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Report on Soil Investigations

in the

PROPOSED SUNGAI SARAWAK PADI SCHEME AREA

1st Division

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Contents

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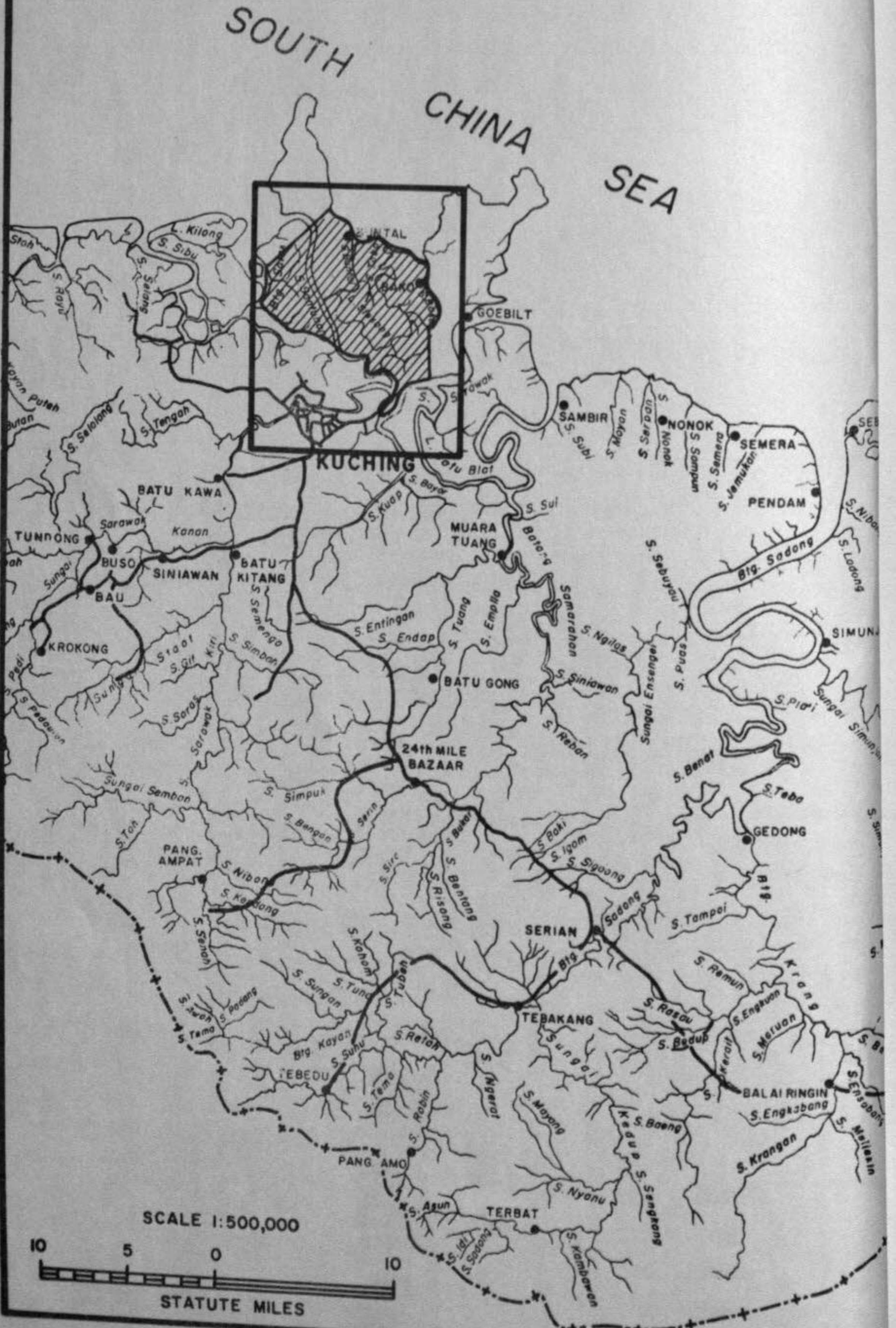
1 Location Map (Map 1) scale 1:500,000

Volume II to this report contains:

- Map 2 - Reconnaissance Soil Map scale 1:50,000
- Map 3 - Location of sample areas scale 1:50,000
- Map 4 - Soil acidity scale 1:10,000 sheet A and B
- Map 5 - Soil salinity scale 1:10,000 sheet A and B
- Map 6 - Soil Sulphur contents scale 1:10,000 sheet A and B
- Map 7 - Vegetation map and occurrence of mud lobster mounds scale 1:10,000 sheet A and B.

Location of SUNGAI SARAWAK PADI SCHEME



REPORT ON SOIL INVESTIGATIONS IN THE PROPOSED SUNGEI SARAWAK PADI SCHEME AREA - FIRST DIVISION

by

J. P. Andriesse and E. S. Sim.

This report is divided into three parts. Part I deals with field investigations carried out by the Soils Division of the Research Branch in the Agriculture Department, while Part II deals with laboratory investigations carried out on soil samples by the Chemistry Division of the same branch in the Agriculture Department. Part III deals with the results of both types of investigation.

Part I - FIELD INVESTIGATIONS

Introduction

The proposed area for the Sungei Sarawak Padi Scheme is situated in the Sarawak river delta as indicated on the location map. (Map 1). The exact boundaries of the area cannot be given since these can only be drawn after the feasibility survey has been completed. The land to be used for this scheme, however, is situated within the area embounded on the location map.

Reasons for the initial selection of this area for a wet padi scheme are manifold: the main considerations, however, being that it is the only suitable (that is flat land) of the required extent (that is, at least 20,000 acres) available in Sarawak for wet padi cultivation. All other land, from a topographical point of view perhaps suitable for wet padi cultivation, being either deep peat or the land consists of a multitude of small areas for which a large scheme would not be feasible.

Another major consideration was that the area is mainly unencumbered State Land so that it could be made available for a Scheme without much difficulty.

The whole area was soil surveyed at a reconnaissance level during 1965 (Soil Survey Report 25/2 refers) and it was then reported that the majority of the area contained soils of the Rajang and Pendam families, the former being characterised by strong to moderately saline conditions while in the latter saline conditions are moderate to low. Details on the soils can be found in Appendix A. Map 2 is a reproduction of the reconnaissance soil map for the area and is extracted from Soil Survey Report 25/2. Both soil families have poor physical conditions which before cultivation must be improved upon. The watertables are generally too high, frequently at the surface in natural condition and flooding

.../2

can be expected throughout the year, particularly at times of spring tides. Bunding and drainage therefore are prerequisites for the economic success of any agricultural enterprise.

For many decades the coastal people in Sarawak have tried to develop such soils with moderate success. A typical example is the Nonok Peninsula. It was noted that in many such areas coconut did not grow very well since it was thought that the drainage was not sufficient and that salt water incursion might damage the coconut. Consequently it was advocated that bunding and the construction of proper drains would improve the cultivation of coconut.

It has also been known for some time that the Rajang and Pendam series upon drainage change their characteristics due to a high content of sulphur which is not harmful in a soil when it is waterlogged but with increasing drainage such sulphur compounds are oxidised and become toxic to plants. Studies into this harmful effect of drainage on these soils were carried out in Nonok during 1964 but the extent of damage due to the toxic soils appeared to be small which was probably due to the fact that nowhere in the Nonok Peninsula the land is really deeply drained and dried out sufficiently to being about this harmful effect. With the initiation of the Santubong Coconut Drainage Scheme during 1966 a chance to study this change in chemical characteristics upon drainage was created and subsequently a proposal was made to study such soil changes from the beginning of the scheme so that valuable information could be collected on the intensity of such changes and their possible effect on crop growth. In December 1966, a report was issued on the first sampling and analytical work and it was found that a potential danger for the formatioh of such toxic soils, called 'cat-clays' was existent but that the location of sites where this danger was present was too erratic to map it properly. Although it could be established that a potential danger was existent the effect of the formation of catclay upon reclamation on coconut cultivation cannot be assessed until coconut is actually grown on such soils. The Santubong Drainage Scheme is in that sense a pilot scheme aimed at studying these factors.

With the selection of the Sarawak Padi Scheme Area this problem has become of major importance. The soils in this scheme area are identical to those found in the Santubong Drainage Scheme and it was obvious that a study into the occurrence of potential 'catclays' (termed 'mud-clays') had to be the major task in the soil investigations to be carried out.

Potential catclays ('mud-clays') cannot be studied or mapped in the field since catclays proper only form after the soil is oxidised upon provision of drainage. Therefore such oxidizing conditions had to be simulated under laboratory conditions to approach the natural conditions as much as possible. Details on the methods employed can be found in the introduction to Part II in this report. Such studies had to be done over a great number of soil samples to get the desirable statistically sound results.

Such a study over an area of 20,000 acres would have involved the taking of thousands of samples which, with the subsequent laboratory studies, would have taken a long time before a satisfactory answer could be produced.

For this reason sample areas were selected in the whole Scheme Area (a total of 7). These areas are marked on Map 3. The selection of the sample areas was approved by the Drainage and Irrigation Department which from the beginning of this study showed great interest in the project.

Methods employed

In each sample area rentises were cut at a distance of 400 m (440 yard) and running as far as feasible parallel to each other. To speed up the work rentises were cut on compass bearings and they can therefore not be regarded as perfectly straight. The thick stand of Nipah made it also impossible to keep straight lines. The rentises therefore do not serve as a basis for a correct soil map but must be considered as sample strips for which the relatively inaccurate position is not a necessity. Within the sample strips the following observations were made and recorded:-

(i) - vegetation
(ii) - intensity of the occurrence of mud lobster mounds
(iii) - average height of mounds
(iv) - depth of watertable
(v) - presence of organic matter

Observations on vegetation and mud lobster mounds were recorded at every 25 m point in the cutlines. Soil samples approx. 1 lbs each were collected at every 150 m point, together with the records on presence of organic matter and the depth of watertable. At every sampling point three samples were collected: top sample 0 - 6 inches, first subsoil sample 12 - 18 inches, second subsoil sample 24 - 30 inches. The samples were sealed in polythene bags to keep them in field condition. The location of the sample points in relation to the occurrence of mud lobster mounds were recorded as follows:

a. On top of mound
b. On slope of mound
c. On foot of mound
d. In between mounds
e. No mounds.

