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Report on a Detailed Soil Survey  
of  
**SEMONGOK AGRICULTURAL  
STATION AND PROPOSED  
EXTENSIONS**

1st Division

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Soil Survey Division  
Research Branch

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Sarawak

The soil survey of Semongok Agricultural Station and part of its adjacent reserved land was conducted as a detailed soil survey (i) to assist in planning future land use of the Station and (ii) to provide further information regarding the area to the extent of the Station report which might be required when planning the layout of a proposed school of agriculture, (iii) to assess the suitability of the area for a proposed agricultural Research Centre and, in particular, the degree to which the soil - sun, moisture, and physical work on them - can be taken as representative of other areas in the area.

**REPORT ON A DETAILED SOIL SURVEY** Detailed information on the chemical analysis of the soil is given in any experimental work or tests.

OF

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PURPOSE AND SUMMARY OF RESULTS.

The soil survey of Semongok Agricultural Station and part of the adjacent reserved land was undertaken at a detailed level (1) to assist in planning future land-use of the Station itself, (2) to provide further information regarding the area to the south of the Station proper which might be relevant when planning the layout of a proposed School of Agriculture, (3) to assess the suitability of the area for a proposed Agricultural Research Centre and, in particular, the degree to which the soils - and, therefore, experimental work on them - can be taken as representative of other areas in the country and, finally, (4) to provide detailed information on the chemical status of the main soils prior to any experimental work on them.

A little over five hundred acres were surveyed and seven Soil Series separated. The most widespread of these - Semongok Series - is found extensively in First and Second Division and results of experiments on it will be relevant to many other soils elsewhere. Slopes are varied and the rolling topography which is dominant is also typical of conditions in many parts of Sarawak. With the exception of the large grazing area included in the Station - which bears a very poor soils unsuitable for experimental work - there is little alluvial land. Experimental work on the Station must therefore be mainly concerned with upland soils.

Discussions regarding planning of the School of Agriculture and the Agricultural Research Centre continued during the survey and plans were finalised in advance of this report. The report is thus mainly concerned with characterising the soils found in the area.

In Parts I and II the area and its soils are described and the classification of the latter set out. An independent study of the topsoil is reported on in Part III, this section being contributed by the second author. Detailed descriptions of selected profiles, with chemical analyses, are found in Part IV.

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## LOCATION

The area surveyed is indicated on fig. 1. The station itself extends from the Penrissen Road at mile 12/13 $\frac{1}{2}$  to the Kuching-Serian Road at mile 12/12 $\frac{1}{4}$ . Included in the survey was a large area to the south of the station, lying partly in Agricultural Reserve land and partly in land designated as Leper Settlement Reserve.

In the north the station boundary has been taken as the limit of the survey (or the Sg. Sibirch where this runs outside that boundary.) The station limits have also been followed where they coincide with the two existing roads and have a common boundary with the neighbouring Javanese settlement. In the west the line of a proposed main road was followed although some land lying beyond the road line (i.e. between the proposed road and the present Penrissen Road) was included. In the east the boundary runs with that of land already designated as a proposed Secondary School Site. In the south and southeast straight rentis lines cut for the survey were adopted.

It can be seen, then, that for much of its length the boundary of the surveyed area is quite arbitrary. Its choice has been governed by the need for a relatively compact block, at least 500 acres in size, on reserved land for which no other intensive use is at present envisaged and which is available for use by the Department of Agriculture. There remains a considerable acreage of Government Reserve to the southeast of the surveyed area.

The area surveyed has been calculated as 502 acres. The official acreage of the Agricultural Station itself, which is included in this figure, is 182.46 acres (ref. Lands and Surveys Dept. Miscellaneous Plan 1216/14).

## CLIMATE

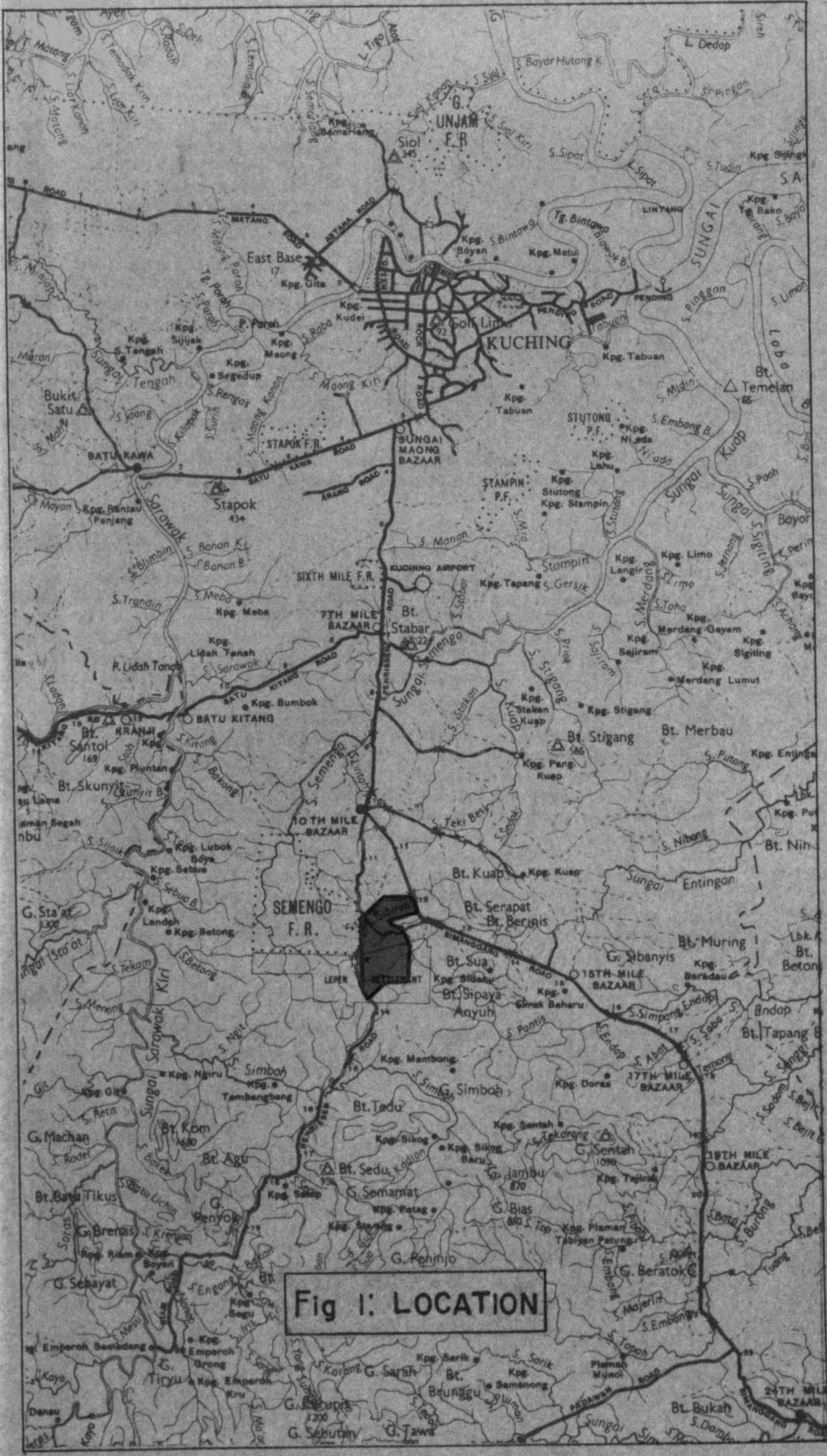
Most of the data in this section are obtained from the meteorological station at Kuching airport, some six miles from the survey area. Detailed records are now taken at Semongok Agricultural Station but a continuous record only exists for the past five years. Rainfall appears to have been recorded there from the time of the establishment of the station but only isolated records are now available.

### Rainfall.

The average annual rainfall recorded at Kuching over the period 1946 - 1957 was 158.11 inches and it is likely that the figure for Semongok differs little from this. Over the period 1959 - 1964 records at Semongok give an average figure of 162.18 inches but three years are included in which rainfall during January, February and March was exceptionally high.

The wettest months are October - March, heavy rain being associated with the northeast monsoon. During the southwest monsoon from April to August relatively little rain falls. One can therefore talk of a wet season and a dry season, but the terms are purely relative. In no month does the average fall below 7 inches and only four months have an average figure of less than 10 inches of rain, (fig.2). In extremely dry years less than 3 inches is occasionally recorded during the period June - September but this is rarely the case. The area falls well within the 'continuously wet' belt of Mohr's classification, (1).

Monthly totals vary considerably from year to year. At Semongok the records for January show a fall of 17 inches in 1960, 50 inches in 1963 and for July show a fall of 11 inches in 1960 and less than 3 inches in 1962. Records for Kuching over a much longer period show even greater variety. Average figures, therefore, only indicate part of the picture. It is worth noting, however, that monthly totals appear to vary only within definite limits, in that the trends of



**Fig 1: LOCATION**

monthly extremes (figs. 2 and 3) maintain the division into two seasons given by monthly averages. This is not true for stations in Fourth and Fifth Divisions or, to a large extent, for stations in Third Division. While too variable to allow forecasting, then, rainfall in this area does appear to be somewhat less erratic than further north in the country.

Single days without rain (or when less than 0.01 inches of rain were recorded) occur in every month but longer periods of drought are largely confined to the period April - August. Fig. 4 is based on records from Semongok over only four years and may not give a balanced picture but during this period continuously dry spells of seven or more days were largely confined to July and August. There appears to be no data on critical levels of drought for any major annual crop in Sarawak, a gap which might be borne in mind when planning a future research programme.

While continuous records are made at the Kuching station, an analysis has not been published and information on rainfall intensity cannot be given.

#### Temperature

Air temperatures are fairly constant throughout the year. At 0800 hours the general range is from 70° to 80°F; at 1400 hours from 75° to 90° F.; at 1800 hours from 75° to 85°F. Temperatures tend to be somewhat lower during the rainy season than during the dry season (maximum/minimum ranges being roughly 65° - 90°F. as against 70° - 100°F.) but this weak trend is largely masked by day-to-day variations.

Earth thermometers are established at Semongok but the records from them have not been averaged out. The temperature at grass level ranges from 68° - 73°F. At a depth of 1 foot a fairly constant temperature at about 76° or 77° is recorded, at 4 feet readings are up to 1° higher. During January and February the subsurface readings appear to drop (sometimes to 69°F.) on isolated days. The site is on a shallow lower slope and at the height of the wet season the water table is at or within 1 foot of the surface on many days. This is probably the cause of these fluctuations. Readings on an upper slope or summit site would probably be more uniform and possibly slightly higher throughout the 4 feet profile. Earth thermometer readings at Kuching airport on a site with better drainage conditions give an average which never falls below 81°F. (2).

#### Bright sunshine.

Data have only been published for Kuching airport. The daily mean reflects the distribution of rainfall through the year, rising from 2.82 hours in December to a peak of 6.98 hours in May, with an annual mean of 4.90, (2).

#### Relative humidity

At Kuching airport mean values at 2 p.m. rise from 63.5 in May to 79.9 in December, with a mean value of 70.6, (2).

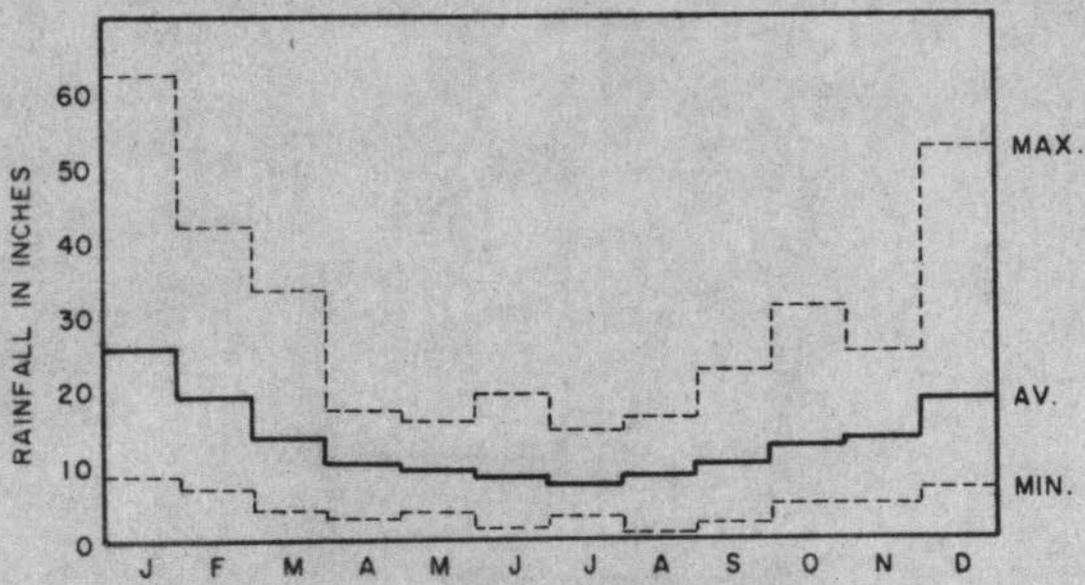


Fig. 2: Average and extreme monthly rainfall at Kuching over 71 years

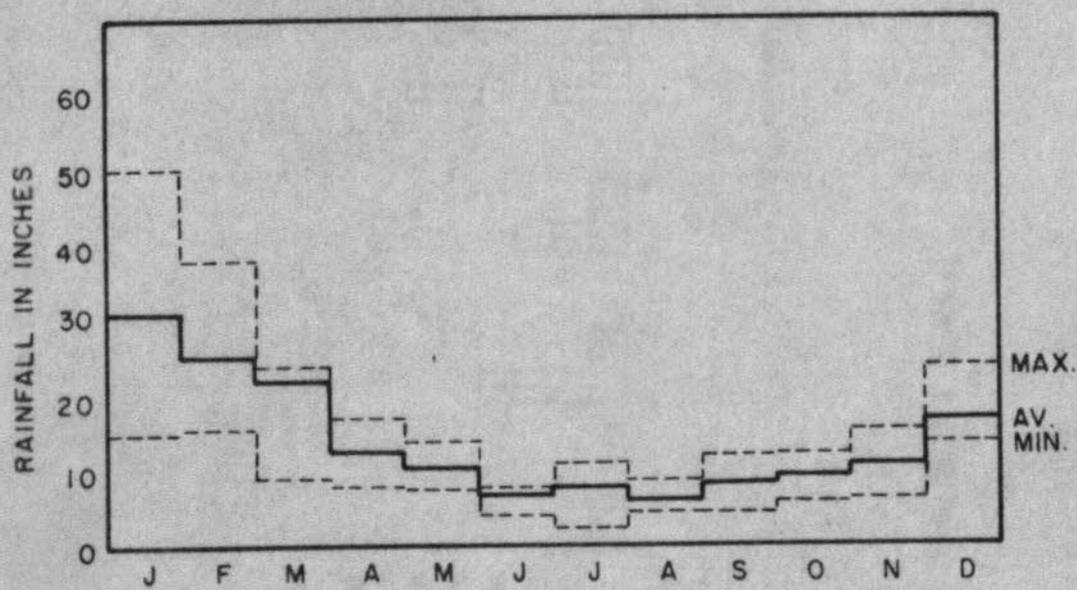


Fig. 3: Average and extreme monthly rainfall at Semongok over 4 1/2 years

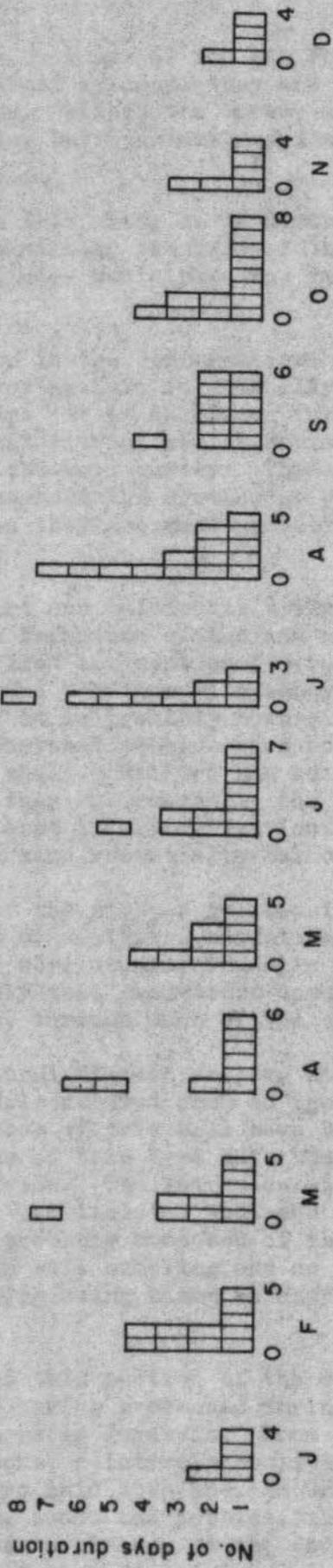


Fig. 4: Maximum frequency of dry periods of Semongok (1960-1963)

GEOLOGY AND SOIL PARENT MATERIAL

The geology of this part of First Division has been reported on by Wilford (3). Most of the following information is based on his report.

