746
Unclassed	5,814*	-	-	-	-	-	-	-
Total	407,309	8,864	246,754	63,956	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 and III 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 37,000 acres, which are highly suitable for agriculture, it is reasonable to say that Malacca has a reasonable resource of land available for future development.

Land 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 Rengam 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 diversify into oil palms are available in this category.

Land 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.

TABLE 3

ACREAGE BREAKDOWN OF SOME FOREST RESERVES INTO SOIL SUITABILITY CLASSES

Soil Suitability Class	FOREST RESERVES								
	Bukit Sedana Ac	%	Bukit Senggeh Ac	%	Merlimau Ac	%	Ayer Panas Ac	%	Total
I	6,406	90.2	1,179	12.1	1,267	36.0	2,826	92.3	11,678
II	-	-	3,926	40.3	1,760	49.9		-	5,686
III	794	9.9	1,140	11.7	493	14.2	-	-	
IV	-	-	-	-	-	-	-	-	
V	787	9.9	3,487	35.8	-	-	246	7.7	
Total	7,987	100	9,732	100	3,520	100	3,072	100	

There are more than 17,000 acres of Classes I and II soils which are highly suitable for agriculture under the principal Forest Reserve areas. These soils are mainly of granitic origin. Presently about 70% of Malaya is covered by forest and in the national context, it is unnecessary for a developed State like Malacca to maintain these lands 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 the Class II soils, especially the Riverine Alluvium under Forest Reserves can be utilized in the future for food and fodder crops. West Malaysia imports a variety of agricultural produce 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
Kementarian Pertanian dan Sharikat Kerjasama.
Malaysia Barat.

The acreage under these crops should be expanded wherever possible to reduce our dependence on imports for basic foodstuff. This will also result in conserving foreign exchange and providing employment for the rural population.

Unalienated State Land

Another area with potential for agricultural development is located abreast the lower reaches of the Kesang river. For the most part it is covered by Briah Series - a Class II soil derived from River Alluvium. The area of interest occupying some 4,000 acres is presently under swamp forest and unalienated. 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 and mapping combined with available soil information, can be utilized to critically analyse 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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Discussion

Ysselmuiden: With reference to your Table 2, could you explain which soil suitability classes you have used? I do not find any descriptions of them in the text. Did you use the standard Malayan Classification?

Siew: Yes.

Allbrook: In Table 2 you place 4,023 acres of Class II soils in a swamp. Class II soils should normally have only a minor limitation while swamps are normally placed in Class IV or V.

Law Wei Min: This swamp (identified from air-photographs and lying adjacent to a present river) is classified as Class II because it is liable to flooding once in two year or so. Soils belong to the Briah series, which is a good soil, normally Class I, but because of flooding its suitability is lowered to Class II.

Ashworth: Are you using the same classification as described in the handbook supplied to this Conference? (see Paper 3 in this session).

Siew: Yes, this classification is by Panton and Leamy (1966) but modified by Wong (1966). This classification is for tree crops only; with special reference to oil palm. As such soils highly suitable for padi cultivation may be inappropriately downgraded.

Paramananthan: The soil suitability classification was drawn up by the Soil Surveyors. This map was also drawn by the Soil Surveyor and not by Mr. Siew.

Chan: As Dr. Ashworth and Mr. Ysselmuiden have been enquiring into the soil suitability classes used by Mr. Siew may I refer them to the 5 classes denoted in Paper 6 in this session (Soil Suitability Classification in Malaya - some critical comments by K. T. Joseph). They are all mentioned there.

Singh: A critical examination of the performance of crops already existing would perhaps prove of benefit in the assessment of soil suitability.

Siew: I would agree, but for the purpose of this paper the time was too short to do this.

Paramananthan: We hope to continue this Land Use Survey with the collection of data on crop yield. We will then be able to present such follow up work on this subject.

Donaldson: It was not our intention when doing the Land Use Survey to make a qualitative analysis of land use. The relationship between soil suitability and land use, however, produces facts e.g. there is 106,000 acres of rubber on Class I land which means to the planner that here is a possibility to diversify agriculture here. We intend to follow up the land use survey with studies into the relationship between land use and soil suitability.

Moormann: To come back to the soil suitability classification it does not seem correct to class 'swamp land' in Class I or II, which is suitable land. The fact that the land is not used points to the severe limitation of flooding. Either the land has severe limitations or the land is not 'swamp'. Therefore, although the capability can be high provided you flood control, the present day soil suitability is low.

Siew: The soil suitability depends on the degree of flooding, a lot of this land has already been drained and the soils are good.

Donaldson: The large acreage of swamp shown as Class II is an area of Briah soil. These, when drained, are excellent soils and so some upgrading to Class II is considered necessary. The following are some of the reasons for the present undeveloped nature of the area:

a) periodic flooding;

b) still unalienated state land;

c) the area lies abreast of the Johore-Malacca boundary along the Kesang river and so this is politically 'no-mans land'. Its development may present some administrative difficulties.

Gwilliam: The confusion arises because there are two factors involved, soil and drainage. The soil may be suitable but the land suitability is not so high due to the drainage drawbacks.

Moormann: A possible explanation of the controversy is that what you call swamp may not be swamp at all. If I think of a swamp I refer to land which is waterlogged all or most of the time and hence cannot be used for agriculture. You say it only floods one in the two year, but is it therefore really swamp?

Siew: To a certain extent you are correct because the aerial photographs taken at that particular instance could display temporary characteristics of swamp land and so were interpreted as swamp.

Ng: The likely explanation for this problem is that the soils were classified in the field as Class I and II soils. The air-photo interpretation done at another time classes this area in 'swamp', possibly at that time (when the photographs were taken) the area was actually flooded.

Andriesse: Possibly the problem arises from the fact that here soils are classified on suitability after amelioration and not on suitability in the present state. A Soil or Land Suitability Classification should be based on present conditions.

Recter: The term Land Suitability Classification is a new one to me. Could you please explain what you mean by that? Is it in use in Sarawak?

Moormann: The term Land Suitability Classification has been in use by the U.S. Bureau of Reclamation. They have a Land Suitability Classification for irrigation. This term is, therefore, already in use for a long time.

Thomas: I refer back to the controversy on this soil suitability classification of the reasonably flooded Briah soils. Surely, if a limitation can be removed at an acceptable economic margin this limitation is not considered and only the continuing limitations are considered.

Ashworth: This is a valid point. A good soil should not be downgraded excessively if the removal of the limitation is not expensive. You can place it in a subclass which indicates its value after removal of the limitation.

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 predicted. 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 disability. The range of crops for which they are suitable is restricted in some cases by the type of limitation, e.g. susceptibility to flooding or 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 most 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.

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."

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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. Andriesse (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. Invariably 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:

	Yields (Kg./ha.)	
	1st cycle	2nd cycle
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. The 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 near 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 countering 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 difference between class 2 and class 3 in the scheme proposed. Andriesse (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, we need 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 the profile. Joseph (1964) proposed the use of such areas for sugar cane cultivation in North Kedah where the climatic features were conducive to its growth. Although erodibility of soils have been made implicit in the scheme proposed (by the use of topographical differentiae), finer distinctions need to be made e.g. Terrace soils, alluvial soils, humic 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 sandy beach deposits of the East Coast of Malaya. How can we best use such areas? Groundnuts for disturbed tin-tailings? A legume/grass pasture for limited grazing under coconut palms or pine forests on the bris soils of Eastern Malaya? How best can we use our acid sulphate soils? Is ameriolation 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 dissertions it would be found inadequate. It would be no detraction, indeed it may be inevitable, even desirable that special classifications need to be carried along simultaneously with the general classification. The soil series 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 play 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 system 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 on Mg. status, nitrogen content, C.E.C. etc. In any soil/crops relationship a number of variable are involved. Computerisation is the only ultimate answer to the problem of solving complex data involving multivariate functions for the creations of a truely sophisticated scheme of soil suitability.

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Discussion

Andriesse: In your Paper I read that you object to a Soil Suitability Classification geared to one crop only, while your closing sentence just now was 'every Soil Suitability Classification should be geared to one specific crop.' Could you please explain the apparent contradiction?

Joseph: If you ultimately want to diversify agriculture then computerisation of relevant data is the only means to assess the situation for each crop. Data on specific plant requirements have to be fed in for decision to be made with respect to the best crop for any particular soil type. There are also going to be changes in the soil status as a result of continued fertilisation etc. In order to incorporate further information we must allow for these changes in our scheme and a punch card system can allow for this.

Andriesse: Am I right to think that you want to put all your information on punch cards and then to leave it to the computer to work out the situation for each crop, rather than having a fixed scheme?

Joseph: No, the second part of my paper is related to future prospects and is not really related to soil suitability in terms of land use for the present.

Ashworth: My experience as an ex-extension worker is that you cannot use computerised material to predict fertilizer needs except for a short time after the information was collected.

Guha: It is appropriate to comment at this juncture that a punch card system to record all physical and chemical properties of soil and site characteristics is being practised in R.R.I. These cards are used to evaluate different soil properties with regard to their effect on growth and yield of the specific crop rubber. We started in 1964 and have at present 4,000 of such cards. We find them very useful, since, prior to 1964 soil analysis were carried out on samples for which we had no detailed information and such analyses prove now to be of little value. The punch card system is not only of value in respect to soil use but also to advisory work concerning rubber.

Ysselmuiden: In Brunei we use punch card descriptions but we only store simple soil data; when storing complex data one needs a card of 10 inches or more which is not manageable in the field. Transferring data from description sheets in the field to punch cards is a waste of time. The field card should be the final card for storing.

Joseph: I think the issue is being confused. The Soil Suitability Classification for broad land use planning was the subject of the first part of my paper. The second part touches upon future prospects for the creation of a truly sophisticated scheme where computerizing of data is essential for advisory work in relation to maintaining productivity of soils. Soil Suitability must ultimately cover both Land Use Planning for development as well as serve extension needs.

Singh: Computerization for advisory purposes is already being used in Holland and in Australia. This paper shows the numerous variables to keep in mind in interpreting soil suitability classes and the scientific approach as suggested by this paper is commendable.

Paramananthan: The idea of a computerized Soil Suitability Classification is a good one but we must leave nutrient levels of soils out of it since most tropical soils are poor. Physical characteristics should be emphasized. Then, if we have worked out the physical requirements of a particular crop and feed the information in the computer each soil will fall into its respective soil suitability class for that crop. It is impossible to have one soil suitability classification encompassing all crops.

Law Wei Min: I agree with Paramananthan that a so-called universal system is impossible, when comparing two contrasting countries such as New Zealand and Malaysia. We see that in New Zealand the main crop is pasture and soil suitability is mainly interpreted for grasses but other crops such as orchards are also catered for.

In Malaysia, the crop range is too wide for a universal soil suitability classification. We have to divide the crops into groups such as the tree crops, shrub and low trees, annuals like root crops, and padi.

Chan: I disagree with Dr. Ashworth statement that he cannot see how punch cards can be of lasting use for the extension worker. In my experience, the system is very valuable. The R.R.I. has this facility in their advisory service and can now easily get some idea of the particular farm's soils and management practises to aid them in their advisory work at any one time.

Ashworth: You are possibly right if single values are concerned but in general, fertilizer needs can only be predicted with certainty given regular analyses.

Andriesse: To comment on this. In Holland, apart from having these punch cards which are used for keeping a yearly check on the farm, analyses on soils are regularly carried out. Then, with the analyses and the history of the farm given in the punch card fertilizer recommendations can be made. We should, however, keep in mind that here advisory work is concerned and not soil suitability as such. One can keep a check on a farm but not on a whole soil series on which the management practises may vary widely.

Guha: There is no point in arguing over this. It appears that only a demonstration is needed to convince everybody. Fertilizer recommendations for a soil series as a whole are actually given for rubber. (see Paper 4, Session 4).

Ng: As a general comment, I would like to state that if we are aiming at results there should be total intergration between the work of the Soil Surveyors and that of the Agronomists. If we want to create an objective classification than we have to carry out trials with all our crops on the major soil series and intergrate in these trials as much as possible economics so that the ecomomic viability can be studied.

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 as 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 low level.

All the developing countries are trying to increase food production, but so far have only succeeded in barely maintaining the same per capat 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 1949-53 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 same 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 being 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 formation 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 per-cent 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, Equador, 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 the 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 offerred 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. Usually 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 inputs and 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 the 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. Some 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, physiological 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 Ceylon from 2-14 September, 1968, and 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 very high yields of rice". The subject of obtaining high rice yields have become very important in recent years due to the growing food shortage. Since its inception in 1949, the International Rice Commission had pointed out that the rice varieties grown in the topics, grow tall and lodge when higher doses of nitrogen are applied, and cannot give very high yields, like the dwarf varieties grown in the temperate regions. Hence, the IRC started a co-operative rice hybridization project to obtain dwarf varieties which would show high fertilizer response. Much work on this line has since been done, and in recent years, some 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 Syntha in Indonesia, have been evolved which show very high response to higher doses of fertilizers. However, farmers in the different tropical countries have been obtaining 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 fertilizers 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 Afganistan, 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, vehicles, equipment etc., of which the total cost may approach one million dollars for a 5-year probject. In addition to simple trials on farmers' fields, and 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 operational in Korea, Philippines and Thailand. Another SF project viz., "Pilot Farm 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 work 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 rapidly increase production. FAO is assisting the Member Countries through "production-oriented" projects, concerning the promotion of fertilizer use amongst farmers. The farmers' varieties give over 50 percent yield increase due to fertilizer application and the improved varieties show much higher increases. 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 and 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 - 1952/63	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	16 446	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
Sabah	12.6	23.9	42	85	44	88
Sarawak	-	9.5	103	107	103	107
Nepal	-	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
Thailand	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**

APPENDIX II

Fertilizer Consumption in Relation to Arable Land - 1965/66

Cpimtry	Average consumption per 1000 ha. of arable land 1/ N	P_2O_5 2/	K_2O	Total N. P_2O_5 and K_2O	Arable Land
	.... Metric tons			....	1000 ha.
Burma	0.32	0.06	-	0.38	14,948
Cambodia	0.10	0.34	0.10	0.54	2,984
Ceylon	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
Thailand	1.60	0.89	0.44	2.93	10,604
Viet-Nam, Rep. of	9.00	18.88	3.79	31.67	3,082

1/ 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 moving or pastures, garden land, and land under fruit trees, vines and fruit-bearing shrubs.

2/ Data exclude ground rock phosphate.

* 1963/64

APPENDIX III

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 Requirements in 1965/66 1/	Surplus (+) or Deficit (-) in 1965/66	Actual Cons'n in 1961/62	Actual Cons'n in 1965/66	Estimated Domestic Requirements in 1965/66 1/	Surplus(+) or Deficit(-) in 1965/66	Actual Cons'n in 1961/62	Actual Cons'n in 1965/66	Estimated Domestic Requirements in 1965/66 1/	Surplus(+) or Deficit(-) in 1965/66
	......1 000 metric tons N......				......1 000 metric tons P_2O_5......				......1 000 metric tons K_2O......			
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	545.0	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	40.1	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	...	...
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	4.0	+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 Fertiliser 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 evolved 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 facilities 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, bad 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 matters 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 need be, of appropriate methods for analysis of such soils.
11. Perfection of techniques for the detection of nutrient deficiencies during 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

1. Opening of Meeting
2. Election of Chairman and Vice-Chairman
3. Adoption of Agenda
4. Election of Drafting Committee

Technical Matters

5. 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
6. Practical methods of increasing efficiency of irrigation.
7. (a) Reclamation and water and soil management in acid, saline, alkaline and degraded soils.
   (b) Classification of rice soils
8. Water and fertilizer management for rice grown under upland conditions
9. Factors responsible for very high yields of rice.
10. The use of soil and plant analysis in determining the fertilizer requirements of rice.
11. Time and method of fertilizer application
12. Response of rice to micronutrients
13. Kinds of fertilizer materials
14. Discussion on hand book on water control and management
15. 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 to 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, plant 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 agriculture 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 on 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 the 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 improvement of existing agricultural co-operative organization would 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 in 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, local 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 about 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, Dahomey, Togo, Ghana, Cameroon, Ivory Coast, Gambia, Sierra Leone, Senegal, Guatemala, El Salvador, Hondurus, Nicaragua, Costa Rica, Panama, Columbia, Ceylon, Ecuador, and India. By the end of 1966, some 88,200 fertilizer demonstrations, and 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, but traditional farmers, fertilizers have almost everywhere given increased yields, on an average of 58 percent. Results of 23,446 demonstrations showed that in 92 percent of them 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 trialment was 8.4.

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, and 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 on 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-scale 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 nearly 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 soils in north-east Thailand, which tend to subside during ploughing and show salt concentrations in some areas, presented a number of problems. Heavy phosphate 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.

<u>Discussion</u>

Singh: Does FAO play a part in the education of the farmer?

Mukerjee: Yes. Apart from the assistance given by FAO to the Member Governments, in accurately determining\the economical rates of different plant nutrients for different crops under different soil conditions, and finding out the measures needed to improve soils with negative factors, FAO operates a sizeable programme to educate the farmers on the benefits to be obtained from fertilizer use, under the Freedom-from-Hunger Campaign. In this programme, FAO supplies fertilizers to Governments, which are distributed to farmers on credit and applied to their fields by FAO specialists, according to the previous experimental results. These demonstrations serve as excellent education to the farmers, who not only pay for the fertilizers after harvest, but start purchasing fertilizers on cash in subsequent years.

Ysselmuiden: Is FAO undertaking any research in hill padi? There are large numbers of people in South East Asia depending on this crop.

Mukerjee: Yes. The FAO projects on Soil Fertility Research and Promotion of Fertilizer use are working on all crops including hill paddy. This subject has been included in the agenda for the Working Party Meeting on Rice Soils, Water and Fertilizer Practices of the FAO-organized International Rice Commission to be held in Ceylon during September 1968, as item No. 8 "Water and fertilizer management for rice grown under upland conditions". Results obtained in the different countries with upland rice would be discussed at this meeting.

A RAPID ACID DISSOLUTION METHOD FOR THE DETERMINATION OF CATIONS IN PLANT MATERIALS USING ATOMIC ABSORPTION AND EMISSION FLAME SPECTROPHOTOMETRY

by

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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 SP 900A, is reported.

INTRODUCTION

Analysis of plant material in Malaysia is generally carried out by dry or wet ashing of the plant material (MIDDLETON, GYSS, FALLOWS AND VARLEY, 1964). These methods normally require 1 to 2g of the plant material for the determinations of K, Ca, Mg 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 shaking of plant material with dilute hydrochloric acid, which has been successfully used elsewhere (TALIBUDEEN, 1968) being examined.

PROCEDURE

50 ml of 0.5N HCl is added to 0.1 to 0.4g of oven-dry plant 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 SP900A flame spectrophotometer which is calibrated to measure 0 to 0.5 ppm. This normally requires a 100 to 500 fold dilution of the plant 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 first 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 RATNASINGAM, 1966). High reproducibility was obtained, the coefficient of variation between the replicates being less than 3.5% 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 the same dry ashed extracts were analysed by atomic absorption and 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 mean recovery of the 9 samples being 100± 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 retain an advantage where P analysis is also required as P can be determined colorimetrically on the same dry ashing extract. Since 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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Discussion

Chui: What are the concentrations of phosphorus, aluminium and silicate in the final sample solution?

Singh: The levels of phosphate, silicate, etc. were not studied. As our analysis was on 100 to 500 fold diluted extracts, these levels in the atomising solutions would indeed be small. We found that addition of La and Sr for Ca and Mg determinations respectively diminished any interference that may have been present in the extracts.

Chui: What is the definition of the percentage mean recovery of added Ca and Mg?

Singh: The range of percentage mean recovery of samples is given in Table 1, together with the coefficient of variance of these recoveries from the means. Since the coefficient of variance values are low, most of the values were very close to the mean.

TABLE 1 REPRODUCIBILITY OF THE 0.5 N HYDROCHLORIC ACID/PLANT EXTRACT*

Leaf Concentration as % Oven-Dry Material

Ref. No. *	Replicates						C.V. (%)	Mean	Dry ashing values
				POTASSIUM					
3348	2.317	2.283	2.263	2.317	2.358	2.358	1.7	2.32	2.38
3486	.663	.639	.639	.639	.663	.650	1.8	.65	.66
2561	1.051	1.051	1.051	1.091	1.125	1.125	3.4	1.08	1.09
2570	2.763	2.790	2.790	2.763	2.776	2.790	0.5	2.78	2.68
				CALCIUM					
3348	.553	.575	.558	.575	.558	.575	1.8	.56	.49
3486	.712	.712	.720	.720	.720	.720	0.6	.72	.68
2561	.749	.736	.728	.744	.744	.749	1.1	.74	.71
2570	.888	.861	.875	.875	.875	.888	1.2	.88	.79
				MAGNESIUM					
3348	.247	.260	.260	.271	.271	.260	3.4	.262	.27
3486	.236	.250	.249	.244	.250	.250	2.3	.247	.237
2561	.296	.305	.288	.305	.305	.307	2.5	.301	.300
2570	.190	.190	.195	.190	.190	.190	1.1	.191	.189

* 3348, 3486 = *Hevea* leaves
2561, 2570 = *Pueraria*
0.4 g plant material in 50 ml 0.5 N HCl.

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	SP 900A	SP900A	Eel	SP900A	Eel	Eel	SP 900A	SP 900A	SP900A	EDTA	SP900A	EDTA	EDTA	SP900A	SP900A	SP900A	EDTA	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	.51	.32	.50	.49	.50	.48	.48
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	.12	.12	.12	.12	.12	.13	.11
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	.21	.22	.21	.21	.20	.21	.20
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	.31	.32	.31	.29	.30	.29	.26
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	.54	.33	.33	.34	.31	.33	.32	.30
5780	4.10.65	RRI 623	0.78	.81	.75	.80	.75	.79	.79	.59	.64	.66	.62	.65	.62	.68	.23	.24	.25	.24	.25	.24	.16
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	.35	.36	.36	.33	.36	.33	.30
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	.13	.14	.13	.13	.13	.14	.11
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	.21	.22	.22	.22	.20	.21	.18
7162	14.12.65	RRI 623	0.64	.67	.66	.68	.66	.67	.64	.75	.79	.83	.79	.80	.79	.80	.19	.19	.20	.19	.20	.20	.19
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	.36	.36	.36	.32	.35	.32	.35
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	.34	.35	.34	.32	.33	.32	.28
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 hydrochloric acid
Dry Ashing : 5g plant material, dry ashed and dissolved in 250 ml 1.6% nitric acid
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 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 ¼" 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 6½" 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% K_2O) 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
1.	P-O	Basal dressing only
2.	C-1	Basal dressing + 1 cwt. of C.I.R.P. per acre (0.25 grammes per pot)
3.	C-2	" " + 2 cwts. " " " " (0.5 " " ")
4.	C-4	" " + 4 cwts. " " " " (1.0 " " ")
5.	C-8	" " + 8 cwts. " " " " (2.0 " " ")
6.	D-1	" " + 1 cwt. of D.S.P. per acre (0.25 " " ")
7.	D-2	" " + 2 cwts. " " " " (0.50 " " ")
8.	D-4	" " + 4 cwts. " " " " (1.0 " " ")
9.	D-8	" " + 8 cwts. " " " " (2.0 " " ")

N.B. C.I.R.P. = Christmas Island Rock Phosphate (36% P_2O_5 - water insoluble).

D.S.P. = Double Superphosphate (40% P_2O_5 - water soluble)

For the second crop, the basal dressing (only) was again applied to all 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, Muriate of 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 P 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.)

<u>Treatments</u>

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% P_2O_5 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% K_2O)
= 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 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).