This was thought necessary in order to be able to interprete the chemical values of the samples correctly, since it is assumed that the top of the mounds consist of subsoil as generally material from below the surface is brought to the surface by these lobsters. The number of mounds occurring per 25 meter of sampling strip was recorded in order to investigate whether the occurrence of potential catclay or the depth at which it occurred was in any way related to the occurrence of lobster mounds. Also the height of the mounds was noted. These possibly reflect height of flooding and if a level survey is made at a later stage a correlation may possibly be found.

Organic matter was noted to investigate whether accumulation of debris from Nipah palms would correlate with the occurrence of high sulphur contents in the soils. A sample of the record sheet can be found in Appendix B.

Initially, it was attempted to carry out Electric Conductivity tests (indicative of soluble salt content in the soil) in the field. With the laboratory nearby in Kuching and a faulty meter in the field, it appeared to be more sensible to make these tests in the laboratory. Also, the difficulty to find fresh water for cleaning the instrument in a general saline environment made it difficult to continue with these tests.

At regular periods, the samples were dispatched to Kuching for onward transmission to Semongok Chemistry Laboratory. In all 1,980 soil samples were collected from the 7 sample areas. The field investigations which started on 1st May, 1968 were broken off on the 30th May and continued again on 17th June. The survey was completed on 29th June.

PART II - LABORATORY INVESTIGATIONS

Introduction

Because of the possibility that catclay would form after reclamation of the Rajang and Pendam family soils (see also under Introduction to Part I) investigation emphasis has been given to this aspect. Throughout the text of this report the following meanings must be attached to the used nomenclature: (ref. 3).

Acid-Sulphate soils - soils in which materials occur which give rise to high acidity upon oxidation. This term includes also soils in the non drained, non-oxidised state under Mangrove and Nipah vegetation in which such materials may be found. The latter are also called mudclays.

Catclays - Acid soils in the oxidised state showing straw yellow mottlings and streaks of basic ferric sulphate.

It should be realised that the area under study does not contain catclays in any appreciable amounts but that the likelihood of the formation of such catclays has been studied.

Acid sulphate soils, commonly known as 'catclays' occur widely in tropics as well as in temperate zones, particularly in the most tropical countries adjacent to the sea like Vietnam, Thailand, East Pakistan, Indonesia, coastal areas of Sumatra, Malaya, Borneo, East and West coasts of the continent. It can be expected that after reclamation this type of soil will also form in the tidal nipah and mangrove swamps along Sungei Sarawak, the proposed padi scheme area now under investigation.

Conditions of formation

As the name implies, acid sulphate soils are characterised by high acidities due to the presence of excessive amounts of oxidisable sulphur compounds, mainly iron sulphides. Although there are different forms of sulphides, the marine sediments contain sulphides mainly in the form of pyrite FeS_2. The sources of sulphur are the sulphates in sea-water, organic sulphur and the sulphur in sulphur-bearing rocks. Under submerged conditions, the pH of the subsoil remains slightly acid or even alkaline. Under sufficiently reducing conditions, hydrogen sulphide is produced by microbiological reduction of sulphates and in the presence of iron compounds forms FeS. H_2O (hydroxoilite) and in turn converts into $FeS_2.H_2O$ (malnikovite). Both $FeS.H_2O$ and $FeS_2.H_2O$ are black and give the soils a black colour. Therefore the conditions of formation are a supply of sulphates, the quantity of organic matter present, other reducing environment and the presence of reactive iron.

Oxidation

When the reducing conditions are terminated by drainage and reclamation, air penetrates into the soil to oxidise the sulphides, converting them into ferreous sulphate and H_2SO_4. The oxidation process is attributed to biological factors (1) and the rate (2) is controlled by moisture content, form of sulphide and particle size distribution of the sulphide compounds. The optimum moisture content for sulphide oxidation is about 30%, oxidation proceeds more slowly by air drying. In the Sierra Leone soils, a stable pH value was attained after drying for 28 days (1). At present there is no information on the form of sulphides in Sarawak soils. The fact that large quantities of the pale yellow basic ferric sulphate are found suggests that the greater proportion is FeS_2H_2O (malnikorite) and FeS_2 (pyrite) because oxidation of FeS will not produce any yellow basic ferric sulphate (3). Oxidation of pyrite is normally regarded as being important only below pH 3.0 (2).

Ferrous sulphate formed by oxidation of pyrites is further oxidised to ferric sulphate which is then readily hydrolysed to basic ferric sulphate $Fe_2 (SO4)_2 (OH)_2$ and sulphuric acid. This yellow basic ferric sulphate is deposited in the soil along the cracks and root fissures and can be converted into the yellow mineral jarosite $K Fe_3^{3+} (SO4)_2 (OH)_6$.

Agricultural problem

The acid sulphate soil presents a major agricultural problem because the introduction of air will initiate the oxidation processes and a very low pH develops. In the absence of $CaCO_3$ the resulting sulphuric acid acts upon exchangeable bases and causes the breakdonw of the clay lattices Aluminium and iron released will be available for exchange reactions, giving rise to a highly toxic effect on crops.

In general, acid sulphate soils are low in fertility level and poor in physical soil conditions and show unfavourable characteristics for agricultural use. The value of the soils is largely dependent upon the potential acidity and on the original sulphur content. The lower this content, the less serious is the problem. In Vietnam, most soils with a low pH value of 3.5 or less are not cultivated. Moist soils of which the low pH value varies from 3.5 to 5 are being used for rice. In the Mekong delta, even soils with a potential pH minimum of 2.8 are in continuous use for rice cultivation [3].

Characterisation by chemical analysis

Suitable routine chemical analysis for characterising acid sulphate soils would be of great value if they are to be mapped.

The pH of the soil (before and after drying in the case of soils not yet oxidised) and the content of sulphur are probably the most important values in characterising acid sulphate soils. (Laboratory identification is reliable and soils which develop a low pH and high sulphate content on drying are definitely acid sulphate soils. According to J.K. Coulter [2], an acid sulphate layer could be defined as one with a pH of about 3.3 or less on the air dried soil and a soluble sulphate content in the air-dried soil exceeding 0.1%.

pH values alone cannot indicate the magnitude of potential acidity which in fact is largely dependent on the sulphur content. The total sulphur indicates relatively more resistant material while soluble sulphate and extractable sulphates indicate a more active component.

.../7

Salinity

Since the soils concerned are classified as Saline Gley soils, it is important also to measure the soil salinity. One simple and rapid method of determining concentration of total salts in soil is the measurement of conductivity of the soil extract. Moreover, the conductivity of the saturation extract is recommended as a general method for appraising soil salinity in relation to plant growth.

Materials

The 1980 soil samples (660 soil profiles) collected under field conditions are referred to as wet soils. These were air-dried for one month, alternated with wetting at 5 - 6 days' intervals, and finally sun-dried for about 8 hours and are referred to as air-dried soils.

Methods of Analysis

pH: This was determined for the wet and air-dried soil at a soil : water ratio of 1 : 2.5 using a PYE pH meter. The reading was taken immediately after soil suspension was prepared for 'wet' pH and after overnight for 'dry' pH.

Water soluble sulphate

This was carried out on air-dried soils according to the method [4] of Massoumi and Cornfield except a soil : water ratio of 1 : 5 was used instead of 1 : 2 for extraction. An aliquot was taken to form turbidity with barium chloride in the pressence of HNO_3, acetic - phosphoric acid and gum acacia. Optical density was measured with a Hilger Spekker absorptiometer using dark blue filter.

Extractable sulphate

This was also determined turbidometrically [5]. 5 gms of air-dried soil were extracted with 50 mls of Morgan reagent (pH 5.0) and approximately 0.1 gm charcoal. An aliquot was taken to form turbidity with $BaCl_2$ and hydrochloric acid in the presence of gum acacia. The optical density was measured in a EEL colorimeter using blue filter.

Total sulphur

This was also determined turbidometrically according to the method of Butters and Chenery[6]. 1 gm of air-dried soil was heated with a solution of magnesium nitrate evaporated to dryness and gently ignited. The soilwas then extracted with nitric acid and dilute to 50 ml. An aliquot was taken to develop turbidity with $BaCl_2$ in the presence of acetic acid - phosphoric acid and gum acacia. The optical density was measured in Hilger Spekker absorptiometer using Kodak filter No. 3.

Conductivity

This was determined for the wet and air-dried soils at 1 : 5 soil : water ratio after shaking end-over-end for one hour or leaving it for overnight using a Mullard Conductivity Bridge.

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(1) Hart M.G.R., Plant and soil 1959 11, 215.
(2) J.K. Coulter, acid-sulphate soils in Malaya.
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(4) A. Massoumi and A.H. Cornfield, Analyst 1963 88 p.321.
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(7) M.L. Jackson, Soil Chemical analysis 1958 p.244. (adapted from Diagnosis and Improvement of Saline & Alkali Soils U.S.D.A. Agric. Handbook 60 p.9 1954).
(8) C. Bloomfield Report on a visit to Malaya, under the Colombo Plan, 25th April to 4th June, 1967.
(9) T.A. EL Baradi, Acid sulphate soils in the Tropics. Trop. Abs. 1967 22 p.137 - 140.
(10) Beers W.E., J. Van. Acid sulphate soils. Bull. Int. Inst. Land Reclamation & Improvement. 1962. 3. p. 1 - 31.

PART III - RESULTS OF INVESTIGATIONS

Mode of presentation of results

Field and laboratory investigations yielded a vast amount of factual data from which it is extremely difficult to extract salient points without a statistical analysis.

For this reason instead of producing this bulk of analytical information, only the statistical analysis is presented in a number of diagrams, maps and tables for which the interpretation is given in the text of this report.

The material is presented in such an order that each factor which plays a role in the formation of catclays can be studied separately.

The first section of Part III deals specifically with the statistical analysis of laboratory results while the second section attempts to correlate these laboratory results with field information collected on vegetation and the occurrence of mud lobster mounds which, as it will appear, are playing a major role in the development of high acidity in top soils in a considerable part of the area.