The survey area is underlain by rocks of the Bau Formation which vary greatly in lithology. On fossil evidence they are dated as Upper Jurassic to Upper Cretaceous. Within the survey area the dominant rock types are limestone and shale, but mudstone, sandstone and conglomerate are also present.

The presence of limestone in this area, as is discussed below, is largely inferred. It is dominant near the base of the Formation and tends to be massive, fine-grained, quite pure and in places is at least 1,000 feet thick.

The bulk of the Bau Formation in the Semongok area is derived from clayey or silty shale. Within the survey area it is generally hard and is grey, dark grey or bluish grey in colour. It is in places interbedded with mudstone. Siltstone, while present within the Bau Formation, was not seen in the Semongok area during the soil survey. These argillaceous rocks are dominant or common throughout the Cretaceous part of the Bau Formation. Within the survey area they are most probably of Lower Cretaceous age.

Conglomerate, sandstone, chert and calcareous sediments are described as being interbedded with the Bau Formation shales and mudstones. During the soil survey only the first two mentioned were noted. A finely-graded conglomerate was found together with sandy shale at the base of one soil inspection pit. It is probably more widespread than this single record suggests. Occasional pebbles were noted in more than a few soil profiles underlain by shale. Wilford has not described such inclusions in the Bau shales but they are common in the associated conglomerates. This seems their most likely derivation. There is little independent evidence to suggest a more recent alluvial origin.

Sandstones outcrop in some of the steeper gullies in the east of the area and occasional pieces of weathered sandstone were recorded in soil profile pits. The latter were usually found in conjunction with shale fragments. It is likely that sandstones occur sporadically, thinly interbedded with the shale, through much of the survey area.

On one hill (on the Agricultural Station proper, at present under rubber in tapping) distinctive soils derived from an igneous rock were noted. Surface boulders at the base of this hill have been identified as quartz-diorite. Intruded rocks of this type have been recorded by Wilford in many parts of the Division. The intrusion within the survey area is probably Tertiary in age. An isolated and much lower hill in the extreme north of the area is probably composed of the same material. Parent material was not reached in soil sampling and no rock outcrops were seen, this provisional grouping being based on characteristics of the soil profile.

In late Jurassic time much of this section of the country was a shallow sea, subaerial and marine erosion having proceeded during a still-stand without folding from at least the early Jurassic. From this sea rose islands of pre-Jurassic igneous rocks, relatively resistant to erosion. In the sea calcareous deposits were laid down and, in Cretaceous time, these were overlaid by muds, sands and pebbles, the deposits varying in constitution from place to place. At the end of Cretaceous time folding movements occurred, these sediments were uplifted and basins formed, the latter being generally filled with rather coarse-grained Tertiary sediments. Further earth movements contorted these rocks during mid-Tertiary times and were accompanied by intrusions predominantly

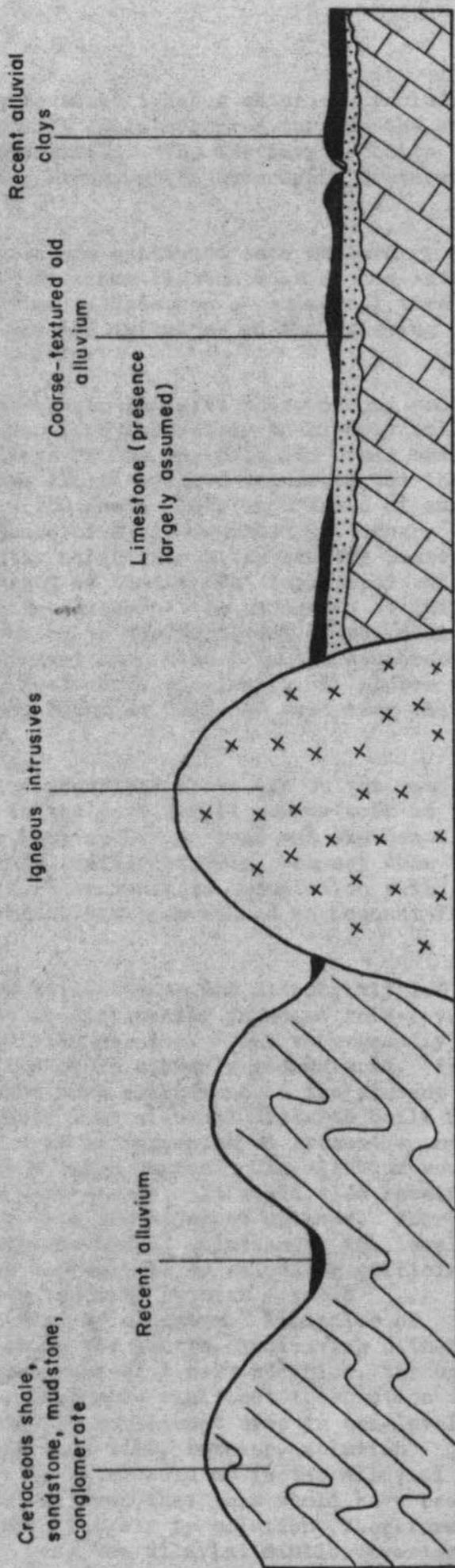


Fig. 5: Diagrammatic relationship between main rock types and associated soils (roughly oriented S ← N)

of acid and intermediate with some basic igneous material, including the diorite mentioned above. Uplift again occurred towards the end of the Tertiary and erosion was intensified. The Tertiary deposits were in many places completely eroded, exposing the underlying Cretaceous beds, as in the Semongok area.

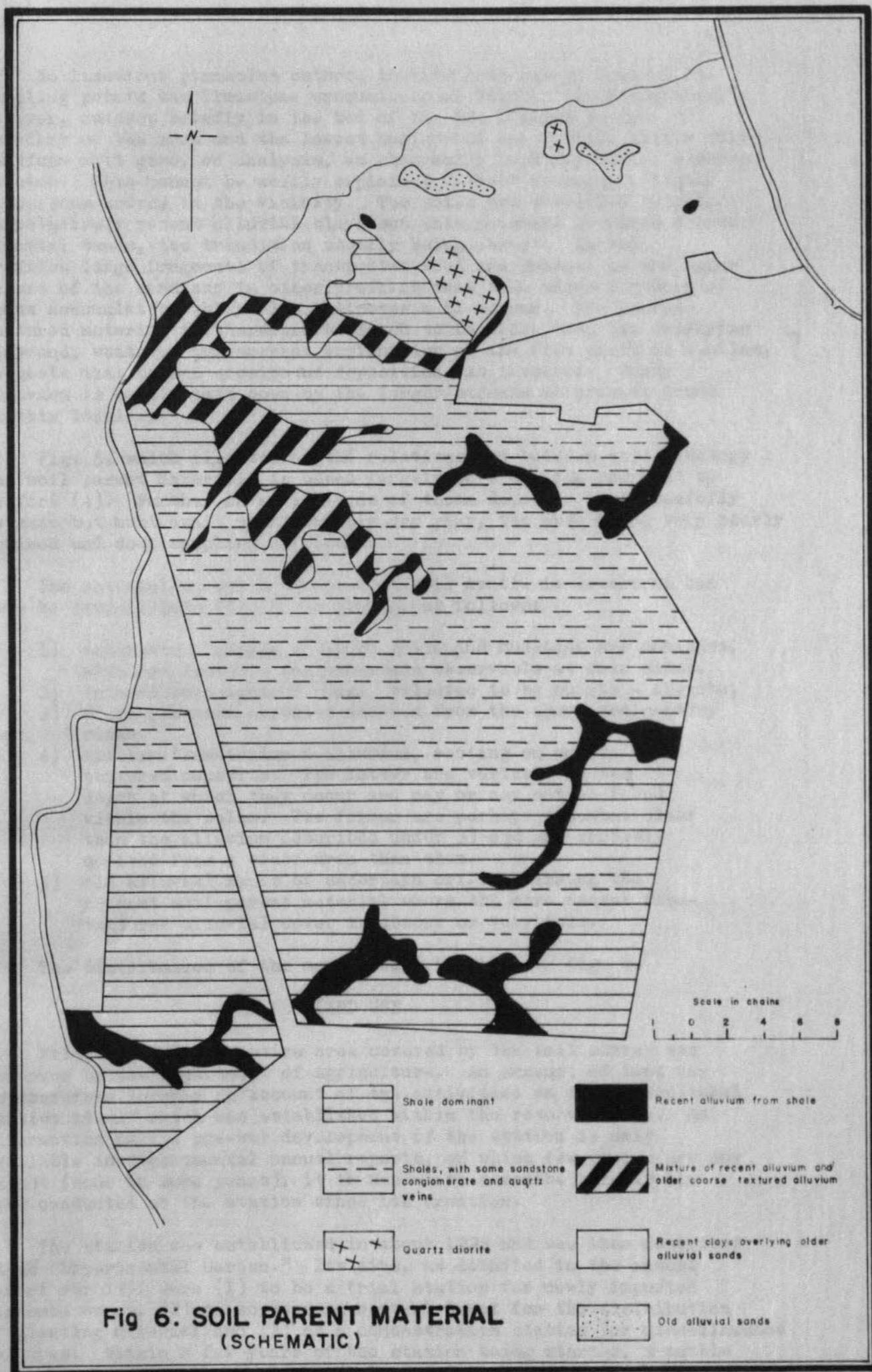
This latest period of erosion has continued into Quaternary time, being accelerated or interrupted by minor fluctuations in sea-level. These fluctuations are of little consequence on a geological time-scale but they have had a considerable influence on the existing landforms and the present soil mantle.

Shales, and the minor rocks associated with them, occupy some 75 per cent of the survey area and form moderately to steeply rolling country, broken by the deep valleys of the Sg. Dras and other small streams. One hill rises to above 210 feet above sea-level but the majority of summits are at 160 - 180 feet. This accordance of summits perhaps indicates the past presence of a now-degraded Quaternary erosion surface at about 200 feet. In the north this hilly country passes abruptly into a wide lowlying tract of almost flat topography which is drained by a misfit stream, the Sg. Sibireh. An extension of this tract spreads into the hilly country in the southwest of the station proper, the drainage being discordant here also. In the southeast this tract is at little more than 80 feet above sea-level. It slopes very gently to the east and northeast, being at below 60 feet near the Kuching-Serian road.

The extensive low-lying flat described above may be the result of a still-stand at this level in the past. Soil survey work at present in progress between the Kuching-Serian road and the coast at Nonok may throw more light on this. Alternatively, one may note that similar flats are not uncommon further south in association with limestone hills and one theory which has been raised to account for them is given below.

One of the major Quaternary still-stands was at roughly 100 feet and pre-recent alluvial deposits are frequently found at this level, i.e. at some height above present floodplains. They vary greatly in composition but coarse-sandy alluvium is commonly encountered. It is suggested that, while the sea must have encroached on the present land area to some extent, it is probable that alluvial deposits built up and out at the level of the still-stand - as is happening at present - and contained the encroaching sea to a large degree. The alluvium would be low-lying and would have a high water-table. It would also receive periodic flushes of runoff water from the adjacent uplands. Where these alluvial flats abutted on a limestone massif solution at the level of the groundwater - which would be replaced by rainwater sufficiently rapidly for it to be rarely saturated with calcium - would develop a limestone platform mantled by alluvium. Pinnacles of limestone would in places rise above the mantle, indicating either the core of the original hill or a band of limestone which, through a difference in composition, was rather more resistant to solution than the surrounding rock. Following the subsequent drop in sea-level erosion would recommence. At the same time, however, solution of the limestone platform itself by water held up in the alluvial mantle would become important and it is believed that this could have been more rapid than subaerial erosion. Largely by solution, therefore, the limestone platform, together with the alluvial mantle covering it, would be lowered to the new groundwater level. At this point drainage of the landform would become slow, the groundwater would be largely calcium-saturated and the process would cease to operate.

The present aspect of such an area would be a wide alluvial flat, bounded abruptly by hilly country (of limestone or other rocks) and drained by a misfit stream. From the alluvium small isolated limestone pinnacles might rise.



**Fig 6: SOIL PARENT MATERIAL  
(SCHEMATIC)**

No limestone pinnacles outcrop in this area and at none of the sampling points was limestone encountered at depth. Limestone does, however, outcrop briefly in the bed of the Sg. Sibireh on the boundary of the area and the lowest horizon of one profile within this landform unit gave, on analysis, an abnormally high figure for reserve calcium. This cannot be easily explained without assuming a highly calcareous source in the vicinity. The soils are developed largely in relatively recent alluvial clays but this material overlies coarse alluvial sands, the transition usually being abrupt. In some profiles large fragments of transported wood are present in the upper layers of the sand and in other profiles this zone shows features of humus accumulation which also indicates a bi-sequum. The coarse-textured material is therefore believed to be older than the overlying clay and, whatever the correct explanation of the flat which it mantles, ? suggests that marine erosion and deposition was involved. Sandy alluvium is rarely laid down by the larger streams at present found in this locality.

Fig. 5, which illustrates the relationships between solid geology and soil parent material, is based largely on a diagram prepared by Wilford (4). Further investigations of these deposits could usefully be made but must await an abnormally dry year, the area being very poorly drained and deep sampling difficult.

The material in which the present soil mantle is developed can thus be divided into five broad groups, as follows:

- 1) sedimentary rocks, of which shale and mudstone are dominant, with conglomerate and sandstone observable at some sites.
- 2) intermediate igneous rocks, believed to be quartz - diorite,
- 3) fresh alluvial deposits derived from the above sedimentary rocks.
- 4) similar fine-textured alluvium, resting on coarse-textured deposits. The latter are variable in the depth at which they occur and may or may not be found within the solum. The former are perhaps somewhat older than the alluvium described under 3) and are probably derived from a wider area than them.
- 5) old alluvial sands of uncertain origin, forming the present soil parent material where the more recent fine-textured alluvial cover is absent or very thin.

The distribution of the main groups is shown in fig. 6.

#### LAND USE

Prior to 1950 the entire area covered by the soil survey was reserved by the Department of Agriculture. An account of land use is therefore largely an account of the activities on the Agricultural Station itself which was established within the reserved area. As information on the pre-war development of the station is only available in departmental annual reports, of which few copies are now extant (none in some years), it is useful to describe briefly the work conducted on the station since its creation.

The station was established in about 1925 and was then described as an "Experimental Garden." Its aims, as detailed in the annual report for 1931 were (1) to be a trial station for newly imported economic crops, (2) to serve as a central depot for the distribution of planting material and (3) as a demonstration station for miscellaneous cultures. Within a few years of the station being started, a cattle farm was also set up, on adjoining land on which is now the "Proposed Secondary School site."

The original station was very small, covering only 36 acres in 1930. From then on, however, new land was cleared and planted as required. The figures reported are inconsistent as in 1940 93 acres are reported as opened up although individual records in the intervening decade would seem to bring this figure to at least 135 acres out of a total reserved area of 629 acres. The original buildings comprised only coolie lines and an attap hut to accommodate the 'Agricultural Inspector-in-charge' but control of the station work suffered from the lack of a resident senior officer and in 1932 a bungalow for such an officer was reported as 'being in course of construction.' It was presumably finished and occupied in the following year. Also by 1932 a road running through the station from the Penrissen road to the new cattle farm was completed. It was 15 feet wide but was not suitable for car traffic in wet weather. By 1936 two clerks' bungalows had been erected and material collected for building small houses to accommodate students on training courses at the station. The increased importance of the establishment during the late 30's is reflected in its title. "Experimental Garden" was soon dropped and by 1940 reference is invariably made to the "Central Agricultural Station".