B. 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.

C. Plant analysis procedures.

Individual plants are harvested, weighed for fresh weight immediately, then oven dried at 60-70°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 fresh weight 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 negligeable yields from the minus P (P-O) 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 in 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 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 are 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 4A 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 C-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 in 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 fertilizer tend to show increasing concentrations of calcium.

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.

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 <u>Pueraria phoseoloides</u> 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 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 <u>Amaranthus gangeticus</u> (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 D.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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Discussion

Ysselmuiden: Is it correct to assume that the Nyalau and Semongok series have a lower natural fertility level than the Tarat series?

Watson: Yes, in their natural status. In general basic igneous rock derived soils are superior to soils derived from sedimentary rocks.

Guha: Comment. Application of phosphate to rubber is expected to give responses in most upland soils in West Malaysia, except possibly in soils derived from basic igneous rocks. For annuals even soils from basic igneous rocks will possibly give response.

For comparison between rock phosphate and super phosphate we find that soil pH is the determining factor. Above pH of 5.5 superphosphate gives better response, per unit of P_2O_5 applied, than rock phosphate. At pH 5.5 and below they are about equally effective. Under these conditions, the cheaper price of rock phosphate on a unit of P_2O_5 basis makes it preferable to superphosphate. Continuous applications of ammonium sulphate to rubber over about 5 years or so has been shown to lower the pH of the soil by about 0.5 unit. Under such circumstances, the critical pH value of 5.5 may be lowered to 5.0. The above experience is with trees like rubber where some delay for the P_2O_5 in rock phosphate to become available is not very critical. For short-term crops, particularly in pots, however, the above comparison may not hold good as the time required for the P_2O_5 to become available becomes critical.

Watson: This particular study was to compare soils, not fertilizers. The responses to the different types of fertilizers was only one outcome of the experiment. Your explanation on how these differences are obtained may well be applicable here.

Ng: Can you explain why in the Merit soil the yield of the second crop was greater than for the first crop? This may suggest that there was some limiting factor in the first crop. This is very unusual.

Watson: This was also the case with the Merit soil nr 2 to an extend where they are comparable with the results obtained with Merit soil nr 1. You will note that the general pattern is the same. An immediate explanation is, however, difficult to give.

Ng: It is rather surprising that increasing rates of rock phosphate or double superphosphate increased potassium concentration in Bayam tops because calcium is known to be antagonistic to potassium. Were the tops of identical, physiological age when sampled for analysis?

Watson: The tops were all of the same physiological age I refer to Bailey's studies prior to this experiment. He found with hill padi depression in Ca levels with high K levels of application and subsequently an effect on yield. But generally in this study this factor appears to be present on average in all soils and in all experiments. I admit that there is a great range in levels of potassium in the soils used, apart from the amounts we were applying.

Mukerjee: Was C.I.R.P. applied on total P_2O_5 basis or on the basis of citric acid soluble phosphate? In the case of the latter it may give better plant growth from an economic point of view and this may be determined.

Watson: The applications were based on total water insoluble phosphate (36% in the case of C.I.R.P.)

Guha: Comment. The rock phosphate generally used in Malaysia is from the Christmas Islands. The guaranteed composition is 36% total P_2O_5. Citric acid soluble P_2O_5 is not quoted by the suppliers and is known to vary. Some analyses show that about 12 percent is in the citric acid soluble form.

FIGURE I MEAN YIELDS - FRESH BAYAM TOPS

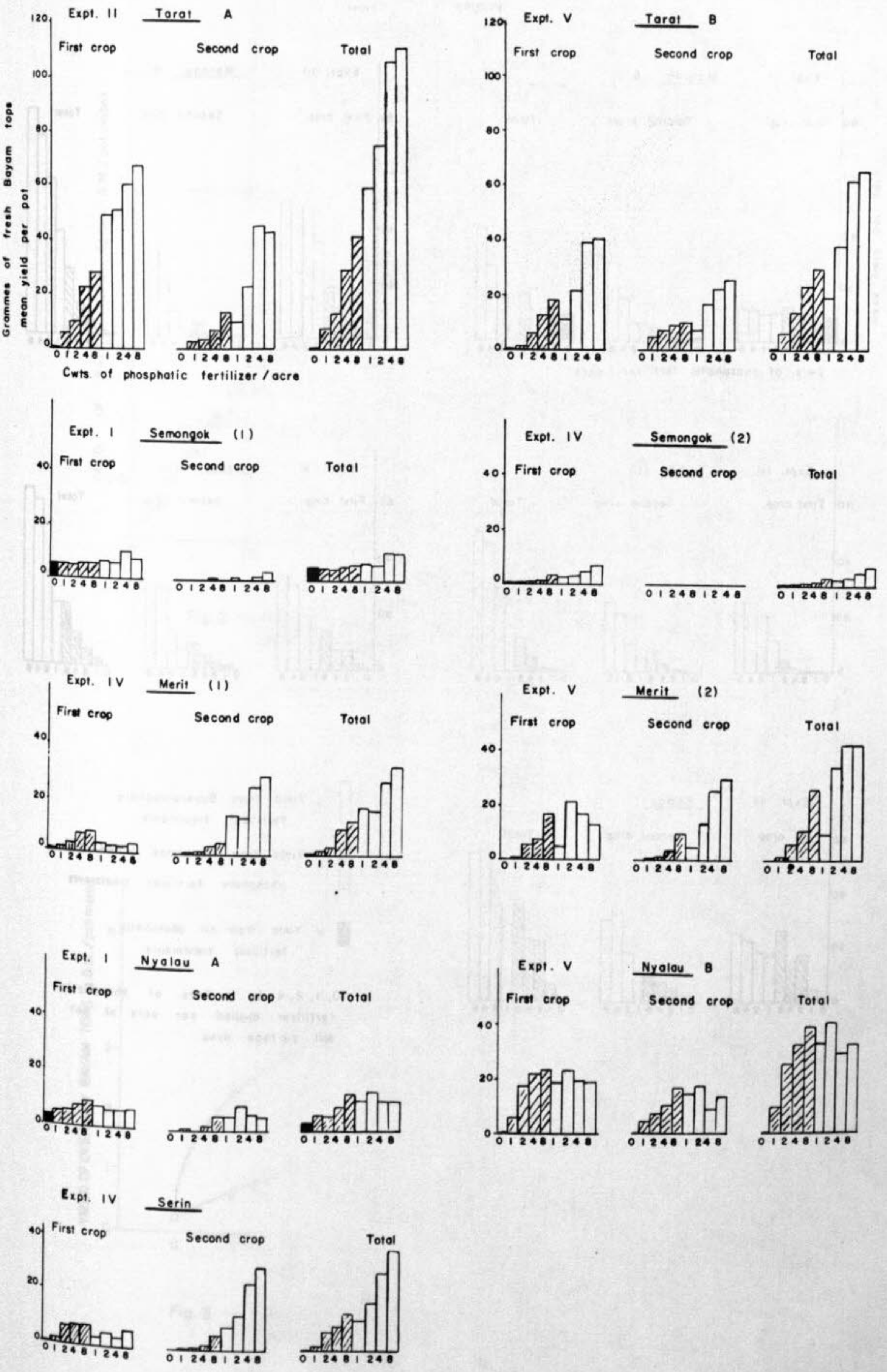
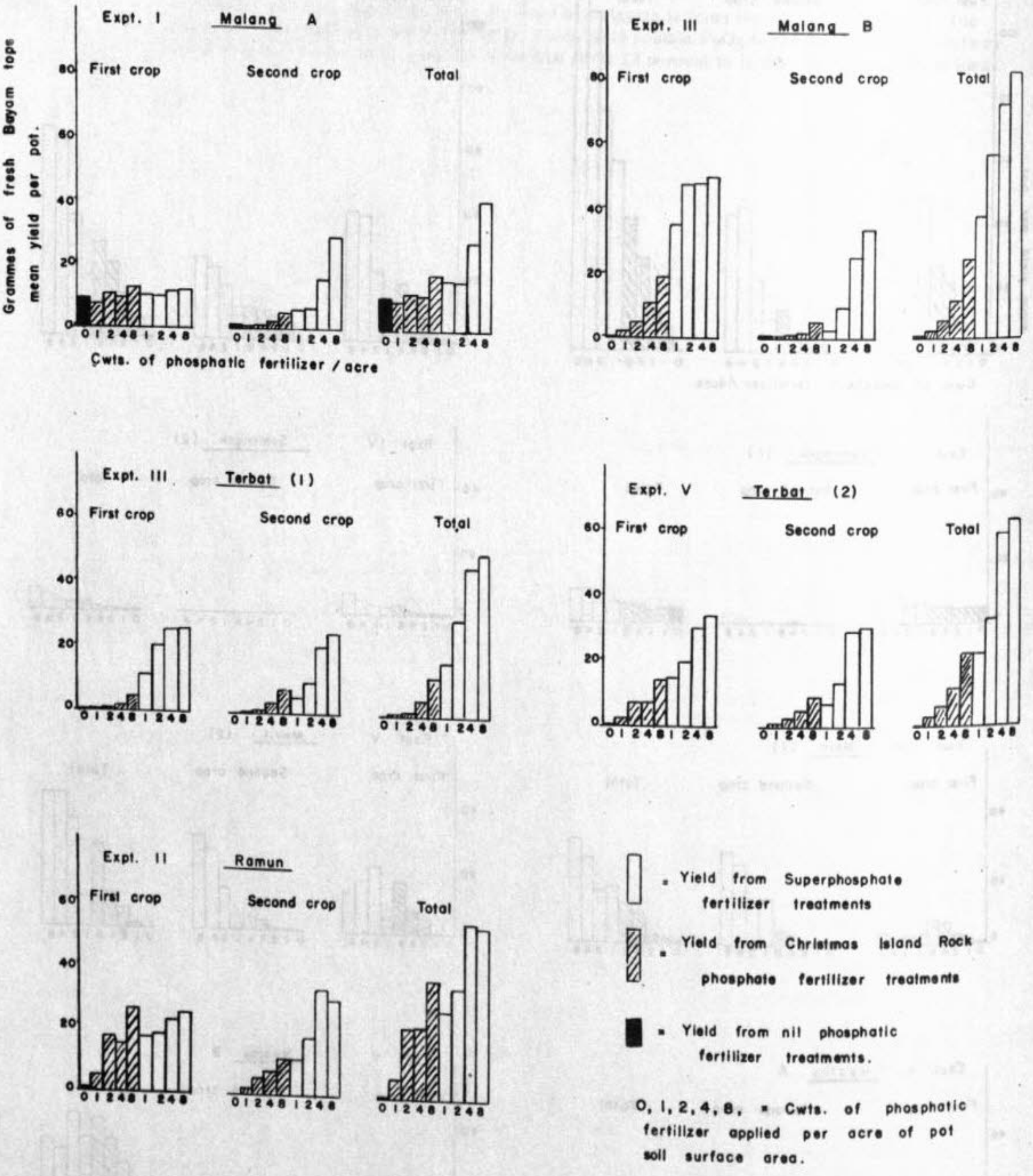


FIGURE I Contin.



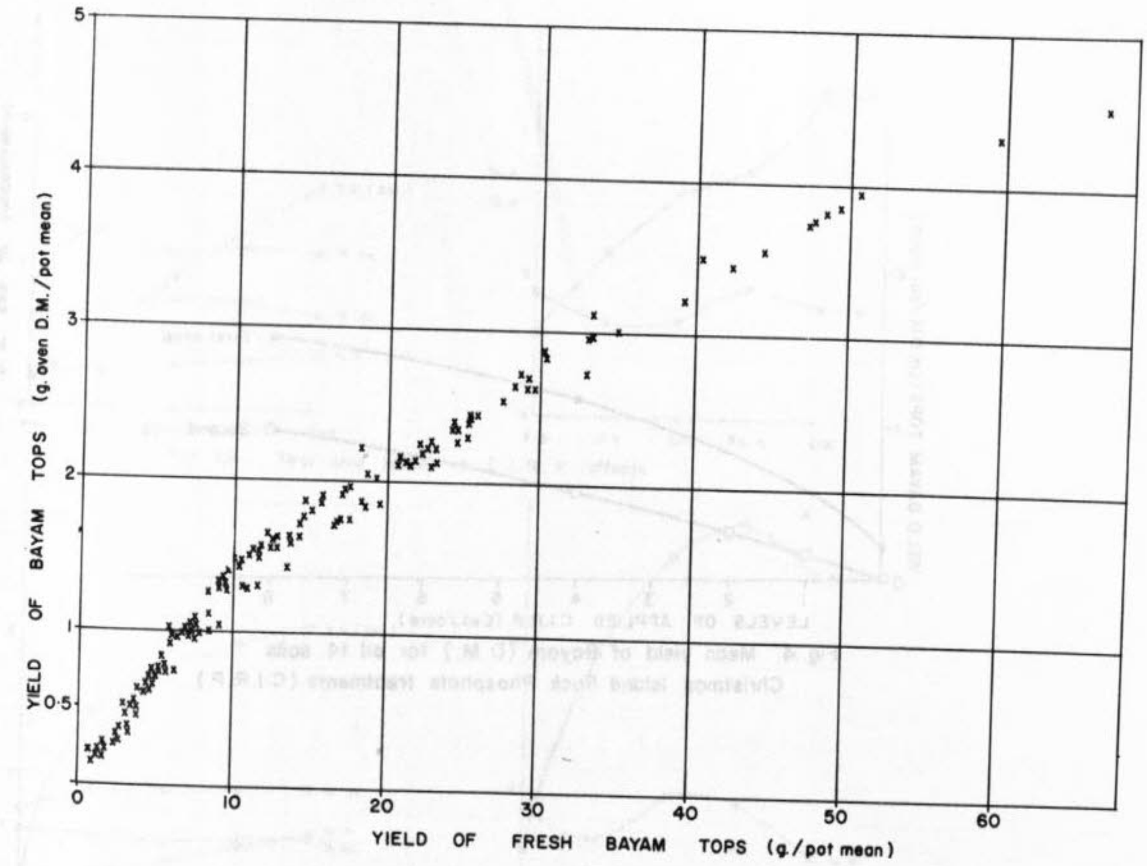


Fig. 2 — Yield of oven dry Bayam tops against fresh cut tops. Mean of recordings per treatment.

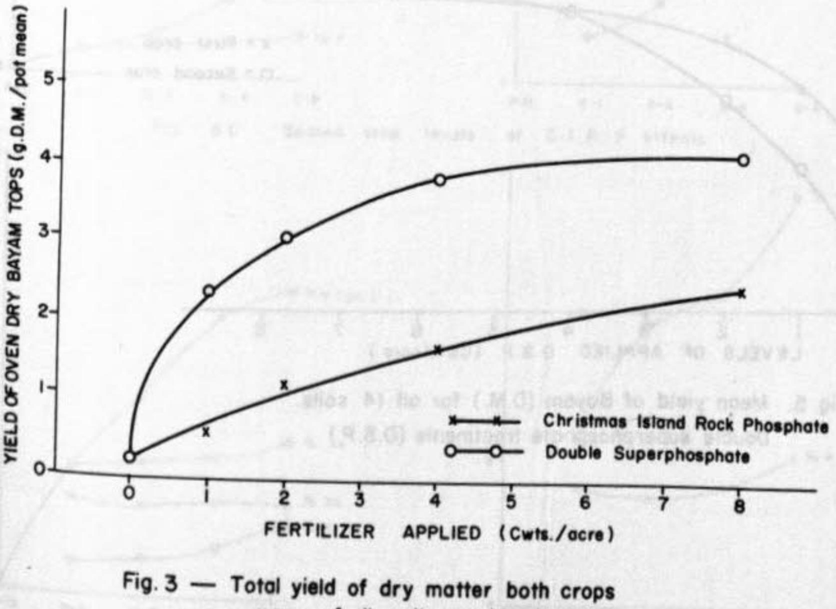


Fig. 3 — Total yield of dry matter both crops mean of all soils combined

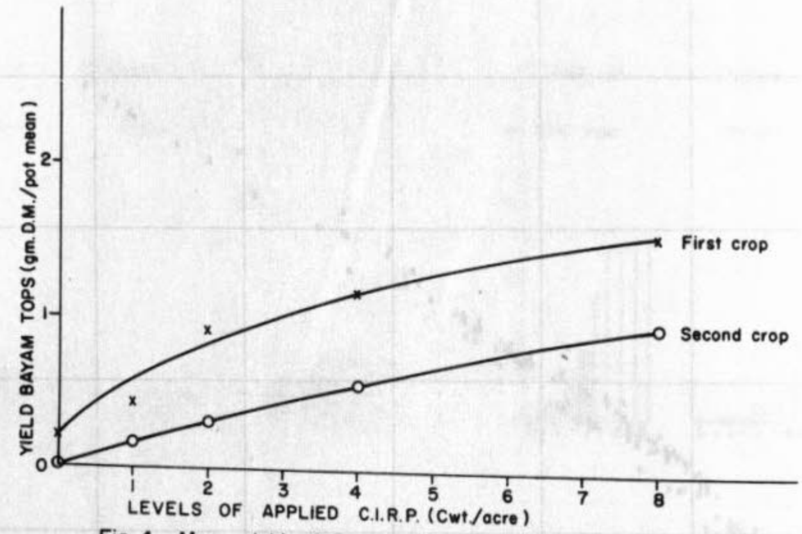


Fig. 4. Mean yield of Bayam (D.M.) for all 14 soils
Christmas Island Rock Phosphate treatments (C.I.R.P.)

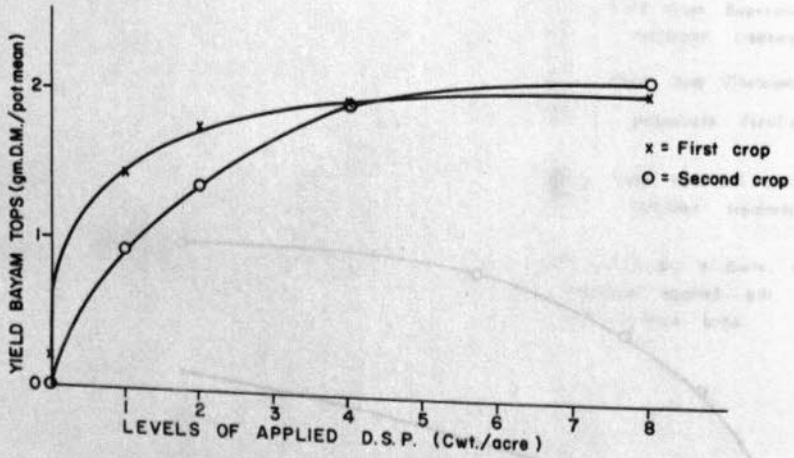


Fig. 5. Mean yield of Bayam (D.M.) for all 14 soils.
Double superphosphate treatments (D.S.P.)

Figures 6A — 6D

Mean Bayam Yields (D. M.) and % Concentration of N, P, K, Ca, and Mg in Bayam Tops for all soils