1. RESULTS OF LABORATORY INVESTIGATION by E. S. Sim.

Studies on Soil Acidity

The pH of soil influences the availability and uptake of mineral elements by the plant. Although good paddy soils usually range from 5.5 to 6.5 different varieties of rice are adapted to pH conditions ranging from 3.5 to 8.4. In West Africa Tomlinson* found that below pH 4.0 growth of paddy was greatly reduced and below pH 3.0, it could not survive. Soils with pH values less than 3.5 generally lack nutrients and have low base saturation. High acidity can render phosphorus unavailable and leaches plant nutrients from the soil, while on the other hand, it produces toxic amount of iron and aluminium in soil. At pH values below 2.5, acidity can even be by itself harmful to the plant.

The pH of Sarawak soils normally ranges from 4.0 - 6.0. For the sake of appraisal, the soil acidity could be arbitrarily classified as follows:

pH	Soil Acidity
≤ 3.5	high
3.6 - 4.5	medium
4.6 - 5.9	low
> 6.0	very low (neutral/alkaline)

Reference Map 4 The individual distribution of soil acidity of the 660 soil profiles on the sampling localities for both wet and air-dried conditions is shown in Map 4. Four pH groups namely:

pH	< 3.5
pH	3.5 - 4.5
pH	> 4.5
pH	> 4.5 (drop of at least 1 unit after air-drying)

were used for mapping. Generally speaking, low pH is associated with H2S and H_2SO_4 production and high pH associated with salinity. Soils with pH > 4.5 and a drop of at least 1 unit on drying are believed to be associated with oxidation of sulphur compounds in the soil.

As seen from the maps, soils having potential high acidity occur scattered throughout the whole area and are not confined only to particular locations.

* Tomlinson T. E. (1957) Emp. J. Exp. Agric. 25.108.

.../10

Reference Diagram 1

This diagram shows the frequency distribution of pH values for wet and air-dried samples at three depths. Table 1 shows the changes in percentage of each acidity group within each depth along the profiles under field and dry conditions and the effect on soil acidity upon drying.

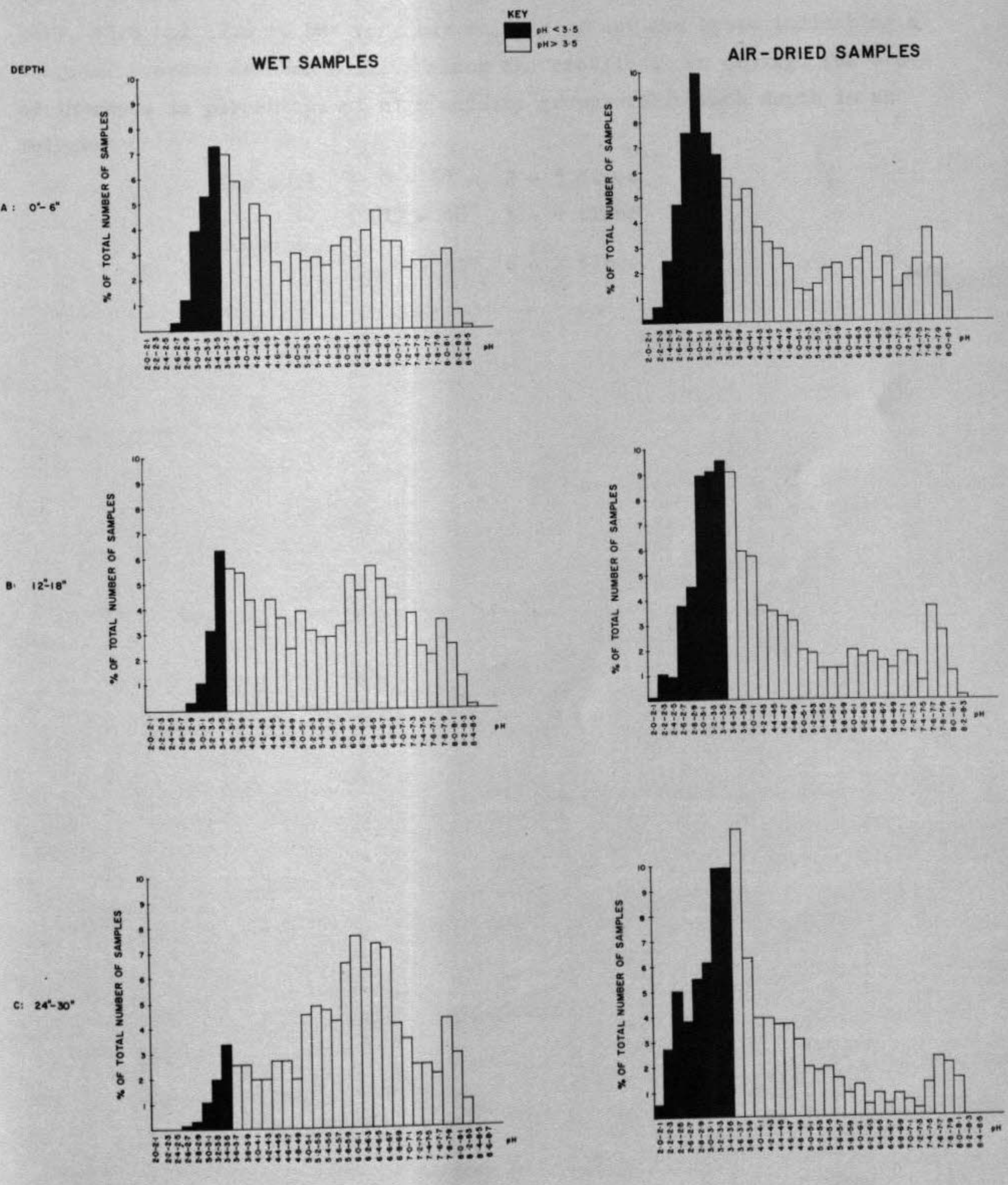
Table 1 % age of each acidity group within each depth

Condition	Wet				Air-dried			
Acidity	high	medium	low	very low	high	medium	low	very low
pH / Depth	pH<3.5	pH 3.6–4.5	pH 4.6–5.9	pH>6.0	pH<3.5	pH 3.6–4.5	pH 4.6–5.9	pH>6.0
0 - 6	18.0	26.1	19.2	36.7	39.6	22.8	13.6	24.0
12 - 18"	10.9	25.2	22.3	41.6	38.0	28.0	14.0	20.0
24 - 30"	6.7	11.7	29.4	52.2	43.4	29.2	15.1	12.3

DIAGRAM I.

FREQUENCY DISTRIBUTION DIAGRAM OF pH VALUES FOR WET AND AIR-DRIED SAMPLES AT 3 DEPTHS.

(660 PROFILES)