Any species introduced on the off-chance that it might thrive in the Sarawak environment was directed to this station and in 1928, when a fairly detailed report was made, a bewildering variety of plants was being grown there. It is only possible to summarise some of the more interesting data here.

Of vegetables Artichokes, numerous Carilla, Chilli, Egg Plant, various beans and Sweet Potatoes are mentioned. Beans generally suffered from drought but, with the exception of Chilli, which grew poorly 'due to inferior soil', all varieties produced sufficient seed or cuttings for distribution to local farmers. Most of the initial stock came from the then Federated Malay States. In 1931 successes were reported in growing and distributing varieties of Soya Bean and in 1936 Gingelly and Green Gram are included in the crop trials listed. In 1937 the station supplied all the Carpet Grass used on the old airfield.

Numerous fruits were planted, 31 species being listed in 1928. With a few exceptions, all performed well. It is perhaps worth noting, however, that the comment against the rather tolerant Custard Apple is 'growth stunted on hill tops' which suggests that some, at any rate, of the station's soils had been heavily farmed before the station was established. The recollection of one officer, stationed there from 1933 to 1940, is that beyond the cleared area the land was almost entirely under untouched jungle. Of fruits which were doing well in 1931, mention is made of Mexican Cherry, Avocado Pear, Mango, Citrus and, in particular, Grapefruit, the latter being described as having 'excellent flavour and juiciness.' Variety trials of Pineapples are mentioned in 1936 and in the same year a trial shipment of pines was forwarded to Kuala Lumpur for canning, the result showing 'that Sarawak pines can hold their own with the Singapore variety'.

Seeds of seven varieties of Coffee were received in 1928 from Ceylon and a dozen varieties are mentioned in 1931. Robusta, Excelsa and Liberica showed the best growth and seedlings were in great demand, but there is little subsequent mention of this crop. By 1932 ten varieties of tea had been planted out, the majority having apparently come from the plantations on Matang. Their condition is described at length in the report for 1931 but, as with coffee, tea is rarely mentioned thereafter. In 1931 the presence of Cocoa was also briefly noted, as were Oil Palm (Dura Deli) and Illipe Nut.

Some attention was paid to rubber but this crop seems to have been mainly confined to a 20 acre Isolation Garden sited in the adjacent Forest Reserve (outside the surveyed area).

The economic importance of pepper was reflected in the early policy of the station. Initially the Garden was divided into two sections - for Miscellaneous Cultures and for Pepper. Both variety and manurial trials on pepper were carried out but in the early 30's the plots suffered severely from 'Black Fruit Disease' and from about 1935 on little if any work on this crop seems to have been done.

Apart from "trials" of fodder grasses, which featured in the station programme throughout this period, work on pastoral agricultural was naturally left to the adjoining cattle farm. By 1936, however some heifers appear to have been based on this station and, in 1940, breeding stocks of good quality pigs (locally obtained Berkshire-Chinese crosses) and poultry (Rhode Island Reds) had been obtained from Malaya and further stock was later introduced from Australia.

Padi also received little if any attention until 1940, when much of the present rough grazing area was opened up and bunded in 10-acre plots. The scheme was intended both for variety trials and as a means of feeding the station coolies. Poor soil and unsatisfactory water control forced the scheme to stop after two indifferent crops had been taken.

The above remarks - albeit very incomplete - give some indication of the wide diversity of activities centred on this station before the war. Unfortunately none of the available annual reports given any indication of the location of the major crops within the station and no map is ever attached. Neither are any profile descriptions included of the soils involved (although they are invariably described as 'poor'). Present knowledge is largely based on the recollection of officers who worked on the station before the war and on post-war aerial photographs. Most of the cultivated area seems to have been on the lower slopes of the hills surrounding the flat in the south of the station rather than further north as is now the case. The present main station road existed but ran only to a pig shed near the present rubber blocks.

In view of the site chosen for development it is hardly surprising that in report after report it is stated that heavy rain and subsequent flooding destroyed much of the year's work. Flooding appears to have been as big a factor in ruining the pepper on the station as was the 'Black Fruit Disease'. In about 1930 considerable ditching was carried out but the problem does not seem to have been solved. Frequent reference is also made through the years to the poverty of the soils and the unsatisfactory nature of the site in general.

Work on the station came to an abrupt halt in 1941 when the Japanese invaded the country. In the few days of confusion immediately following the invasion the local inhabitants of the district efficiently looted the station, removing everything portable of value from office furniture to pedigree pigs. The Japanese occupied the station in time to save the buildings themselves which they then dismantled and moved to 34th mile, (the present Tarat Agricultural Station). Many tree crops of intrinsic value were cut down and the site left more or less derelict, although it remained officially in existence as a station until the end of 1942. Subsequently the only organised agricultural endeavour in this locality was an extensive sweet potato garden in the adjacent cattle farm. Rice prices spiralled in Kuching as the war progressed and the Agricultural Reserve land was largely cleared and planted and planted by the local people. Much of this land must have previously been under old secondary, if not primary, forest.

At the time of the liberation, therefore, the station was in a state of complete neglect and the majority of the facilities had been destroyed or removed. Development had thus to start virtually from the beginning again. Opinions on the advisability of this are summarised in the report for 1947 (p.17): "The site was found prewar to be in

many ways unsuitable for an agricultural station especially with regard to soil and as it is now badly infested with 'lallang' and appears to be in a malarial belt it seems very doubtful if it will be worth considering re-establishment of a large station on the site".\* Two points, were however, in its favour. Many of the permanent crops had survived, although overgrown, and were a valuable source of budding material (especially imported fruit trees from Malaya). Equally important, the site still had the advantage of being accessible from Kuching on a good road. It was therefore retained and as there was a desperate need for planting material, a rubber budwood nursery and small propagation areas for other crops were established there. Following 1950 the station became the main centre for pig-breeding work and later a number of fish ponds were also established. Now a variety of work is once more going on at Semongok although it has not regained the dominant place which it had before the war.

Map 3 shows the distribution of land use at the time of the survey (mid-1963). Some generalisation has been necessary and this map was out of date before the end of that year, some grassland having been ploughed in for other crops. Further fishponds have also been developed.

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\*The statement assumes that a renewal of the station's pre-war function as a propagation centre was envisaged. For an experimental centre - the present plan-many of the points mentioned are advantages, making the station typical of many parts of the country. The malaria situation has improved considerably in the last 17 years.

P A R T   I I

S O I L S

METHOD OF SURVEY

A party of 3 - 6 junior staff (the number varying at different stages of the survey) were engaged on the project, which occupied them from June until September, 1963. The survey can therefore be considered one of the most expensive undertaken by the Branch. This can be put down to a number of factors. Firstly, a fairly intensive rentis grid (fig. 7) was laid down and, as most of the area is covered by a thick tangle of regrowth vegetation, this work of necessity proceeded very slowly. Secondly, this is the largest block of land surveyed at a detailed level so far in Sarawak and it was surveyed at a time when considerable attention was being focused on the problem of soil classification in this country, to which rules formulated and problems encountered on detailed surveys have considerable application. More auger samples were taken and more soil pits dug, therefore, than might otherwise have been seemed adequate. Thirdly, should the area prove suitable for a research centre, it is hoped to lay down a variety of experimental trials on these soils and it was felt essential that as clear a picture as possible should be obtained of their chemical fertility at the present time. For this purpose, in addition to the samples collected for routine analysis as part of the survey proper, the survey staff was partly engaged on collecting 688 topsoil samples and 43 150 lb. bulk samples for laboratory and greenhouse work by the Agricultural Chemist.

On other detailed soil surveys in the future much of the work mentioned above will either not be necessary or can be allowed for prior to the start of the project. There is, however, a further factor which extended this survey to be taken into account; the lack of a complete topographical base map. Portions of the area were covered by two form line plans issued by Land and Survey Department. (Miscellaneous Plans 601/94 and 701) and these were of very great assistance. The remainder of the area had not, however, been surveyed. At a detailed level of soil mapping form lines are essential and it was necessary to give one assistant special training and to employ him for much of the survey on levelling along rentises. Considering that he had no previous experience in such work a very competent result was achieved but a wide degree of error had sometimes to be accepted and form lines between rentises had, of course, to be interpolated. The form lines produced, therefore, cannot be considered particularly accurate although the cost of this part of the project was probably little short of that which would have been entailed in the production of a reliable form line map by Land and Survey Department. This is a very important point as, at any level of soil mapping, boundaries are interpolated to a great extent and in judging their position one is greatly guided by the topography. If the topographical data is quite inaccurate in any locality the soil map is likely to be equally inaccurate.

It is suggested, therefore, that before further detailed soil surveys are undertaken - and particularly surveys of large areas such as that reported on here - an accurate form line map is obtained. A suitable base map would show form lines at 5 ft. or 10 ft. intervals on a scale of 4 or 6 chains to one inch and would include any buildings, paths and streams. If Land and Survey Department are unable to supply such a map the survey is best shelved until they can. Otherwise, money invested in a soil survey may be partly spent to little effect and where misleading information is issued in a survey report the inaccuracies are unlikely to become apparent until further time and money has been possible misapplied as a result of that report.

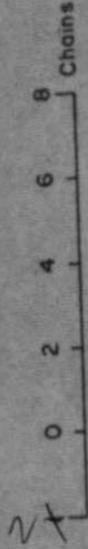
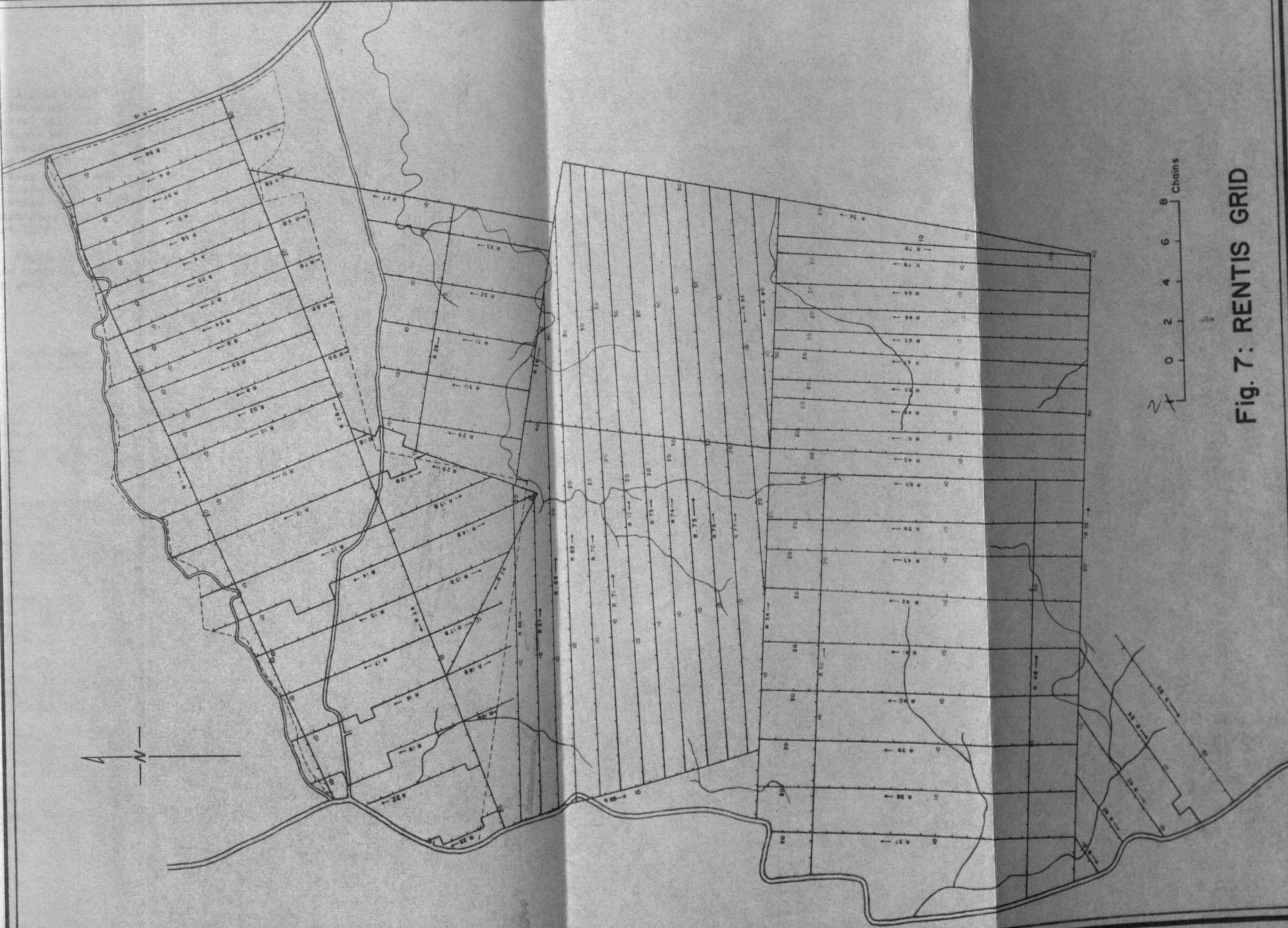
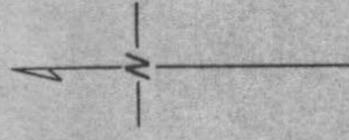


Fig. 7: RENTIS GRID

A grid of parallel rentises was laid down through the area (fig.7) The interval between rentises ranged from 100 to 300 feet, a close interval being adopted where most accurate form line data was available and the relationships between soils and topography could most profitably be studied in detail. Routine sampling of soils by auger was made at 100 feet intervals along each rentis and further checking on and off the rentis made where necessary. Once soil boundaries had been established over forty pits were dug and sampled at representative sites. The further sampling of topsoils was then undertaken. This is described under the section on 'Chemical Fertility' (Part III).

Vegetation and land use was recorded at each rentis sampling point. These records, together with data from recent air photographs, have been used to draw up the Vegetation and Land Use Map (Map 3.)

### SOIL CLASSIFICATION

The problems of soil classification are receiving considerable attention in Sarawak at the present time and views are by no means fixed.

At the level of Orders, Suborders and Great Soil Groups the United States classification as set out by Thorp and Smith (5) is followed. Many of the Great Soil Groups are not represented in Sarawak and the classification as it applies in this country (or appears to apply as far as present evidence goes) is set out in Table 1.

In some respects the classification of some Groups by other workers appears preferable to Sarawak Soil Surveyors. This is particularly the case with the Red-Yellow Podsolics Soils for which some distinctions set down by Harris (6) seem practical, for the Podsol Soils which were classified in Sarawak by Dames (7) and the Hydromorphic Soils for which the classification of Cline (8) seems easily applied. It is felt, however, that the virtue of using a widely known classification would be greatly lessened if it were modified in any way and, for the present, any divisions made by these or other authorities which appear useful are made at a lower level than the Great Soil Groups.

Within the survey area representatives of the following Great Soil Groups are found: Red-Yellow Podsollic Soils, Reddish brown Lateritic Soils and Low Humic Gley Soils. A minor unclassified Soil Series is probably best placed in the Group of Podsol Soils.

Below the level of Great Soil Groups but above the level of the Soil Series the soils are grouped in Soil Families. This term is used in a number of senses and much of the work at present being undertaken on standardising the classification of Sarawak soils involves discussion of definitions at the Family level. At the present time it will only be stated that Semongok Series is considered the type Series within the Semongok Family and that for other Series found within the survey area no Family classification is given in the report.

ORDER	SUBORDER	GREAT SOIL GROUPS REPRESENTED IN SARAWAK	REPRESENTED IN SURVEY AREA
Zonal soils	Light-coloured podzolised soils of the timbered regions	Podsol soils	?
Intrazonal soils <i>Top</i>	Lateritic soils of forested warm-temperate and tropical regions	Red-yellow Podzolic soils	Yes
	Halomorphic soils of imperfectly drained arid regions and littoral deposits	Reddish Brown Lateritic soils	Yes
Azonal soils <i>PM</i>	Hydromorphic soils of marshes, swamps, seep areas, and flats	Latosols	-
		Saline soils	-
		Bog soils Half-Bog soils Low Humic Gley soils Planosols Groundwater Podsol soils Groundwater Laterite soils	- - Yes - - -
		Lithosols Regosols Alluvial soils	Yes but not mappable and not described. - -

Table 1: Soil Classification

At Soil Series level the classification follows the rules laid down for the United States Soil Survey (9). The detailed application of these rules in the field is at present the subject of joint discussion between Soils Specialists throughout Malaysia and will not be dealt with here. Suffice to say that classification at the level of Soil Series serves to group together those soils within a Family which are agriculturally similar and for which the same agricultural recommendations can be given. As there are few agronomic data available to guide the surveyor in this country, classification at this level must rely greatly on rules which work in other countries.