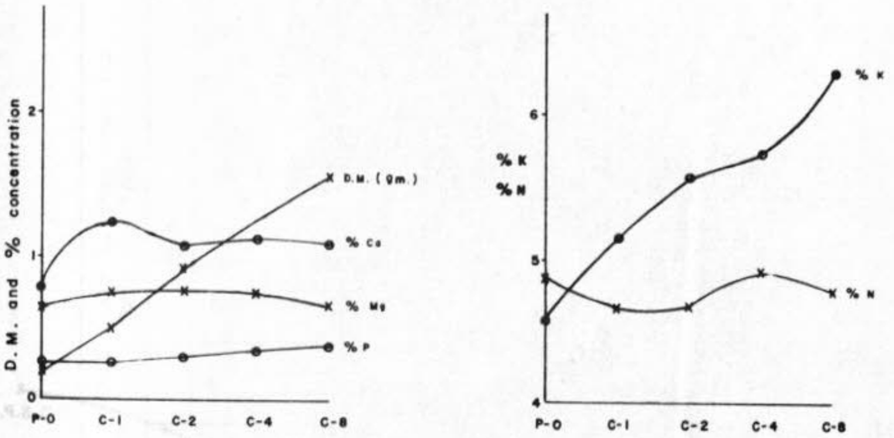


Fig. 6A First crop levels of C. I. R. P. effects

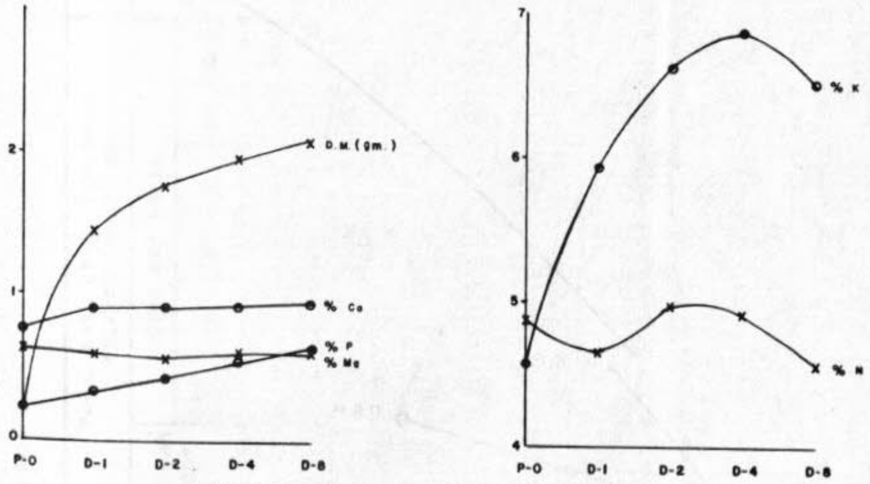


Fig. 6B First crop levels of D. S. P. effects

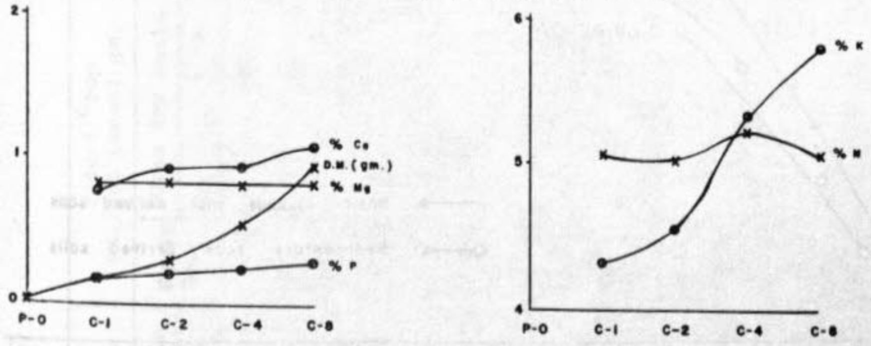


Fig. 6C Second crop levels of C. I. R. P. effects

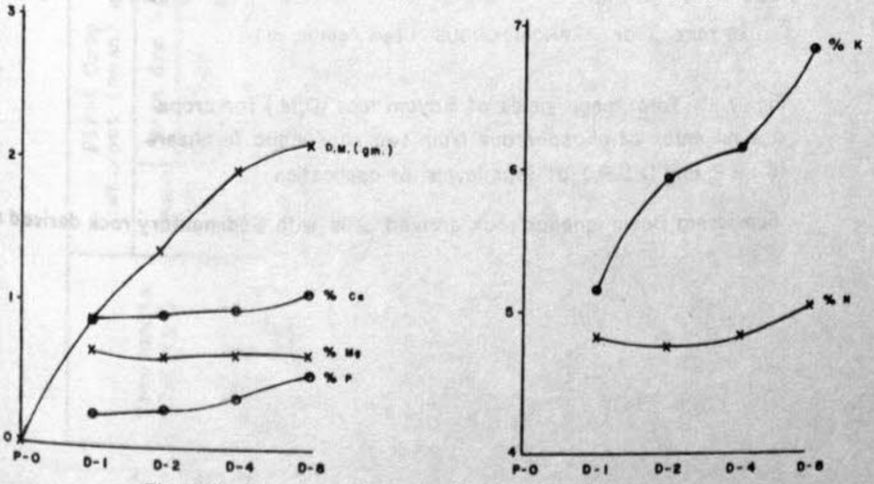


Fig. 6D Second crop levels of D. S. P. effects

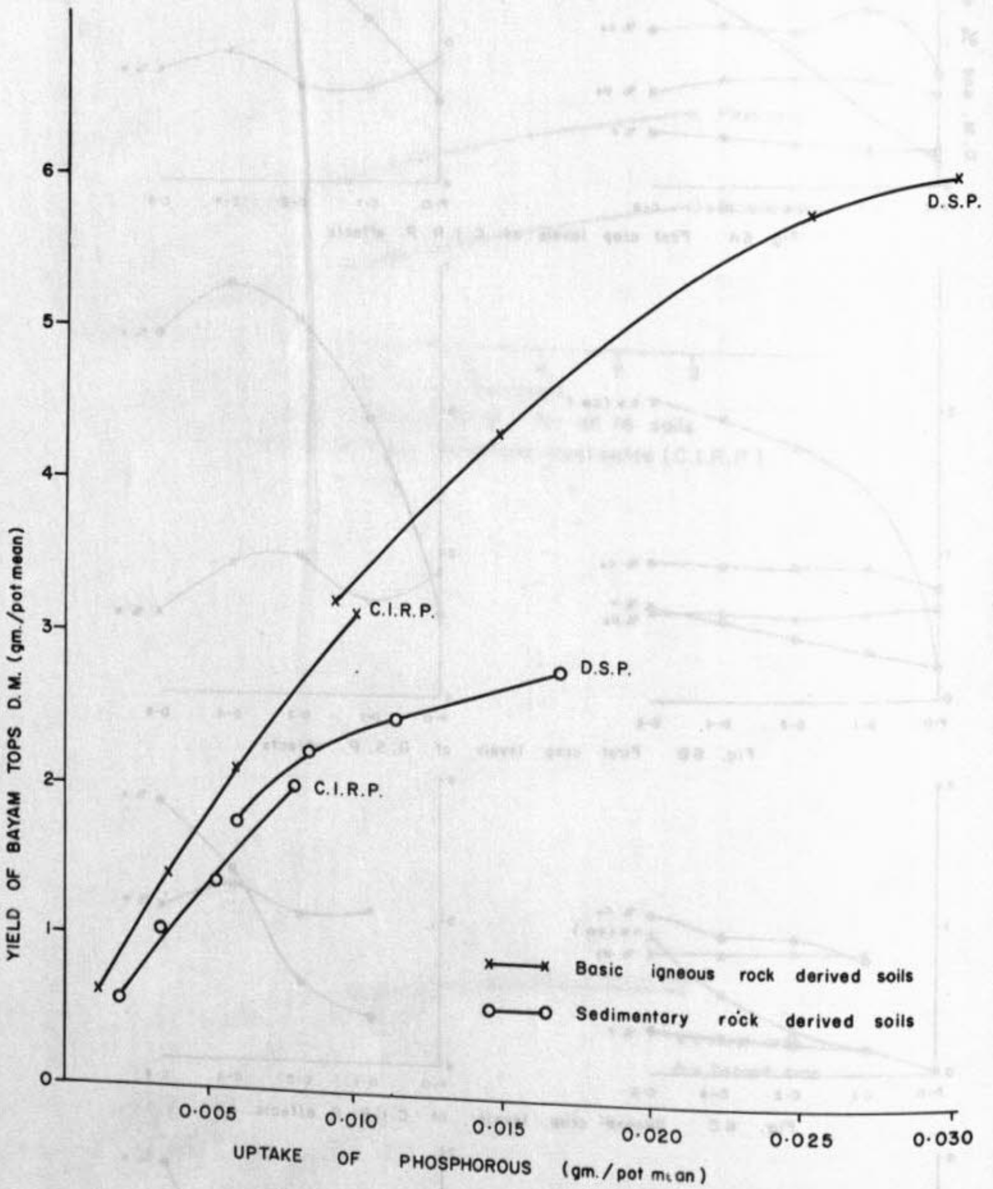


Fig. 7. Total mean yields of Bayam tops (D.M.) for crops against mean of phosphorous from two phosphatic fertilizers (C.I.R.P. and D.S.P.) at four levels of application.

Comparing Basic igneous rock derived soils with Sedimentary rock derived soils.

Table 1/A

Experiment 2. Soil - <u>Tarat</u> A

Treatments (T=Tarat)	First Crop Wt./pot (mean) gm. Fresh tops	First Crop Oven dry basis Dry tops	First Crop Oven dry basis %P	First Crop Oven dry basis P Total	Second Crop Wt./pot (mean) gm. Fresh tops	Second Crop Oven dry basis Dry tops	Second Crop Oven dry basis %P	Second Crop Oven dry basis P Total	Total both crops (recovery) Wt./pot (mean) gm. Fresh tops	Total Oven dry basis Dry tops	Total Oven dry basis P	Total Oven dry basis N	Total Oven dry basis K	Total Oven dry basis Ca	Total Oven dry basis Mg	Soil analysis post cropping Oven dry basis pH (H_2O)	p.p.m. P 'Res'	p.p.m. P 'Av.'	p.p.m. K 'Res.'	p.p.m. Ca 'Res.'	p.p.m. Mg 'Res.'	Total % N
(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	0.333
(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	0.289
(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	0.285
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	0.310
(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 cropping:-

pH (H_2O)	P 'Res'	P 'Av.'	K 'Res.'	Ca 'Res.'	Mg 'Res.'	Total % N
4.6	464	9	3843	776	2129	0.244

C.E.C. m. equ. % (O.D.) : 10.1%
Group III oxides % (O.D.) : 17.9%
P retention (% fixed) : 47.0%

TABLE 1/B

Experiment 5. Soil - Tarat B.

Treatments (Ta = Tarat)	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_2O)	p. p. m.					Total % N
		Dry tops	% P	P Total		Dry tops	% P	P Total		Dry tops	P	N	K	Ca	Mg		P 'Res.'	P 'Av.'	K 'Res.'	Ca 'Res.'	Mg 'Res.'	
(Ta) P-0	0.50	0.09	-	-	0.00	0.00	-	.0000	0.50	0.09	.0000	.000	.000	.000	.000	5.0	747	5	1337	2000	2303	0.337
(Ta) C-1	1.39	0.21	0.19	.0004	4.91	0.70	0.20	.0014	6.30	0.91	.0018	.038	.039	.018	.011	4.8	748	12	1397	1904	1876	0.383
(Ta) C-2	6.15	0.87	0.22	.0019	7.28	0.95	0.25	.0024	13.43	1.82	.0043	.079	.087	.034	.027	4.8	719	12	1364	2157	1942	0.382
(Ta) C-4	12.63	1.58	0.29	.0046	10.93	1.31	0.31	.0041	23.56	2.89	.0087	.129	.171	.056	.039	4.9	811	15	1304	1827	2135	0.374
(Ta) C-8	18.29	2.24	0.31	.0069	11.61	1.34	0.35	.0047	29.90	3.58	.0116	.157	.196	.070	.048	4.9	936	60	1419	2122	2313	0.379
Mean C.I.R.P	9.62	1.23	0.25	.0035	8.68	1.08	0.28	.0032	18.30	2.30	.0066	.101	.123	.045	.031	4.9	804	25	1371	2003	2067	0.380
(Ta) D-1	11.88	1.50	0.24	.0036	7.41	1.03	0.18	.0019	19.29	2.53	.0055	.103	.142	.034	.032	4.7	778	9	1334	1605	1768	0.368
(Ta) D-2	21.95	2.17	0.35	.0076	16.40	1.74	0.33	.0057	38.35	3.91	.0133	.167	.276	.055	.044	4.8	841	8	1412	1845	2097	0.377
(Ta) D-4	39.43	3.28	0.48	.0157	22.46	2.24	0.34	.0076	61.89	5.52	.0233	.253	.459	.088	.063	4.9	845	12	1322	1543	1708	0.372
(Ta) D-8	40.24	3.50	0.49	.0172	25.14	2.31	0.40	.0092	65.38	5.81	.0264	.271	.405	.097	.067	4.9	905	19	1408	1741	1922	0.339
Mean D.S.P	28.38	2.61	0.39	.0110	17.85	1.83	0.31	.0061	46.23	4.44	.0171	.199	.321	.069	.052	4.8	842	12	1369	1684	1874	0.364
Mean total (9)	16.94	1.72	-	.0064	11.79	1.29	-	.0041	28.73	3.00	.0105	.133	.197	.050	.037	4.9	814	17	1366	1860	2007	0.368
Soil analysis pre cropping:-																5.8	723	4	1336	1763	2115	0.358

C.E.C. m. equ. % (O.D.) : 15.2%
Group III oxides % (O.D.) : 35.2%
P retention (% fixed) : 59.0%

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.							Soil analysis post cropping Oven dry basis						
	Fresh tops	Oven dry basis			Fresh tops	Oven dry basis			Fresh tops	Oven dry basis						pH (H_2O)	p. p.m.					Total % N
		Dry tops	% P	P Total		Dry tops	% P	P Total		Dry tops	P	N	K	Ca	Mg		P 'Res.'	P 'Av.'	K 'Res.'	Ca 'Res.'	Mg 'Res.'	
(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

C.E.C. m. equ.% (O.D.) : 22.2%

Group III oxides % (O.D.) : 7.6%

P retention (% fixed) : 75.1%

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						
	Fresh tops	Oven dry basis			Fresh tops	Oven dry basis			Fresh tops	Oven dry basis						pH (H_2O)	p.p.m.					Total %N
		Dry tops	%P	P total		Dry tops	%P	P total		Dry tops	P	N	K	Ca	Mg		P 'Res.'	P 'Av.'	K 'Res.'	Ca 'Res.'	Mg 'Res.'	
(s) P-0	0.23	0.04	0.40	.0002	0.00	0.00	-	-	0.23	0.04	.0002	.002	.002	.000	.000	4.1	130	14	1792	370	1056	0.290
(S) C-1	0.16	0.03	-	-	0.00	0.00	-	-	0.16	0.03	-	.001	-	-	-	4.1	125	26	1716	493	1500	0.291
(S) C-2	0.33	0.05	0.31	.0002	0.00	0.00	-	-	0.33	0.05	.0002	.002	.003	.000	.000	4.1	213	44	1659	505	1464	0.309
(S) C-4	1.28	0.19	0.31	.0006	0.00	0.00	-	-	1.28	0.19	.0006	.009	.011	.002	.001	4.1	229	71	1933	318	1848	0.293
(S) C-8	3.69	0.54	0.32	.0017	0.00	0.00	-	-	3.69	0.54	.0017	.024	.031	.004	.002	4.1	167	86	1840	403	1176	0.283
Mean C.I.R.P.	1.37	0.20	-	.0006	0.00	0.00	-	-	1.37	0.20	.0006	.009	.011	.002	.001	4.1	184	57	1787	430	1497	0.294
(S) D-1	3.04	0.52	0.20	.0010	0.00	0.00	-	-	3.04	0.52	.0010	.019	.021	.003	.001	4.0	131	27	2129	465	1464	0.287
(S) D-2	3.88	0.55	0.35	.0019	0.00	0.00	-	-	3.88	0.55	.0019	.031	.033	.003	.001	4.1	166	41	1605	465	1356	0.289
(S) D-4	4.48	0.62	0.50	.0031	0.00	0.00	-	-	4.48	0.62	.0031	.028	.038	.004	.002	4.0	232	50	1307	510	1560	0.294
(S) D-8	7.35	1.01	0.79	.0080	0.00	0.00	-	-	7.35	1.01	.0080	.048	.067	.005	.002	4.1	182	121	2262	668	1692	0.301
Mean D.S.P.	4.69	0.68	0.46	.0035	0.00	0.00	-	-	4.69	0.68	.0035	.032	.040	.004	.002	4.1	178	60	1826	527	1518	0.293
Mean total (9)	2.72	0.39	-	.0018	0.00	0.00	-	-	2.72	0.39	.0018	.018	.023	.002	.001	4.1	175	53	1805	466	1457	0.293

Soil analysis pre cropping:-	pH (H_2O)	P 'Res.'	P 'Av.'	K 'Res.'	Ca 'Res.'	Mg 'Res.'	Total %N
	4.6	160	7	2616	348	1342	0.249

C.E.C. m. equ.%(O.D.) : 15.8%
Group III oxides % (O.D.) : 9.3%
P retention (% fixed) : 32.6%

Table 1/E

Experiment 4. Soil - <u>Merit</u> (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						
		Oven dry basis				Oven dry basis				Oven dry basis							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	pH (H_2O)	P 'Res.'	P 'Av.'	K 'Res.'	Ca 'Res.'	Mg 'Res.'	Total %N
(Mt) P-O	0.39	0.06	0.13	.0001	0.05	0.00	-	-	0.44	0.06	.0001	.003	.002	.000	.000	4.5	21	8	938	422	1032	0.121
(Mt) C-1	1.63	0.25	0.34	.0009	0.19	0.03	-	-	1.82	0.28	.0009	.014	.012	.003	.002	4.5	44	15	815	483	1008	0.110
(Mt) C-2	3.15	0.39	0.40	.0016	0.60	0.11	0.16	.0002	3.65	0.49	.0018	.025	.026	.004	.002	4.4	61	22	970	525	720	0.123
(Mt) C-4	6.15	0.78	0.44	.0034	3.48	0.50	0.24	.0012	9.63	1.28	.0046	.070	.077	.008	.005	4.4	80	47	918	475	1116	0.122
(Mt) C-8	7.71	0.94	0.44	.0041	5.06	0.71	0.36	.0026	12.77	1.65	.0067	.091	.106	.009	.006	4.4	115	82	818	540	900	0.132
Mean C.I.R.P.	4.66	0.59	0.41	.0025	2.33	0.34	-	.0010	6.97	0.93	.0035	.050	.054	.006	.004	4.4	75	42	880	506	936	0.122
(Mt) D-1	3.15	0.39	0.55	.0021	14.81	1.81	0.32	.0058	17.96	2.20	.0079	.110	.128	.012	.008	4.4	56	21	870	468	936	0.132
(Mt) D-2	2.63	0.30	0.57	.0017	13.49	1.67	0.43	.0072	16.12	1.97	.0089	.123	.109	.008	.009	4.5	44	23	670	438	732	0.129
(Mt) D-4	2.13	0.29	0.79	.0023	25.44	2.44	0.42	.0102	27.57	2.73	.0125	.138	.211	.013	.010	4.5	170	37	723	538	780	0.117
(Mt) D-8	3.15	0.38	1.00	.0038	29.19	2.62	0.60	.0157	32.34	3.00	.0195	.166	.221	.017	.014	4.6	149	95	718	518	852	0.123
Mean D.S.P.	2.77	0.34	0.73	.0025	20.73	2.14	0.44	.0097	23.50	2.48	.0122	.134	.167	.013	.010	4.5	105	44	745	491	825	0.125
Total mean (9)	3.34	0.42	0.52	.0022	10.26	1.10	-	.0048	13.59	1.52	.0070	.082	.099	.008	.006	4.5	82	39	827	490	897	0.123
Soil analysis pre cropping:-																5.1	83	7	881	411	677	0.115

C.E.C. m. equ.% : 6.0%

Group III oxides % (O.D.) : 14.4%

Pretention % (fixed) : 30.1%

TABLE 1/F

Experiment 5. Soil - Merit (2)

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						
	Fresh tops	Oven dry basis			Fresh tops	Oven dry basis			Fresh tops	Oven dry basis						pH (H_2O)	p. p. m.					Total % N
		Dry tops	% P	P Total		Dry tops	% P	P Total		Dry tops	P	N	K	Ca	Mg		P 'Res.'	P 'Av.'	K 'Res.'	Ca 'Res.'	Mg 'Res.'	
(Mt) P-O	0.00	0.00	-	-	0.00	0.00	-	.0000	0.00	0.00	.0000	.000	.000	.000	.000	4.3	70	8	906	334	678	0.110
(Mt) C-1	0.66	0.11	0.14	.0002	0.22	0.06	0.15	.0001	0.88	0.17	.0003	.008	.006	.003	.001	4.2	81	15	1010	209	753	0.111
(Mt) C-2	5.53	0.80	0.21	.0017	0.67	0.10	0.15	.0002	6.20	0.90	.0019	.044	.038	.006	.004	4.2	109	33	1028	340	689	0.113
(Mt) C-4	7.54	0.97	0.38	.0037	3.76	0.53	0.21	.0011	11.30	1.50	.0048	.072	.077	.010	.009	4.2	112	27	1110	334	826	0.111
(Mt) C-8	16.96	1.76	0.37	.0065	9.67	1.30	0.22	.0029	26.63	3.06	.0094	.142	.193	.023	.011	4.2	134	44	952	416	786	0.110
Mean C.I.R.P	7.67	0.91	0.28	.0030	3.58	0.50	0.18	.0011	11.25	1.41	.0041	.067	.079	.011	.006	4.2	109	30	1025	325	764	0.111
(Mt) D-1	4.80	0.60	0.36	.0022	4.46	0.66	0.17	.0011	9.26	1.26	.0033	.062	.068	.008	.004	4.2	82	12	1074	339	801	0.108
(Mt) D-2	21.00	2.17	0.37	.0080	13.62	1.62	0.27	.0044	34.62	3.79	.0124	.172	.235	.031	.008	4.2	111	38	1005	417	625	0.113
(Mt) D-4	16.85	1.74	0.50	.0087	25.22	2.44	0.36	.0088	42.07	4.18	.0175	.211	.292	.031	.020	4.2	116	42	900	353	636	0.110
(Mt) D-8	12.60	1.66	0.54	.0090	29.77	2.62	0.44	.0115	42.37	4.28	.0205	.139	.297	.045	.018	4.4	212	107	956	438	614	0.103
Mean D.S.P	13.81	1.54	0.44	.0070	18.27	1.59	0.31	.0065	32.08	3.38	.0134	.146	.223	.029	.013	4.3	130	50	984	387	669	0.110
Mean total (9)	9.55	1.09	-	.0044	9.71	1.04	-	.0033	19.26	2.13	.0078	.094	.134	.017	.008	4.2	114	36	993	353	712	0.109
Soil analysis pre cropping:-																5.0	72	4	1032	156	685	0.107

C.E.C. m. equ. % (O.D.) : 5.7%
Group III oxides % (O.D.) : 4.3%
P retention (% fixed) : 60.5%

TABLE 1/G

Experiment 1. Soil - Nyalau A

Treatments	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						
(N = Nyalau)	Fresh tops	Oven dry basis			Fresh tops	Oven dry basis			Fresh tops	Oven dry basis						pH (H_2O)	p. p. m.					Total % N
		Dry tops	% P	P Total		Dry tops	% P	P Total		Dry tops	P	N	K	Ca	Mg		P 'Res.'	P 'Av.'	K '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	.006	.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	.012	.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

C.E.C. m. equ. % (O.D.) : 10.4%
Group III oxides % (O.D.) : 18.8%
P retention (% fixed) : 33.5%

TABLE 1/H

Experiment 5. Soil - <u>Nyalau</u> B

Treatments (N = Nyalau)	First Crop Wt./pot (mean) gm. Fresh tops	First Crop Oven dry basis: Dry tops	First Crop Oven dry basis: % P	First Crop Oven dry basis: P Total	Second Crop Wt./pot (mean) gm. Fresh tops	Second Crop Oven dry basis: Dry tops	Second Crop Oven dry basis: % P	Second Crop Oven dry basis: P Total	Total both crops (recovery) Wt./pot (mean) gm. Fresh tops	Total both crops Oven dry basis: Dry tops	Total both crops Oven dry basis: P	Total both crops Oven dry basis: N	Total both crops Oven dry basis: K	Total both crops Oven dry basis: Ca	Total both crops Oven dry basis: Mg	Soil analysis post cropping Oven dry basis: pH (H_2O)	p. p. m. P 'Res.'	p. p. m. P 'Av.'	p. p. m. K 'Res.'	p. p. m. Ca 'Res.'	p. p. m. Mg 'Res.'	Total % N
(N) P-0	0.15	0.04	-	-	0.00	0.00	-	.0000	0.15	0.04	.0000	.000	.000	.000	.000	4.4	44	7	355	513	197	0.089
(N) C-1	5.43	0.76	0.39	.0030	4.25	0.63	0.19	.0012	9.68	1.39	.0042	.073	.066	.016	.010	4.5	69	20	355	245	343	0.089
(N) C-2	17.18	1.94	0.36	.0070	7.90	1.09	0.25	.0027	25.08	3.03	.0097	.118	.180	.025	.016	4.4	74	27	507	511	61	0.086
(N) C-4	21.59	2.11	0.47	.0099	10.73	1.30	0.35	.0046	32.32	3.41	.0145	.172	.244	.021	.015	4.4	121	56	304	532	86	0.089
(N) C-8	23.10	2.15	0.57	.0123	16.55	1.73	0.41	.0071	39.65	3.88	.0194	.195	.291	.023	.020	4.4	222	112	408	864	222	0.102
Mean C.I.R.P	16.83	1.74	0.45	.0081	9.86	1.19	0.30	.0039	26.69	2.93	.0120	.140	.195	.021	.015	4.4	122	54	394	538	178	0.092
(N) D-1	18.38	1.89	0.42	.0079	14.41	1.77	0.25	.0044	32.79	3.66	.0123	.163	.242	.020	.016	4.6	69	17	407	411	185	0.099
(N) D-2	23.11	2.21	0.53	.0117	17.50	1.79	0.39	.0070	40.61	4.00	.0187	.202	.314	.021	.017	4.4	74	38	356	411	197	0.102
(N) D-4	19.73	1.89	0.65	.0123	8.90	1.00	0.61	.0061	28.63	2.89	.0184	.152	.250	.016	.012	4.5	127	71	407	349	246	0.093
(N) D-8	18.73	1.85	0.71	.0131	13.62	1.42	0.71	.0101	32.35	3.27	.0232	.171	.259	.017	.011	4.4	222	137	356	411	123	0.101
Mean D.S.P	19.99	1.96	0.58	.0113	13.61	1.50	0.49	.0069	33.60	3.46	.0182	.172	.264	.019	.014	4.5	123	66	382	396	188	0.099
Mean total (9)	16.38	1.65	-	.0086	10.43	1.19	-	.0048	26.81	2.84	.0134	.138	.205	.018	.013	4.4	114	54	384	472	184	0.094
Soil analysis pre cropping:-																4.6	66	5	510	391	136	0.103

C.E.C. m. equ. % (O.D.) : 5.4%
Group III oxides % (O.D.) : 1.3%
P retention (% fixed) : 12.3%

TABLE 1/I

Experiment 1. Soil - <u>Malang</u> 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						
	Fresh tops	Oven dry basis			Fresh tops	Oven dry basis			Fresh tops	Oven dry basis						pH (H_2O)	p. p. m.					Total % N
		Dry tops	% P	P Total		Dry tops	% P	P Total		Dry tops	P	N	K	Ca	Mg		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
Soil analysis pre cropping:-																4.7	216	4	3435	194	1432	0.180

C.E.C. m. equ. % (O.D.) : 11.2%
Group III oxides % (O.D.) : 5.6%
P retention (% fixed) : 49.1%