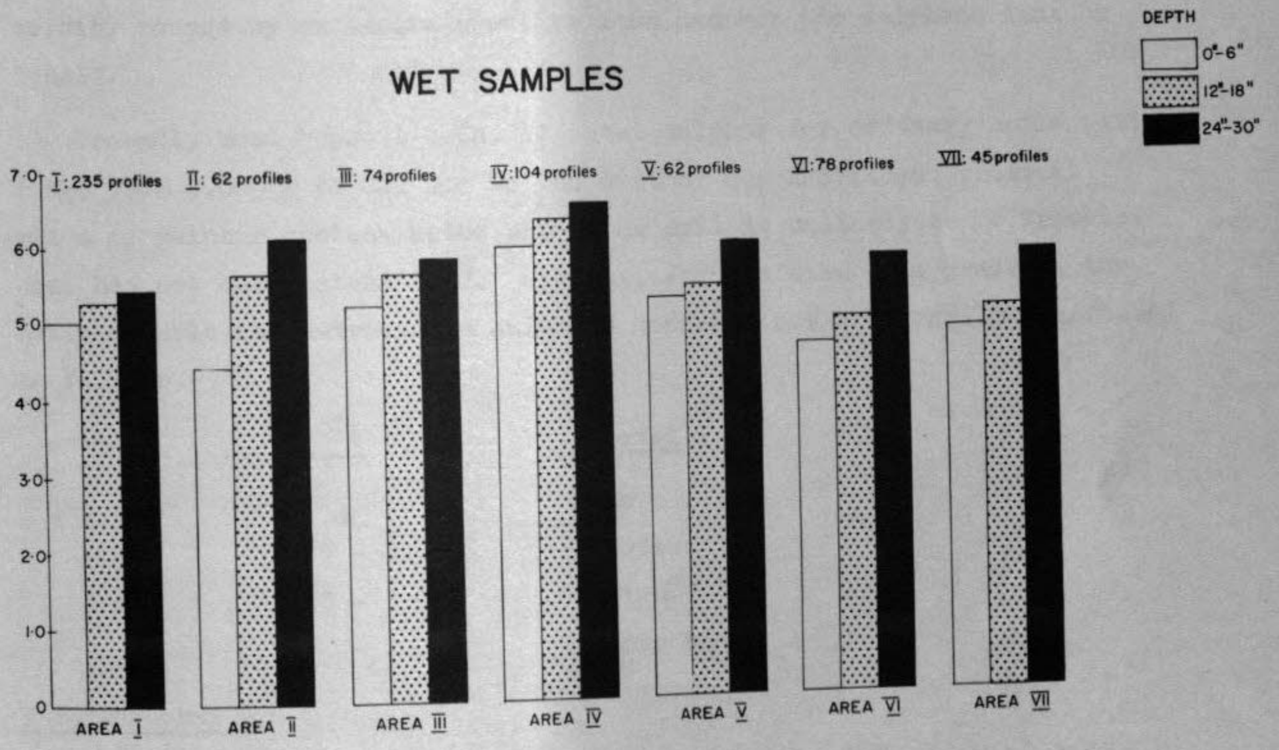


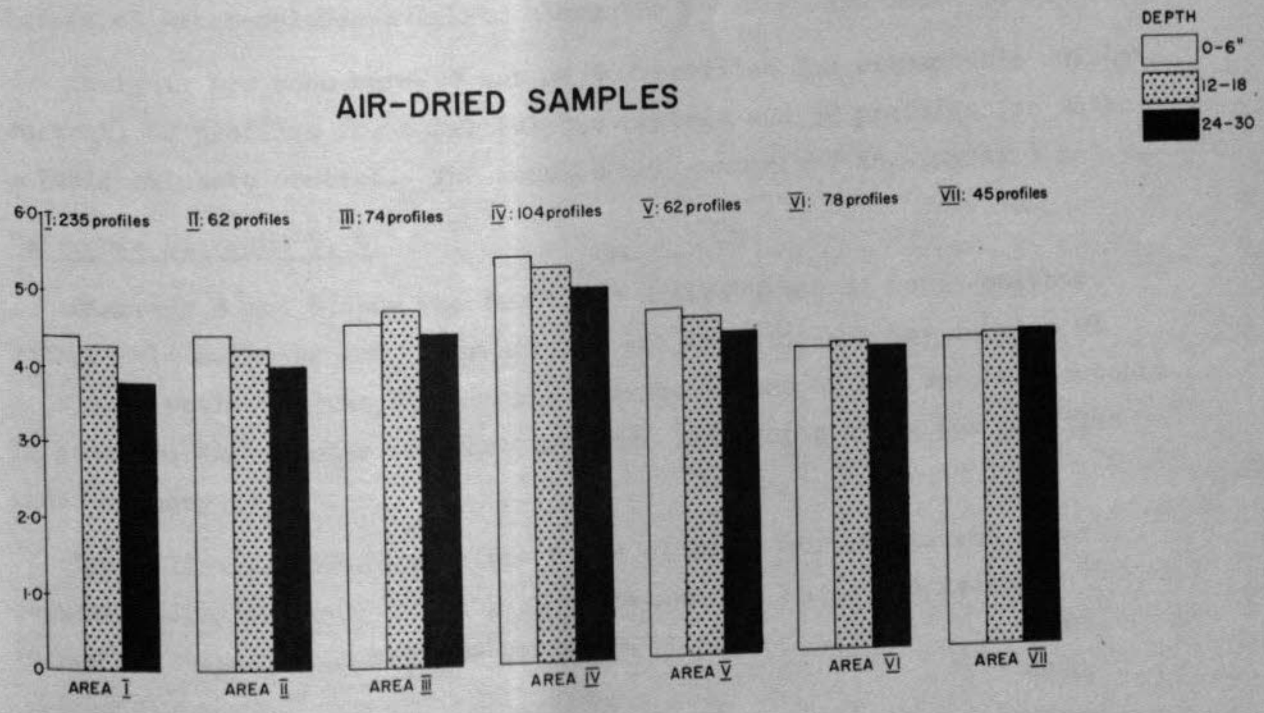
Regardless of the sampling locations, approximately 40% of the total no. of samples will develop high acidity on drying and drainage. Under field conditions, the changes in percentage of each acidity group along the profiles are 18.0, 10.9 and 6.7, on the high acidity group and 36.7, 41.6 and 52.2 on the very low acidity group, and hence indicating a decreasing order of soil acidity along the profiles. On drying, the order of increase in percentage of high acidity group within each depth is as follows:

Top soil	0 - 6"	2 - 3 times
Subsoil	(12 - 18"	3 - 4 times
	(24 - 30"	6 - 7 times.

DIAGRAM 5

AVERAGE DIAGRAM OF pH VALUES OF WET AND AIR-DRIED SAMPLES AT 3 DEPTHS FOR SAMPLE AREAS I-VII





Studies on Sulphur Contents

Soils in coastal areas carrying mangrove, nipah and other species contain large amounts of sulphur. The amount of sulphur in soil is not by itself critical to plant growth. This should be considered together with the cations present such as Ca, Mg, K, Fe, Al, Mn, etc. A soil with high S content may be neutralised by sufficient metallic cations and hence could be good to padi while another with less S and cations would be worse. The factor which inhibits plant growth is in fact potential acidity caused by excessive negative ions and not the sulphate ions by itself.

Probably most topsoil value of total sulphur for ordinary soils will range from 0.005 % to 0.2 %. To the best of our knowledge, critical value of sulphur content below which the soil is unlikely to be troublesome has not been established. However, for the sake of appraisal, the water-soluble and extractable sulphate contents are arbitrarily classified as follows:-

% SO_4	Level
< 0.1	Low
0.1 - 0.5	Medium
0.5 - 1.0	High
> 1.0	Very high

Reference Map 6

The sampling localities of the selected profiles analysed for total sulphur, morgan-extractable sulphate and water soluble sulphate and the levels of water-soluble sulphate along the profiles are shown in Map 6.

Analysis has been carried out on 107 profiles for extractable sulphate content, 62 profiles for total sulphur content and 52 profiles for water-soluble sulphate content. The results are summarised in Diagram 3 and 4.

Reference Diagrams 3, 4

Diagrams 3 and 4 show the frequency distribution of total sulphur, extractable sulphate and water-soluble sulphate for air-dry samples at 3 depths, while diagram 6 shows the average values of the sulphur contents. In general, the sulphur contents increase with depth along the profiles under air-dry condition.

The following tables show the % age of each extractable and water-soluble sulphate group within each depth and the range and average values of sulphur contents respectively.

DIAGRAM 3

FREQUENCY DISTRIBUTION DIAGRAM OF SOLUBLE SULPHUR CONTENTS OF AIR-DRIED SAMPLES AT 3 DEPTHS (ON OVEN-DRY BASIS)

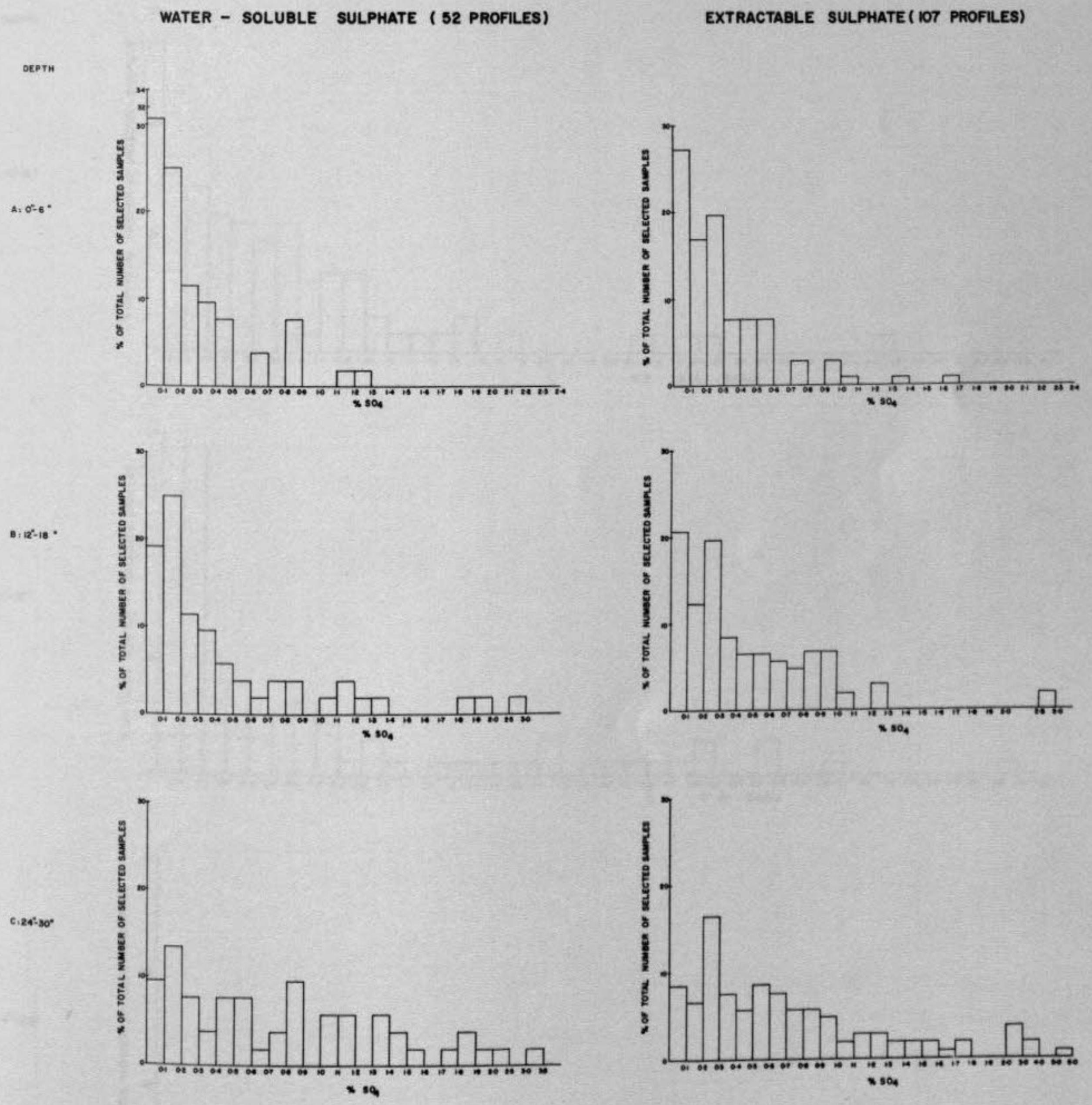


DIAGRAM 4

FREQUENCY DISTRIBUTION DIAGRAM OF TOTAL SULPHUR CONTENTS OF AIR-DRIED SAMPLES AT 3 DEPTHS (62 PROFILES)