Where a Soil Series has been the subject of a detailed soil survey, it has often been possible to separate phases within the series. Drainage phases are based on definitions used by the United States Conservation Service (10).

In the following sections the Soil Series are described in turn. In the range of physical characteristics given under each series the full range permissible within the concept of the Series is given, whether or not that range has been seen in the field. In the range of chemical characteristics the limits are those found in analysed samples. In the case of some Series only one profile has been analysed and further work may therefore extend these ranges.

#### DESCRIPTION OF THE SOIL SERIES

In this section each Series is described and its range of characteristics given. The main soil in the area - Semongok Series - has been studied elsewhere in First Division and is now fairly well characterised. Other Series, however, have been established on the present survey and study of them has been limited to the survey area. The survey area is small and it is probable that only part of the range of characteristics acceptable under the Series is present. Study of these Series at a detailed level in other areas may thus lead to expansion of the characteristics described below.

#### SEMONGOK SERIES (code number 3101)

Semongok Series has been classified within the Great Soil Group of Red-Yellow Podsollic Soils and is the type Series within the Semongok Family.

The Series is clayey and is characterised by 'gley mottles' throughout the subsoil.

#### General description.

The most commonly encountered profiles of this Series have the following characteristics:

0 - 3 to 8 inches Dark greyish brown to brown fine sandy loam to clay loam, with possible distinct medium and fine light grey mottles. A medium subangular blocky or medium to fine granular structure may be weakly developed. Well rooted.

-15 to 24 " Yellow to reddish yellow (typically brownish yellow) clay loam to clay or fine sandy clay, with distinct to prominent, medium and fine light grey mottles. A medium or coarse subangular blocky structure may be weakly apparent when dry, rarely when moist. Poorly rooted. Possible inclusions are quartz stones, fragments of weathered shale and iron concretions; inclusions are rarely present and never more than few in number.

- 36 to 48 inches Colour as above, but often reddish-yellow rather than brownish-yellow in colour. Clay to fine sandy clay. Structure as above. Inclusions as above but fragments of weathered shale are often many, and in the shallow phase are dominant.

below 36 - 48 " Well-weathered grey or dark grey shale, sometimes with hard bands of iron accumulation along cleavage planes. Alternatively light grey heavily mottled clay or silty clay from weathered shale.

Range of characteristics.

Parent material: Well-weathered Cretaceous rocks, dominantly shale. The lithology is, however, variable and profiles underlain by sandy shale, mudstone, shale with conglomerate or shale with sandstone have been grouped in this Series provided that the non-argillaceous parent rock is sufficiently limited in areal extent not to alter the character of the A and B horizons to a degree beyond the ranges described below. This particularly applies to texture.

Topography: From lower slopes to summits of gently to steeply rolling topography. Of the phase distinctions (described below) imperfectly drained (strongly mottled) profiles commonly occur downslope of and in less well-drained sites than imperfectly drained (weakly mottled) profiles. The shallow phase is typically encountered on the steepest portions of hill flanks (which may exceed 35°.) While these tendencies exist, however, there is little consistent correlation between profile characteristics and site within the range covered by the series. Weakly and strongly mottled profiles occupy positions in the relief with little or no regard to slope and the shallow phase is sometimes encountered on quite flat slope facets.

Occurrence: the series has been mapped in First and Second Division and is widespread where Cretaceous shales are present.

Diagnostic horizons: the series is characterised by the following genetic horizons:

- A1 - variable in thickness and may be destroyed by cultivation
- A2 - may be only weakly expressed and the transition to the B horizons is often gradual.
- B - sometimes only weakly expressed in the field though distinct in the analytical data.
- C - often beyond augering depth but shallow phases are common.

Colour: Matrix colours in the subsoil range from yellow to reddish-yellow, the most common colours being brownish-yellow and yellowish-brown. Matrix colours above the C horizon appear to be invariably of Hue 10YR. The subsoil invariably has many distinct medium and/or fine (rarely coarse) mottles, usually grey or light grey in colour. In the surface soil mottles are usually present but are normally indistinct.

Texture: Topsoil texture is variable but surface textures lighter than sandy loam have not been recorded. Subsoil textures range from clay loam to clay above a depth of 24 inches and from fine sandy clay to clay below 24 inches. Where sandstone is intermixed with shale or mudstone in the parent rock fine sandy clays tend to occur; coarse sandy clays have not been recorded.

Structure and consistency: Coarse subangular blocky structure develops in the subsoil and, depending on past land use, a medium or coarse granular structure may develop in the surface soil. These features are only weakly expressed. They may not be apparent in the dry soil and are rarely apparent in the moist soil.

Drainage: Internal drainage is imperfect in most profiles seen, although much of the mottling is probably unconnected with groundwater drainage conditions. External drainage is moderate to rapid.

what is s.m.  
of moist soil  
then?

Rooting depth: The profile is porous in the upper subsoil but may be only slightly porous in the lower subsoil (below 24 inches). Below 6 inches roots and rootlets are generally few in number but they are usually present throughout the 0-48 inch profile or, in the shallow phase, above the C horizon.

Phases: Two phases have so far been set up as mapping units; an imperfectly-drained phase and shallow phase. The imperfectly-drained phase shows a range of variation in the intensity of mottling and on the present soil map it has been possible to separate weakly mottled from strongly mottled profiles within this phase unit. In terms of agriculture it is not known how much significance should be attached to this distinction.

Imperfectly drained (weakly mottled): mottles are obvious in the profile but the majority are faint; Fragments of rock are not frequent above 24 inches.

Imperfectly drained (strongly mottled): mottles are obvious in the profile and the majority are distinct (in some profiles prominent, it being difficult to establish the matrix colour in the B horizon.) Fragments of rock are not frequent above 24 inches.

Shallow: fragments of weathered rock are frequent above 24 inches. In such profiles rock fragments are normally the dominant feature of the soil below 36 inches.

Variant: On the present survey soils were encountered in association with Semongok Series which differ in profile character only in the matrix colour of the subsoil, this being pale yellow, but other less constant contrasting features were also recorded. Small quartz pebbles (presumed to be from weathered conglomerate) tend to be more frequently encountered in these profiles than in those of Semongok series, the subsoil texture is commonly sandy clay rather than fine sandy clay and weathered shale, where apparent at depth, is usually very pale in colour. This soil has provisionally been set up as a variant of Semongok Series and is separated on the soil map as such. Two phases - imperfectly drained and shallow - were recorded, their ranges being identical with those of the normal Semongok Series which are described above.

#### Chemical and mineralogical features.

Clay minerals: (from one profile) Kaolin dominant.

Small traces of limonite, goethite and carbonaceous matter.  
(by D.T.A.)

Other mineralogical data: (from one profile) Heavy mineral suite:- zircon/tourmaline with secondary (?) anatase and rutile, 10 - 35% opaques; light mineral suite:- 50-80% quartz, bulk of remainder rock fragments; organic SiO<sub>2</sub> - not more than 2%; ore:- 1-11%.

Silica/sesquioxide ratios: No data.

Sesquioxide ratios: No data

Cation exchange capacity: 10 - 25, usually highest in the topsoil, but often rising again in the B horizon.

Base saturation: low in all horizons, greatest in the A<sub>1</sub>. Generally below 20 and often below 5 in the A<sub>2</sub> and B horizons.

Acidity: Topsoil:- 3.0-4.5, subsoil: 3.5-5.0

'Reserve' Phosphorus in ppm: generally 100-250 in topsoil, 50-150 in subsoil.

'Reserve' cations in ppm:

Calcium - up to 700 in the topsoil (very variable),  
50 - 200 in subsoil.

Magnesium - generally 1,000-2,000 in topsoil,  
1,000-4,000 in subsoil.

Potassium - generally 1,500-3,000 in topsoil,  
2,000-5,000 in subsoil.

Group III elements: 8-33% recorded, about 20% on average, never as high as 40%.

Remarks: The low P figures and high K figures are characteristic of the Series.

Features contrasting with those of similar series.

Some other Series have been established which are sufficiently similar to Semongok Series for it to be worth pointing out the differentiating features. They are Bedup, 'Ri-i' and an un-named series in the present area.

Bedup Series: is equivalent to Semongok Series over Triassic, not Cretaceous, parent rocks. Differences are not apparent in the profile but are evident in the chemical analysis, the Triassic shales being rather richer in potash-bearing minerals than Cretaceous shales.

"Ri-i" Series: (within inverted commas as the name is at present provisional). Like Bedup Series, "Ri-i" Series is found over Triassic, not Cretaceous, parent material and is believed to be associated with tuffaceous shales. In addition, it has a better structure, a subangular blocky structure being easily apparent in the moist soil. Because of the superior drainage, the soil is only faintly mottled.

(Unnamed): A minor soil was noted on the present survey, in association with Semongok Series, which covers too small an area to be mapped. A profile is included in Part IV (Profile 5) but this soil is not otherwise discussed. The profile is similar to "Ri-i", that is: better structured and more faintly mottled than Semongok Series. Such soils, if found elsewhere to be sufficiently extensive for formal recognition as a series to be desirable, could be considered as the equivalent of "Ri-i" Series over Cretaceous parent rocks. The profile noted on this survey contained pieces of iron-rich conglomerate at depth, a feature perhaps connected with the reddish colours of the subsoil.

*This seen similar to many F 80*

PANTIS SERIES (code number 1201)

Pantis Series has been classified in the Great Soil Group of Reddish-Brown Lateritic Soils. In profile character it is very similar to Abok series. The latter is developed over rather more basic parent rocks and Pantis Series is separately classified until more chemical data are available on these two soils.

General description

The following profile typifies the range of features found within the series on the present survey:

- 0 - 3 to 4 inches      Greyish or dark greyish brown loam to clay loam, perhaps faintly mottled on lower slope sites. Granular or fine subangular blocky structure, well rooted.
- 9 - 15      "      Light olive brown clay, perhaps faintly mottled on lower slope sites, where colluvial weathered boulders of the parent rock may also be present. Subangular blocky structure. Sparsely rooted.
- 48      "      Olive yellow unmottled clay. Subangular blocky structure. Sparsely rooted. Possible few fragments of well-weathered rock at depth.

*Shen of st expre*

Range of characteristics

Parent material: Intermediate igneous rocks classified as quartz-diorite, ranging in age from Carboniferous to Triassic.

Topography: Steeply rolling. The igneous rocks normally give rise to isolated hills or ridges rising above surrounding shale country and having rather more steeply sloping flanks than hills composed of the adjacent sedimentary rocks.

Occurrence: Established on the present survey. Similar soils occur in many parts of First Division.

Diagnostic horizons: The following genetic horizons are characteristic;

- A1 - present but thin
- A2 - very weakly expressed
- B - well-developed

(C and D - not encountered within augering depth on this survey).

Colour: Below a slightly darker topsoil a quite uniform light olive brown to olive yellow subsoil in the 2.5Y Hue.

Texture: Surface textures under mature rubber and secondary forest range from loam to clay loam. Below 6 inches the texture is a uniform and rather heavy clay.

Structure and consistency: A good structure is characteristic but as the soil is usually moist may be only weakly apparent. A granular structure is common in the surface soil. The A2 and B horizons have a coarse subangular blocky structure which breaks easily to very fine or fine subangular blocky. Topsoils are friable, subsoils friable to firm.

Drainage: Internal drainage is moderately good to good, except on lower slope sites where suggestions of surface gleying may be seen. External drainage is moderate to very rapid depending on site.

Rooting depth: Below the surface 3 - 6 inches the soil is generally sparsely rooted but there is no impedence to roots in the 0 - 48 inch zone (or, on summit and upper slope sites, down to 70 inches).

Inclusions: Summit and upper slope soils are free from inclusions beyond occasional fine pieces of weathered rock at depth. On lower slope sites

They have only been noticed in the surface 12 inches, above an inclusion-free subsoil and have obviously been washed downslope from surface outcrops.

Phases: No phase separation has been made.

Chemical and Mineralogical features.

Clay minerals: No data.

Other mineralogical data: None

Silica/sesquioxide ratios: No data

Sesquioxide ratios: No data

Cation exchange capacity: 12 in the surface soil, 6 to 9 in the subsoil (from 2 profiles). Little trend in the subsoil.

Base saturation: No data

Acidity: 4.6 in the surface soil. rising to 5.1 in the B horizon (1 profile).

'Reserve' phosphorus in ppm: 90 to 230 in the surface soil, 80 - 120 in the subsoil.

'Reserve' cations in ppm:

Calcium	- 100-200 in the topsoil, 40-200 in the subsoil.
Magnesium	- 800-850 in the topsoil, 800-7,000 in the subsoil
Potassium	- 550-650 in the topsoil, 400-600 in the subsoil

(All data from 2 profiles).

Group III elements: 20-37% increasing down the profile (from 2 profiles).

ABAT SERIES (code number 4301)

Abat Series has been classified in the Great Soil Group of Low-Humic Gley Soils.

General description.

- 0 - 3 to 6 inches Yellowish brown to greyish brown loam to clay loam. Weak blocky or granular structure. Well rooted.
- 18 to 30 " Brownish yellow mottled clay. Weak coarse blocky structure. Sparsely rooted. Possible small pebbles.
- 48 " Light grey clayey gleyed horizon. May overlie hard shale or mudstone within augering depth.

Range of characteristics.

Parent material: Recent alluvium from (largely) argillaceous Tertiary sedimentary rocks.

Topography: Alluvial flats. The series is found either in narrow valleys where the stream has cut well below the level of the alluvial deposits or in better-drained portions of larger bottomlands.

Occurrence: Unknown. The series was established on this survey.

Diagnostic horizons: The following horizons are characteristic:-

- A1 - thin  
2 - brownish yellow mottled zone  
3 - gley zone  
C - may not be within augering depth.

Colour: Below a thin, somewhat darker-coloured A1 horizon, a brownish yellow to yellowish brown zone, mottled light grey and sometimes reddish yellow. This overlies a light grey zone, mottled yellowish brown or with many rusty root channels or both. Where solid rock is present within augering depth the rock is usually grey or light grey in colour.

Texture: Loam to clay loam in the surface soil; clay, fine sandy clay or silty clay in the subsoil.

Structure and consistency: Granular or fine subangular blocky structure weakly developed in the topsoil, coarse subangular blocky structure in the subsoil. Topsoil friable, subsoil firm.

Drainage: External drainage is slow to moderate. Internal drainage is imperfect.

Rooting depth: The C horizon impedes roots but is rarely found within 3 feet of the surface and is commonly below augering depth. Rooting depth otherwise depends on local groundwater levels.

Inclusions: Random rock fragments of local origin are in places found in the subsoil and small water-worn quartz pebbles are seen in some profiles. Such inclusions are always rare or few.

Phases: No phase separation has been made on the map but a shallow phase, in which the C horizon approaches to within 24 inches of the surface, was locally encountered.

Chemical and mineralogical features.

Clay minerals: No data.

Other mineralogical data: None

Silica/sesquioxide ratios: No data

Sesquioxide ratios: No data

Cation exchange capacity: less than 10 in the surface soil, 15 in the subsoil (1 profile).

Base saturation: No data

Acidity: 3.9 - 4.0 throughout the profile (1 profile).

'Reserve' Phosphorus in ppm: Phosphorus - 80-200 in the topsoil,  
75-150 in the subsoil.

'Reserve' cations in ppm: Calcium - 120-400 in the topsoil,  
60-620 in the subsoil.

Magnesium - 300-350 in the topsoil,  
500-3,000 in the subsoil.

Potash - 600-9,000 in the topsoil,  
1,000-3,000 in the subsoil.

(All data from 2 profiles).

Group III elements: 2.5-4.1% in the topsoil, 8-17% in the subsoil  
(2 profiles).

#### DRAS SERIES (code number 4302)

Dras Series has been classified in the Great Soil Group of  
Low-Humic Gley Soils.