TABLE 1/J   Experiment 3. Soil - <u>Malang</u> B

Treatments (M = Malang)	First Crop Wt./pot (mean) gm. Fresh tops	Oven dry basis Dry tops	% P	P Total	Second Crop Wt./pot (mean) gm. Fresh tops	Oven dry basis Dry tops	% P	P Total	Total both crops (recovery) Wt./pot (mean) gm. Fresh tops	Oven dry basis Dry tops	P	N	K	Ca	Mg	Soil analysis post cropping Oven dry basis pH (H_2O)	p. p. m. P 'Res.'	P 'Av.'	K 'Res.'	Ca 'Res.'	Mg 'Res.'	Total % N
(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	0.22	.0005	0.58	0.06	-	-	2.28	0.30	.0005	.014	.011	.003	.002	4.0	533	70	1702	1182	1289	0.410
(M) C-2	4.71	0.68	0.21	.0014	0.80	0.09	0.23	.0002	5.51	0.77	.0016	.043	.039	.010	.005	3.9	572	44	1647	1109	1996	0.401
(M) C-4	10.59	1.46	0.29	.0042	1.38	0.20	0.25	.0005	11.97	1.66	.0047	.101	.088	.022	.010	4.0	648	86	1701	1503	1933	0.384
(M) C-8	18.94	2.04	0.32	.0065	5.09	0.77	0.27	.0021	24.03	2.81	.0086	.153	.184	.037	.016	3.9	702	114	1648	1396	1868	0.384
Mean C.I.R.P	8.98	1.10	0.26	.0031	1.96	0.28	-	.0007	10.95	1.38	.0038	.078	.080	.018	.008	3.9	614	78	1674	1297	1771	0.395
(M) D-1	35.03	3.03	0.34	.0103	2.65	0.38	0.23	.0009	37.68	3.41	.0112	.180	.198	.043	.019	4.0	515	11	1884	1384	1592	0.382
(M) D-2	47.55	3.75	0.39	.0146	9.16	1.32	0.27	.0036	56.71	5.07	.0182	.265	.325	.074	.030	3.9	572	26	1485	923	1384	0.412
(M) D-4	47.74	3.77	0.54	.0204	24.76	2.39	0.44	.0105	72.50	6.16	.0309	.340	.377	.084	.034	4.0	575	38	1384	1230	2080	0.365
(M) D-8	49.50	3.88	0.58	.0225	33.14	2.93	0.46	.0135	82.64	6.81	.0360	.348	.424	.094	.038	4.0	647	55	1522	1097	2108	0.375
Mean D.S.P	44.95	3.61	0.46	.0169	17.43	1.75	0.35	.0071	62.38	5.36	.0241	.283	.331	.074	.030	4.0	577	32	1569	1158	1791	0.383
Mean total (9)	23.99	2.10	-	.0089	8.70	0.91	-	.0035	32.69	3.01	.0124	.161	.183	.041	.017	4.0	587	53	1611	1258	1804	0.391
Soil analysis pre cropping:-																4.5	451	7	1266	778	2069	0.297

C.E.C. m. equ. % (O.D.) : 11.7%
Group III oxides % (O.D.) : 15.0%
P retention (% fixed) : 48.1%

TABLE 1/K

Experiment 4. Soil - Serin

Treatments (Sn = Serin)	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_2O)	p. p. m.					Total % N
		Dry tops	% P	P Total		Dry tops	% P	P Total		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	.0000	0.00	0.00	-	-	0.26	0.04	.0000	.002	.001	.000	.000	4.4	127	6	1800	385	1140	0.226
(Sn) C-1	1.60	0.26	0.17	.0004	0.18	0.03	-	-	1.78	0.29	.0004	.012	.013	.002	.001	4.6	58	14	1562	353	684	0.240
(Sn) C-2	6.64	0.99	0.31	.0031	0.38	0.06	0.13	.0001	7.02	1.05	.0032	.048	.054	.004	.006	4.6	172	23	1581	405	720	0.234
(Sn) C-4	7.18	1.00	0.43	.0043	1.54	0.25	0.18	.0005	8.72	1.25	.0048	.066	.071	.008	.004	4.5	106	30	1702	355	816	0.214
(Sn) C-8	7.61	1.04	0.48	.0050	5.64	0.80	0.26	.0021	13.25	1.84	.0071	.091	.110	.011	.008	4.6	220	73	1690	383	852	0.215
Mean C.I.R.P	5.76	0.82	0.35	.0032	1.94	0.29	-	.0007	7.69	1.11	.0039	.054	.062	.006	.005	4.6	139	35	1634	374	768	0.226
(Sn) D-1	3.29	0.48	0.40	.0019	8.32	1.12	0.31	.0035	11.61	1.60	.0054	.094	.070	.009	.007	4.3	142	10	1569	243	816	0.223
(Sn) D-2	4.66	0.65	0.50	.0033	12.74	1.61	0.25	.0040	17.40	2.26	.0073	.115	.113	.010	.009	4.6	142	13	1518	360	984	0.234
(Sn) D-4	3.89	0.51	0.78	.0040	24.43	2.40	0.34	.0082	28.32	2.91	.0122	.147	.165	.016	.010	4.6	104	18	1455	405	792	0.233
(Sn) D-8	5.80	0.75	0.81	.0061	30.53	2.81	0.54	.0152	36.33	3.56	.0213	.181	.273	.024	.014	4.7	188	65	1496	460	924	0.210
Mean D.S.P	4.41	0.60	0.62	.0038	19.01	1.99	0.36	.0077	23.42	2.58	.0116	.134	.155	.015	.010	4.6	144	27	1510	367	879	0.225
Mean total (9)	4.55	0.64	0.44	.0031	9.31	1.01	-	.0037	13.85	1.64	.0069	.084	.097	.009	.007	4.5	140	28	1597	372	859	0.225
Soil analysis pre cropping:-																5.3	152	3	1517	111	935	0.207

C.E.C. m. equ. % (O.D.) : 7.3%

Group III oxides % (O.D.) : 21.6%

P retention (% fixed) : 45.0%

Table 1/L

Experiment 3. Soil - Embang

Treatments (E=Embang)	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_2O)	p.p.m.					Total %N
		Dry tops	%P	P Total		Dry tops	%P	P Total		Dry tops	P	N	K	Ca	Mg		P 'Res.'	P 'Av.'	K 'Res'	Ca 'Res.'	Mg 'Res.'	
(E) P-0	0.00	0.00	-	-	0.00	0.00	-	-	0.00	0.00	-	-	-	-	-	4.3	155	8	406	301	301	0.171
(E) C-1	0.28	0.04	-	-	0.00	0.00	-	-	0.28	0.04	-	-	-	-	-	4.3	428	41	508	513	493	0.177
(E) C-2	0.05	0.00	-	-	0.00	0.00	-	-	0.05	0.00	-	-	-	-	-	4.3	137	71	509	616	185	0.232
(E) C-4	0.04	0.00	-	-	0.00	0.00	-	-	0.04	0.00	-	-	-	-	-	4.2	178	60	560	515	432	0.174
(E) C-8	0.26	0.04	-	-	0.00	0.00	-	-	0.26	0.04	-	-	-	-	-	4.2	174	172	457	308	246	0.171
Mean C.I.R.P.	0.16	0.02	-	-	0.00	0.00	-	-	0.18	0.02	-	-	-	-	-	4.2	229	86	508	488	339	0.188
(E) D-1	0.09	0.02	-	-	0.00	0.00	-	-	0.09	0.02	-	-	-	-	-	4.2	155	57	457	301	242	0.183
(E) D-2	0.08	0.02	-	-	0.00	0.00	-	-	0.08	0.02	-	-	-	-	-	4.3	239	71	560	720	371	0.164
(E) D-4	0.00	0.00	-	-	0.00	0.00	-	-	0.00	0.00	-	-	-	-	-	4.4	454	141	706	619	2166	0.132
(E) D-8	0.11	0.03	-	-	0.00	0.00	-	-	0.11	0.03	-	-	-	-	-	4.2	164	252	407	411	432	0.174
Mean D.S.P	0.07	0.02	-	-	0.00	0.00	-	-	0.07	0.02	-	-	-	-	-	4.3	253	130	533	513	803	0.163
Mean total (9)	0.10	0.02	-	-	0.00	0.00	-	-	0.10	0.02	-	-	-	-	-	4.3	232	97	508	478	541	0.175
Soil analysis pre cropping:-																4.0	66	11	'Trace'	409	368	0.125

C.E.C. m. equ. % (O D.) : 4.9%
Group III oxides%(O.D.) : 0.6%
P retention (% fixed) : 10.7%

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_2O)	p.p.m.					Total %N
		Dry tops	%P	P total		Dry tops	%P	P total		Dry tops	P	N	K	Ca	Mg		P 'Res'	P 'Av.'	K 'Res'	Ca 'Res'	Mg 'Res'	
(Te) P-0	0.08	0.01	-	-	0.00	0.00	-	-	0.08	0.01	-	.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	-	.001	-	-	-	4.0	1218	14	1949	536	3217	0.636
(Te) C-2	0.70	0.08	0.23	.0002	0.45	0.05	0.21	.0001	1.15	0.13	.0003	.007	.008	.002	.002	4.3	1101	22	2174	1183	2712	0.288
(Te) C-4	1.39	0.20	0.18	.0004	3.56	0.51	0.23	.0012	4.95	0.71	.0016	.040	.037	.009	.008	4.0	1117	24	1930	983	3604	0.310
(Te) C-8	4.24	0.62	0.23	.0014	7.65	1.09	0.34	.0037	11.89	1.71	.0051	.097	.094	.026	.019	4.0	1280	65	1994	960	3330	0.307
Mean C.I.R.P.	1.37	0.23	-	.005	2.94	0.42	-	.0013	4.56	0.65	.0018	.036	.035	.009	.007	4.1	1179	31	2012	913	3217	0.385
(Te) D-1	11.61	1.53	0.30	.0046	4.74	0.69	0.29	.0020	16.35	2.22	.0066	.122	.111	.028	.021	4.0	813	9	1811	738	3304	0.638
(Te) D-2	20.30	2.14	0.40	.0086	9.41	1.35	0.22	.0030	29.71	3.49	.0116	.191	.173	.043	.035	3.9	730	12	1894	964	2036	0.308
(Te) D-4	25.56	2.44	0.41	.0100	20.57	2.14	0.34	.0073	46.13	4.58	.0173	.145	.242	.060	.050	4.1	1084	16	1714	742	3856	0.205
(Te) D-8	25.80	2.45	0.56	.0137	24.79	2.37	0.54	.0128	50.59	4.82	.0265	.284	.239	.068	.051	4.2	1163	20	1948	1178	3277	0.294
Mean D.S.P.	20.82	2.14	0.42	.0092	14.88	1.64	0.35	.0063	35.70	3.78	.0130	.186	.191	.041	.039	4.1	948	14	1842	906	3186	0.361
Mean total (9)	9.98	1.05	-	.0043	7.92	0.91	-	.0034	17.90	1.97	.0076	.099	.100	.026	.021	4.0	1067	21	1948	893	3030	0.369
Soil analysis pre cropping:-																4.8	992	1	1265	1124	2146	0.338

C.E.C. m. equ.% (O.D.) : 17.3%

Group III oxides % (O.D.) : 26.7%

Pretention (% fixed) : 71.3%

TABLE 1/N   Experiment 5. Soil - <u>Terbat</u> (2)

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_2O)	p. p. m.					Total % N
		Dry tops	% P	P Total		Dry tops	% P	P Total		Dry tops	P	N	K	Ca	Mg		P 'Res.'	P 'Av.'	K 'Res.'	Ca 'Res.'	Mg 'Res.'	
(Te) P-0	0.15	0.03	-	-	0.00	0.00	-	.0000	0.15	0.03	.0000	.000	.000	.000	.000	4.5	879	7	2155	1789	5010	0.304
(Te) C-1	2.31	0.33	0.19	.0006	0.51	0.08	0.19	.0002	2.82	0.41	.0008	.018	.018	.006	.005	4.4	900	9	2351	2111	6192	0.329
(Te) C-2	6.86	0.95	0.25	.0024	2.53	0.36	0.20	.0007	9.39	1.31	.0031	.060	.061	.022	.016	4.4	965	13	2262	1699	4450	0.320
(Te) C-4	7.28	0.96	0.29	.0028	4.53	0.66	0.25	.0017	11.81	1.62	.0045	.078	.078	.030	.022	4.4	1049	27	2313	2030	5453	0.308
(Te) C-8	13.79	1.61	0.28	.0045	8.28	1.05	0.30	.0032	22.07	2.66	.0077	.129	.156	.042	.033	4.5	929	33	2126	2245	4357	0.316
Mean C.I.R.P	7.56	0.96	0.25	.0026	3.96	0.54	0.24	.0015	11.52	1.50	.0040	.071	.078	.025	.019	4.4	961	21	2263	2021	5113	0.318
(Te) D-1	14.71	1.74	0.28	.0049	6.88	0.95	0.15	.0014	21.59	2.69	.0063	.128	.134	.042	.032	4.5	967	7	2158	1653	4375	0.316
(Te) D-2	19.46	2.07	0.33	.0068	12.95	1.58	0.20	.0032	32.41	3.65	.0100	.175	.216	.051	.041	4.5	906	7	2295	1787	4893	0.306
(Te) D-4	30.11	2.87	0.44	.0126	28.93	2.73	0.30	.0082	59.04	5.60	.0208	.270	.319	.090	.072	4.6	1016	8	2129	1943	5590	0.302
(Te) D-8	33.44	3.12	0.47	.0147	30.36	2.76	0.34	.0094	63.80	5.88	.0241	.286	.354	.103	.083	4.6	1031	24	1965	1453	3381	0.299
Mean D.S.P	24.43	2.45	0.38	.0098	19.78	2.01	0.25	.0056	44.21	4.46	.0153	.215	.256	.072	.057	4.6	980	12	2137	1709	4560	0.306
Mean total (9)	14.23	1.52	-	.0055	10.55	1.13	-	.0031	24.78	2.65	.0086	.127	.148	.043	.034	4.5	960	15	2195	1857	4856	0.311
Soil analysis pre cropping:-																5.0	801	4	1901	1536	4409	0.278

C.E.C. m. equ. % (O.D.) : 17.8%
Group III oxides % (O.D.) : 26.8%
P retention (% fixed) : 69.4%

TABLE 1/C Experiment 2. Soil - <u>Ramun</u>

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_2O)	p. p. m.					Total % N
		Dry tops	% P	P Total		Dry tops	% P	P Total		Dry tops	P	N	K	Ca	Mg		P 'Res.'	P 'Av.'	K 'Res.'	Ca 'Res.'	Mg 'Res.'	
(R) P-0	0.76	0.08	0.12	.0001	0.00	0.00	-	-	0.76	0.08	.0001	.005	.002	.001	.001	3.9	670	11	2894	314	1592	0.346
(R) C-1	4.22	0.62	0.27	.0017	1.89	0.28	0.17	.0005	6.11	0.90	.0022	.046	.050	.008	.007	4.0	591	26	2730	624	1122	0.322
(R) C-2	17.08	1.92	0.36	.0069	4.65	0.68	0.24	.0016	21.73	2.60	.0085	.130	.160	.020	.019	3.6	669	23	2892	848	764	0.331
(R) C-4	15.06	1.80	0.33	.0059	6.95	1.00	0.23	.0023	22.01	2.80	.0082	.152	.173	.022	.016	4.0	718	40	2660	737	1264	0.335
(R) C-8	25.67	2.44	0.41	.0100	11.50	1.55	0.32	.0050	37.17	3.99	.0150	.152	.284	.031	.023	4.1	958	82	2926	843	1453	0.324
Mean C.I.R.P	15.51	1.70	0.34	.0061	6.25	0.88	0.24	.0024	21.76	2.57	.0085	.120	.167	.020	.016	3.9	734	43	2802	763	1151	0.328
(R) D-1	16.86	1.90	0.39	.0074	11.00	1.50	0.26	.0039	27.86	3.40	.0113	.163	.216	.023	.019	4.2	590	18	2727	935	1994	0.322
(R) D-2	17.45	1.96	0.47	.0092	17.51	1.96	0.31	.0061	34.96	3.92	.0153	.197	.288	.036	.020	4.0	656	18	2937	307	1496	0.308
(R) D-4	22.50	2.26	0.55	.0124	33.05	2.93	0.41	.0120	55.55	5.19	.0244	.266	.378	.042	.029	3.9	660	20	2693	418	1882	0.160
(R) D-8	24.58	2.37	0.67	.0159	29.48	2.70	0.50	.0135	54.06	5.07	.0294	.250	.375	.044	.032	4.2	901	107	2597	944	1448	0.339
Mean D.S.P.	20.35	2.12	0.52	.0112	22.76	2.27	0.37	.0089	43.11	4.40	.0201	.219	.314	.036	.025	4.1	702	41	2739	651	1705	0.282
Mean total (9)	16.02	1.71	0.40	.0077	12.89	1.40	-	.0050	28.91	3.11	.0127	.151	.214	.025	.018	4.0	713	38	2784	663	1446	0.310
Soil analysis pre cropping:-																4.0	226	13	2729	788	1661	0.427

C.E.C. m. equ. % (O.D.) : 14.6%

Group III oxides % (O.D.) : 15.7%

P retention (% fixed) : 64.7%

TABLE 2A

Yield of Fresh Bayam Tops (gm./pot mean)

Levels of fertilizer 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														
P-0	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
C-1	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
C-2	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
C-4	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
C-8	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
D-1	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
D-2	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
D-4	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
D-8	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•
Mean	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														
P-0	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
C-1	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
C-2	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
C-4	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
C-8	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
D-1	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
D-2	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
D-4	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
D-8	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•
Mean	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														
P-0	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
C-1	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
C-2	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
C-4	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
C-8	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
D-1	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
D-2	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
D-4	104.68	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
D-8	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•
Mean	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.

Fertilizer 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														
Mean CIRP	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
Mean D.S.P	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
Mean Total	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
Ratio D.S.P / CIRP	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														
Mean CIRP	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
Mean D.S.P	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
Mean Total	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
Ratio D.S.P / CIRP	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														
Mean CIRP	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
Mean D.S.P	86.56	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
Mean Total	54.51	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
Ratio D.S.P / CIRP	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															
Ratio	D-8 / C-8	D-8 / C-8	D-4 / 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	
=	2.7	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)

Levels of fertilizer 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								
P-0	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
C-1	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
C-2	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
C-4	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
C-8	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
D-1	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
D-2	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
D-4	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
D-8	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•
Mean	2.62	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								
P-0	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
C-1	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
C-2	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
C-4	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
C-8	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
D-1	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
D-2	2.29	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
D-4	3.59•	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
D-8	3.46	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•
Mean	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								
P-0	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
C-1	1.15	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
C-2	1.85	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
C-4	3.20	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
C-8	4.19	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
D-1	5.20	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
D-2	6.24	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
D-4	7.91	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
D-8	8.01•	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•
Mean	4.20	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.

Fertiliser 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														
Mean CIRP	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
Mean D.S.P	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
Mean Total	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
Ratio D.S.P/CIRP	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														
Mean CIRP	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
Mean D.S.P	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
Mean Total	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
Ratio D.S.P/CIRP	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														
Mean CIRP	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
Mean D.S.P	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
Mean Total	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
Ratio D.S.P/CIRP	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														
Ratio	D-8/C-8	D-8/C-8	D-4/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	
=	1.9	1.6	2.0	1.9	1.8	1.4	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)

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														
C - 1	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
C - 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
C - 4	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
C - 8	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
D - 1	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
D - 2	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
D - 4	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
D - 8	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														
C - 1	2.1	3.6	0.0	0.0	-	0.3	0.3	3.1	0.0	0.3	-	-	0.5	1.3	0.8
C - 2	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
C - 4	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
C - 8	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
D - 1	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
D - 2	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
D - 4	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
D - 8	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														
C - 1	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
C - 2	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
C - 4	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
C - 8	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
D - 1	31.4	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
D - 2	20.9	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
D - 4	17.0	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
D - 8	10.2	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.

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														
Mean 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
Mean 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
Mean Total	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
Ratio $\frac{D.S.P.}{C.I.R.P}$	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														
Mean 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
Mean 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
Mean Total	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
Ratio $\frac{D.S.P.}{C.I.R.P}$	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														
Mean 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
Mean 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
Mean Total	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
Ratio $\frac{D.S.P.}{C.I.R.P}$	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
(N.B. IN ALL ABOVE MEANS UNAVAILABLE DATA IS INCLUDED AS BEING NEGLIGIBLE)															
Ratio $\frac{D-1}{C-1}$	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
Ratio $\frac{D-2}{C-2}$	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
Ratio $\frac{D-4}{C-4}$	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
Ratio $\frac{D-8}{C-8}$	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. Means of above ratios are of determinations available only.

TABLE 5.

Phosphorus concentration in Bayam tops (% in D.M.)

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														
P - 0	.14	-	.31	.40	.13	-	.35	-	.09	.31	-	-	-	.12	.23
C - 1	.18	.19	.28	-	.34	.14	.39	.39	.17	.34	.22	-	.19	.27	.26
C - 2	.17	.22	.33	.31	.40	.21	.39	.36	.31	.30	.21	.23	.25	.36	.29
C - 4	.24	.29	.29	.31	.44	.38	.36	.47	.43	.34	.29	.18	.29	.33	.33
C - 8	.30	.31	.30	.32	.44	.37	.43	.57	.48	.38	.32	.23	.28	.41	.37
D - 1	.28	.24	.26	.20	.55	.36	.44	.42	.40	.45	.34	.30	.28	.39	.35
D - 2	.31	.35	.34	.35	.57	.37	.60	.53	.50	.43	.39	.40	.33	.47	.42
D - 4	.46	.48	.37	.50	.79	.50	.67	.65	.78	.50	.54	.41	.44	.55	.55
D - 8	.43	.49	.48	.79	1.00	.54	.76	.71	.81	.63	.58	.56	.47	.67	.64
Total mean	.28	.32	.33	.40	.52	.36	.49	.50	.50	.41	.36	.33	.32	.40	.39
	SECOND CROP														
P - 0	-	-	-	-	-	-	-	-	-	.18	-	-	-	-	-
C - 1	.21	.20	..	-	-	.15	.15	.19	-	.17	-	-	.19	.17	.18
C - 2	.24	.25	-	-	.16	.15	-	.25	.13	.15	.23	.21	.20	.24	.20
C - 4	.26	.31	-	-	.24	.21	.19	.35	.18	.14	.25	.23	.25	.23	.24
C - 8	.22	.35	-	-	.36	.22	.30	.41	.26	.22	.27	.34	.30	.32	.30
D - 1	.22	.18	-	-	.32	.17	.17	.25	.31	.19	.23	.29	.15	.26	.23
D - 2	.26	.33	-	-	.43	.27	.23	.39	.25	.16	.27	.22	.20	.31	.28
D - 4	.27	.34	.16	-	.42	.36	.41	.61	.34	.23	.44	.34	.30	.41	.36
D - 8	.46	.40	.36	-	.60	.44	.65	.71	.54	.49	.46	.54	.34	.50	.50
Total mean	.27	.30	-	-	.36	.25	.30	..40	.29	.21	.31	.31	.24	.31	.30
	FIRST CROP														
Mean CIRP	.22	.25	.30	.31	.41	.28	.39	.45	.35	.34	.26	.21	.25	.34	.31
Mean DSP	.37	.39	.36	.46	.73	.44	.62	.58	.62	.50	.46	.42	.38	.52	.49
	SECOND CROP														
Mean CIRP	.23	.28	-	-	.25	.18	.21	.30	.19	.17	.25	.26	.24	.24	.23
Mean DSP	.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.)

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								
P - 0	4.61	-	3.54	4.32	4.64	-	4.39	-	5.06	4.46	6.45	5.42	-	5.84	4.87
C - 1	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
C - 2	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
C - 4	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
C - 8	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
D - 1	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
D - 2	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
D - 4	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
D - 8	2.62	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
Total mean	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								
P - 0	-	-	-	-	-	-	-	-	-	5.52	-	-	-	-	-
C - 1	4.94	4.1[illegible]	-	-	5.54	4.99	5.57	5.19	5.43	5.16	-	-	4.46	5.19	5.06
C - 2	4.90	4.26	-	-	4.90	4.60	-	4.90	5.64	4.80	5.95	5.54	4.29	5.51	5.03
C - 4	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
C - 8	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
D - 1	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
D - 2	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
D - 4	2.94	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
D - 8	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
Total mean	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								
Mean CIRP	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
Mean DSP	3.31	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								
Mean CIRP	5.03	4.50	-	-	5.47	4.76	5.29	5.12	5.41	5.00	6.00	5.61	4.61	4.87	5.14
Mean DSP	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.)