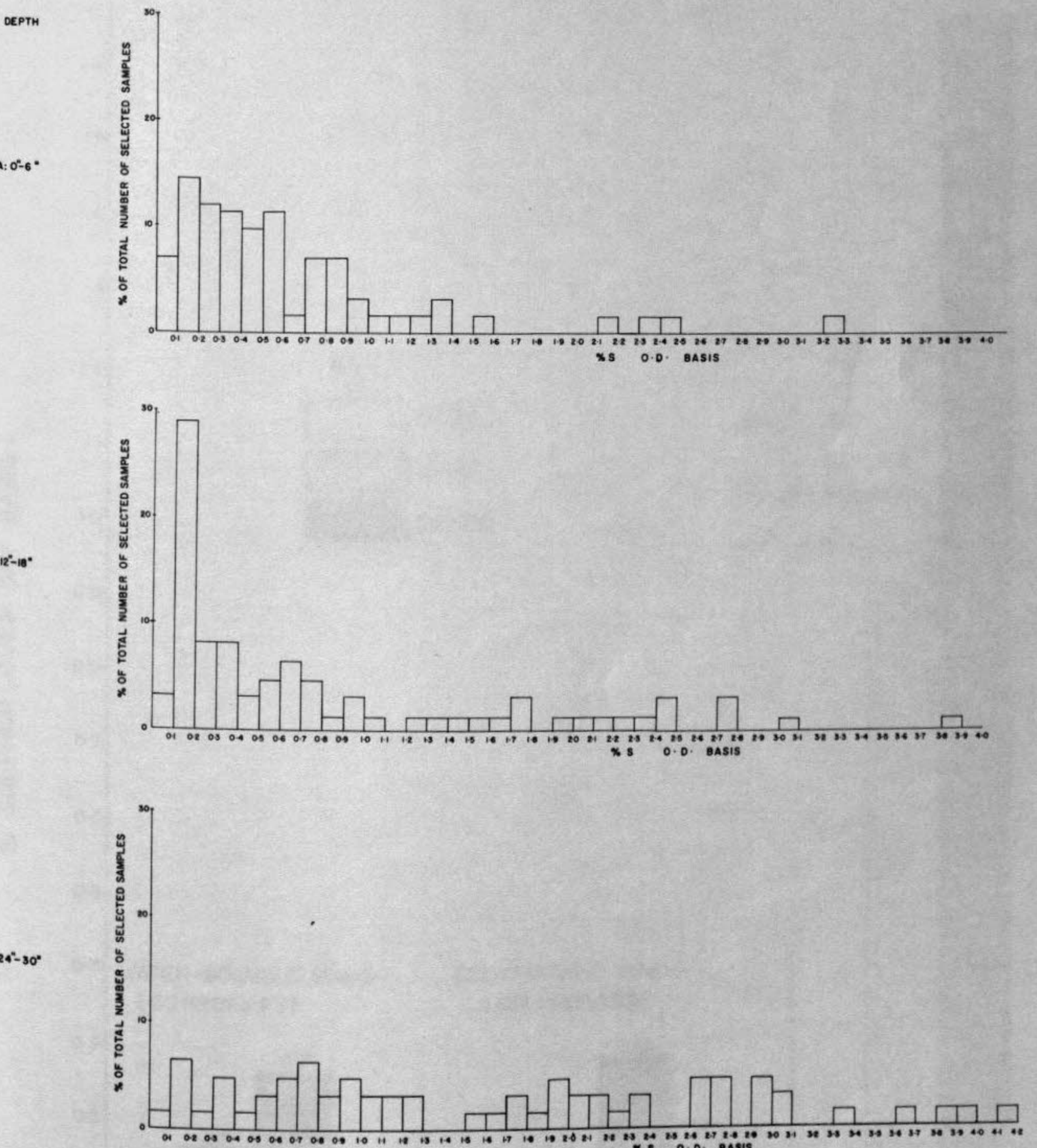
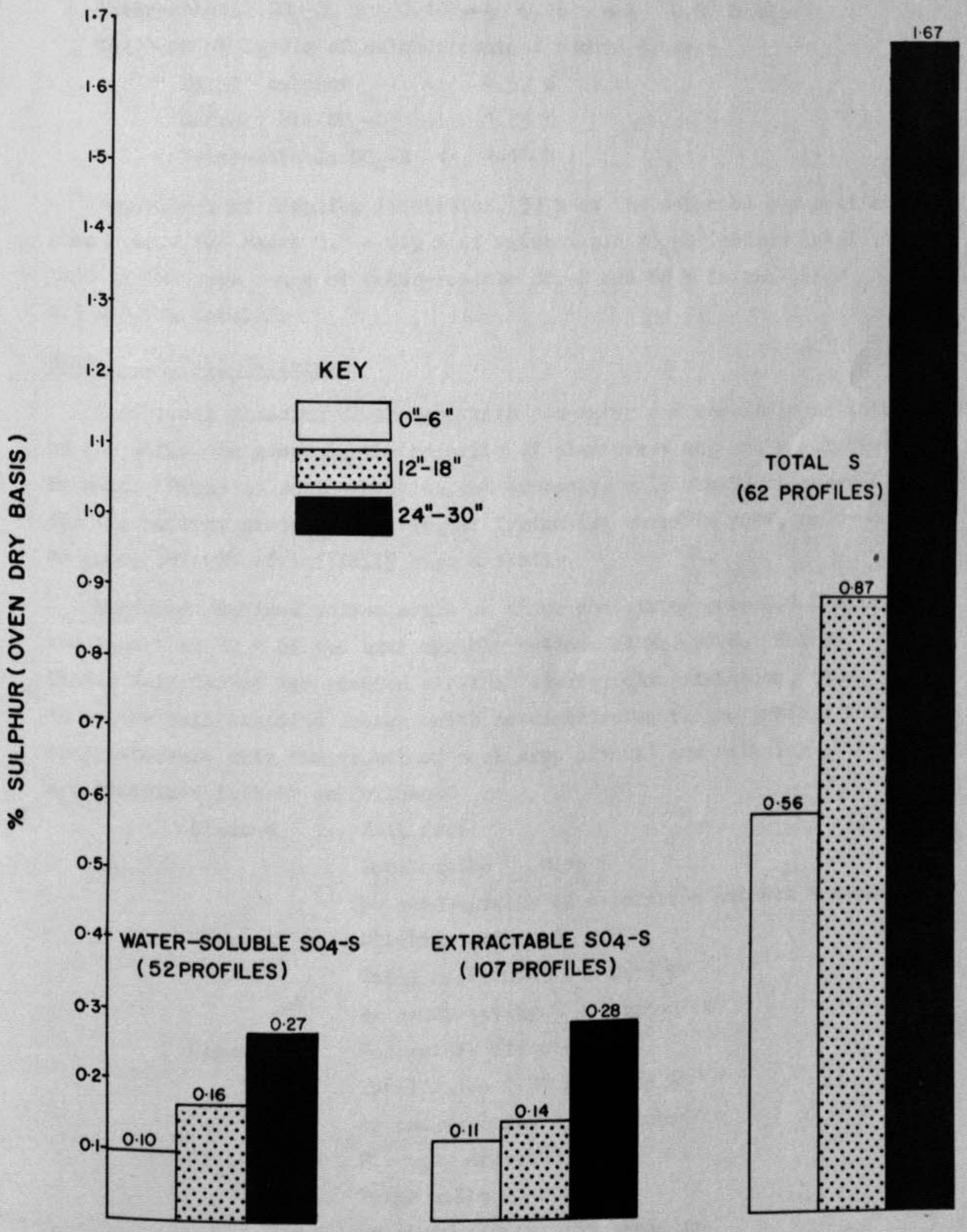


DIAGRAM 6

AVERAGE DIAGRAM OF SULPHUR CONTENTS OF AIR-DRIED SAMPLES AT 3 DEPTHS.



It can be seen from Table 3 and 4 respectively that the values in the low level and medium level groups decrease, while those in the high level and very high level groups increase with depth, hence indicating an increase in sulphur content along the profiles. The average increase in total S, morgan-extractable SO_4-S and water-soluble SO_4-S is shown in Table 5 as follws:

Content		0 - 6" --- 12 - 18" --- 24 - 30"
Total S	:	0.56 ⟶ 0.87 ⟶ 1.67 % S
Extractable SO_4-S	:	0.11 ⟶ 0.14 ⟶ 0.28 % SO_4-S
Water-soluble SO_4-S	:	0.10 ⟶ 0.16 ⟶ 0.27 % SO_4-S

The highest levels of sulphur content recorded are:-

Total sulphur	:	4.57 %
Extractable SO_4-S	:	1.83 %
Water-soluble SO_4-S	:	1.14 %

Regardless of sampling localities, 51 % of the selected top soil samples lie in the range 0.1 - 0.5 % of extractable SO_4-S (medium level), 54 % in the same range of water-soluble $S\theta_4$-S and 66 % in the range 0.1 - 0.7 % total S.

Studies on Soil Salinity

Occasional flooding of an area with sea-water can result in salinity of the soil. In general, the majority of plants are adversely affected by salt. Paddy is salt sensitive and excessive salt should be removed for its healthy growth. However, if irrigation water is good, paddy may be grown in soil of initially high salinity.

Magistad* defined saline soils as those containing over 0.1 % salt and less than 12 % of the exchangeable cations as Na and K. United States Soil Survey has adopted a rather similar classification, thus 'A saline soil contains enough salts so distributed in the profile that they interfere with the growth of most crop plants' and salinity classes are described further as follows:-

Class 0	:	Salt free Total salts 0.15 % or conductivity of saturation extract 4 mmhos/cm
Class 1	:	Slightly affected Total salts 0.15 % - 0.35 % or conductivity 4 - 8 mmhos/cm
Class 2	:	Moderately affected Total salts 0.35 % - 0.65 % or conductivity 8 - 15 mmhos/cm
Class 3	:	Strongly affected Total salts 0.65 % or conductivity 15 mmhos/cm

.../16

While U.S. Salinity Laboratory has adopted a very similar and more detailed classification for appraising soil salinity in relation to plant growth.

Salinity Scale

Conductivity of saturation extract of soil (millimhos/cm at 2 °C)

0	2	4	8	16
Non saline	Very slightly saline	Moderately saline	Strongly saline	Very strongly saline
Salinity effects mostly negligible	Yields of very sensitive crops may be restricted.	Yields of many crops restricted. Alfalfa, cotton, sugar beets, <u>cereals</u>, and grain sorghums adapted	Only tolerant crops yield satisfactorily. Bare spots appear because of injury to germination	Only a few very tolerant crops yield satisfactorily. Only salt tolerant grasses herbaceous plants, shrubs and trees grow

The latter system is used for mapping and appraisal in this report.