#### General description

The following profile is typical of the series;

0 - 3 to 12 inches Greyish brown to brownish yellow clay loam,  
mottled. Weak subangular blocky structure.  
Well-rooted.

-24 to 48 " Grey or light grey mottled clay to sandy clay.  
Structureless. Sparsely rooted. Possible  
quartz gravel.

below 24-48 " Hard, slightly weathered pale-coloured shale  
or mudstone.

#### Range of characteristics.

Parent material: Recent alluvium from (largely) argillaceous  
Tertiary sedimentary rocks.

Topography: Alluvial flats. The Series is generally found in association  
with Abat Series. Dras Series occupying the more poorly-drained  
portions of the bottomland.

Occurrence: Unknown. The Series was established on the present  
survey.

Diagnostic horizons: The following horizons are characteristic  
of the Series:

- A1 - thin
- 2 - brown mottled zone, not deeper than 12 inches.
- 3 - gley horizon
- C - commonly below augering depth.

Colour: Above 12 inches greyish brown to brown or yellowish  
brown. The surface 4 inches may be unmottled, but light grey  
mottles become distinct within 12 inches of the surface. The gley  
horizon is grey to light grey, mottled with brownish yellow. Colours  
are generally in the 10YR Hue throughout. Where the C horizon  
occurs within augering depth, the rock is pale-coloured but with some  
brown staining along cleavage planes.

Texture: Clay loam to clay in the surface soil, becoming clay or  
sandy clay in the subsoil.

Structure and consistency: A weak medium or coarse subangular blocky  
structure is apparent in the surface soil. The gley horizon is  
structureless. The surface soil is friable, the subsoil firm.

Drainage: External drainage is slow. Internal drainage is poor.

Rooting depth: The C horizon impedes roots and may be found within 3 feet of the surface. High water tables also limit root development but some roots were noted throughout the gley horizon in profiles studied.

Inclusions: Some quartz gravel or small quartz pebbles may be present in the lower subsoil.

Phases: A shallow phase, in which the D horizon is found within 24 inches of the surface was recognised but has not been mapped. It is inextensive.

Chemical and mineralogical features.

Clay minerals: No data

Other mineralogical data: None

Silica/sesquioxide ratios: No data

Sesquioxide ratios: No data

Cation exchange capacity: 10-15 in the topsoil, 8-12 in the gley horizon. (1 profile).

Base saturation: No data

Acidity: 3.9-4.1, dropping to 3.2 in the C horizon. (1 profile)

'Reserve' Phosphorus in ppm: 140-160 in the surface soil, 80 in the gley horizon (1 profile).

'Reserve' cations in ppm: Calcium: 350-500 in the topsoil,  
300-350 in the gley horizon.  
Magnesium - 60 in the surface 4 inches,  
1,300 -500 in the subsoil  
Potassium - 1,000-1,500 throughout rising to  
5,000 in the lower subsoil.

(All data from 1 profile)

Group III elements: 8-13% throughout the profile.

EMBANG SERIES (code number 4303)

Embang Series has been classified in the Great Soil Group of Low Humic Gley Soils. A bisequum profile is apparent within auger depth, the present soil resting on (?) a truncated B horizon of a past Humus Podsol.

General description.

3 to 6 inches Greyish to very dark greyish brown loam. Weak blocky structure. Sparsely rooted.

24 to 48 " Grey to light grey clay loam to clay, mottled or with rusty root channels. Structureless or weakly blocky. Sparsely rooted.

below 24-48 " Light brownish grey coarse or medium sand, humus stained and with possible pieces of rotting wood.

Range of characteristics.

*cf 1966 amendment.*

Parent material: Recent riverine alluvium, although the profile may incorporate coarse material from the older alluvial material on which it has been deposited.

Topography: Wide alluvial flats.

Occurrence: The Series was established on the present survey.

Similar soils are found in many parts of First Division.

Diagnostic horizons: The following sequence is characteristic:

A0 - may be present but always very thin

A1 - may be weakly expressed

3 - gleyed clay

4 - humus stained sand (may not be within augering depth).

→ Should be II B<sub>2</sub>.

Colour: The A1 horizon ranges from grey to very dark greyish brown, the gley zone from light grey to grey, with a variable degree of mottling. Where sandy horizons underlie the profile, they are light brownish grey to brownish grey.

Texture: Loam to fine sandy loam in the surface soil, sandy clay loam to clay in the subsoil.

Structure and consistence: Poor structure. Weak coarse or very coarse subangular blocky structure may be apparent in the A horizon and the upper part of the gley zone. Friable in the surface soil, becoming firm in the subsoil.

Drainage: External drainage is slow to very slow. Internal drainage is poor to very poor.

Rooting depth: The soil is sparsely rooted to 3 feet. There is no barrier to root penetration apart from waterlogging at depth during much of the year.

Inclusions: Pieces of rotting wood are characteristic of the underlying sandy horizon where it is present within augering depth and such inclusions may be incorporated in the base of the clayey horizons.

Phases: Poorly drained and very poorly drained phases have been separated.

Chemical and mineralogical features.

Clay minerals: No data

Other mineralogical data: None

Silica/sesquioxide ratios: No data

Sesquioxide ratios: No data

Cation exchange capacity: 3-5 in the topsoil, rising to 20 in the lower subsoil. (2 profiles).

Base saturation: no data

Acidity: 4.8 - 5.0 throughout (1 profile)

'Reserve' Phosphorus in ppm: 50-100 in the topsoil, 60-100 in the subsoil.

'Reserve' cations in ppm: Calcium - 80-400 in the topsoil, 100-800 in the subsoil.

Magnesium - 180-750 in the topsoil, 160-2000 in the subsoil, increasing downwards.

Potash - 500-3500 in the topsoil, (higher in the poorly drained phase), 700-4000 in the subsoil, increasing downwards. (All data from 3 profiles).

Group III elements: 2-6% in the topsoil, 4-16% in the subsoil.

TAPAH SERIES (code number 4401)

Tapah Series is developed in coarse-textured material believed to be drowned old alluvium deposited at a higher level than its present position. A humus-stained zone is seen at depth. This minor soil is unclassified but probably best placed in the Great Soil Group of Podsol Soils.

General description:

0 - 3 to 6 inches	Dark or very dark greyish brown clay loam. Well-rooted.
24 to 48 "	Light brownish grey to grey or dark grey sand
below 24-48 "	Olive grey or light grey clay.

Range of characteristics.

Parent material: Coarse-textured alluvium believed to have been deposited on a terrace flat.

Topography: Wide bottomlands.

Occurrence: The Series was established on this survey. Similar soils are found elsewhere in First Division.

Diagnostic horizons: The following horizons are characteristic:

- A1 - usually well-developed.
- A2 - may be deep
- Bh - may be below augering depth or absent
- 4 - (clays) may be below augering depth.

Colour: Topsoils range from greyish to dark or very dark greyish brown, subsoils grey or light brownish grey. The Bh horizon where present is often brown or dark brown. Underlying clayey horizons are dark grey to grey or olive grey. Colours are normally in the 10YR Hue throughout.

Texture: Surface texture ranges from sandy loam to sandy clay. The A2 horizon is normally loamy sand but the addition of more recent clayey alluvium to the surface may give a texture ranging from clay loam to loamy sand down the profile. The Bh horizon, where present, is medium or coarse sand.

*How abrupt in textural bds*

*what about clay? w/ clay - s*

Structure and consistence: The soil is structureless throughout and loose to friable, above the clayey horizons.

Drainage: External drainage is slow to very slow. Internal drainage is poor to very poor.

Rooting depth: The Bh horizon is not a barrier to roots, which are sparsely present throughout the profile unless clayey horizons occur.

Inclusions: In the Bh horizon and sometimes in underlying clayey horizons pieces of rotting wood may be many.

Phases: poorly and very poorly drained phases have been recognised.

Chemical and mineralogical features.

Clay minerals: No data

Other mineralogical data: None

Silica/sesquioxide ratios: No data

Sesquioxide ratios: No data

Cation exchange capacity: less than 7 throughout.

Base saturation: No data

Acidity: 3.5 - 5.0.

'Reserve' phosphorus in ppm: less than 50 throughout

'Reserve' cations in ppm: Calcium - 120-480 in the topsoil, 200-250 at depth

Magnesium - 0 in the topsoil, 20-400 in the subsoil

Potash - 500-1000 in the topsoil, rising to 1200 in the subsoil.

(All data from 2 profiles).

Group III elements: less than 40% throughout.

BURONG SERIES (code number 430.1)

Burong Series has been classified in the Great Soil Group of Low-Humic Gley soils.

General description.

0 - 3 to 6 inches Light grey to brownish grey loam, perhaps mottled. Well-rooted. Blocky structure.

24 to 48 " Brownish to reddish yellow, mottled light grey, clay loam to clay. Sparsely rooted. Blocky structure.

below 24-48 " Light grey mottled clay. Structureless.

Range of characteristic.

Parent material: Recent alluvium

Topography: Low levees in association with wide bottomlands mantled by Embang and Tapah Series.

Occurrence: Unknown. The Series was established on this survey.

Diagnostic horizons: The following horizons are characteristic:

A1 - usually thin

2 - brown-mottled horizon, at least to 24 inches

3 - gleyed horizon.

Colour: Light grey or brownish grey in the A1 horizon, brownish yellow to reddish yellow or yellowish brown, mottled light grey or pale yellow, in the upper subsoil. Light grey, mottled brownish yellow or reddish yellow, in the gley horizon. All matrix colours in the 10YR Hue.

Texture: Loam to clay loam in the topsoil, clay loam to clay in the subsoil, becoming heavier at depth. In the lower subsoil patches of sand may occur.

Structure and consistence: Medium to coarse subangular blocky structure above the gley horizon which is structureless. Friable to firm.

Drainage: External drainage is moderately rapid. Internal drainage is imperfect.

Rooting depth: To the gley horizon, usually below 3 feet.

Inclusions: None seen.

Phases: No phases have been separated.

Chemical and mineralogical features.

Clay minerals: No data

Other mineralogical data: None

Silica/sesquioxide ratios: No data

Sesquioxide ratios: No data

Cation exchange capacity: 12-14 in the topsoil, 7-10 in the subsoil (25 in the gley horizon).

Base saturation: No data

Acidity: 4.8-5.0 throughout, increasing slightly with depth.

'Reserve' phosphorus in ppm: 100-150 in the topsoil, 20-80 in the subsoil

'Reserve' cations in ppm: Calcium - 200-500 in the topsoil, 40-120 in the subsoil (1,900 in the gley horizon).

Magnesium - 1100-160 in the topsoil, 700-1100 in the subsoil (4500 in the gley horizon).

potash - 1500-2000 in the topsoil, 1400-1600 in the subsoil (4800 in the gley horizon).

(All data from 1 profile).

Group III elements: 9-15% throughout (30% in the gley horizon).

PART III

CHEMICAL STUDIES

OF

THE SURFACE SOIL:

## INTRODUCTION

During the soil survey a number of profile pits were dug and sampled for laboratory analysis. Descriptions of selected profiles and available analytical data are given in Part IV of this report.

The chemistry of the profile as a whole, and trends and contrasts within the A2 - B - C horizon succession in particular, is of importance in soil classification. From the viewpoint of the agronomist, however, the soil chemistry of the rooting zone is of greatest importance. For most crops the majority of roots are in the surface 24 inches and there is a particular concentration within the surface 6 inches. A study of this part of the profile, independent of genetic horizon characteristics, is thus of agronomic value. 'Topsoil' - the word being used here in the sense of the surface 6 inches, regardless of the genetic horizons involved - has therefore been made the subject of a separate study, with which this part of the report is concerned.

## CHEMICAL STUDIES OF THE SURFACE SOIL

The study was undertaken with the following objects in view:

- (a) to characterise the surface soil of the area chemically and agronomically,
- (b) to find the variation in chemical properties within small sampling areas and between sampling areas, of soils which appear physically similar,
- (c) to carry out pot tests, using the subtractive nutrient method, to find out which elements are limiting crop growth and to determine the variation in crop response within sampling areas and between sampling areas of soils which appear physically similar,
- (d) to relate soil analysis data with crop responses.

The normal practice in 'topsoil' sampling is to take sixteen samples (an arbitrary but widely accepted figure) with an auger to a depth of 6 inches at a number of regularly spaced points along arms of a cross, on parallel lines, or on a similar convenient plan which will allow objective sampling. The sixteen samples extend over a variable area but commonly, as in this project, represent a site 1/10th of an acre in size. The technique has been described elsewhere in more detail (11). The samples are bulked and quartered in the field and the laboratory receives for analysis a single composite sample. A drawback of the technique is that at no time can one gauge to what extent the apparent physical uniformity of the site is reflected in chemical uniformity. This detailed survey provided the opportunity to collect data on this point, which is of obvious importance if small areas are to be used for experimental plots. In composite 'topsoil' sampling here, therefore, the sixteen samples were forwarded without bulking to the laboratory and analysed separately, any bulking being done later on the figures rather than on the samples.

Fortytwo sites were sampled (located on fig.9). The sites were chosen to give a fair scatter through the area and to provide a reasonable balance between the upland residual soils, the alluvial soils derived from them and the rather contrasting alluvial soils found in the extensive flat in the north of the survey area. In the accompanying text figures the results are laid out in these groups and, on fig. 8, the series classification is also included. It should be noted, however, that series classification is based largely on the character of subsurface horizons and that the characteristics of the A1 horizon are not used in classification above the phase level, surface soil being influenced strongly by the recent history of the site and other ephemeral factors. At a series or phase level, therefore, contrasts between the

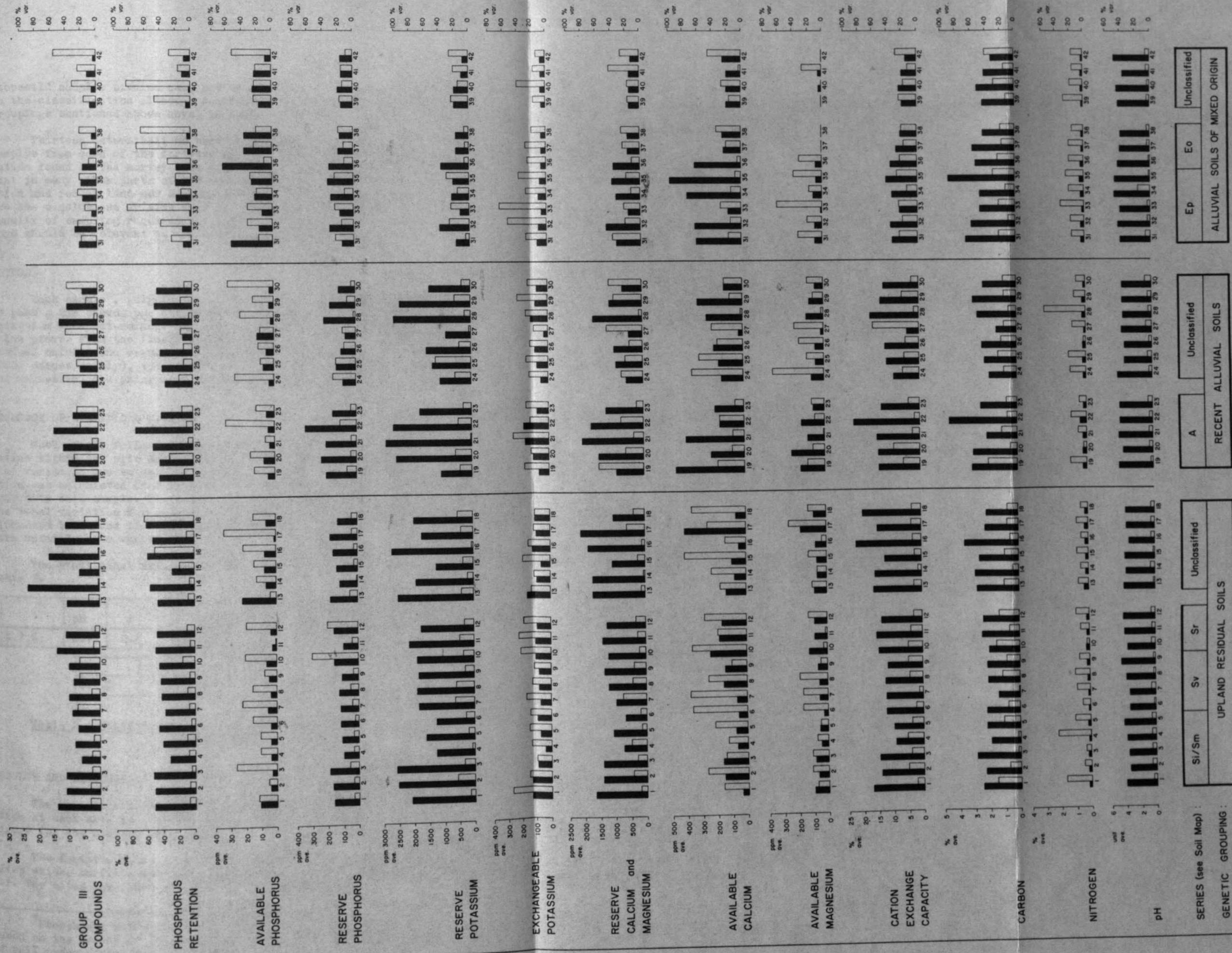


Fig. 8: COMPOSITE TOPSOIL ANALYSES FROM

42 SITES - AVERAGE VALUES AND SITE VARIATION FOR 13 DETERMINATIONS.

In black, average value for sixteen samples from one site. Left-hand scale refers.