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								
P - 0	4.41	-	5.59	4.17	3.41	-	7.05	-	2.76	6.85	-	-	-	2.50	4.59
C - 1	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
C - 2	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
C - 4	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
C - 8	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
D - 1	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
D - 2	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
D - 4	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
D - 8	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
Total mean	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								
P - 0	-	-	-	-	-	-	-	-	-	3.61	-	-	-	-	-
C - 1	5.74	4.27	-	-	-	3.25	4.08	4.56	-	3.27	-	-	4.64	4.76	4.32
C - 2	3.20	4.80	-	-	3.31	4.03	-	5.18	3.10	3.39	6.10	5.92	4.65	6.64	4.57
C - 4	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
C - 8	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
D - 1	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
D - 2	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
D - 4	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
D - 8	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
Total mean	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								
Mean CIRP	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
Mean DSP	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								
Mean CIRP	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
Mean DSP	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.)

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														
P - 0	1.46	-	1.22	0.28	0.55	-	0.85	-	0.33	0.82	-	-	-	0.84	0.79
C - 1	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
C - 2	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
C - 4	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
C - 8	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
D - 1	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
D - 2	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
D - 4	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
D - 8	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
Total mean	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														
P - 0	-	-	-	-	-	-	-	-	-	0.24	-	-	-	-	-
C - 1	1.48	2.02	-	-	-	0.38	0.06	0.77	-	0.25	-	-	0.91	0.44	0.79
C - 2	1.20	2.02	-	-	0.52	0.22	-	0.87	0.18	0.91	1.22	1.32	1.36	0.46	0.93
C - 4	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
C - 8	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
D - 1	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
D - 2	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
D - 4	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
D - 8	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
Total mean	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														
Mean CIRP	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
Mean DSP	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														
Mean CIRP	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
Mean DSP	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.)

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								
P - O	0.98	-	1.32	0.57	0.31	-	0.39	-	0.30	0.49	-	-	-	0.80	0.64
C - 1	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
C - 2	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
C - 4	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
C - 8	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
D - 1	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
D - 2	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
D - 4	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
D - 8	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
Total mean	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								
P - O	-	-	-	-	-	-	-	-	-	0.67	-	-	-	-	
C - 1	0.97	1.23	-	-	-	0.51	0.49	0.61	-	0.74	-	-	1.20	0.85	0.83
C - 2	0.90	1.53	-	-	0.41	0.49	-	0.55	0.56	0.77	0.73	1.27	1.02	0.89	0.83
C - 4	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
C - 8	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
D - 1	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
D - 2	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
D - 4	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
D - 8	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
Total mean	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								
Mean CIRP	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
Mean DSP	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								
Mean CIRP	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
Mean DSP	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.

TABLE 10/A.

Dry matter yields and leaf analytical data for the highest yielding treatment for each soil

		A. Basic igneous rock derived soils						B. Sedimentary rock derived soils.							
		Tarat A.	Malang B.	Terbat (2)	Tarat B.	Ramun	Terbat (1)	Merit (2)	Malang A.	Nyalau B.	Serin	Merit (1)	Nyalau A.	Semongok (1)	Semongok (2)
Highest yielding 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
Mean dry wt. yield (gm./pot)	1st crop	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
	2nd	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. (% of D.M.)	1st crop	2.62	4.[illegible]9	4.72	4.82	5.25	4.72	2.14	5.04	5.27	5.12	5.18	4.94	4.90	4.80
	2nd	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 (% of D.M.)	1st crop	.43	.58	.47	.49	.55	.56	.54	.63	.53	.81	1.00	.76	.37	.79
	2nd	.46	.46	.34	.40	.41	.54	.44	.49	.39	.54	.60	.65	.16	-
% K (% of D.M.)	1st crop	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
	2nd	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	-
% Ca (% of D.M.)	1st crop	1.0[illegible]	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
	2nd	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	-
% Mg (% of D.M.)	1st crop	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
	2nd	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

Dry wt. 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
N	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*
P	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*
K	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
Ca	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
Mg	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).

TABLE 11.

Soils, comparative highest Bayam yields (D.M.) and pre fertilizing soils analytical data, - Summary.

Soil Series	Highest yielding treatments. Yields (D.M. gm./pot mean)		Total % N	p. p. m. O.D.					pH (H_2O)	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

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.)	4

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 from 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. HRS 1, 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 and 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	0.106	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 monvalent cations. This was supported by experimental results contained in Table V which showed 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 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.

Soil A 5705 Quoin Hill (Tawau)

Fig. I Exchangeable K. 0·35 m.e. %

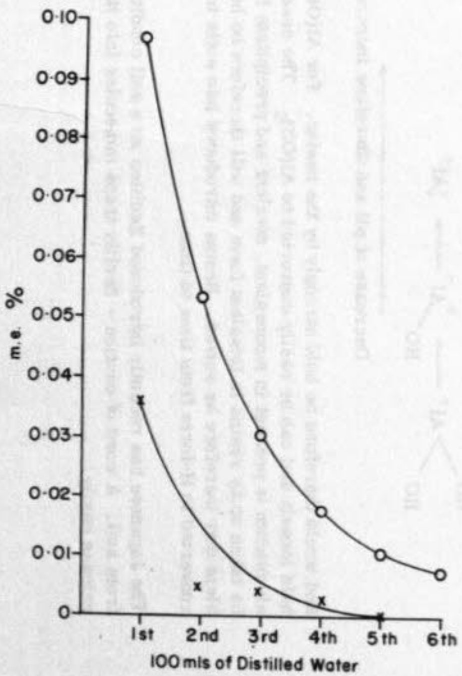


Fig. II Exchangeable Ca. 1·63 m.e. %

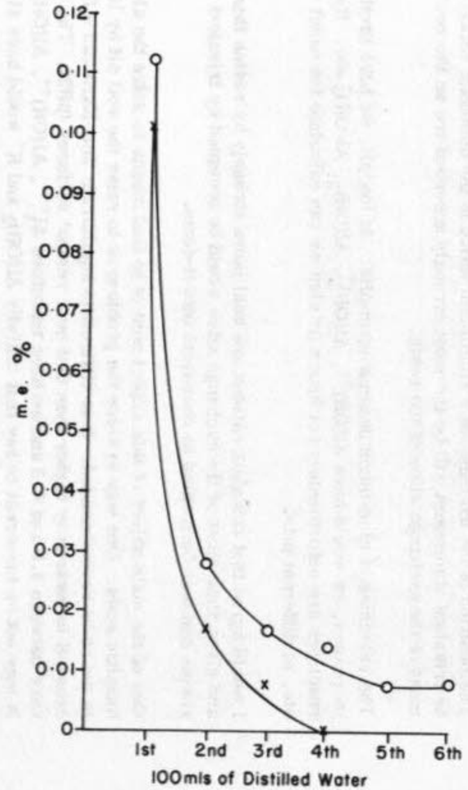
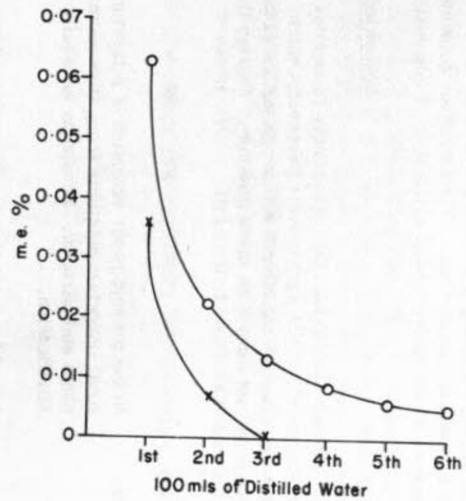


Fig. III Exchangeable Mg. 1·62 m.e. %



O for soil x for soil + resin

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

The authors wish to take this opportunity to express their thanks and gratitude to Dr. Y. T. Shao, Assistant Director (Research) of the Agricultural Research Centre, Department of Agriculture, State of Sabah, for his original idea, his time and unending efforts with us giving his valuable suggestions, encouragement and guidance without which this paper would not have been made possible. We also thank the Cartographic Division of the Centre for drawing the graphs designated as Figs. I, II and III.

Discussion

Mukerjee: In the present paper retention of potassium, calcium and magnesium has been studied. However, the most important nutrients from an economic point of view to most farmers in South East Asia are phosphate and nitrogen. Phosphate is usually retained in the soil but nitrogen disappears quickly due to nitrification.

I would suggest th : nitrification inhibitors such as N-serve at present being studied in Japan should be tested to make nitrogen gradually available throughout the active absorption stage of the crop. Nitrification is not stopped but rather slowed down. Such a study would nicely fit in with the one presented in the paper under discussion.

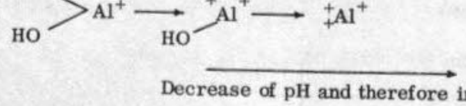
Singh: The position of the exchangeable aluminium which is the dominant cation in acid soils, must be considered, as trivalent aluminium will be the most strongly absorbed ion on the resins and will therefore occupy most of the exchange sites of the resin.

Shao: The valencies of aluminium depends upon pHs. At low pH, we have predominantly Al^{+++} but as pH increases, we would have $Al(OH)^{++}$, $Al(OH)_2^+$, $Al(OH)_3$, $Al(OH)_4^-$ etc. Hydrolysis constants of these reactions are unfortunately not known or else we can calculate the exact amounts of Al^{+++}, $Al(OH)^{++}$ etc. at different pHs.

I would agree that trivalent cations are held more strongly by resins than divalent and monovalent cations and given time most of the exchange sites would be occupied by trivalent cations. When this occurs, resins can ther be treated to reconvert into H-form.

One of the main object of this experiment is to find means to solve the aluminium toxicity problem of our basaltic soils. One way to solve the problem is to raise the soil pH by liming which for economic reasons is not to be recommended. It is difficult to equilibrate Zeo-Karb 225 - H form resins in water; the aqueous pH is invariably higher than that near resins' surfaces (pH2). The pH values of our problem soils vary between 3.9 and 4.3 and we have therefore Al^{+++}, $Al(OH)^{++}$, $Al(OH)_2^{++}$, $Al(OH)_3$ in various proportions. It may not be incorrect to say that initially $Al(OH)_2^+$ and K^+ would have similar chances to be adsorbed onto resins but as $Al(OH)_2^+$ approaching gradually towards resins' surfaces, it would be converted to $Al(OH)^{++}$ and Al^{+++} due to drops in pHs,

Approaching resin surfaces



Decrease of pH and therefore increase in positive charge.

and would therefore be held strongly by the resins. For $Al(OH)_3$, one of the hydroxyl groups is being held loosely and can be easily converted to $Al(OH)_2^+$. The essence of this phenomena is that although aluminium is present in monovalent, divalent and precipitate forms in our problem soils, it will eventually be taken up by resins in trivalent form and will therefore be held strongly. The aluminium toxicity problem may therefore be solved. Resins introduced into soils in nylon bags would enable them to be reconverted to H-form from time to time.

The Japanese has recently introduced Zeolites as a soil conditioner to prevent nutrients being leached off from soil. A word of caution - Zeolite traps molecules into its micropores which may not be able to release easily.

Singh: Will the addition of ion-exchange resins to the soil remove 'available' nutrient elements from the soil and make them more difficulty available?

Shao: The main purpose of introducing cation exchange resins into soils is to prevent valuable plant nutrients being leached off from soils.

The cation exchange resins being simple chemical compounds is less likely to convert "available" nutrient elements into "difficulty available" form. To enable resins to work properly, they have to be kept wet. Frequent drying would cause elements being more tightly held by resins but thorough wetting would increase availability once again.

The possibility of the formation of complex by elements adsorbed on cation exchange resins can not be totally excluded. But since the exchange reaction is a dynamic one, the chances of converting available nutrients into difficult available forms are negligible.

Mukerjee: It is suggested that the release of cations from resins should be determined by actually growing crops in pots.

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

by

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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%.

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 equilibriation 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 (Figure 1) To determine the number of equilibriations 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 (Figure 2)

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 La^{++} for potassium and calcium determinations and 500 ppm Sr^{++} 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 (BREMNER 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 N NH_4OAc method. Exchangeable aluminium values obtained with 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 N neutral NH_4OAc and 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 N NH_4Cl by extracting at the pH of the soil than by 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 the 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 stu'' 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%.

ACKNOWLEDGEMENTS

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

Soil	pH(a)	% Silt+Clay	milli equivalents in 100 g soil						
			NH_4 Cl Method				$NH_4$0Ac 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} $\underline{M}$ $CaCl_2$

(b) MOHINDER SINGH and RATNASINGAM (1966)

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

Soil Series	C.E.C.(CONWAY) me/100g	C.E.C. (Distillation) me/100g	Sum of Exch. Cations(a) 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 = $\frac{Al}{K+Ca+Mg+Al} \times 100$

FIGURE 1. EFFECT OF TIME OF EXTRACTION ON THE EXTRACTION OF EXCHANGEABLE CATIONS IN SOIL BY N AMMONIUM CHLORIDE SOLUTION

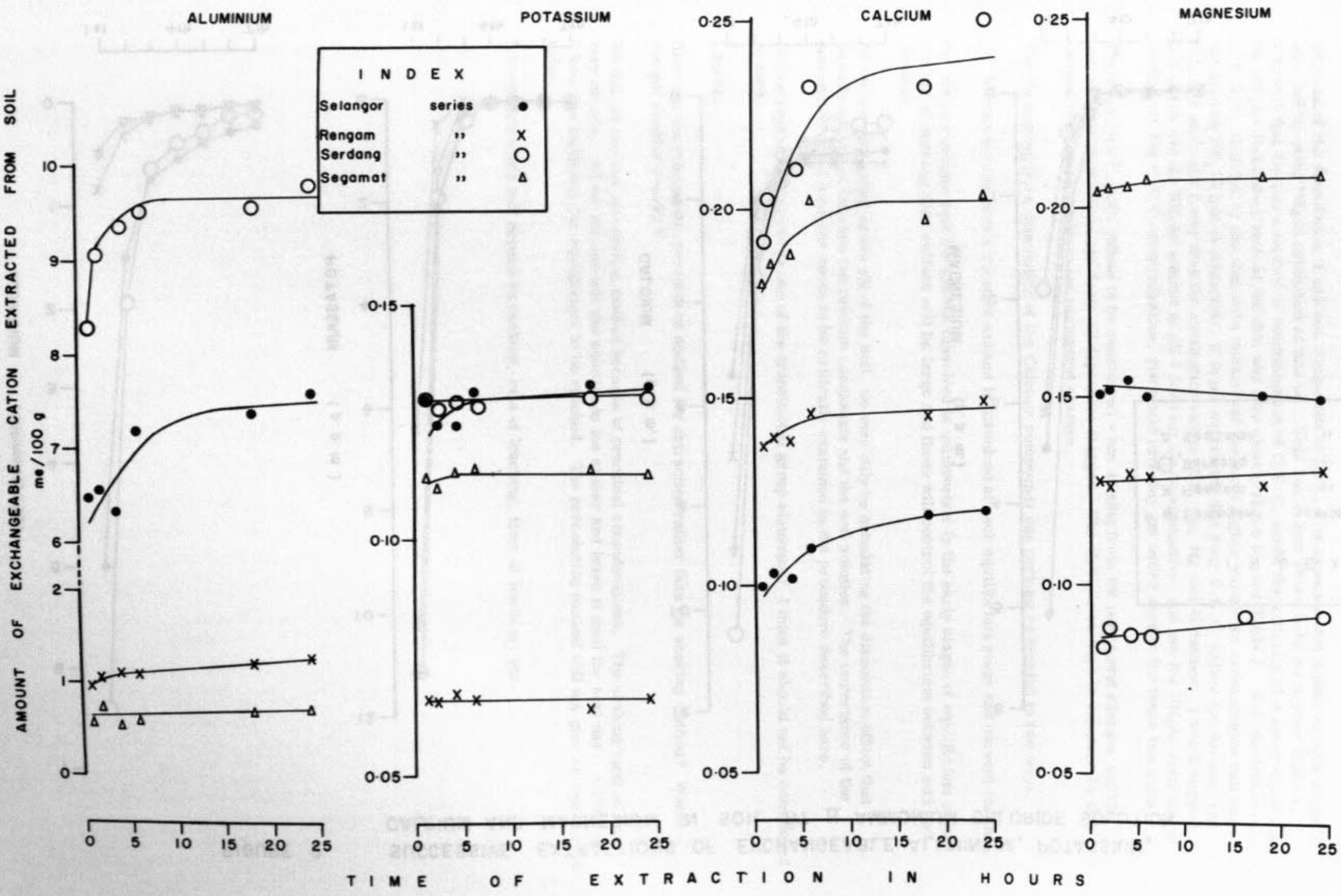
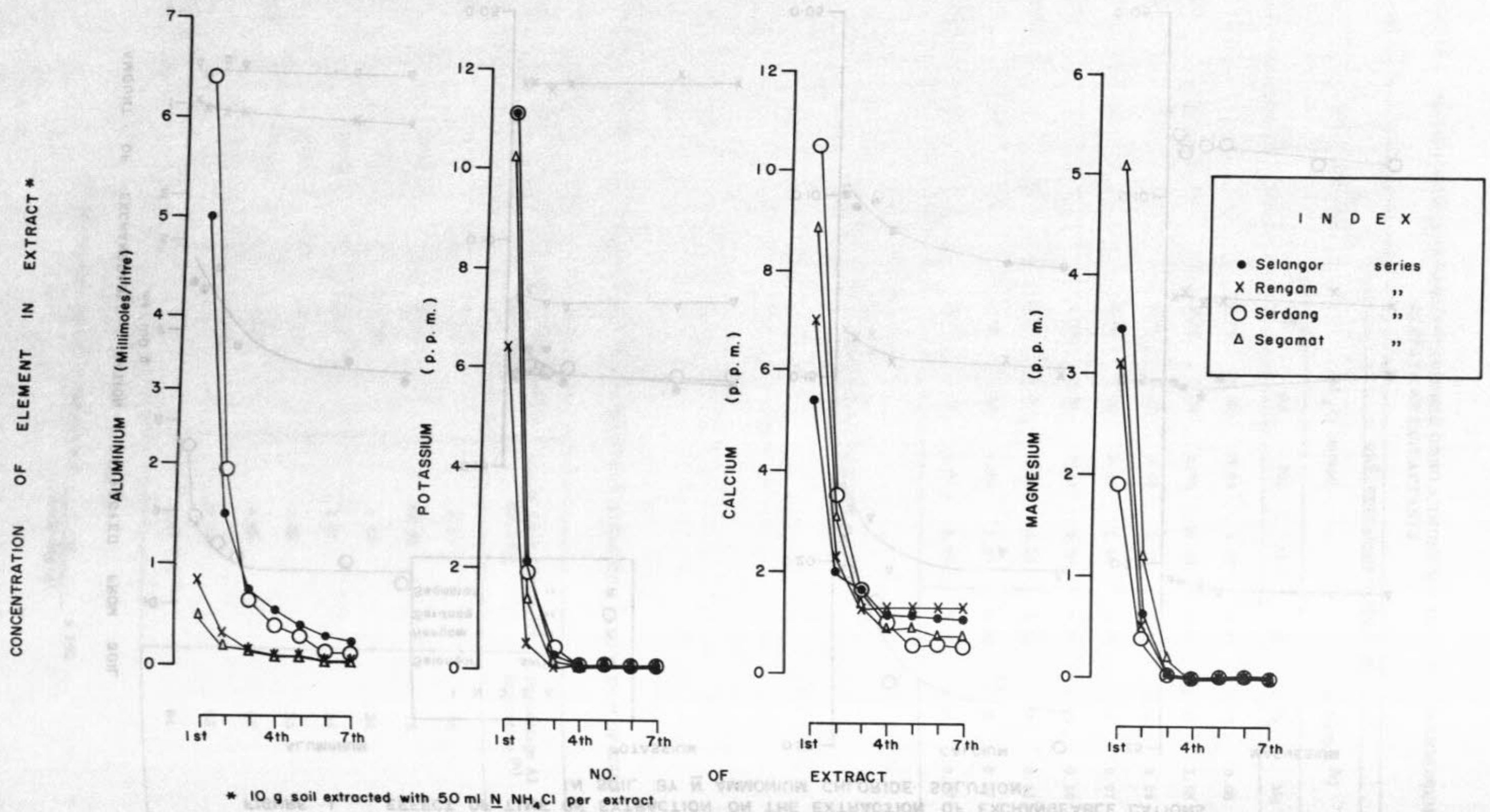


FIGURE 2. SUCCESSIVE EXTRACTIONS OF EXCHANGEABLE ALUMINIUM, POTASSIUM, CALCIUM AND MAGNESIUM IN SOIL BY N AMMONIUM CHLORIDE SOLUTION



Discussion

Shao: Because of the dissolution of calcium compounds at pH 4, it is expected that higher results would be obtained by using NH_4Cl extractant at this pH. This was in fact shown to be so in your Table 1. I also feel that Conway's method of determination of C.E.C. would theoretically give lower value than the NH_4Ac distillation method and this was also clearly shown in your Table 2. With the lower value of C.E.C. obtained by the Conway's method and the much higher values for exchangeable calcium obtained by NH_4Cl (pH 4) extractant, it is not surprising that your C.E.C. values for Serdang and Selangor soils are lower than the summation values of K, Ca, Mg and Al cations. I would suggest that if you use the NH_4Ac method at pH 7 for your Ca determination, and use the NH_4Ac distillation method for the C.E.C. determination, you would probably get better results for these two soils.

Singh: There are two C.E.C. values to be considered - one arising from the permanent charges and the second from this source and from pH dependent charges. The C.E.C. we hope to measure by this method is that arising from the permanent charges.

The Ca arising from dissolution of the Calcium compounds can perhaps be treated in two ways.

(a) We can assume that a constant amount is dissolved at each equilibrium stage and correct for this.

(b) We can assume that the amount dissolved is unimportant in the early stages of equilibrium since amount of exchangeable cations will be large and these will control the equilibrium between soil and solution.

As we are measuring at the pH of the soil, we may only be simulating the dissolution effect that already may exist between the calcium compounds and the soil solution. The importance of the dissolution effect however needs to be critically examined in the procedure described here.

Sim: Do you regard aluminium as one of the transitional group elements? I think it should not be considered as such.

Singh: I agree.

Allbrook: Have you considered the percolation method for extraction rather than the shaking method? Would you get similar results?

Singh: We did not use the percolation method because of practical considerations. The shaking method was very simple. All we did was add the solution to the shaker and leave it until the next day. A time of 6 hours is sufficient for equilibrium to be reached. The percolation method will not give an equilibrium value.

Amount extracted will depend on packing, rate of leaching, time of leaching, etc.

MANURING OF RUBBER IN RELATION TO SOIL TYPE: 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, 1968a).

PHYSICAL PROPERTIES

Distribution

Rengam series soil besides being probably the most widespread and 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 to a few thousand cares in area.

Terrain

It can occur under a wide range of terrain conditions, varying 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.

Soil Profile

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

Horizon	Depth	Description
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.

Range 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 (2.5YR 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 B_2 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 1 and 7 ppm, for the two soil layers respectively.

Unlike organic carbon, total nitrogen and phosphorus, 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 3.00 and 3.60%, while the highest and lowest values recorded were 4.26 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 magesium 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 potimum 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, 1968b). 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. Although no inference can be drawn fron the soil data, the leaf phosphorus content, being mostly below that of the control plot, 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 recommendationswere 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 then obtained for the soil type as a whole together with the 95% confidence limits for the mean x (Table 1).