<u>Reference Map 5</u>

The individual distribution of soil salinity of the 660 soil profiles on the sampling localities for wet and air-dried conditions is shown in Map 5. Five salinity groups namely:-

<u>Conductivity micro mhos/cm at 25°C</u>	<u>Level</u>
0 - 2000	None saline
2001 - 4000	Very slightly saline
4001 - 8000	Moderately saline
8001 - 16000	Highly saline
> 16000	Very highly saline

are used for mapping. Generally speaking, soil profiles near the rivers are only very slightly saline, but more saline than those further away from the rivers. The latter is chiefly of non-saline group, but becomes very slightly or moderately saline after drying.

<u>Reference Diagram 2</u>

This diagram shows the frequency distribution of conductivity values for wet and air-dried samples at three depths. Table 6 shows the changes in % age of each salinity drop within each depth along the profiles under field and dry conditions and the effect on soil salinity upon drying.

DIAGRAM 2.

FREQUENCY DISTRIBUTION DIAGRAM OF CONDUCTIVITIES OF SOIL EXTRACTS FOR WET AND AIR-DRIED SAMPLES AT 3 DEPTHS.

(660 PROFILES)

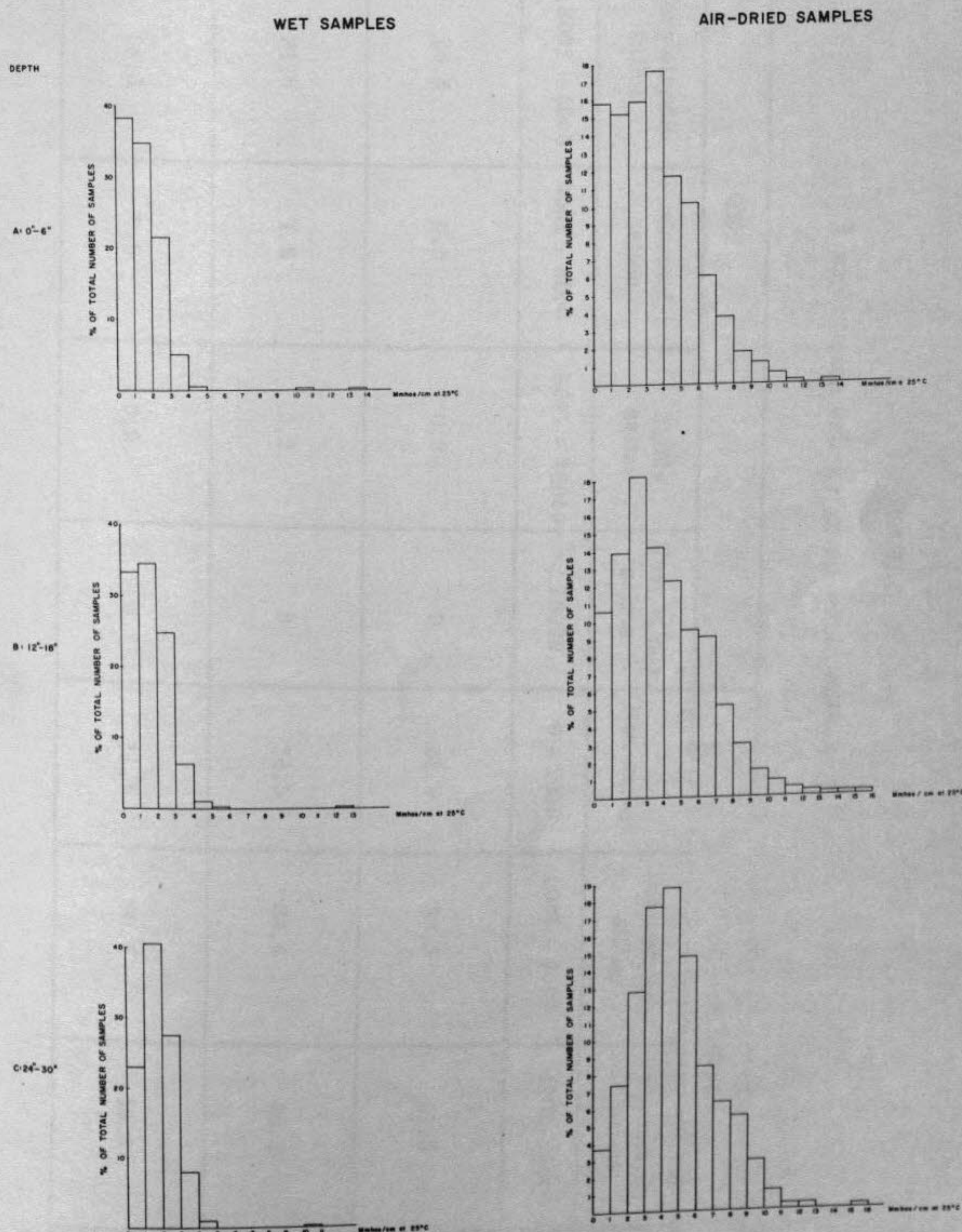


TABLE 6

% age of each salinity group within each depth.

Conditions / Salinity group / Conductivity Mcromhos/cm at 25°C / Depth	WET					AIR-DRIED				
	Non-saline	Very slightly saline	Moderately saline	Highly saline	Very highly saline	Non-saline	Very slightly saline	Moderately saline	Highly sline	Very highly saline
	0 - 2000	2001 - 4000	4001 - 8000	8001 - 16000	> 16000	0 - 2000	2001 - 4000	4001 - 8000	8001 - 16000	> 16000
0 - 6"	72.9	26.4	0.5	0.2	0	31.0	33.5	31.5	4.0	0
12 - 18"	67.5	31.0	1.3	0.2	0	24.5	32.4	36.3	6.8	0
24 - 30"	63.4	35.5	0.9	0.2	0	11.1	30.5	48.3	10.1	0

It can be seen from the table that, approximately 99 % of the total no. of samples are none saline to very slightly saline under field condition and 42 - 65 % under dry condition. Upon drying, the soil salinity increases at all depths of the profiles and the magnitude of the increase is greater in the subsoil than the top soil.

* Methods of Chemical analysis for soil survey samples - A. J. Metson. 1956 p. 134

2. RESULTS OF FIELD INVESTIGATION BY J.P. ANDRIESSE

Studies on vegetation and mud lobster mounds

Reference map 7

The type of vegetation was noted at each sampling point in the cutlines and these observations were used to evaluate the analytical results obtained from the soil samples.

Apart from noting vegetation in the field, vegetation associations were mapped from new air photographs (scale 1:10,000). Apart from the fact that the vegetation noted at each sampling point does not necessarily needs to correspond with the vegetation association in which the sampling point is located it is also very difficult to draw a vegetation map just from observations in the cutlines because the boundaries of the vegetation types are not regular which makes interpolation between cutlines impossible.

From the air photographs 12 vegetation types and associations could be singled out. They are:

Natural vegetation

- Mangrove - Majority Api-api (Avecennia species) and Pedada (Sonneratia species) with some Nipah (Nipah Fruticans).
- Nipah - Majority Nipah with some Mangrove.
- Mangrove/Nipah - Almost in 50-50 ratio Carapa species (Nyireh) and Nipah.
- Nibong - Majority Nibong (Oncosperma Filamentosa).
- Nibong/Nipah - Almost in 50-50 ratio.

True mangrove species belonging to the Rizophoraceae are rare in the area studied. This is mainly because these normally occur in pioneer areas where mudbanks rise just above sea level and which are flooded twice daily.

The area under study is building up and floods only occasionally which is the reason why Rhizophora species are seldom found.

Areas with api-api and pedada are usually found just along the rivers, on the banks. Areas with a mixed nipah/mangrove vegetation are usually found behind these banks but the mangrove species are here Carapa species the api api and pedada being rarely found away from the river.

The Nibong occurs in clusters, probably the highest points in the area where floodwater only seldom comes.

Disturbed vegetation

Old coconut - Already in bearing.

Young coconut - Recently planted. Coconut not visible in air photographs but drainage system was indicative to the land use.

Wet rice - Difficult to separate and often mixed with young coconut. The impression is that much land mapped as under young coconut is also used for wet padi cultivation (interrow cropping).

Mixed young coconut and wet padi - A complex.

Cleared land with bushes - Probably in use for wet padi (shifting cultivation).

Old secondary forest - The nature of the forest could not be established neither the reason why it is there and why the land was not used. Some Nipah is mixed up with this forest but the impression is that most species are not normally found in peatforest.

Old rubber - Only one area was mapped.

Most of the cultivated areas occur in one block in sample area I where the Jol family occurs. It cannot be assessed whether the mucky topsoils found there are due to the wet padi cultivation in past and present or whether this is a natural characteristic and indicative to former swampy conditions.

Mud lobster mounds

Most of the area is infested by the mudlobster (Thallassima anomala). They built up mounds in which much of subsoil material is brought to the surface. It is not known to what depth these lobsters operate and it is quite possible that material they use for building up the mounds is brought up from below augering depth (4 feet). From the start it was realised that the location of the sampling points in relation to the lobster mounds was important since samples taken in a lobstermound are not truly representative for topsamples. It is therefore possible that samples taken away from a lobstermound, even to a depth of 30 inches, do not reveal the presence of potential catclay material but catclay would have been found if the sample was taken in a lobstermound. Apart from carefully noting the locations of the samples, the number of mounds were counted along the cutlines so that an impression could be got on the severity of the infestation. In order to be able to map this the mounds were counted per 25 meter section. The following groups were then set up:

1. no mounds within 25 meter section
2. 0-5 mounds per 25 meter section
3. 5-10 mounds per 25 meter section
4. 10-15 mounds per 25 meter section
5. more than 15 mounds per 25 meter section

It appeared there were rarely more than 15 mounds per 25 meter section, the maximum did not exceed 25 mounds, which is probably the optimum population density under the given conditions. The majority of the mounds were of a height 2-3 feet, while the diameter at a base was on average about three feet.