In white, percentage coefficient of variation between sixteen samples from one site. Right-hand scale refers.

NB \*

'topsoil' samples studied need not be expected to reflect divisions in the classification although contrasts between the three broader groupings mentioned above have, in fact, been found.

Thirteen determinations were undertaken on each of sixteen samples from each of the fortytwo sites. The degree of chemical variation found in the survey area as a whole is probably similar to that in many other parts of the country where similar soils, vegetation and recent land-use history are found. Of particular importance are the conclusions arising from the data regarding the technique and density of sampling required for specific determinations. The conclusions should be relevant to the country as a whole.

METHOD

Each sample, weighing about two pounds, was air-dried and ground to pass a 2mm sieve. pH, cation exchange capacity and exchangeable potassium were determined. The soil was subsampled and ground to pass a 1mm sieve. From the finely ground sample 'reserve' phosphorus, potassium, calcium and magnesium, Group III compounds (iron and aluminium oxides mainly), total nitrogen, carbon, available calcium, and magnesium, and phosphorus retention\* were determined.

ACCURACY OF ANALYTICAL METHODS

Much of the following discussion deals with the degree of variation within the site and it was therefore important to isolate that variation due to method. Method variation for each determination was calculated from sixteen determinations on a well-mixed composite soil sample. The method variation was then subtracted from the total variation for each determination at each site. Variations discussed below and illustrated in fig. 8 and figs. 10 - 13 are therefore entirely site variations.

The statistical accuracy of each determination is given in Table 2.

	pH	N	C	Av.Mg	Av.Ca	Reserve Ca+Mg	Ex.K	Res.K
C.V.%	0.7	2.8	2.3	14.8	14.3	6.4	2.2	3.8
		Res.P	P ret.	Gp.III	Av.P			
C.V.%		5.2	2.5	4.6	6.9			

Table 2 : Coefficients of variation for the methods used in the study

RESULTS AND DISCUSSION

The variation between the sixteen samples for each determination at each site is illustrated (in white) on fig. 8. The mean figure for the sixteen samples as a whole is also given (in black).

The fortytwo sites have been arranged in this diagram so that sites which, on field evidence, appear comparable are grouped together. The sites have been classified in three broad groups, as follows:

\* Phosphorus retention needs some explanation. The figure is based on the amount of soluble phosphate which is retained by 5gms of soil under controlled laboratory conditions. 15.5 mgms of phosphate are added, in solution, to each soil.

the upland residual soils (Semongok Series or Semongok Variant), the recent alluvial soils (Abat and Dras Series) and the soils of the buffalo grazing area (Embang Series) which, for want of a better term, are styled in this subsection alluvial soils of mixed origin, although the pre-recent parent material is only found at depth in the profile and not in the surface 6 inches.

Sites with  
Parent, Burong  
Tapak  
not anal?

Within each of these three groupings field records were examined from each site. In conjunction with the 'topsoil' sampling four augerings to a depth of 48 inches were described from the site and from these augerings the soils of the site were classified. Sites at which the soils were transitional at the series level were then discarded. Also discarded were sites at which the vegetation was atypical for the group. One recently burnt site on Semongok Series was discarded for this reason, as were sites in the third grouping bearing a cover of lallang rather than the more common shrubs. Further discards were made of sites in which the Al horizon was much thicker or much thinner than normal for sites within the group. (For one or other of the above reasons all sites on Dras Series were discarded, leaving only representatives of Abat Series classified in the second group.) Those sites not discarded were considered on the evidence of routine field records to be comparable within a grouping. These are found on the left of the column for each of the three main groupings in fig. 8. Where marked variation is seen in the left-hand group of sites the inference is that such variation is a 'built-in' feature which cannot be identified by field evidence at the sites themselves and is only found on analysis. The discarded samples in each grouping are found on the right of each column (styled 'unclassified' and variety within these groups may be reflected in easily observable field features. Unless otherwise stated the discussion in this subsection deals only with the soils on the left of the column for each main grouping as the 'unclassified' sites would not be chosen for experimental purposes because of their visible lack of uniformity. It is the chemical uniformity or lack of it in sites which appear to be physically uniform (and thus apparently suitable for trial purposes) which is of most importance and of which prior knowledge is needed.

Table 3 summarises the levels found (all determinations) but excludes 'unclassified' soils. All nutrient were at low levels with the exception of available phosphorus, which was medium in the alluvial soils of mixed origin, and both exchangeable and reserve potassium, which were at medium levels in the other two groups. All other determinations gave medium level values for sites 1 - 30 and, except for carbon and pH, low level values for sites 31 - 42.

In Table 4 are illustrated contrasts between the three groups which are statistically significant at the  $P = 0.01$  level. It can be seen that for each determination there is a significant contrast between the upland residual soils (Semongok Series) and the alluvial soils of mixed origin (Embang Series), with the exception of nitrogen and reserve phosphorus. The recent alluvial soils (Abat Series) are comparable to the other alluvial soils for some determinations but for others reflect closely the levels in the upland soils from which they are in part derived. It should be noted that the alluvial soils of mixed origin, while lowest in phosphorus retention and Group III compounds, are highest in available phosphorus.

Results from a pot experiment using the subtractive nutrient technique showed that local spinach (bayam) only grew satisfactorily on Embang Series with those treatments which included phosphorus and nitrogen. Soils of Semongok Series in the experiment failed to grow even with the complete nutrient treatment. In the laboratory study most of the upland residual soils and recent alluvial soils (which are partly derived from them) needed about 7mgms of

<u>Determination</u>	<u>Upland Residual Soils</u>	<u>Recent Alluvial Soils</u>	<u>Alluvial Soils of Mixed Origin</u>
pH	4.0	4.4	4.4
Reserve phosphorus (ppm)	135	230	123
Available phosphorus (ppm)	5	5	18
Reserve calcium (ppm)	292	396	337
Available calcium (ppm)	130	301	268
Reserve magnesium (ppm)	953	1093	323
Available magnesium (ppm)	73	131	31
Reserve potassium (ppm)	1937	2186	590
Exchangeable potassium (ppm)	89	115	40
Nitrogen (%)	0.18	0.28	0.21
Cation exchange capacity (me/100gm)	13	15	8
Carbon (%)	2.3	3.1	2.9
Phosphorus retention (%)	46	51	12
Group III compounds (%)	10	11	4

Table 3 : Average values for all determinations for  
the three soil groupings

<u>Determination</u>	<u>Upland Residual Soils</u>	<u>Recent Alluvial Soils</u>	<u>Alluvial Soils of Mixed Origin</u>
pH	*	***	***
Reserve phosphorus	*	***	*
Available phosphorus	*	*	***
Reserve calcium	*	***	***
Available calcium	*	***	***
Reserve magnesium	***	***	*
Available magnesium	***	***	*
Reserve potassium	***	***	*
Exchangeable potassium	***	***	*
Nitrogen	*	***	*
Cation exchange capacity	***	***	*
Carbon	*	***	*
Phosphorus retention	***	***	*
Group III compounds	***	***	*

Table 4 : Comparison of levels for each determination  
for the three soil groupings

\*\*\* = relatively high      \* = relatively low

(where two groups are relatively high - or low  
- in comparison with the remaining group, differences between the two groups themselves are  
in no case statistically significant at the P =  
0.01 level.)