As can be seen in Table 1 the mean amounts of N, P_2O_5, K_2O and MgO found required by rubber trees on Rengam series soil were 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.

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

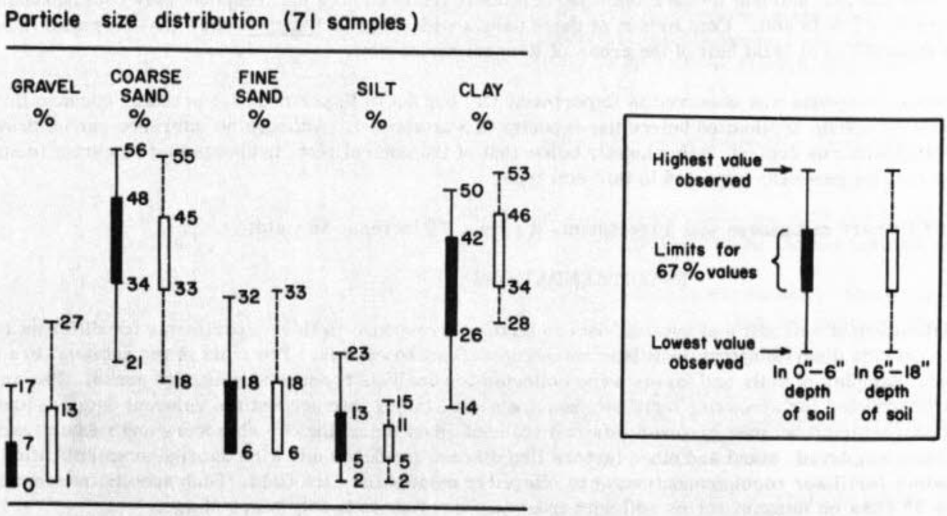

FIGURE 2. CHEMICAL ANALYSES OF RENGAM SERIES SOIL

(NUMBER OF SAMPLES: 112)

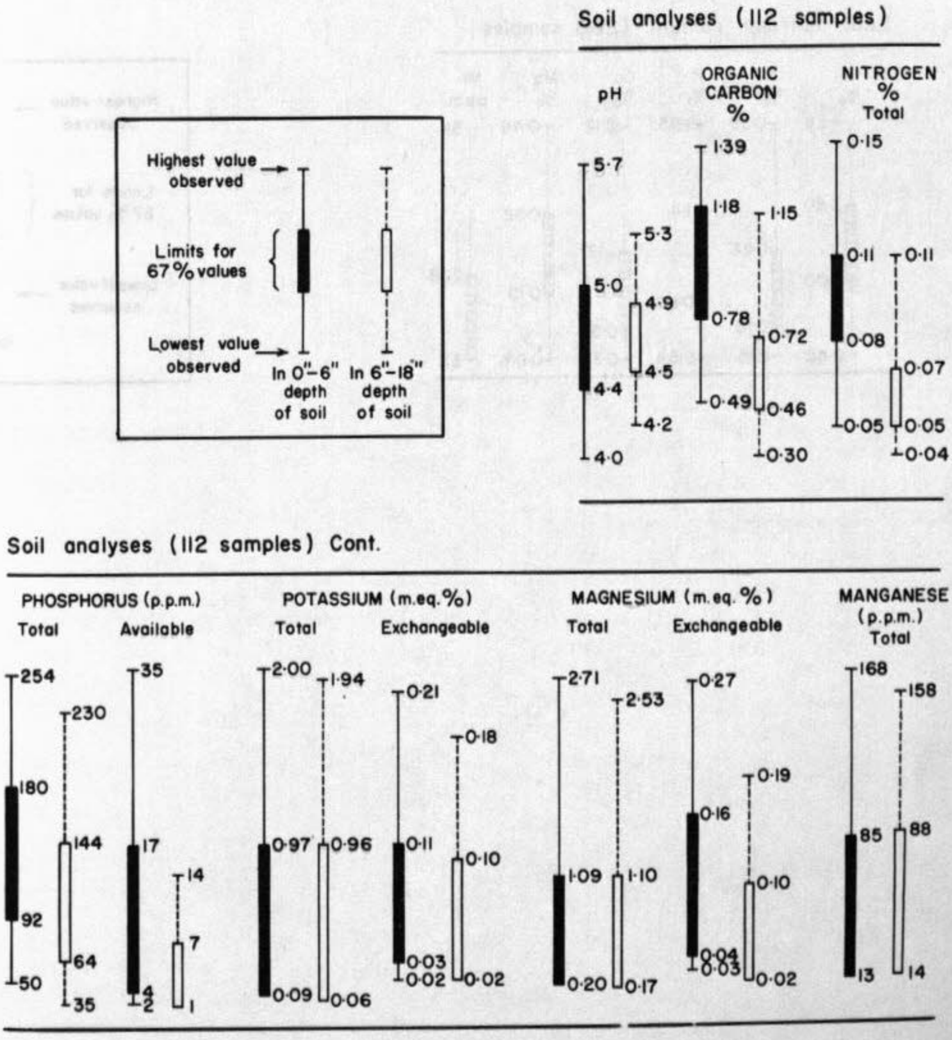

FIGURE 3. NUTRIENT COMPOSITION OF RUBBER LEAVES ON RENGAM SERIES SOIL

(NUMBER OF SAMPLES: 263)

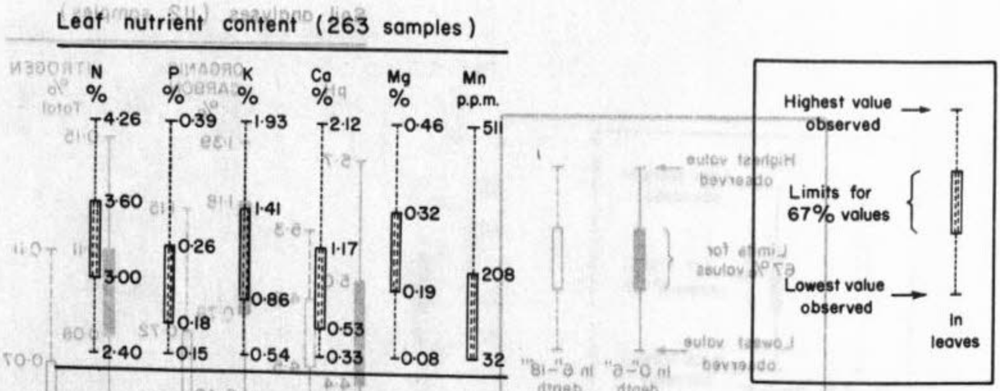

FIGURE 4. DISTRIBUTION OF SOIL AND LEAF NUTRIENT CONTENTS FOR RENGAM SERIES SOIL IN RELATION TO THE CONTENTS IN THE CONTROL PLOTS OF THE EXPERIMENTS

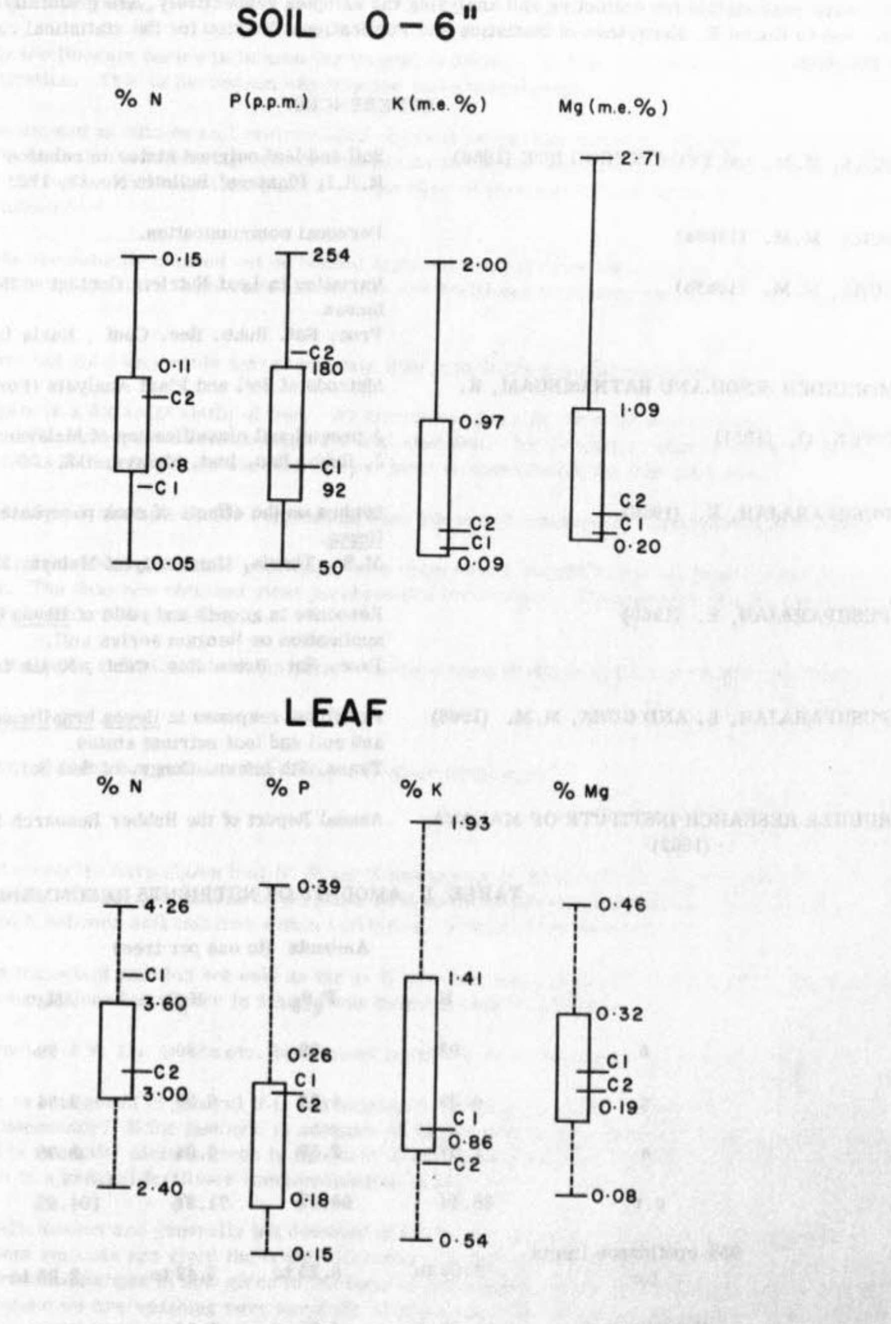

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TABLE 1 AMOUNTS OF NUTRIENTS RECOMMENDED

Amounts (in ozs per tree)

	N	P_2O_5	K_2O	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 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
x = mean
s = standard deviation
c.v. = coefficient of variance

Discussion

Law: Soil mapping in the field is such that the criteria and definition of the series is narrow enough not to bring in too contrasting characteristics. Variation in parent rock will reflect differences in the soils as the series definition is based on similarity of parent materials.

On igneous rocks then e.g. acid granites will give rise to the Tampin series while on the normal granite the Rengam series will be found. But even then a fine grained granite will form a fine textured Rengam (phase). On shale, because of variability in composition the definition and characterisation of the soils are a more difficult problem.

Chan: I think probably the Rengam series is in area the largest in Malaya, at least the most important one for the rubber cultivation. This is the reason why this one was studied first.

Watson: I appreciate the amount of data on soil chemical and physical properties and leaf analyses obtained but there appears to be rather a lack of agronomic data available for the fertiliser recommendation you have provided. Did the two experiments take place from the time of planting right up to the present time when yields were obtained?

Chan: The experiments are actually carried out on budded material when it came into tapping. Superimposed on previous fertiliser applications, which are known, the new fertiliser treatment was given after tapping started.

Watson: But you still have not got comparable agronomic data with your leave and soil analyses.

Guha: No, leave analysis is a different kettle of fish. We have been carrying out a 60 experiments. In all these experiments on different types of soil we scale the leaf analyses. We find out at what level in the leaf we do not get responses to fertiliser and use that critical level in interpreting the leaf analyses.

Mukerjee: Has any single factor or multiple factor correlation been attempted between soil composition and yield?

Guha: Multivariant correlation was attempted previously with some crude results using one year's yield, but without success. The data now obtained gives yield results for 5 years. When enough results are obtained such correlation will be tried again.

Mukerjee: Do the recommendations relate to maximum yield or to maximum profit or return per dollar invested?

Chan: Maximum yield.

Mukerjee: Have the recommendations been retested by using 50% more fertilisers?

Chan: Not yet.

Mukerjee: With rice, some countries have shown that N, P and K resources in the soil vary with texture, soil type and parent material. Largest variations in response to N and P are between soil types within parent materials, and to K between soil textures within soil types. Is that so in rubber?

Chan: Texture plays an important part but not only as far as K is concerned but also N. In fact the previous crude fertiliser recommendations for rubber in Malaya was based mainly on texture.

Mukerjee: Have any deficiencies of S, Cu, B, Zn etc. been found in rubber as is the case with rice in some soils?

Chan: As far as rubber is concerned in general it is not necessary to apply Ca or trace elements. In localised areas it may be necessary. B for instance is adequate in most soils, even may reach toxic levels in some coastal soils. S is normally already given in the form of ammonium sulphate, but not as a trace element. Zn does not come in a general fertiliser recommendation at all.

Guha: Trace element deficiencies are generally not detected in the field. In the glasshouse it is demonstrated that if not sufficient amounts are given the trees will suffer. S has in the past been given as ammonium sulphate but at present nitrogen is now given in the form of ammonium nitrate (this being manufactured in Malaya) and therefore we are watching very carefully whether signs of S - deficiency will occur in the field.

Chui: Have the authors investigated the possibility of toxicity of aluminium which might cause the shortage of phosphorus?

Guha: Aluminium toxicity has not been detected for rubber in West Malaysia. Response to phosphorus application is observed for trees during immaturity and in mature trees which have not received adequate phosphorus during the immature period. Thus, aluminium toxicity does not appear to have affected the response to phosphorus application in these experiments.

Thong: Could the leaf analysis values within the 67% limits be taken as threshold values for the nutrients in the soil series? If not, then would it not be better to establish and ultilise actual threshold values for the soil series so that prediction of nutrient responses can be made with more confidence.

Guha: The critical levels of leaf nutrient contents are not shown in the paper. These levels, based not only on these two experiments but on a great number of experiments on all soils, about 60 or more were published in R.R.I. Annual Report and are used for interpretation of results from individual fields.

Nitrogen response was in fact observed in one experiment but this was complicated by interaction with potassium which fell much below the critical level and effected the growth and yield. The interaction was not discussed here just for brevity. Agronomic results can be fully discussed only in a separate paper.

Guha: Comment. As has been shown by this paper, practical assessment of soil and improvement of yield can be obtained only by marrying soil survey and classification, soil chemistry and agronomic studies. It seems vital to me that the work on these related subjects should always be intergrated as closely as possible. Such intergration has been possible in R.R.I. mainly because the work on all the allied subjects are carried out virtually under one roof.

THE SOIL DAMAGE FACTOR IN PRESENT DAY LOGGING IN SABAH

by

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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 speetra 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 and 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. Occasionally 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 I.

R.P. 203 LUNGMANIS - SEGALIUD LOKAN FOREST RESERVE

TRACTOR PATHS SURVEYED AFTER LOGGING 1966 FELLING AREA.

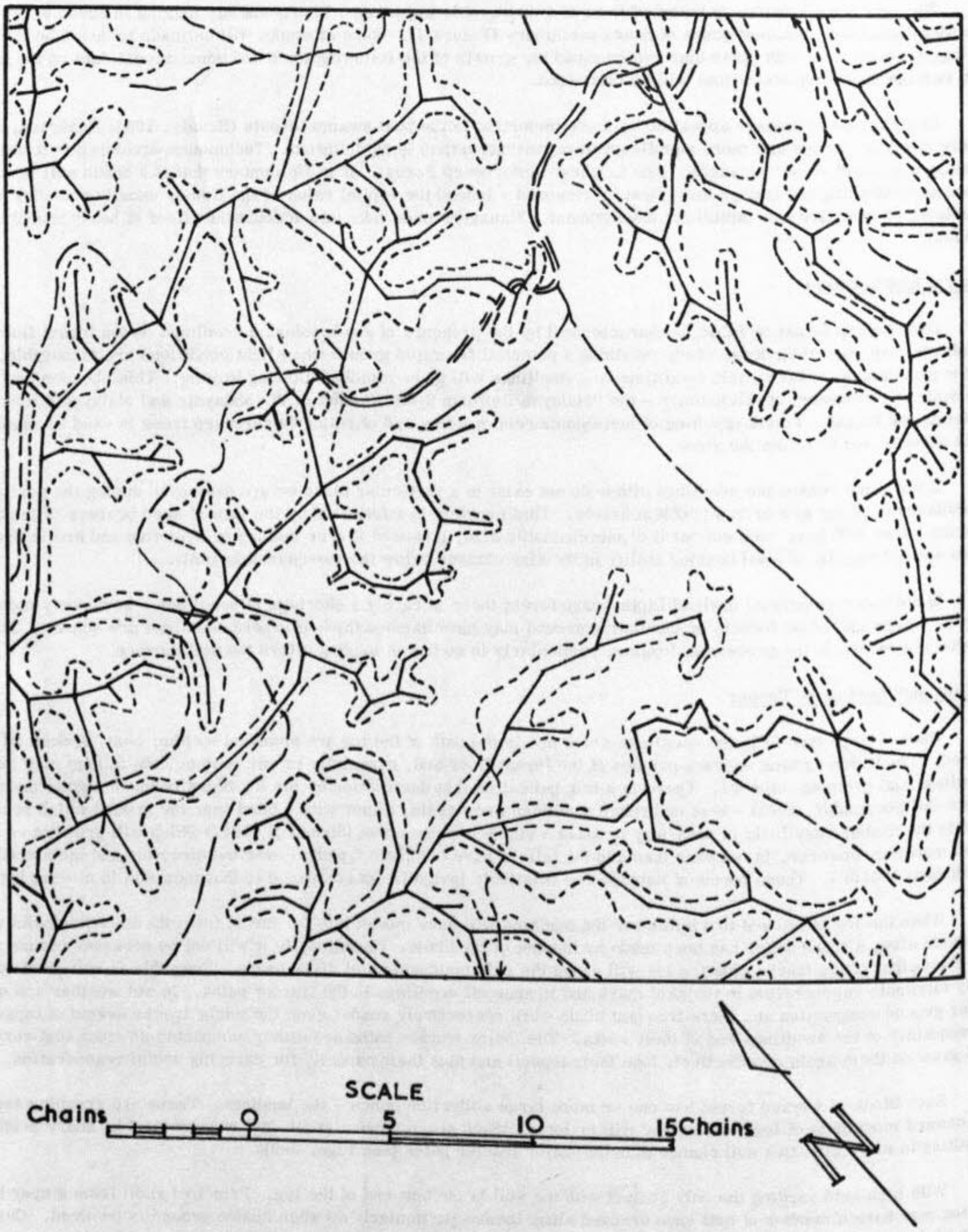

Fig. 2 A large landing and associated tractor workings.
Segaliud — lokan Forest Reserve

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

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 1,000 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 2,060 sampled quadrats with tractor damage or 41.7 percent. A survey of tractor paths (see Figure 1) 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 Foenander, 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 the results of another study (RP.135) in the Segaliud-Lokan F.R.

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

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. 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 apalling 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 two 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.

Fig. 4

A TD 25 Bulldozer preparing major extraction route.

Fig. 5

Soil surface in Virgin Dipterocarp Forest.

Cicada exit hole.

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.

Changes Following Logging

The average annual litter production for forest in the equatorial zone is about 11 tons per hectore 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 dessicated by the hot sun or develops fungal infection causing the death of the root and shoot tips. If the seedling can withstand these the radicale 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 the 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.

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 peruse 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

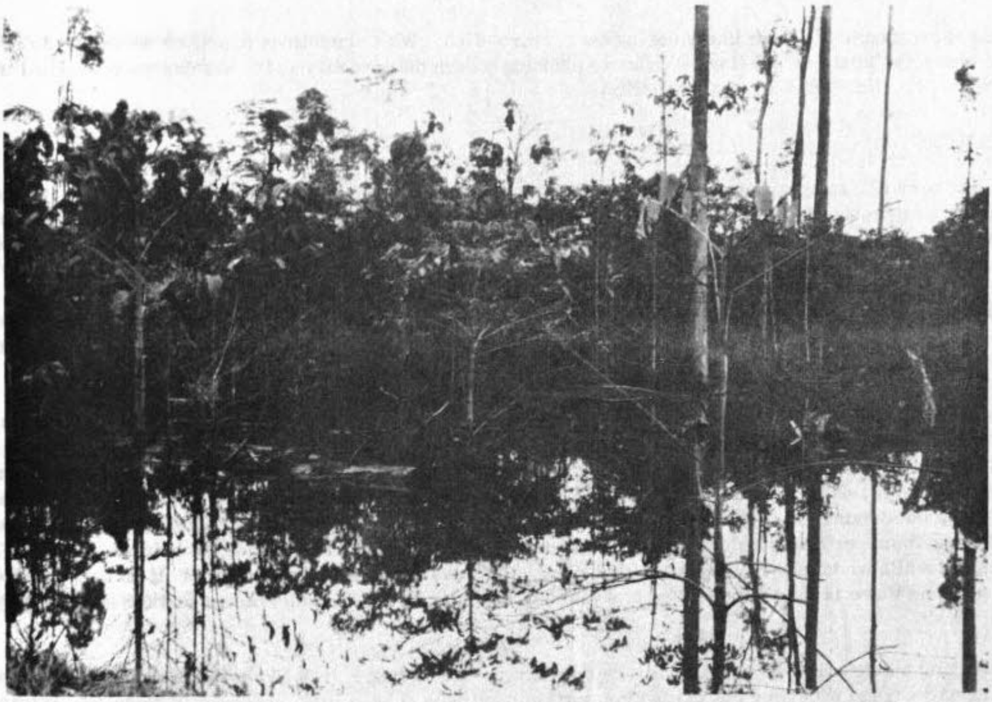

Fig. 6

Drainage pattern blocked by road-making.

Fig. 7

An old extraction path, abandoned 30 months before. The seedling has been planted in a pot.

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 to 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 type. 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 subdivisions 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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Discussion

Clarke: Is there any control of extraction methods by the Forest Department? For example, is a logging extraction plan submitted for approval before exploitation commences?

Fox: There is no requirement imposed on a concessionaire to submit a plan of extraction methods. Each licencee is issued coupe following submission to the Department of a technically sound map showing the area to be worked. Provision exists in the Agreements relating to the avoidance of damage to forest growth and stating the contractors liability for compensation in respect of damage to forest growth.

Murthy: What was the time lapse between the date of exploitation and the recording of observations?

Fox: In discussing the extent of tractor damage I referred to six studies made by the Forest Department. The time lapse with these varied from three months to one year. I believe the area reported by McCredie was logged several years prior to his survey and the survey was based on aerial photography.

Andriesse: Comment. It has been noted that in the Land Development Schemes in Sarawak on which clearing and terracing was done by bulldozers, The rubber was doing invariably worse than in the schemes where manual labour was employed for this work. This is quite possibly mainly due to removal of topsoil and destruction of structure.

Mukerjee: Comment. When forest is cleared by bulldozers to make bunded plots for resettling farmers from inundated land in irrigation dam sites, the subsoil which is exposed appears to be very bad. But heavy applications of super-phosphate and green-manuring with crotolaria juncea improved the soil in three seasons.