This means that the percentage of the area affected within the groups given above will be:

1. nil percent affected
2. 3.6 - 19% affected
3. 19 - 36% affected
4. 36 - 54% affected
5. more than 54% affected

The maximum amount of 25 corresponds with a 90% area affected. The 5 mentioned groups are shown in map 7 together with the vegetation mapped from air photographs. This was done to find out whether there was any relationship between the presence of lobstermounds and vegetation. There appears to be little logic in the pattern and for this reason the density of population of lobsters away from the cutlines cannot be mapped from the information available. Much more information is needed from the areas in between the cutlines to be able to make any reliable interpolations. However, an approach to assess the total area affected by lobster mounds was made as follows:

Assuming that the area cut through by the rentises was representative of the whole area, the severity of the infestation by lobster mounds could be assessed as follows:-

The length of each lobster mound group along each rentise in each of the sample areas was measured respectively and the results are given in Table 8. The % age of the area affected by lobster mounds was then calculated to be 25%.

Table 8: Lobster mound

(Length in cm) Scale 1 cm = 100 m

Mounds/25 m section / …mple …rea	NIL	1 - 5	6 - 10	11 - 15	15	Total
I	95.50	66.50	115.50	39.50	7.25	324.25
II	14.25	12.25	50.50	8.50	0	85.50
III	10.25	21.00	40.25	16.50	12.50	100.50
IV	5.50	15.00	77.75	25.25	14.25	137.75
V	1.75	11.50	71.50	3.00	0.50	88.25
VI	20.00	27.50	60.00	7.00	0.25	114.75
VII	2.25	4.25	44.00	11.25	3.25	65.00
Total	149.50	158.00	459.50	111.00	38.00	916.00
…e of the …otal	16.32	17.25	50.17	12.11	4.15	100
…e affected …in each group	NIL	3.6 - 18.5 Av. 11.1	21.6 - 36 Av. 28.8	39.6 - 54 Av. 46.8	54%-90% Av.72	-
…e affected …the whole …	0	1.9	14.5	5.7	3.0	25.1

It must be pointed that sample area 1 has been affected by cultivation and hence population density of lobster mounds has been greatly reduced. Bearing this fact in mind, we can say that one quarter of the whole area was affected by occurrence of lobster mounds under the given conditions. The relationships between the vegetation, mud lobster mounds, acidity and salinity are discussed in the following section.

On the relation between soil acidity, vegetation and occurrence of mudlobstermounds

a. The factor vegetation

An attempt was made to correlate the acidity of topsoils with the natural vegetation. Only the acidity after drying was taken into account so that any influence of reducing conditions in the field could be ruled out.

Table 9 gives the distribution of samples over the various vegetation types which were recognized in the field.

Table 9

Vegetation type	number of topsamples	percentage of total
Mainly Mangrove	59	9%
Mainly Nipah	309	45.3%
Mangrove/Nipah	137	20.7%
Mangrove/Nipah/Nibong	5	1%
Nipah/Nibong	28	4.24%
Nibong	31	4.7%
Cultivated	53	8%
Cleared	31	4.7%
Sec. Forest	7	1%
Total	660	99.64%

Samples which were taken under disturbed vegetation or under cultivation had to be discarded because it is impossible to correlate for these locations acidity with the natural vegetation which once existed. Also samples taken under a vegetation type for which the number of samples did not exceed 8% of the total were discarded since this number is too low to attach any significance to possible correlations which may be found. Therefore the only samples which were suitable for statistical calculations appeared to be those under a. Mainly Mangrove

b. Mainly Nipah

c. Mangrove and Nipah (approx. 50-50%)

Table 10 shows the distribution of the air dried top samples over the pH groups used in map 4 (Soil Acidity) and in relation to their natural vegetation.

Table 10

pH of dry topsoil (0 - 6 inches)

Vegetation type	4.5	4.5-3.5	3.5	4.5 (drop of more than 1 unit after drying)
Mangrove	42.4%	22%	22%	13.6%
Mangrove/Nipah	46.9%	20%	18%	15.0%
Nipah	33.1%	19%	44%	4%

There is an indication that under Nipah the topsoils tend to have a lower pH than under Mangrove. Under a Mangrove or Mangrove/Nipah vegetation the pH tends to be higher but a considerable amount of the samples show a drop of more than 1 unit after drying. This indicates that an appreciable amount of oxidizable materials is present even under Mangrove vegetation. That the pH does not drop below 4.5 after drying may possibly be due to the fact that the soils under Mangrove tend to have a higher salinity than soils under Nipah vegetation. The sodium chloride may be responsible for the higher pH in general. This salt is present in the exchangeable and soluble form and will after leaching under field condition disappear. For this reason it is impossible to say whether upon reclamation the topsoils under Mangrove vegetation will not reach a low pH in the same number as found under a Nipah vegetation. Conclusively it can be said that under Nipah vegetation about 50% of the soils can be expected to have a considerable amount of oxidizable materials in them which upon reclamation will give rise to the formation of catclays. This proportion will be slightly less under a Mangrove and Mangrove/Nipah vegetation but still according to the figures obtained, in the 30 to 35% range.

Since there is the possibility that the present vegetation does not necessarily causes low acidity in the soils upon drying and that the deeper subsoil may have been deposited under a totally different vegetation type than found at present a similar correlation as done for the air-dried topsoil was attempted for the lower subsoil (samples taken at a depth of 24 - 30%).

For these samples table 9 is also relevant and only samples occurring under vegetation types a), b) and c) were studied.

Table 11 shows the distribution of the subsoil samples (air-dried) over the same pH groups and vegetation types as used in Table 10.

Table 11

	4.5	4.5-3.5	3.5	4.5 (drop of more than 1 unit after drying
Mangrove	28.6%	44.8%	12.5%	14.8%
Mangrove/Nipah	23.9%	34.9%	23.9%	17.2%
Nipah	13.7%	39.0%	30.6%	16.5%

Table 11 shows that under all three vegetation types the largest amount of samples of airdried subsoils (24-30 inches) falls in the pH group 4.5-3.5, the difference between the vegetation types being very small.

Nevertheless the highest percentage for the lowest pH group is found under Nipah vegetation and the lowest under Mangrove. The reverse trend can be noticed in the percentages for the highest pH group.

Thus even subsoils under Nipah vegetation tend to have a higher acidity than subsoils under Mangrove, the mixed Mangrove/Nipah vegetation being intermediate. The relative large proportion of samples with a high pH but showing a drop of more than 1 unit after drying indicates that salinity in all subsoils tends to raise the pH but this is under all vegetation types of about equal significance.

From table 10 and 11 it can be concluded that both topsoil and subsoil tend to have the lowest pH under Nipah vegetation. For topsoils the chance of a low pH is about twice as high under Nipah than under Mangrove while for subsoils this is slightly more.

b. The factor lobster mound

It was assumed that the presence of mudlobstermounds would indicate that material from the subsoil is brought to the top and that in case there would be any potential catclay material in the subsoil topsoils would be affected. For this reason the position where the samples were taken was carefully noted in the field so that the relation between potential catclay and the presence of mudlobstermounds could be studied.

Locations were described in the following manner:

1. On top of lobstermound
2. On slope of lobstermound
3. On foot of lobstermound
4. In hollow between lobstermound
5. No lobstermounds present - flat

The same 660 air dried topsamples as used in the correlation with the vegetation types were distributed over the pH groupings as used for the soil acidity map (Map 4) but now in relation to the 5 locations as described above.

Table 12 gives the results:

Table 12

Percentage of total samples	Location	pH groups air dried topsoils			
		4.5	4.5-3.5	3.5	4.5 (drop of more than 1 unit
30	On top of lobster mound	4.5%	18%	75%	1.5%
10	On slope of lobster mound	20%	40%	35.3%	4.7%
13.5	On foot of lobster mound	36.4%	30%	22.7%	10.9%
12.7	In between lobster mound	38.1%	16.7%	28.5%	16.7%
34	No lobstermound	54%	30%	9%	7%

From table 12 it can be clearly seen that the higher one goes up the lobstermound the greater the change that the pH of the topsoil falls in the lowest group. This is on top of the lobstermound 75% while at the foot of the mound this is only 23%. Significant is that where no mounds are present only 7% of the samples fall in the lowest pH group and that more than 80% can be considered as being safe. The relative high amount of samples falling in the group with high pH but with a drop of more than 1 unit after drying, in locations on foot and in between mounds may indicate that oxidizable materials are present but that salinity (sodiumchloride content) is higher here so that the pH in the presence of these salts does not fall to such an extent as happens on the slope and on top of the mounds. Here, the soil is above floodlevel of brackish water and non-saline.

After leaching of salts the respective 10.9% and 16.7% would probably have to be added to a lower pH group.

The significant relation between low pH of topsoil and the occurrence of lobstermounds would point that upon reclamation and levelling of these mounds a significant amount of subsoilmaterial is added to the topsoil and that catclaymaterial is distributed over the surface. Potential catclay material in the subsoil and the presence of mounds is therefore an undesirable combination.

Although no significant correlation could be found between pH of topsoil and vegetation type, would perhaps the relationship between Nipah and low pH come better to the force if the factor lobstermounds is brought into this study.

Table 13 and 14 gives the distribution of the number of samples (air dry topsoils) in the pH groups in relation to the main vegetation types but taken respectively in areas without mounds and on top of mounds.

It has been established that the location of the samples in the lobstermound has a bearing on the acidity found in topsoils. Does the sample apply to subsoils also.

To study this the subsoilsamples (depth 24-30 inches) where placed in the 4 acidity groups in relation to the 5 sample localities as has been done for the topsoils (table 12).

Table 15 gives the results.

Table 15

Percentage of total samples	Location	pH groups air dried subsoils			
		> 4.5	4.5-3.5	< 3.5	> 4.5 (drop of more than 1 unit.)
30	On top of mound	4.5%	48.2%	37.5%	9.6%
10	On slope of mound	13.2%	37.0%	30.0%	20.0%
13.5	On foot of mound	10.2%	39.8%	38.6%	11.3%
12.7	In between of mound	8.75%	34.0%	41.25%	16.0%
34	No mounds	27.3%	21.4%	37.3%	13.6%

It can be seen from table 15 that for subsoils, regardless the sampling localities, about equal proportions fall into the lowest pH group. Only in the top of the mounds salinity does not appear to influence the pH (see 4th pH group). Apparently the subsoils in this locality are still above floodlevel.