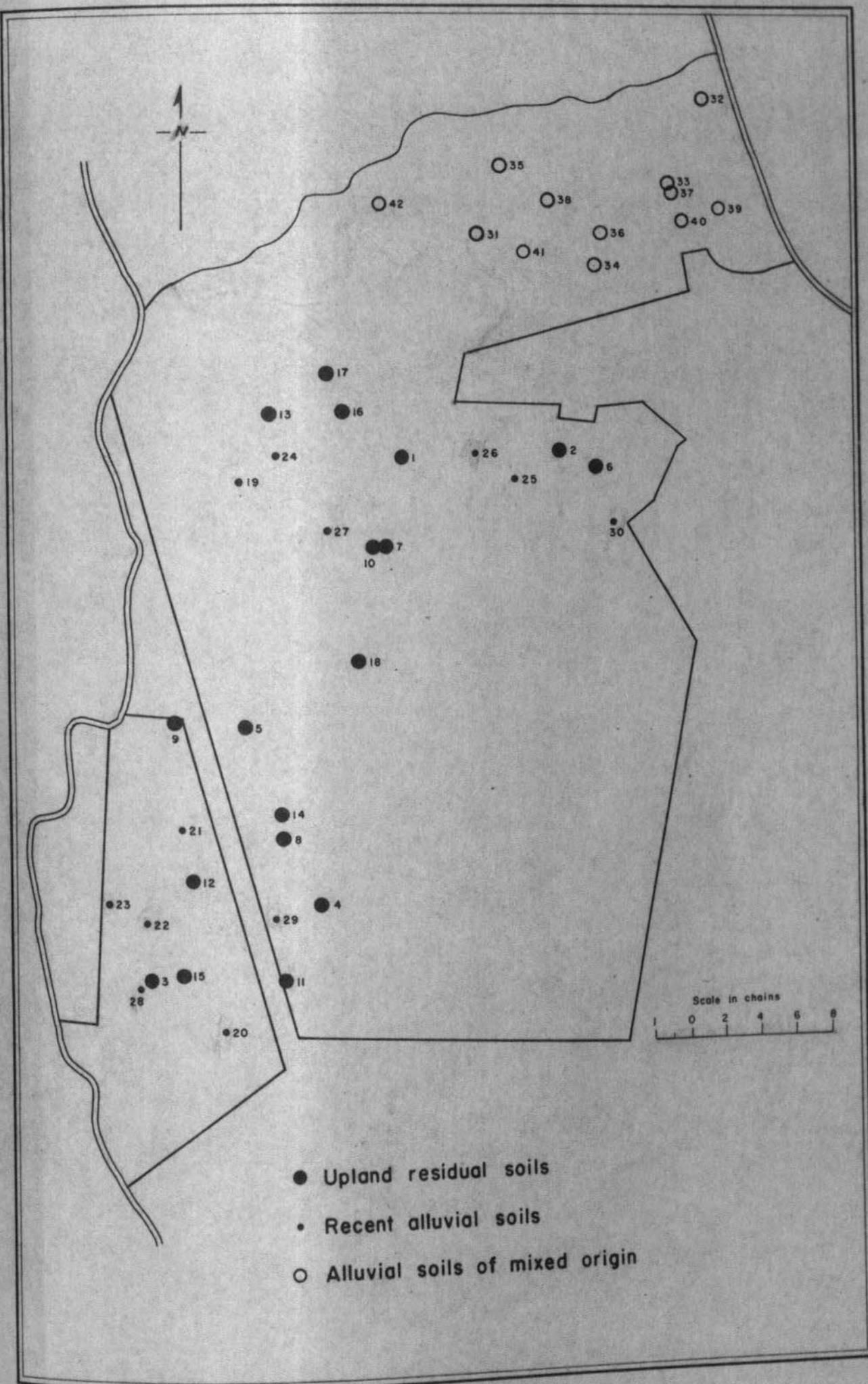


Fig. 9: LOCATION OF TOPSOIL SAMPLES

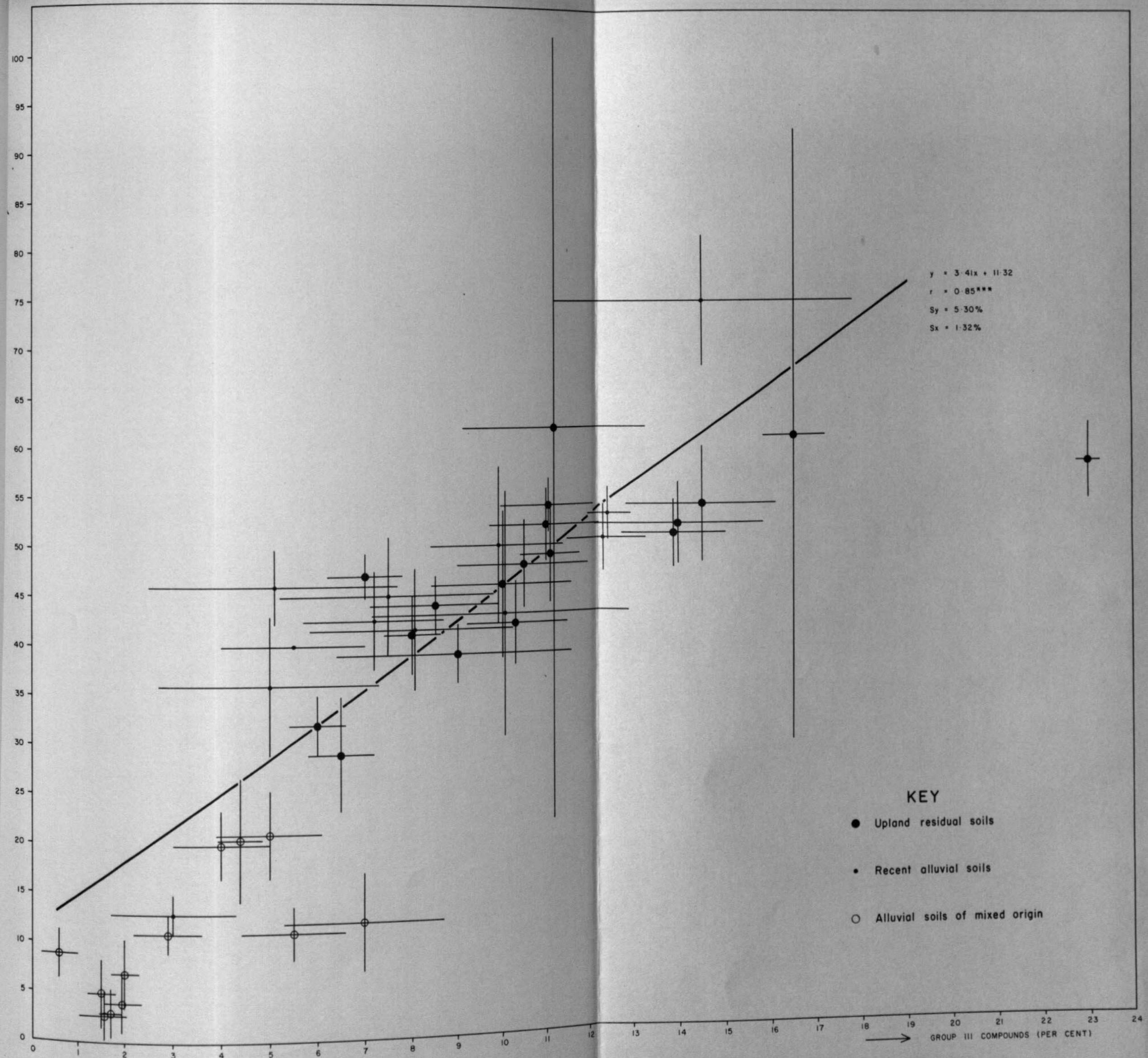


Fig. 10: RELATIONSHIP BETWEEN GROUP III COMPOUNDS AND PHOSPHORUS RETENTION

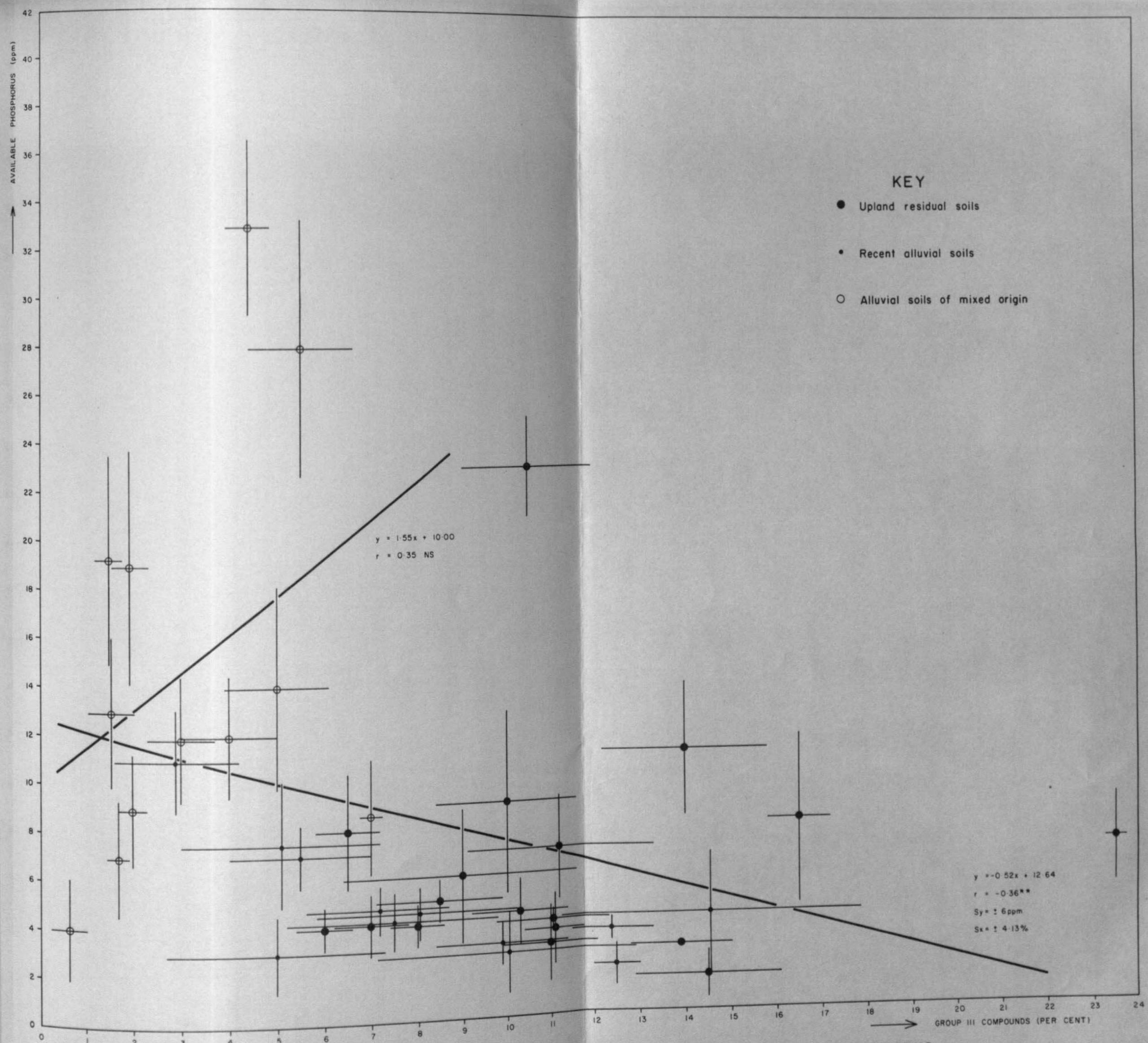


Fig. II: RELATIONSHIP BETWEEN GROUP III COMPOUNDS AND AVAILABLE PHOSPHORUS

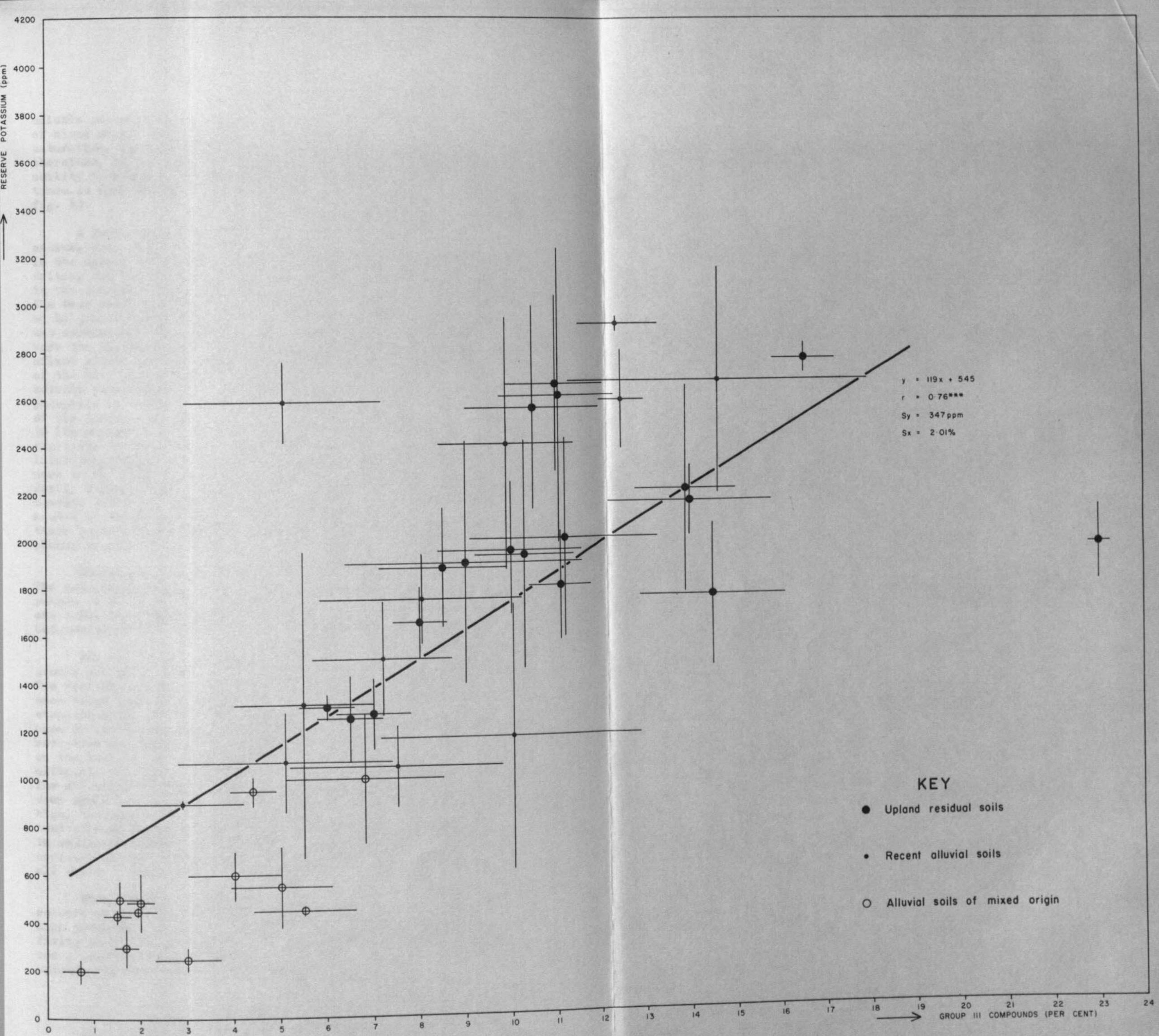


Fig. 12: RELATIONSHIP BETWEEN GROUP III COMPOUNDS AND RESERVE POTASSIUM

soluble phosphate to saturate 5 gms of soil. The alluvial soils of mixed origin only needed about 1 mgm of soluble phosphate for saturation. The difference in field response may be explained, therefore, by the fact that the upland residual soils have the ability to retain, in a form unavailable to plants, about seven times as much phosphate as the alluvial soils of mixed origin (see fig. 8).

A factorial field experiment (nitrogen, phosphate and potassium, each at three levels) on Semongok Series, the main soil in the upland residual soil group, is in progress at time of writing and the results, even after six weeks, show that phosphate is the dominant element in controlling the growth of hill padi, the crop used. An analysis of variance of a set of figures, obtained by growth scoring and subsequent logarithmic transformation, was carried out. The only treatments which showed significance were the phosphate ones. Nitrogen and potassium were having no effect either on their own or in combination on the general growth of the hill padi. This soil retains about 50 per cent of added soluble phosphorus and, in theory, needs about 3,000 lbs of phosphate in solution to saturate 1 acre of 'topsoil' to a depth of six inches. In fact we are getting a large response using only 30 lbs phosphate to the acre (solid superphosphate). This may be explained by the fact that phosphorus in solution is used in the laboratory determination while a solid phosphatic fertilizer was used in the field and the distribution of the latter was necessarily uneven. There are many places where 1 gm of soil is in close contact with more than 1.4 mgm of phosphate, the minimum amount needed to saturate it and roots tend to congregate in and exploit these pockets rather than the adjacent pockets in which all phosphorus is in a fixed form.

Phosphorus retention is related to other chemical properties. The relationship between phosphorus retention and Group III compounds is shown in fig. 10 and that of Group III compounds and available phosphorus in fig. 11. Fig. 12 shows the relationship between Group III compounds and reserve potassium.

Fig. 10 shows that the correlation between Group III compounds and phosphorus retention is good and highly significant. The vertical and horizontal lines show the standard deviations of each value (each value being the mean of sixteen samples). The standard error of the trend line is given by  $S_y$  and  $S_x$ . In this case Group III compounds vary by  $\pm 1.3$  per cent and phosphorus retention by  $\pm 5.30$  per cent. Fig. 11 shows two trend lines. The line on the left for the alluvial soils of mixed origin is not significant, but this may be due to lack of samples. The trend line for all soils represents a significant negative correlation between Group III compounds and available phosphorus. The scatter is high, however. This negative correlation means that as the content of iron and aluminium oxides increases there is a decrease in available phosphate levels. Fig. 12 shows a good positive correlation between reserve potassium and Group III compounds for all soils in the area.

These trends underline the fact that strong red and yellow colours in upland soils (which indicate at least a moderately high percentage of Group III compounds) commonly imply high fixing powers of phosphatic fertilizers. Given the same application a greater response is thus to be expected from a pale-coloured upland soil than from one with more reddish colours.

#### DO WE TAKE ENOUGH SAMPLES?

It was possible with the number of results obtained to measure the statistical validity of our soil analysis data and in this

<u>Determination</u>	<u>Number of samples</u>	
	<u>Mean</u>	<u>Maximum</u>
Group III compounds	46	282
Phosphorus retention	91	650
Available phosphorus	105	428
Reserve potassium	31	216
Reserve phosphorus	29	335
Exchangeable potassium	95	380
Reserve calcium and magnesium	54	327
Available calcium	163	634
Available magnesium	66	441
Cation exchange capacity	38	357
Carbon	40	151
Nitrogen	40	313
pH	3	26
Grand mean, all determinations	62	

Table 5 : The average and maximum number of samples required per site for accurate results

subsection all fortytwo sites are considered, including those 'unclassified' in fig. 8.

The coefficient of variation was measured for each determination at each site. Using this coefficient it was possible to calculate the number of soil samples needed to be taken from each site to obtain statistically valid results (12). The standards of accuracy taken are based on those accepted in biological sciences: that the determined mean figure should be no more than  $\pm 10$  per cent of the true mean figure in 19 out of 20 cases. The main results are shown in fig. 13.

For each site/determination the scatter of determinations of the sixteen samples was used to calculate statistically the theoretical number of sampling points required, for a site of that degree of variability, so that the mean figure derived from all sampling points would be sufficiently close to the actual average level of the compound or property concerned in the field to satisfy the standard of accuracy defined above. Where all results for a determination are very uniform (as in the case of pH) three or four sampling points might suffice. Where the sixteen samples are widely variable (as in the case of available calcium at some sites) the theoretical number of sampling points needed to give an accurate mean figure may exceed 600.

Each site/determination was studied from this viewpoint and a theoretical number of sampling points for 'accurate' results worked out for it. In fig. 13 the horizontal axis shows the possible number of sampling points per site and the vertical axis the distribution of the fortytwo sites in relation to the horizontal scale. To accentuate the bias of the frequency the horizontal scale is considered in multiples of ten rather than as individual figures.

From this diagram it can be seen that the number of sampling points needed in preparing a composite 'topsoil' sample for laboratory analysis varies greatly, depending on the particular determinations required for the study. It can be seen that for many determinations a sampling density of sixteen points per site is quite inadequate. Conversely, the diagram roughly indicates what degree of confidence can be placed in the figure determined in the laboratory for each determination, given a specific sampling density.

The average and maximum number of sampling points per site required to guarantee 'accuracy' for each determination are given in Table 5. In Table 6 the average figures (all determinations) for all sites within each soil classification unit represented in the study are shown. This table bears out the point mentioned above, that series and phase classifications are, with the exception of poorly and very poorly drained soils, based on properties independent of those studied in this project. Table 7 indicates the number of sites within each main grouping for which the sampling density used was adequate or inadequate for 'accurate' results.

The sampling procedure was statistically acceptable for more sites in the upland residual soils grouping than in either of the alluvial groups and, even then, this applies only to some determinations.

Soil classification unit	Number of samples required per site	Soil classification unit	Number of samples required per site
Semongok (Si/Sm)	42	Mean of recent alluvial soils	54
Semongok Variant (Sv)	61	Embang (Ep)	73
Semongok shallow (Sr)	71	Embang (Ev)	53
Mean of upland residual soils	58	Mean of alluvial soils of mixed origin	53

Table 6 : The average number of samples required per site for accurate results, in terms of the soil classification units

### CONCLUSIONS

The following conclusions are relevant to the survey area:

(1) The general chemical fertility of the area is low.

(2) Embang Series has the most favourable phosphorus status while Semongok and Dras Series are highest in potassium. Nitrogen is highest in Dras Series, where it is almost at a medium level. Acidity is uniformly high and base status uniformly low for all soils studied.

(3) In comparing the data derived from the laboratory studies with available field experimental data the following determinations appear to be of most agronomic value:

- Group III compounds
- Phosphorus retention
- Available phosphorus
- Reserve phosphorus

as phosphorus is invariably the major nutrient in shortest supply and Group III compounds (a simple laboratory determination) reflect closely the phosphorus status of the soil.

(4) From a comparison of laboratory data, field experiments and greenhouse trials it is apparent that placement rather than broadcast application of phosphatic fertilizer is more necessary on soils which have a high phosphorus retention figure than on soils where this is low.

(5) Except for pH determinations a 'topsoil' sampling density of sixteen points per 1/10th acre site is generally inadequate although for upland soils (Semongok Series, that is) the sampling rate was adequate for five determinations at eleven or more sites out of eighteen.

The remaining conclusions are of more general relevance:

(6) The sampling density chosen must be geared to the determinations required. The trends in the sampling density needed for specific determinations brought out by this study will probably hold good for the majority of soils.