Ng: Comment. To follow Andriesse's statement, our experience in West Malaysia has been variable, as far as the damage from logging or mechanical clearing is concerned. In all the F.L.D.A. Schemes logging preceeds the rubber or oil palm cultivation and in most of these schemes the soils are good in terms of depth. The clearing is done not by mechanical means but by hand. This system has been perfected and we find that little damage is done to the soil and the crops are doing well. But on the coastal soils, e.g. the marine clays where oil palm is planted after mechanical clearing the estates have found that quite a degree of compaction takes place in the surface soil, resulting in poor drainage when the oil palm is planted. This is a problem but the oil palm gets over that in a year or so, but it does set back the growing of oil palm initially.

Lee: Logging is less mechanised in West Malaysia and the intensity of major extraction routes for heavy tractors is less. Accordingly, the problem appears to be less severe than in Sabah. With regard to the damage to seedlings, it may be expected that with more intensive silvicultural practices, particularly in the hill forests to attain higher yields, enrichment planting would help to lessen the problem.

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

by

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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 equilibriation procedure of BECKETT. Quantity, Intensity and Buffer Capacity values derived from these Q/I relationships did not give better relation with 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 dif ·rent strengths or salt solutions. These methods, calibrated by laborious field trials, have met with some success. Since SCHOFIELD (1947) introduced his Ratio Law 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 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 $K/\{\sqrt{(Ca+Mg)} + P^3\sqrt{Al}\}$; 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 rubber-growing acid 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.

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Methods

10 g samples were brought to a moisture content of 50% of soil and left overnight. 25 ml of .012$\underline{M}$ $CaCl_2$ 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 equilibriation was plotted against the intensity (I) given by $K/\sqrt{(Ca+Mg)}$. 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_O. 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_O. 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 SINGH and RATNASINGAM. 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 $0.63 \times 10^{-2}\underline{M}$ (Selangor soil) to $0.93 \times 10^{-2}\underline{M}$ (Chemor) while Ca plus Mg. which are normally considered together because of their similar exchange behaviour. was between $0.81 \times 10^{-2}\underline{M}$ (Selangor) to $0.94 \times 10^{-2}\underline{M}$ (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 equilibriating 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 adsorbed by soils from the equilibriating 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 0.02$\underline{M}$ calcium chloride equilibriating solution. the equilibrium solution had a Ca + Mg concentration of 0.0194 $\underline{M}$. This represents a nett change (increase) of only 16% in the initial Ca + Mg status of the soil.

Q_O 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 equilibriates rapidly and is the one measured here as Q_O. 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_O. I_O 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 $I_O - 0.5 \times 10^{-3}$. where I_O 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. 1968). 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_O	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_O	-0.215 NS	-0.314 NS

***: $P < 0.001$ **: $P < 0.01$ *: $P < 0.05$ 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_O 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_O 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. An 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_O) and Buffer Capacity derived from the Q/I curve using calcium ion for equilibriation 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 equilibriating 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 equilibriation. 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).

ACKNOWLEDGEMENTS

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

Soil Series	Mechanical Analysis (a) (% oven dry soil)				pH (b)		Exchangeable cations (c) me/100g						Acid extractable cations (e) me/100g		
	C.S.	F.S.	Silt	Clay	$CaCl_2$	H_2O	K^+	Ca^{++}	Mg^{++}	Al^{+++}	% K in C.E.C.	% Ca + Mg C.E.C. (d)	K^+	Ca^{++}	Mg^{++}
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 $CaCl_2$ used is 0.01 M
(c) to N - NH_4Cl, 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_O	$I_O \times 10^{-3}$ (moles/1)$^{\frac{1}{2}}$	Buffer Capacity			Uptake by *Pueraria* me/100 g
		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

FIGURE I (a) QUANTITY/INTENSITY RELATIONSHIPS OF SOIL POTASSIUM USING CALCIUM CHLORIDE EQUILIBRIATIONS

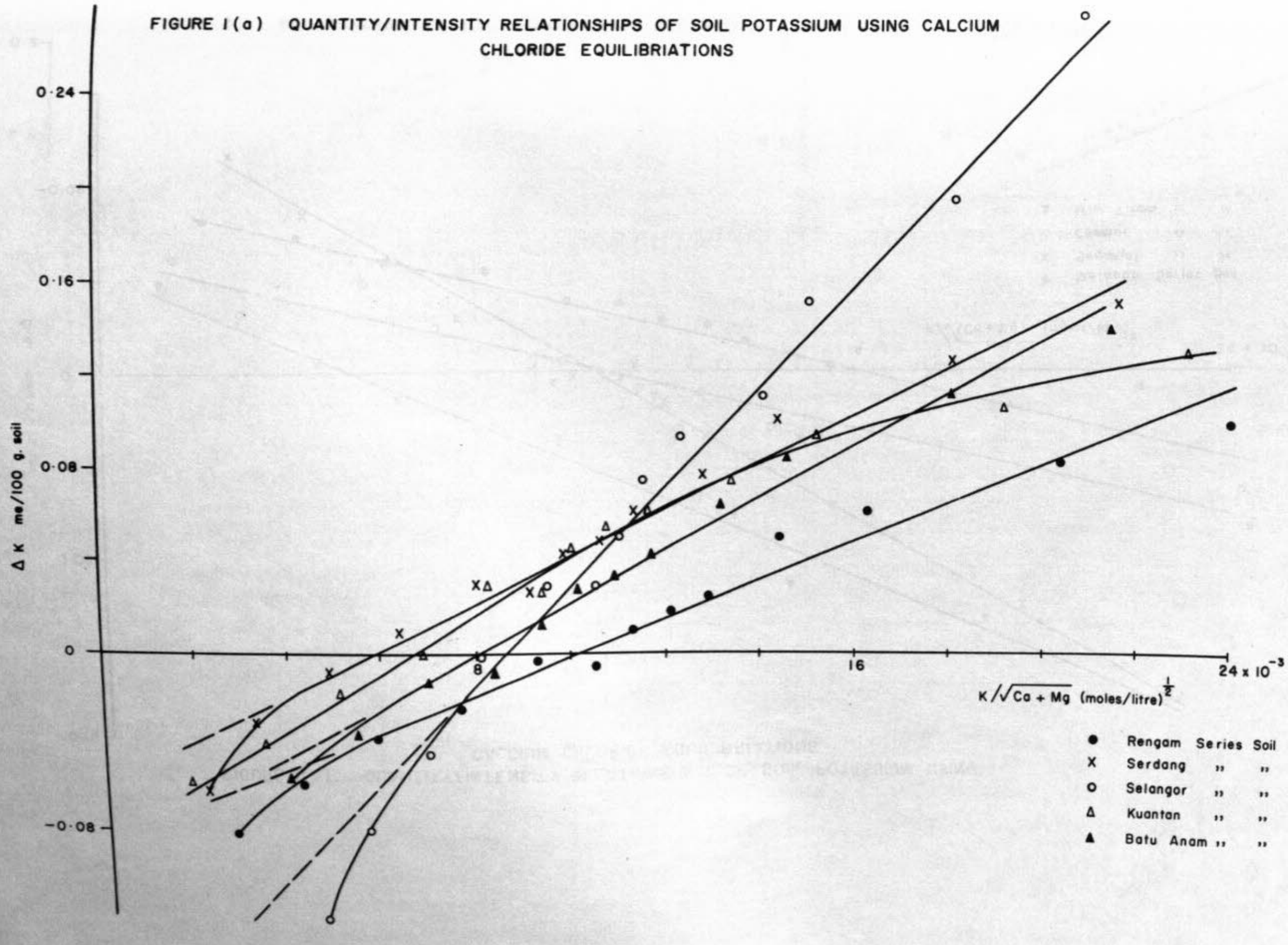


FIGURE 1(b) QUANTITY/INTENSITY RELATIONSHIPS OF SOIL POTASSIUM USING CALCIUM CHLORIDE EQUILIBRIATIONS

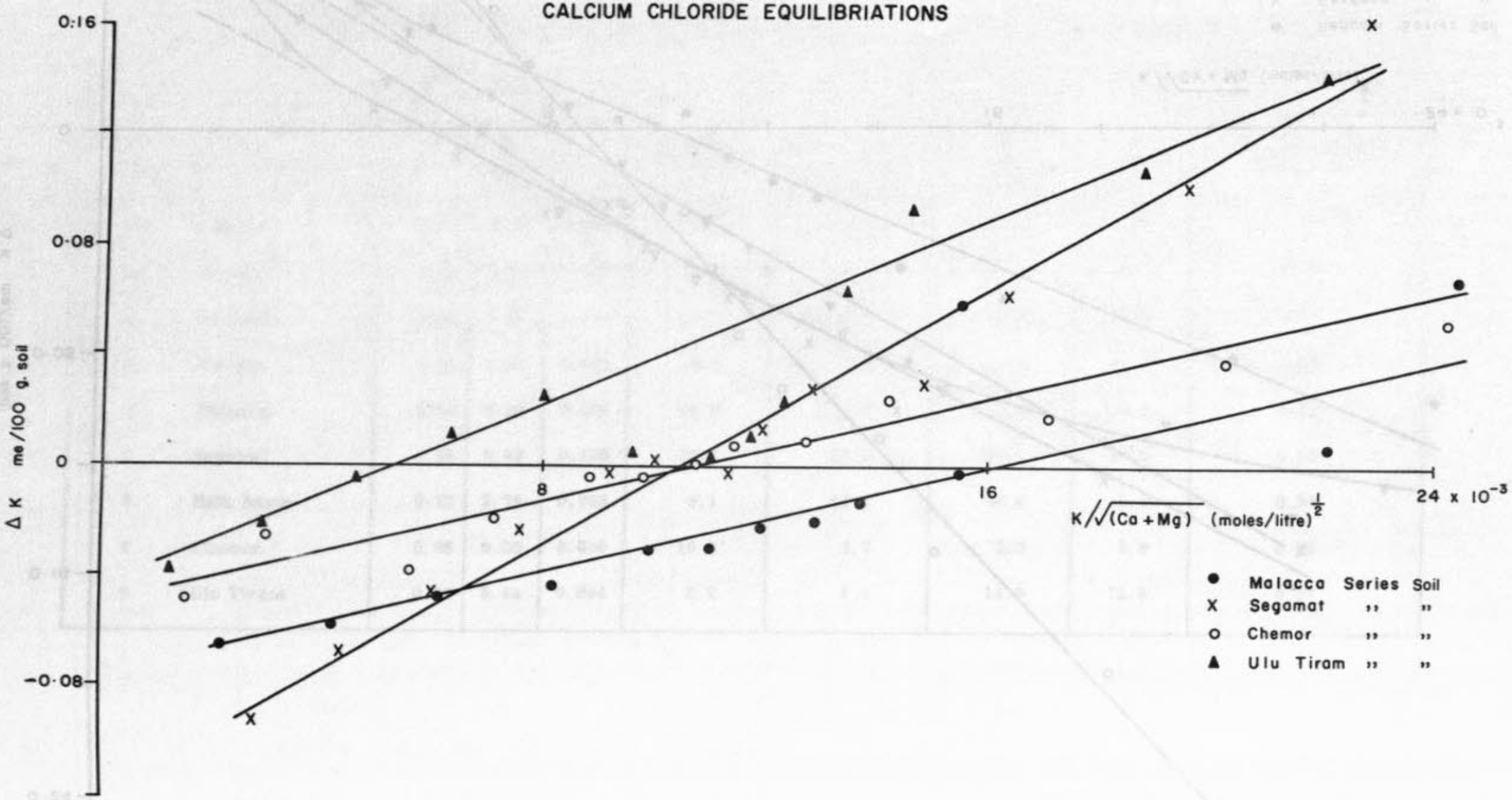
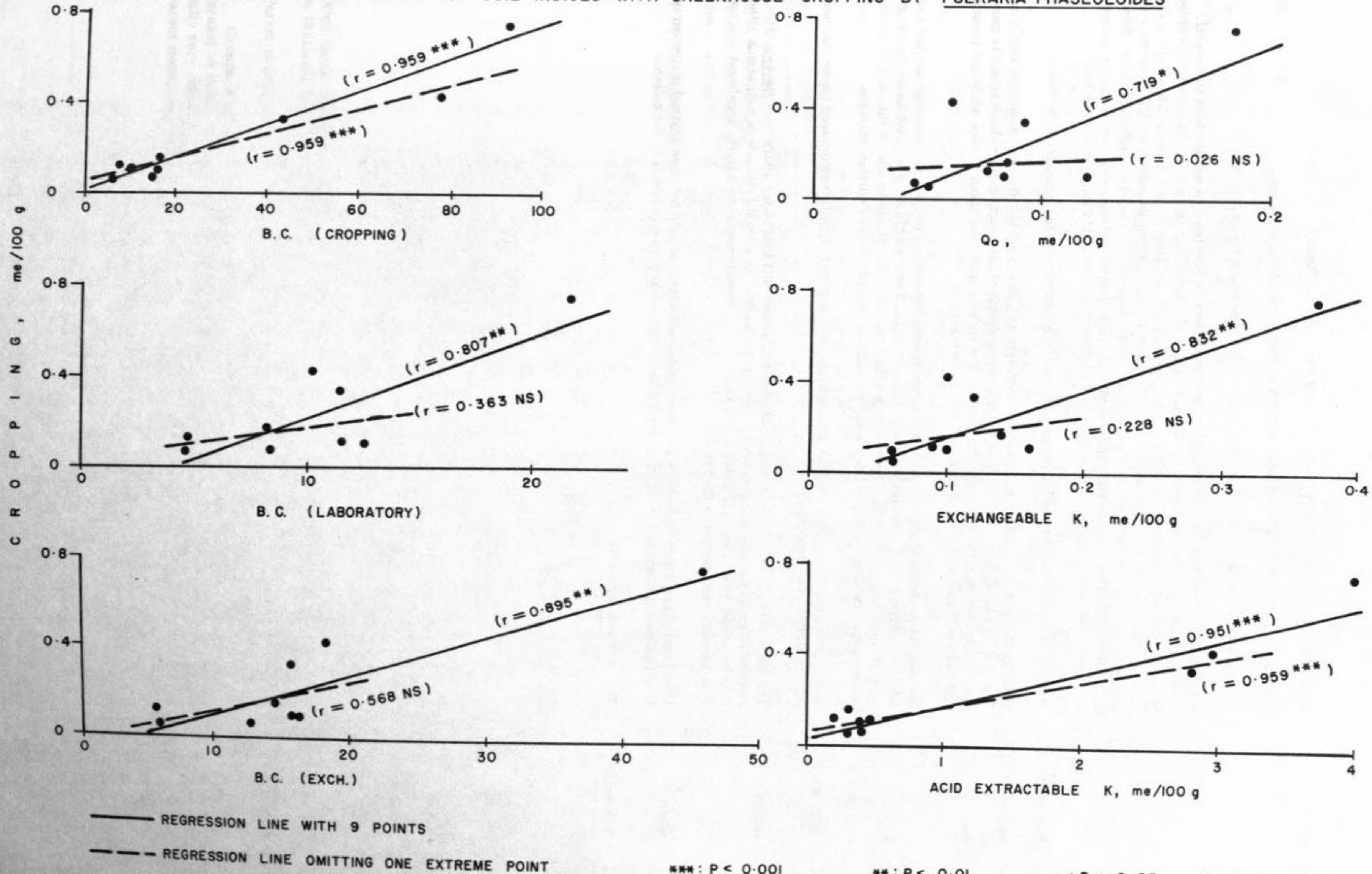


FIGURE 2. RELATIONSHIP OF SOIL INDICES WITH GREENHOUSE CROPPING BY <u>PUERARIA PHASEOLOIDES</u>



Discussion

Chui: What force gives rise to the intensity, mainly electrostatic force?

For different samples the electrostatic forces involved would be different.

Singh: The main force would be the electrostatic force but this is not the only force.

It is difficult to explain this without going into the nature of how the cations are held in the soil, this brings us to colloid science because the soil is a colloid, the cations are distributed accordingly to known, definite, physical chemistry laws and they are not simply distributed. They form a diffuse double layer and as long as the colloid system does not break up (which it will do as the solution becomes too concentrated, as is for instance the case with the acid - sulphate soils in which the sulphate concentration is very high) the double layer will exist and this will control the exchange reaction. One has to go into this double layer to learn exactly how these cations are held.

Ashworth: Would this method not be too laborious and therefore uneconomic for routine use?

Singh: Initially the method was laborious because we tried to understand in detail the reactions that occur. This will not be done in routine work. The measurement of total acid extractable cations is much more laborious than the one presented here. The former may take about a week while the present method would take not more than half a day when routined.

In. nsity is being measured on a routine basis in other places as in England, although not for routine advisory purposes yet, and in Rothamsted a method has been developed where intensity can be obtained very successfully by a rapid successive equilibration method. More details on this will be given in a second paper on this subject. I do think this method is applicable to routine analysis.

Ashworth: Is it right to correlate your method with exhaustive cropping? Can it then be used for recommendations for one single year cropping?

Singh: The ideal correlation would be with field results but this will take many years with Hevea. The relatively rapid method of exhaustive cropping is accepted as a good indicator of soil status although it is removed from many variables in the field. The method once successfully developed will however be ultimately tested in the field.

Chui: Comment. Once a new method is developed, encouragement should be given instead of discouragement. It is realised that more research is needed but it is too early to say that it is not suitable.

Ashworth: This was not my intention.

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 PENDLETON, and published in a report, with a "Provisional Map of the Soils 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 Regional Cartographic Conference for Asia and the Far East, Philippines 1964.

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.:

- the General Soil Map of Thailand, at a scale of 1:1,250,000, now in print,
- 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 was presented at this meeting.

The General Soil Map is based on fieldwork by the authors, existing soil surveys at various scales, generalized interpretation of airphotos and 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 the dominant soils or association of soils, the broad groups of parent material and the landforms as expressed by the general topography of the unit area.

Soils.

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 (1). The Great Soil Groups, mentioned in the legend mostly correspond with those described by DUDAL and MOORMANN (2); additional groups, important in Thailand, were identified by ROJANASOONTHON and MOORMANN (4). The criteria used in describing and classifying the Great Soil Groups are those, set forth in the new USDA soil classification system (6). Map unit areas 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.

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

- Regosols
- Alluvial soils
- Peat and Muck soils (organic soils)
- Low-Humic Gley soils
- Grumusols
- Rendzinas
- Brown Forest soils
- Noncalcic Brown soils
- Red-Brown Earths
- Gray Podzolic soils
- Red-Yellow Podzolic soils (the presence of abundant laterite gravel is indicated as a separate phase for Northeastern Thailand)
- Reddish-Brown Lateritic soils
- Reddish-Brown Latosols
- Red-Yellow Latosols.

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

Parent materials.

Groups of parent materials were distinguished mainly on the basis of their importance in regard to the soils which formed on them. Thus, the classification of parent rocks is hardly a systematic petrographic one, since petrographically very different rocks (e.g. granites and quartzite - phyllites) may produce similar soils. 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 (not or weakly calcareous)
- Marl and limestone alluvium
- Montmorillonitic clay from alluvium, marl and basalt

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- Residuum and colluvium from acid rocks (granite, sandstone, quartzite - phyllite, etc)
- Residuum and colluvium from intermediate rocks (andesite, some grano-diorite, 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 Thailand, 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 colluviated residuum.

Topography.

The topography indications in the legend follow soils slope classes of the 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.

Soil 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 the general fertility status and thus are meaningful in terms of soil management.

Following broad management groupings were made.

- I : Excessively drained sandy soils, low fertility
- II ; Poorly drained clayey soils, high to moderate fertility
- III : Very poorly drained, organic soils (swamps and marshes)
- IV : Poorly drained and well drained soils, mostly loamy and sandy, moderate to low fertility
- V : Well drained to somewhat poorly drained loamy and clayey soils, moderate to high in bases, high fertility
- VI : Well to excessively drained loamy and sandy soils, low weatherable minerals, and bases, low fertility
- VII : Well drained clayey and loamy soils, low in bases, low fertility
- VIII : Well drained clayey and loamy soils, high in aluminium and/or iron oxides, low in bases, moderate to low fertility.
- IX : Miscellaneous soils and land types on hills, mountains, and plateaus.

<u>The legend of the Simplified General Soil Map, scale 1:2,500,000</u>

Most of the elements of the General Soil Map at scale 1:1,250,000 have been maintained on the simplified version.

The definition of the mapping units is based on the dominant soil or soils in the unit area, and on the broad type of parent material, as described in the previous paragraph. The physiographic and topographic element is, 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 way 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 strictly physiographic or topographic. Terrace areas in which hydromorphic soils (Low-Humic Gley soils) are an important element, were grouped with the lower terraces, whereas such areas with predominance of well drained soils are qualified as "Higher terraces". In ab-solute hight, parts of the higher terraces may be lower than parts of the lower terraces; e.g. the well drained marine terraces in Southeast Thailand are situated at a lower elevation than most of the river terraces in the int-erior of the country.

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

Simplification applied on the present map is twofold. Small unit areas were dropped and boundaries were realigned. Certain units of the map at scale 1:1,250,000 were grouped together, and represented as 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.

Availability of the General Soil Map and its Simplified Version

The map showing general soil conditions, at a scale 1:2,500,000, with explanatory text, has been edited in the series Soil Survey Reports of the Soil Survey Division, Department of Land Development. Copies are available upon request to the Director General of Land Development, Ministry of National Development, Rajaelamnoern Ave., Bangkok. The General Soil Map, scale 1:1,250,000 is being printed, and will be available on request at the same address in early 1969.

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Discussion

Law Wei Min: What have you done with the laterite in South Thailand?

Moormann: We do not know enough, as yet, about the distribution of laterite in Southern Thailand. So, we only mentioned in the text that there is much laterite in the south of Thailand. In the N.E. part where we have tremendous surfaces of surface laterite (this is hard gravelly laterite) we made a special unit on the general map (a phase), i.e. Red-Yellow Podsolic soils with 'abundant laterite concretions in the upper layers'.

Law Wei Min: I asked this question because Leamy previously named the laterite as a concretionary oxisol.

Moormann: In the newest development of the 7th approximation, the oxisol order indeed includes soils with plinthite (soft groundwater laterite) at shallow depth. In this context, the hardened laterite, either in pans or in concretions is not considered a diagnostic horizon and, whereas most of the superficial laterite is indeed present in the hard form, few if any of the concretionnary soil would fall under oxisols.

Donaldson: Realising the intention to display on the map the relationship between soils and the various physiographic regions, I wonder why a colour scheme was not chosen to display this relationship more readily?

Moormann: True, we could have used a more 'logic' colour scheme but the colours follow more or less what has previously been used for the 1967 General Soil Map at scale 1:1,250,000. On this map, physiography was not used for grouping the map units.

Chan: This general map gives us useful information for operational work. Is there a need in Thailand for more detailed soil mapping at the moment and what is the progress?

Moormann: Mapping of various detail goes on now in Thailand with over 40 survey parties. The map presented here is the outcome of a separate programme by the authors.

Chan: What are your units of detailed soil mapping?

Moormann: Series and phases, and in some cases series, associations, soil complexes (e.g. in mountain areas).

THE 1968 RECONNAISSANCE SOIL MAP OF MALAYA

by

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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 steepland, 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 Works, 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 steepland 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

Rentis2 - Malay word for a trace cut on a set compass bearing.

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 steepterrain. 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 diorit c 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 phorphyritic 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 soils 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 inparts 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

PRANG 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 Ae/Bt with a friable yellowish brown silty clay loam over lying 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 be 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 recognised 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 onshales 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 ndulating 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 inter-bedded 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 grey silty 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 with 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 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 characterised 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 clayskines, 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 country-side. The slopes are in excess of 20^{o} 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 SENA 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 sub-angular 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 Sungei 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 mildy 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, groundnuts, 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. A 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 subso 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 soils 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 youthfullness 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 is 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 under lying 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 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^{o} 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 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 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. Steepland with average slopes of greater than 20 degree slopes from 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.