Looking at the highest pH group (> 4.5) there is still a much greater proportion of samples in localities not affected by mounds than when mounds are present.

It appears that the influence of locality on the acidity of subsoils is more apparent in the higher pH groups and in general the difference due to occurrence of mounds is found in pH groups which are regarded as not being dangerously affected by presence of catclay forming materials. From table 15 it can be assumed therefore that for subsoils about 37% of the sampled area is affected by high acidity, regardless whether this is in the presence of lobstermounds or not. If we take it that under field conditions salts are leached out upon reclamation then part if not all of the proportion falling in the 4th pH group will have to be added to the 3rd pH group (< 3.5). In that case it must be considered that on average about 50% of all subsoils will upon reclamation and deep drainage turn into catclays.

..../31

These figures are only of statistical value and cannot be used for mapping the areas affected by low acidity.

Although the areas affected by lobstermounds can be mapped as has been done in map 7 it does not mean that the percentages of land area affected by high acidity as shown in table 17 can be applied to every individual area since landuse is playing a role in the presence of non-presence of mounds in some parts. This can possibly be done with some reservation for areas still under natural vegetation but it would still not serve a purpose since no interpolation is possible between the cutlines.

c. The factor salinity

Salinity in general does not appear to be a serious factor in the topsoils examined. Of 630 samples only 5 appeared to be above 4000 micromho/cm and topsoils are therefore at the most only weakly saline with the exception of the 5 samples.

For further studies only the groups 0 - 2000 micromho/cm and 2000 - 4000 micromho/cm, respectively non-saline and very slightly saline are therefore considered.

In order to correlate vegetation with salinity, field conditions should be taken into account and electro conductivity measurements in the field condition (fresh) were taken as being representative.

Table 18 shows the percentages of top samples under the three main vegetation types arranged according to the salinity groups.

Table 18

Percentage of total samples	Vegetation	0-2000 micromho/cm	2000-4000 micromho/cm	
8.7%	Mangrove	34.5%	61.8%	3.6% above
23.0%	Mangrove/Nipah	50%	50%	4000 micromho
48.0%	Nipah	77.6%	22.4%	

Remainder under disturbed vegetation, not considered.

Table 18 indicates that salinity of topsoils tends to be slightly higher under Mangrove vegetation than under Nipah, the mixed mangrove/nipah vegetation occupying an intermediate position. This could be expected since it is known that mangrove vegetation prefers higher saline conditions than Nipah.

The relation between lobstermounds and salinity of topsoils is shown in table 19.

Table 19

Percentage of total samples	Location of samples	0-2000 micromho/cm	2000-4000 micromho/cm
30.7%	Top of mounds	90.5%	9.5%
11.1%	Slope of mounds	63.1%	37.0%
14.6%	Foot of mounds	60.0%	40.0%
13.8%	In between mounds	60.0%	40.0%
29.7%	No mounds present	60.2%	39.8%

From this table it can be seen that most tops of the mounds are non-saline. The amount of top samples which are non-saline decreases away from the top of the mounds. It can be safely assumed that for most of the area (apart from the tops of the mounds) 60% of all cases will have non-saline topsoils, while 40% will be only very slightly saline.

In conclusion it can be stated that salinity in the area is only a minor problem as far as the topsoils (0-6) inches are concerned.

The salinity of subsoils (24-30 inches) in relation to vegetation and locality was studied similarly.

Of 650 samples investigated 5 appeared to have an E.C. of more than 4000 micromho/cm which is neglible, the remainder was distributed over the salinity groups 0-2000 micromho/cm (non-saline) and 2000-4000 micromho/cm (very slightly saline).

Table 20 shows the relation between vegetation and salinity. Only groups of samples having more than 8% of the total collected samples were used, the remainder being discarded together with those found under disturbed natural vegetation.

Table 20

Salinity of subsoil samples in relation to main vegetation types

Percentage of total samples	Vegetation	Salinity 0-2000 micromho/cm	2000-4000 micromho/cm
8.16%	Mangrove	35.8%	64.2%
21.7%	Mangrove/Nipah	32.6%	67.3%
45.7%	Nipah	68.3%	31.7%

..../34

It can be seen from table 20 that under Mangrove a larger proportion of subsoils than under Nipah are in the slightly saline group, the ratio being 2:1. Thus subsoils show the same trend as found in the topsoils. The relation between locality and salinity of subsoils is shown in Table 21.

Table 21

Percentage of total samples	Location of samples	Salinity 0-2000 micromho/cm	2000-4000 micromho/cm
30.1%	Top of lobstermound	83.6%	16.4%
10.5%	Slope of lobstermound	57.3%	42.7%
13.4%	Foot of lobstermound	48.2%	51.8%
12.7%	In between mounds	43.3%	56.7%
33.2%	No crabmounds	57.8%	42.2%

The same trend as found in the topsoils is also present in the subsoils but less strongly. Away from the top of the mounds the proportion of samples in the slightly saline group is increasing finding its maximum in localities in between lobstermounds. It cannot be explained why in areas without lobstermounds the percentage should be less than in areas in between lobstermounds; possibly the number of samples used for the calculation of the latter was too small.

Conclusively it can be said that for both topsoil and subsoil salinity does not appear to be a problem. The saltlevels are throughout quite low. The contents of sodium in the adsorption complex can only be studied when analyses become available.

Appendix A. Notes on the soils of the Sungei
Sarawak Padi Scheme Area.

Reference is made to Map 2, Reconnaissance Soil Map of the area.

Although on the soil map 10 different families are shown we are only concerned with two main families which together form more than 90% of the area and almost 100% of the sample areas which have been studied. These are the Rajang family and the Pendam family.

Both soils have derived from heavy textured deltaic and estuarine deposits which have accumulated in a brackish water environment.

They are situated in extensive mudflats which are liable to brackish water flooding during high tides and possibly to freshwater flooding during the wet season when the saltlevel in the river may be lower than in the dry season. These mudflats are cut by numerous rivercourses, large and small, which are easily mappeable from air photographs and a great number of small creeks which, particularly away from the large streams, are hidden under Forest cover and which cannot be seen on air photographs if the vegetation does not reveal their existence. Twice a day during high tides these streams and creeks are full with brackish water and it depends on the height of the tide and the level of the land whether the land will be totally inundated or only partially.

The vegetation varies from almost pure mangrove forest to a mixture of nipah, mangrove and nibong. Nipah appears to be the dominant species either alone or in combination with Mangrove. Certain parts of the sample areas had been cleared and some are used for coconut and wet padi. Coconut is generally very young and recently planted.

The soils of both families have high to moderately high water tables. It is difficult to study these because the height of the watertable depends on the period of the year, the tide and the location. An average height of 10 to 20 inches appears a reasonable assessment. The Rajang and Pendam soils are typical Gley soils which in the top 20 inches show signs of aeration in the form of yellow mottles, subsoils below 20 inches are generally of a greenish to bluish grey matrix colour and yellow mottles may be present along root channels where air can penetrate. The two families are separated on their salt content. A soil which has an Electro Conductivity of 500 micromho or more falls in the Rajang family while a soil with an E.C.

of less than 500 micromho is mapped as Pendam family. This is done to separate salt affected soils from salt-free soils. However the actual mapping is difficult in the field not only because the chemical data is frequently not available but also the salinity fluctuates during the year with the salinity of the water in the rivers. Therefore for practical reasons soils which are still under a Mangrove, Nipah, Nibong vegetation are mapped as Rajang family while those which are cultivated (reclaimed Rajang land) and leached are mapped as Pendam family. The present map is based on such considerations and for reconnaissance purposes is sufficiently accurate since it separates more or less the soils which are known to be saline and the soils which obviously are non-saline or not saline enough to prevent cropping. For our present purpose the distinction between the two families is less valid and they can just as well be treated as one, especially since the problems involved in reclaiming these soils are synonimous. It was found that in a certain area (sample area 1) which for the majority is used for coconut and wet padi, the topsoils of the Rajang-Pendam soils are mucky. This is elsewhere in Sarawak mapped as the Jol family. It could just as well be treated as an organic phase of the Rajang/Pendam soils. The mucklayer is generally less than 10 inches thick. Thin layers of mucky material may occur in the deeper horizons and this may indicate depositioning of vegetative matter of former vegetations during the depositional stage of these soils. The deposition possibly followed stages of quick and slow accumulation, the periods of slow accumulation being indicated by layers of vegetating material. This characterisitic is very variable and unmappeable.

The internal drainage of the soils is slow which can be expected from such heavy clays, drainage mainly happens through old rotten roots which have left channels in the subsoil. The structure of the soils are typical for sodiumclays, they are pseudo single grain to crumb structured soils which appears very nice when under natural conditions. Once salts are leached out and the soils drained the structure turns into a heavy blocky one, and soils are difficult to work, also internal drainage is unfavourably affected.

Not much analytical data on the Rajang/Pendam soils are available. But from the data obtained from other areas it can be assumed that they are generally better supplied with plant nutrients than usual alluvials soils in Sarawak. Total P tends to be high (mainly organic P), the soils are well supplied with Ca, Mg and K but this may change quickly upon reclamation when these cations are leached out. Possibly one of the most dangerous characteristics of these soils is that in places they have accumulated sulphur compounds in them during their deposition which may become harmful if oxidized when drained. This characteristic is difficult to assess since the formation of catclay does not always take place and even when it has been assessed that conditions in the soil would favour the development of so-called catclay it does not always seem to happen. This is particularly true in many areas which have been reclaimed in the past by the population along the Sarawak coast. That the intensity of drainage has some bearing on this must be studied carefully but this may possibly be the reason why reclamation so far has been moderately successful since the areas reclaimed were never properly drained.

pH of the soils is dependent on salinity and the state of oxidation and reduction of sulphur compounds in the soils and is therefore very variable in these soils. This aspect needs careful study.

The areas of Pendam and Rajang soils are further characterised by the presence of large numbers of mudlobstermounds which particularly appear to abound under Nipah vegetation.

The connection of vegetation and occurrence of these mounds merits further studies.