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Discussion

Andriesse: You stated that in compiling this map, you had the choice of either making a map showing great soil groups or to make a map showing associations of soils such as series. You decided on the latter because the units would be less variable and not so broad as when you had used great soil groups. This would be true if the series within the associations are not of different soil groups, otherwise your map associations would be more variable than when you had used great soil groups as single mapping units.

Law Wei Min: Associations of series do mean that the associations vary and often cut across soil groups. So, the final map showing great soil groups will invairably include associations of Great Soil Groups as well.

Moormann: Given the level of knowledge of Western Malaysian soils, the new soil series association approach seems to be the correct one. It gives in the framework of the scale used, the most information on a national scale. From this map a revised Great Soil Group map can easily be drawn, but such a map has mainly relevancy in terms of international soil correlation, much less in terms of practical use.

Andriesse: In Sarawak we are endeavouring anyhow to map the boundaries of single great soil groups in reconnaissance mapping to enable the compilation of a map at soil group level.

If we only map associations of series or families running across soil groups the land capability (or soil capability) will be very variable, while at least in Sarawak within a group some level of capability can be assessed.

Clarke: Soil maps of various categories are generally too complicated for people who are not soil scientists. Simplified maps for land use departments should be issued.

Law Wei Min: Soil Suitability maps are produced to group all the soils into the five soil suitability classes which we recognise. The suitability classification is based on tree crops and, therefore, such maps would be very useful for foresters as well.

Chan: I would like to hear some elucidation on the position of the Kangkong series. Profile-wise it is difficult to distinguish Kangkong from Selangor series. However, I have seen areas under rubber where the soil profile agrees with Selangor series although not so advanced in development, but the organic matter is quite high (in fact, C/N ratio is about 30, whereas I have found C/N ratios to be around 16 - 18 in Selangor series). Could such soils come under Kangkong series bearing in mind that previous definitions of Kangkong series include a very high organic matter content in the soil profile?

Law Wei Min: Kangkong and Selangor series form a sequence with the Kranji and Telok series, as follows: Kranji-Kangkong-Selangor-Telok. Profile development is invariably less well pronounced in Kangkong if compared with Selangor. Organic matter content may be of help but I would prefer to use it as a phase as we have done in Selangor, organic phase, where the histic epipedon is more than 12 inches thick.

TABLE 1

SOIL ASSOCIATIONS	JOHORE	KEDAH	KELANTAN	MALACCA	NEGERI SEMBILAN	PAHANG	PROVINCE & PENANG	PERAK	PERLIS	SELANGOR	TRENGGANU	TOTAL	% MALAYSIA
Class I													
Kuantan	-	-	-	-	-	30700	-	-	-	-	8000	38700	0.12
Segamat-Katong—Jempol	65400	-	-	-	-	183700	-	-	-	-	5600	254700	0.78
Rengam-Jerangau—Kg. Kolam-Tampin	1175000	33500	195700	143500	291700	605000	39900	298900	-	118000	488600	3389600	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													
Kaia-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-Kedah	7600	-	5600	-	18300	81300	-	48600	-	21500	-	182900	0.56
Durian-Munchong—Serdang	-	-	533300	-	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
Harimau-Tampoi—Ulu Tiram	199700	-	-	-	-	80500	-	-	-	-	-	280200	0.86
Telemong-Akob—Local Alluvium	311700	95700	22700	15100	70100	334800	2000	232000	-	35100	112400	1231600	3.79
Selangor-Organic Clays & Mucks	123600	-	-	-	-	-	32700	-	-	-	-	156300	0.48
Selangor-Telok	-	-	-	-	-	-	-	-	-	40700	-	40700	0.12
	737000	123600	639700	60100	247400	709800	34700	371900	-	234800	112400	3271400	10.05
Class III													
Batu Anam-Bungor—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-Yong Peng	67400	-	-	-	-	-	-	-	-	-	-	67400	0.21
Batu Anam-Malacca—Tavy	232800	-	-	-	49000	80100	-	-	-	-	-	361900	1.11
Kuala Brang-Serdang-Muchong	-	-	-	-	-	45400	-	-	-	-	-	45400	0.14
Marang-Batu 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	530000	1149100	47000	485000	71200	48200	686300	4666200	14.34
Class IV													
Marang-Apek	75700	-	-	-	-	-	-	-	-	-	-	75700	0.23
Malacca-Tavy	54200	-	-	-	8800	106400	-	-	-	3200	-	172600	0.53
Rudua-Rusila-Jambu	34300	34000	49400	-	-	127700	-	13200	-	-	153800	381400	1.17
Kranji-Linau-Telok	249400	9200	-	51000	14700	33100	32700	176200	-	140300	12800	719400	2.21
Peat	455200	-	39100	-	-	601800	-	259000	-	444000	98400	1897500	5.83
	868800	13200	88500	51000	23500	868000	32700	448400	-	587500	265000	3246600	9.97
Class V													
Urban & Mined Lands	-	-	-	-	13600	17500	13600	222800	-	139500	-	407000	1.25
Steepland	585000	1016800	2391100	15000	528900	4336700	34800	2644200	22200	367600	1575900	13518200	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
TOTAL	4710700	2342600	3699300	409500	1657600	8908800	256100	5139100	198400	2016100	3200000	32538200	100

MALAYAN SOILS CLASSIFIED ACCORDING TO THE 7TH APPROXIMATION

by

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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 are now 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 and 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 podsolic 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 irreversably 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_4Cl 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 in 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 acrorthox (the cation retention capacity is an alternative): more than 35% base saturation are the eutrorthox: 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 haplorthox.

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 exceeding 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 typic acrorthox 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 acrorthox due to the presence of concretions at 60 inches.

The eutrorthox is a similar sort of soil to the acrorthox except for its high base saturation, (35%) and higher total bases. Only the Langkawi series developed over limestones fits this group (Joseph 1965).

The haplorthox are again similar to the eutrorthox 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., in press). This therefore, gives us an example of two suborders, 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 placaqods and if it has a histic epipedon then it is a histic placaquod.

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 Lunchu (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 tropofluvent 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 troporthents. The subgroups separate the typic, Holyrood series, from the lithic Bukit Temiang and Bukit Lunchu 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 montmorillionite 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 and 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 aqult, the other examples from the Second 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% plinthite, this seems to vary, the one in South Johore and Selangor may have, but not the Temerloh-Gemas or the Second 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 classification.

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Soil Series Classified According to the 7th Approximation

ORDER	SUB ORDER	GREAT SOIL GROUP	SUB GROUP	SERIES
Entisol	Aquent	Hydraquent	-	Kranji, Linau
		Tropaquent	Typic	Penor
	Orthent	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, Lubock 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
		Haplorthox	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.

Discussion

Moormann: The Holyrood series, well comparable to the Thai Kohong series, should according to its characteristics be classified as a typical Paleudult, in having low weatherable mineral content and a poor differentiation of the A and Bt horizons, with the (weak) Bt horizon being at considerable depth in the profile.

Allbrook: The place of the Holyrood suggests that soils classified as this series do in fact fall into two different orders, viz. entisols and ultisols, and therefore points to the need of tighter soil series classification units.

Moormann: It appears to me that the omission of hardened laterite from the high levels in the classification is relevant. Such material is inert, and basically not different from rocks and gravels. Soft laterite is relatively easy to recognise in field surveys, the more so that hardening can almost always be observed in roadcuts and ditches.

Ng: West Malaysian soils down to the series level were first classified according to the 7th Approximation by Leamy. He based his scheme on criteria of soil morphology, environmental conditions and analytical data. Since Leamy's proposals in 1966, more field and laboratory information has become available and this clearly indicate that a meaningful modification of the present scheme is not justified until more data are collected. It is in this context that Mr. Allbrook's scheme is scrutinized. While many of the suggestions at the order and suborder level are valid, at the lower level, particularly series level, anomalies are quite evident.

Law: Analytical data as demanded by the 7th Approximation should be done first before we begin to attempt to re-classify the soils according to the 7th Approximation. The following anomalies in the present paper are noted:

1) Bukit Lunchau - B. Temiang are shallow Ultisols as these are telescopic. members of the Rengam series.

2) Jambu - on old beach ridges, therefore not aquodic.

3) Gunong Padang - cryaquod because of lower temperature?

4) Bukit Tuku - similar to Holyrood, a Paleudult.

5) Kg Kolam - with reference to Paper 2, Session 1, these soils show a clay bulge, hence are Ultisols.

6) Munchong - this is an intergrade between oxisols and ultisols.

7) Seremban - similar to Tavy series, hence an Ultisol.

8) Briah forms a sequence with Selangor but occupies levees of rivers cutting into the marine plain. Therefore, it is not normal to have a histic epipedon. As a general comment, I would like to add that it is not sufficient to look only at a few soils and try to fit them into the system of the 7th Approximation. We have to look at the range of each series and then choose the modal profiles and fit these modal profiles into the scheme.

Allbrook: The purpose of this paper is to try to fit the new concepts of the 7th Approximation to Malayan soils, not for use as a criticism of previous papers. It is accepted that not sufficient information is available, and pointing out these deficiencies is part of the function of this paper.

METHODS OF DETAIL SOIL CLASSIFICATION AND MAPPING FOR RUBBER GROWING SOILS OF WEST MALAYSIA

by

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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.

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	)
Class C	Moderately well drained	)
Class D	Well drained	) as defined in Soil Survey Manual, USDA.
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 percent 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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Discussion

Law Wei Min: You use as name for your mapping unit e.g. 'Rengam sandy clay 20 to 50 inches deep, 8 to 16 percent slope' I would suggest that instead of using such an unwieldy name use is made of the symbols you already introduced, but with slight modifications in the symbols chosen. Use a capital letter for the depth classes, roman letter for your type of land and perhaps a small letter for the drainage conditions. The name would then become: Rengam sandy clay followed by the appropriate symbols.

Guha: I did not explain the symbols used in our detailed mapping of the rubber growing soils. What we actually do is to use a symbol for each soil mapping unit. The series name is abbreviated with the important letters in its name and written as capital alphabets. This is followed by a small alphabet, from a - z (where necessary this can be further increased in number such as 2a to 2z etc.), to symbolise all soil mapping units at phase level. In the map, the symbols like RGMd or RGM2d represent the soil mapping units. These symbols are explained fully in the legend by giving the full phase characteristics of the soil mapping unit. For example, RGM3c represents Rengam sandy clay, 20 to 50 inches deep and 30 to 65% slope.

Moormann: The suggestion is to use phases as and when required for the specific purpose (in this case rubber growing). Hence, one should introduce phases only when relevant for the specified purpose. This would make the system less top-heavy and 'mechanic'. It is not necessary for every series to have depth phases or drainage phases, this depends on the nature of the series and you can drop drainage phase if the drainage conditions within the series do not vary, but you can make depth phases if this property varies within the series. I would also like to suggest to change the name soil type into soil phase since in the 7th Approximation the name soil type has been dropped.

Guha: If there is general agreement that 7th Approximation will be followed in this respect, the name 'soil type' can easily be dropped from our system.

As pointed out by Dr. Moormann, we do find that some characteristics at the phase level of classification may not be important with respect to a particular soil series, and it should therefore be dropped from consideration while making mapping units at phase level for that particular series. In my paper, I have made reference to a few of such cases. For example, a slope classification is not important in the Selangor Series soils as it invariably occurs on land with less than 3 percent slope

We also find it important that the characteristics of a series, which should be easily recognised either by field or laboratory examination, must be rigidly defined and fixed. If texture etc. of a soil differs substantially so as to affect the growth or yield of rubber, this feature needs to be differentiated at series level. On the other hand, if soils of two different series differentiated on pedological grounds, behave similarly with respect to the growth and yield of rubber, they can still remain separate and be mapped separately. Both soils however, would receive similar recommendation with regard to cultural and fertiliser practices.

Andriesse: Before starting on this project, did you have any indications on the relative importance of the factors you distinguish for phase differentiation for series with reference to rubber growing?

Guha: Yes, e.g. depth. We found that 80% of the feeding roots of rubber are within the top 12 inches; but a depth of about 4 feet of soil is required for the trunk root to give anchorage to the tree. Otherwise the tree may be uprooted by wind, as is often the case with some of the lateritic soils where all the roots are in the topsoil. These judgements are used both in selecting the factors as well as in grading or classifying them.

Ashworth: I note you do not use subsoil texture in your classifications. Is subsoil texture irrelevant to the growth of rubber?

Guha: Subsoil texture is a primary characteristic of a series. If the subsoil texture varies within a series, we first see whether that variability can be allowed without affecting the growth of rubber. If it changes enough to affect the growth of rubber, then we make separate series.

Consideration on topsoil texture is however different. Topsoil texture may depend upon factors like cultivation practice etc. Therefore, it is not considered in the classification at a series level.

Law Wei Min: Dr. Guha is in a fortunate position in that he is dealing with only one crop and a detailed specific system as he is presenting is then possible.

Soil Surveyors are in the unfortunate position where they have to deal with the possibility of growing a wide range of crops and therefore the characteristics cannot be chosen which such a specific purpose in mind. When doing detailed soil mapping for e.g. an Oil Palm Scheme and considering fertiliser recommendations we do map phase of the Rengam Series e.g. Rengam Series, sandy clay and Rengam, coarse sandy clay loam. Such texture differences effect oil palm growing.

Guha: Textural differences become very significant for the growth of rubber at certain textural ranges. For example, in the range of sand - loamy sand - sandy loam, slight differences in texture effect the tree. But in the textural range of clay loam - clay, the textural differences are not that important, but structural differences become more important. These factors are borne in mind in classifying soils for detailed mapping.

Singh: Could you comment on whether chemical nutrient status has a place in your detailed soil classification?

Assuming that our analytical techniques will improve, do you think it possible that we will be able to put phases of series into different fertility levels and do you think that this could then be projected into the phase?

Guha: Most classifications to date in Malaysia are based on physical characteristics only. But should it be found that soils with similar physical characteristics have significantly different chemical composition which affects the performance of the crop, chemical tests and values may be used for classification at phase level. At present it is difficult though may be desirable. With the improvement of analytical techniques this may become possible.

SOIL CORRELATION

SESSION ON SOIL CORRELATION

Introduction by Dr. F.R. Moormann

I am flattered, Mr. Chairman, to have been asked to introduce this subject although, having only been asked yesterday, I have had little time to think about the matter. It is all the more difficult because soil correlation is not a well-defined subject. No one has yet put out a handbook saying how it should be tackled. I propose, therefore, just to give you a few of the factors involved which I consider important.

The first point is that if you want to correlate the soils from various surveys within one country you must standardise your methods of field description and analysis, whether at the series or any other categorical level. The surveys themselves cannot be standardise because this will depend on the techniques used but it is essential to unify the methods of describing the units.

At this Conference the Subcommittee on Standardisation of Analytical Methods has presented a paper of recommendations Already, therefore, you have taken a very important step. Another important advance, in West Malaysia at least, is the Soil Survey Manual for Malayan Conditions produced by Leamy and Panton. This gives descriptions of the main series and, although not complete, is something on which to build. Now you must all agree on which system of profile description you are going to use, what diagnostic characteristics you are going to take to distinguish between units, and so forth, and that must be adhered to.

In other words, if you decide that you are going to use the Malayan manual then even if you find the manual at fault in certain respects you must not alter it at your convenience. This is particularly important when you get technical assistance from outside Malaysia, from Canada, New Zealand, and so forth. When any outside team arrives they must first be told that this is our system of horizon nomenclature, texture descriptions and so on, and they must follow it. At the national level it is essential to impose these conditions. For colour, for example, the Munsell Chart is used by all concerned and not the Japanese or French charts. You are not necessarily saying that that is the best, although you obviously try to get the best, but that you have chosen that one and you are all using that one. If, then, you send assistants abroad for training, don't let them use a different system when they return just because they have been trained in it.

This point is very important in soil correlation. Without such standardisation no one knows what the other man is talking about.

Young soil surveyors will invariably point out that they do not have the experience to describe a soil really well, so it is necessary for the older and more experienced surveyors to explain to them in the field that this is a B horizon and that an A horizon, and so on. You should hold frequent group meetings or seminars to train your young surveyors and exchange them between various areas and this must be a continuing process.

A second point I would make is that Malaysia appears to me to be small enough that you should eventually be able to say for example, that this is a Rengam series and everybody knows what Rengam series is. For this purpose you might think of introducing a system of standard representative profiles. All the soil surveyors, and particularly the senior ones, have in their mind an impression of what a Rengam series is and their impressions are very close together. You should pick out a Rengam in a fairly accessible site and make that a reference site for the series. You do not need to do this for all your series at once. Start with the more extensive ones. At the reference site you then make a detailed profile description or, better still, get all the senior surveyors to make detailed descriptions at the same site. You also send samples from the site to the various laboratories involved so that a fairly good picture of the series can be obtained. From these data you can make a standard soil profile description of your central concept for that series.

You may also consider making monoliths from the representative sites and sending these to other areas in which the series occurs. You can also keep the site in mind so that whenever you have a new intake of assistants you can take them there and say that this is a Rengam, knowing that everyone has agreed on it. In Thailand or Vietnam, even without consciously thinking about it, I have always tended to take new assistants or visitors to sites at which the series classification is well-established and there need be no discussion about it. This system of representative profiles can be refined and, if any conflict arises, you can always go back with the conflicting parties to the type site.

A third point is with regard to the mechanism of correlation. Although I am a democrat at heart I consider correlating is, of necessity, a distatorial business. One man - and usually the best man - should make the final decision on whether a new mapping unit should be a series and, if so, what name it should have. This does not mean that this man has to have personally recognised that soil in the field but he must be the one to take the final responsibility for naming it or at least give his signature to the final name-giving. In the United States, where soil correlation is quite a business due to the size of the country; they have a kind of pyramid system. Every State has a correlator who has the final say at that level in the initial naming or defining of a series. Above him is a regional correlator who covers, say our States so that one can get interstate exchange and see where the series goes to when it crosses a State boundary. Above this man is a senior correlator responsible for broader national areas: the Northeast, the South, the Great Plains, the West Coast, and so on and then right at the top in Washington is the man who makes the final decision. Of course, with 7,000 series established, this man cannot know them all personally but he has the final dictator's power over the whole pyramid.

As I see it, Malaysia should have this sort of system and there should be a senior soil correlator at the Federal level. This system implies a few things. If and when a new survey is started by junior or senior personnel they are forced to use the existing framework of series (the critical descriptions of your series and their permissable variations, which I have already discussed). Now if the surveyor finds something which he says does not fit into the series framework which has been set up, he must not be allowed to set this soil up as a new series, for two reasons. Firstly, the soil may have already been mapped in another area and, especially if he is a junior man, he may not know this. Secondly, his new soil may be of such small importance that you may want to call it a variant rather than a series. In mountainous terrain, in particular, there are always many small variations, particularly in the alluvials, reflecting the variety of the parent materials. To cope with these differences you might establish a thousand series but as their area extend is so small, this is not necessary.

The field man, therefore, does the survey using the series classification which is already established. If something apparently new occurs, I suggest that they map it as an unnamed unit. Do not even give it a name as, once the unit is named, the name tends to stick. In Thailand we use numbers, U1, U2, etc, the 'U' standing for unnamed. At this point your senior correlator takes over. The surveyor says that here are the soils which he cannot classify according to the standardised legend he has been given (or by his understanding of that legend). The correlator will then go into the field and, in many cases, will say that the soil in question is such-and-such a series or is close enough to it to be included within its range. On the other hand the correlator may decide that it is a different soil from those covered by the established classification. In that case, if the soil is sufficiently extensive, then he will give it a provisional name. In Thailand we require that the series be found consistently in two separate areas before we give it a permanent national series name. You may consider it a step system: unnamed mapping unit, provisional series, established series. This system works very well in Thailand and by and large we know what we are speaking about. At the present time there are 120 definite series, about 40 or 50 provisional ones which are used in ad hoc surveys but will probably never become established and quite a number of local unnamed variations.

One final word of warning. Correlation is not a job on which you can put a time-limit. What we do in this respect now is only the best we can do with our present knowledge. If someone like Dr. Guha comes along with evidence that a certain series does not hold together, that we need other limits and so forth, then we must make a new series separation. This brings a whole new problem of correlation and thus the whole thing is in a continual state of flux. Therefore, for your key man, the correlator, it is no use having somebody who is doing the job for only one or two years. It is a fixed and long-term profession. The man should do it for his whole life.

This is certainly not a complete picture but these are some of the points you have to bear in mind. I hope they will be of value to you.

Discussion

Thomas: In one of our correlation subcommittee meetings during the last Conference we did discuss the points which Dr. Moormann has raised. I do think that the ideal situation would be to have a unified official soil survey organisation within Malaysia but such a decision is, of course, way above our heads.

Moormann: I do not think this is possible because you will also have outside organisations, such as Hunting Technical Services, Lockwoods, and so on, coming in to do survey work. What you should insist on is that the final naming of soils and defining of units, even by these outside groups should be done through the soil survey organisation or at least through the soil correlator, and this is where the correlator comes in. Otherwise you are in a mess. In Thailand we have flatly refused to recognise any series which we have not seen ourselves and agreed on the name. This is a very important point. Anyone can do the survey but they must adhere to these rules and submit themselves to your little dictator, the soil correlator.

Thomas: What you have just said was one of the recommendations of our first meeting held in 1964. Soil naming was to be the responsibility of the individual Government soil survey organisations. I do not know how this works out in West Malaysia.

Law: As far as naming series is concerned, there is only one group of outsiders which does not adhere to this and they have been naming soils right and left without describing them. We are, however, moving in the right direction now. The final name is left to me to choose. If the area covered by a particular soil is very small we do not give it a special name.

Andriesse: This may be only my personal view as I have not had much time during the Conference to discuss it with my colleague Mr. Scott but I could not agree more with Dr. Moormann that soil correlation work in Malaysia should be left in the hands of one man who should go around the whole of Malaysia and that we, in the various States, should just have people who would be responsible for getting together the information he needs and for showing him around, rather than setting up a subcommittee for correlation. It is impossible for any member of a committee to know all the soils within Malaysia. He knows his own soils of course but they may be only of small importance from a national point of view. One of our main soil series in Sarawak may cover only a small percentage of Malaysia as a whole. Only a soil correlator for the whole of Malaysia can visualise this and see the relative importance of these differences. So I would say that it is all right to have a subcommittee on correlation at the moment but mainly to make recommendations to Federal Government regarding the establishment of a correlator for the whole of Malaysia as part of the Development Plan. As things are at present I do not think we are likely to end up anywhere. Apart from this, there are a number of expatriate surveyors working in the various States and who do not have a permanent future here. We have accumulated some experience over the years but once we have left who is going to take over? There should be one man, preferably one who is going to stay here, who can accumulate all this knowledge which is required for soil correlating.

Thomas: I would suggest that Mr. Andriesse's suggestion be put forward as a formal recommendation from the Conference.

Andriesse: We should even be prepared to name soils the same if certain soils in East and West Malaysia are proved to be the same. We should not be too nationalistic about such naming and be prepared to discard names if there is something better to put in their place. It is further suggested that the correlation subcommittee which will be meeting tonight discuss this proposal and work out the details of the mechanics of correlation.

Ng: The Malaysian Government has agreed in principle to establish a Malaysian Agricultural Research and Development Institute. This will be based in West Malaysia but it is also envisaged to cover East Malaysia. Details of this organisation are being looked into at present and we do not expect that it will come into being for two or three years yet. But we have the opportunity to discuss with the consultants these proposals for broadening soil science on a nation-wide basis for the future. This may be the appropriate institution under which to have the national soil survey and a national soil correlator.

Andriesse: I would like to emphasise that while soil correlation work should be on a national basis soil survey should not necessarily be so at this stage.