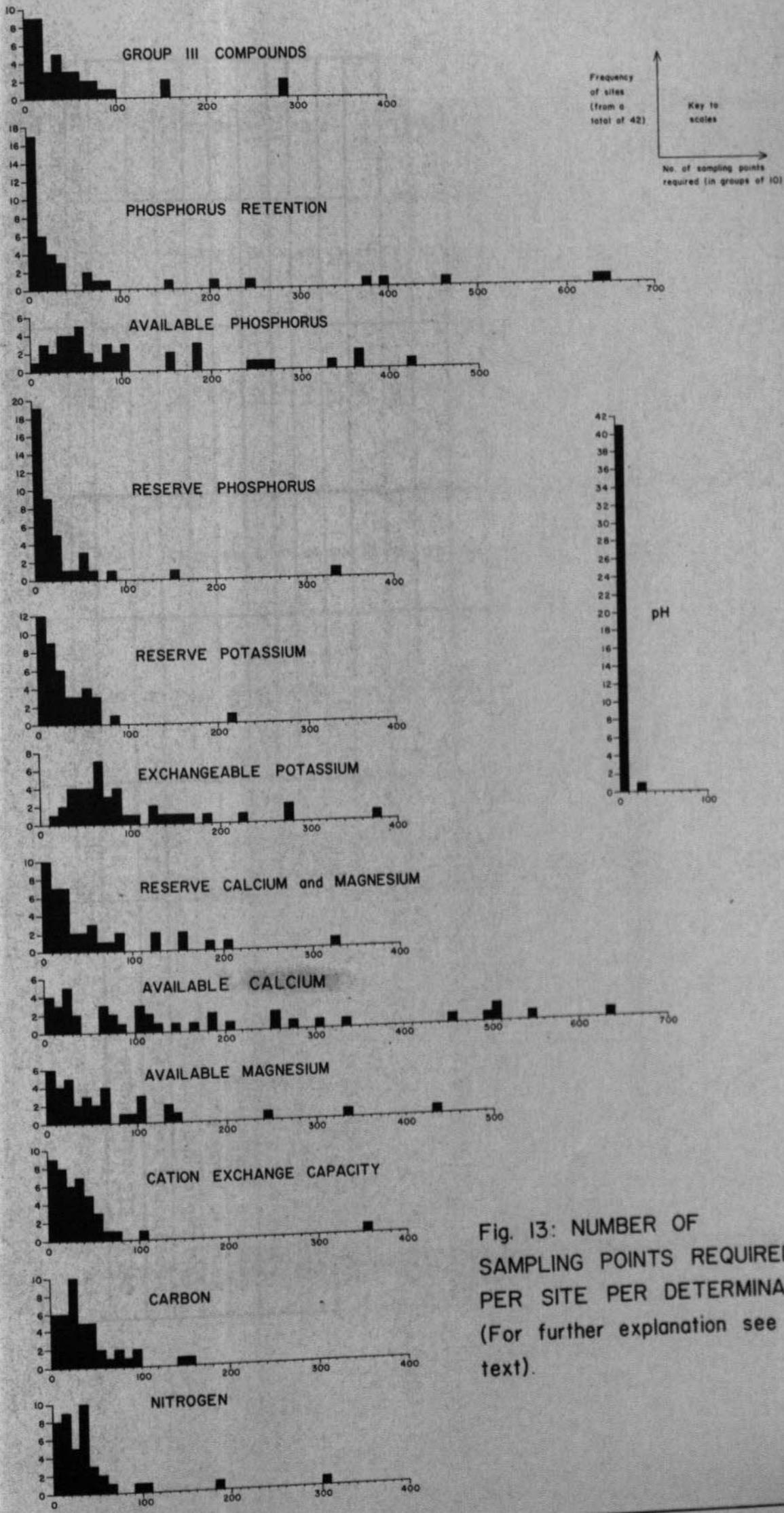


Fig. 13: NUMBER OF SAMPLING POINTS REQUIRED PER SITE PER DETERMINATION (For further explanation see text).

Determination	Upland residual Soils		Recent Alluvial Soils		Alluvial Soils of Mixed origin	
	Adequate	Inadequate	Adequate	Inadequate	Adequate	Inadequate
Group III compounds	13	5	2	10	1	11
Phosphorus retention	14	4	7	5	0	12
Available phosphorus	3	15	0	12	1	11
Reserve phosphorus	16	2	7	5	4	8
Reserve potassium	8	10	5	7	3	9
Exchangeable potassium	0	18	0	12	1	11
Reserve calcium and magnesium	11	7	3	9	2	10
Available calcium	0	18	2	10	3	9
Available magnesium	5	13	2	10	5	7
Cation exchange capacity	9	9	4	8	1	11
Carbon	5	13	2	10	2	10
Nitrogen	8	10	5	7	0	12
pH	18	0	12	0	11	1

Table 7: The adequacy of the sampling density at all 42 sites.

(7) it appears that many more samples are needed for a valid chemical evaluation of surface horizons in alluvial soils than of those in upland residual soils.

(8) It follows from the previous point that it may be possible in practise only to get a chemical evaluation which is valid when dealing with upland soils. The data suggests that prediction, from chemical data, of crop response and fertilizer interactions for alluvial soils would be only an educated guess. There remains, some doubt, however, how representative the alluvial soils studied are in this respect.

(9) The evidence shows, as expected, that morphological uniformity of a site does not ensure chemical homogeneity in the surface horizons of the soil.

PART IV

FORMAL PROFILE DESCRIPTIONS

In this section fourteen profiles dug at representative sites in the area are described in detail. In the case of the most widespread soils more than one profile of the series is described to illustrate some of the variations found within the classification unit. The full range of characteristics is not covered by these examples but has been set down in Part II of the report.

Data on 'reserve' cations are given for each profile. It has been found that these data are more useful in characterising the natural fertility of the soil for agriculture than 'exchangeable' determinations, which are almost invariably too low to show contrasts or allow comparative interpretations.

- 4 - 12 " Brownish-yellow (1000)  
Very fine light-grey  
rock channels, light  
blocky structure, firm.  
firm. Occasional  
distinct earth masses
- 12 - 21 " Brownish-yellow (1000)  
Light fine and medium  
massive, very weak  
structure, firm.  
irregular, diffuse
- 22 - 26 " Brownish-yellow (1000)  
distinct fine and medium  
and very diffuse  
Very rare earth  
subangular  
fragments.
- 30 - 33 " Light grey (1000)  
channels, weak  
plastic, very  
massive gravel  
(52176).
- 41 - 55 " Very light grey (1000)  
massive, weak  
(weak diffuse  
massive, light

PART IV

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Data on 'reserve' cations are given for each profile. It has been found that these data are more useful in characterising the natural fertility of the soil for agriculture than 'exchangeable' determinations, which are almost invariably too low to show contrasts or allow comparative interpretations.

4 - 12 "	Brownish-yellow faint fine light root channels. Heavy blocky structure. Firm. Distinct angular prisms
12 - 22 "	Brownish-yellow faint fine and Noils. Very yellow structure. Firm Firm. Angular
22 - 30 "	Brownish-yellow distinct fine and dark Very very angular rootlets.
30 - 44 "	light grey channeled plastic quartz (02476).
44 - 51 "	grey brownish-yellow (less than 10 soils.)

Profile 1.

Soil Group: - Red-Yellow  
Podsollic

Parent material: Weathered Cretaceous  
Shale.

Family: Semongok

External drainage: Medium to rapid

Series: SEMONGOK

Vegetation/Land Use: Grassland;  
Buffalo grazing area.

Phase: Imperfectly  
drained, weakly mottled.

Altitude: c. 85 ft. above sea level

Location: Semongok Agricultural  
Station, near rentis 13,  
peg 10

Rainfall: c. 160 inches (?)

Rainfall Class (Mohr): I

Latitude: 1° 23' N

Lab. Nos: S2476 - S2480 and S 2486

Longitude: 110° 20'E

Field Nos: A1 - 6

Site: Summit of 20 ft. high  
hill on edge of alluvial  
flat.

Date sampled: 17.7.63

Slope: < 1°

0 - 4 inches

Light yellowish-brown (10YR 6/4) loam to clay loam, with many distinct fine and medium light-grey mottles. Rare rusty root channels. Moist. Weak medium subangular blocky structure, breaking easily to medium and fine granular. Slightly firm. Occasional rootlets. Porous. Distinct wavy boundary. (S2480).

4 - 12 "

Brownish-yellow (10YR 6/6) clay, with many faint fine light-grey mottles. Rare rusty root channels. Moist. Course subangular blocky structure, breaking to coarse granular. Firm. Occasional to rare rootlets. Porous. Distinct smooth boundary. (S2479).

12 - 22 "

Brownish-yellow (10YR 6/6) clay, with many faint fine and medium light-grey mottles. Moist. Very weakly coarse subangular blocky structure. Firm. Rare to very rare rootlets. Porous. Diffuse wavy boundary. (S2478).

22 - 30 "

Brownish-yellow (10YR 6/6) clay with abundant distinct fine and medium light-grey mottles and many distinct fine reddish-yellow mottles. Very rare rusty root channels. Moist. Weak medium subangular blocky structure. Firm. Very rare rootlets. Porous. Diffuse wavy boundary. (S2477)

30 - 44 "

Light grey (10YR 7/1) clay. Abundant rusty root channels. Wet. Slightly sticky. Slightly plastic. Very rare rootlets. Rare medium angular quartz gravel. Porous. Diffuse wavy boundary. (S2476).

44 - 55 "

Grey (7.5YR 5/0) clay, with many distinct fine reddish-yellow mottles. Wet. Structureless (weak coarse angular blocky structure when moist.) Slightly sticky. Slightly plastic. No rootlets. Slightly porous. (S2486).

Laboratory number	2480	2479	2478	2477	2476	2486
Upper depth of horizon (ins.)	0	4	12	22	30	44
Lower depth of horizon (ins.)	4	12	22	30	44	55
Horizon						
<u>PHYSICAL</u>						
Coarse earth (%)						
Fine earth						
Very coarse sand (%)						
Coarse sand (%)						
Medium sand (%)						
Fine sand (%)						
Very fine sand (%)						
Sand (%)						
Silt (%)						
Clay (%)						
<u>CHEMICAL</u>						
pH (H <sub>2</sub> O; 1:2.5)	4.5	4.6	4.8	4.8	4.8	4.7
CaCO <sub>3</sub> (%)						
Available (Morgan's; ppm)						
Calcium	63	0	0	0	0	31
Magnesium	69	0	0	0	0	0
Potassium	38	38	50	75	75	88
Sodium						
Total bases (Meq./100 gm)						
C.E.C. (Meq./100 gm)	18.60	17.35	19.79	21.69	22.86	21.79
% base saturation						
Phosphorus (available)						
P-retention (%)						
Conc. HCl Extractable (ppm)						
Phosphorus	23	102	105	110	115	105
Potassium	1750	2750	3950	3000	5000	3800
Calcium	240	70	160	80	50	140
Magnesium	1563	1929	4481	2306	3133	1713
Iron						
Aluminium						
Group III Elements	12.4	14.4	16.7	12.5	17.1	10.8
Sulphates (Morgan's)						
Nitrogen (%)	0.23	0.09				
Organic Carbon (%)	3.11	0.86				
C/N Ratio.	14	10				

Table 8: Analytical data, Semongok Series (Profile 1)

Profile 2.

Soil Group: Red-Yellow  
Podsollic

Parent material: Weathered Cretaceous  
Shale.

External drainage: Medium to rapid

Family: Semongok

Vegetation/Land Use: Dominantly rasam,  
with some trees and tall grasses.

Series: SFMONGOK

Phase: Imperfectly drained,  
strongly mottled.

Altitude: c. 180 ft. above sea-level

Rainfall: c. 160 inches. (?)

Location: Semongok  
Agricultural Station,  
rentis 39, peg 4.

Rainfall Class (Mohr): I

Latitude: 1° 23'N.

Lab. Nos: S 2805 - S 2808

Longitude: 110° 20'E.

Field Nos: X1-4

Date sampled: 27-8-63

Site: Middle slope of moderately  
rolling topography.

Slope: 4°

0 - 5 inches Grey (10YR 5/1) fine sandy loam, with many distinct fine light-grey and yellow mottles. Rare rusty root channels. Dry. Weakly coarse subangular blocky structure, breaking to fine subangular blocky. Hard. Occasional rootlets. Porous. Distinct smooth boundary. (S 2805).

5 - 15 " Pale-brown (10YR 6/3) clay loam to clay, with many distinct fine and medium reddish-yellow and light grey mottles. Moist. Structureless to weakly medium subangular blocky. Firm. Occasional rootlets. Porous. Indistinct wavy boundary. (S 2806).

15 - 29 " Brownish-yellow (10YR 6/6) clay, with many distinct yellow, reddish-yellow and weak red mottles. Moist. Weak medium and fine subangular blocky structure. Firm. Occasional to rare rootlets. Slightly porous. Indistinct wavy boundary. (S 2807).

29 - 50 " Light grey to grey (10YR 6/1) clay, with many distinct fine and medium yellow mottles. Moist. Structureless. Slightly firm. Very rare rootlets. Slightly porous. (S2808).

Laboratory number	2805	2806	2807	2808
Upper depth of horizon (ins.)	0	5	15	29
Lower depth of horizon (ins.)	5	15	29	50
Horizon				
<u>PHYSICAL</u>				
Coarse earth (%)				
Fine earth				
Very coarse sand (%)				
Coarse sand (%)				
Medium sand (%)				
Fine sand (%)				
Very fine sand (%)				
Sand (%)				
Silt (%)				
Clay (%)				
<u>CHEMICAL</u>				
pH (H <sub>2</sub> O; 1:2.5)	4.1	4.0	3.8	3.8
CaCO <sub>3</sub> (%)				
Exchangeable (Meq./100 gm)				
Calcium				
Magnesium				
Potassium				
Sodium				
Total bases (Meq./100 gm)	10.19	11.41	16.02	12.22
C.E.C. (Meq./100 gm)				
% base saturation				
Phosphorus (available)				
P-retention (%)				
Conc. HCl Extractable (ppm)				
Phosphorus	134	119	157	155
Potassium	1050	1875	2650	4500
Calcium	120	175	100	160
Magnesium	770	1191	1647	833
Iron				
Aluminium				
Group III Elements				
Sulphates (Morgan's)	0.14	0.05	0.06	0.08
Nitrogen (%)	2.15	1.15	0.47	0.50
Organic Carbon (%)	15	23	7	6
C/N Ratio.				

Table 9: Analytical data, Semongok Series (Profile 2)

Profile 3

Soil Group: Red-Yellow  
Podsollic

Family: Semongok

Series: SEMONGOK

Phase: Imperfectly drained,  
weakly mottled.

Location: Semongok  
Agricultural Station,  
rentis 41, peg 19.

Latitude: 1° 23' N

Longitude: 110° 20'E

Site: Lower slope of moderately  
rolling topography.

Slope: 8°

Parent material: Weathered  
Cretaceous shale and subordinate  
sandstone.

External drainage: Moderately rapid

Vegetation/Land Use: Rasam, lallang  
and scattered trees.

Altitude: c. 140 feet above sea level

Rainfall: c. 160 inches (?)

Rainfall Class (Mohr): I

Lab. Nos: S 2697 - S 2701

Field Nos: U 209 - U 203

Date sampled: 23. 8. 63.

- 0 - 3 inches Dark brown (10YR 3/3) clay loam, with few distinct coarse grey mottles and few distinct fine reddish brown mottles. Moist. Very coarse subangular blocky structure, breaking to medium and fine granular. Firm. Many roots and rootlets. Porous. Distinct wavy boundary. (S2697)
- 3 - 12 " Brownish yellow (10YR 6/6) clay to very fine sandy clay, with few faint fine light grey mottles. Moist. Weak coarse subangular blocky structure. Firm. Few rootlets. Porous. Indistinct wavy boundary. (S2698).
- 12 - 13 " Yellow (10YR 8/8) clay, with few faint fine reddish yellow and light grey mottles. Moist. Weak coarse to medium subangular blocky structure. Firm. Few rootlets. Porous. Indistinct wavy boundary. (S2699).
- 23 - 30 " Reddish yellow (7.5YR 7/6) clay, with many faint fine and medium yellow red and light grey mottles. Moist. Structureless. Firm. No roots seen. Slightly porous. Indistinct wavy boundary. (S2700).
- 30 - 42 " Reddish yellow, light grey and weak red clay from weathered rock. Few dark red fragments of well-weathered shale. Few large light grey fragments of fine-grained sandstone. Very rare rootlets. (S 2701).

Rapak?

Laboratory number	2697	2698	2699	2700	2701
Upper depth of horizon (ins.)	0	3	12	23	30
Lower depth of horizon (ins.)	3	12	23	30	42
Horizon					
<u>PHYSICAL</u>					
Coarse earth (%)					
Fine earth					
Very coarse sand (%)					
Coarse sand (%)					
Medium sand (%)					
Fine sand (%)					
Very fine sand (%)					
Sand (%)					
Silt (%)					
Clay (%)					
<u>CHEMICAL</u>					
pH (H <sub>2</sub> O; 1:2.5)	4.2	3.9	3.8	3.7	3.8
CaCO <sub>3</sub> (%)					
Exchangeable (Meq./100 gm)					
Calcium					
Magnesium					
Potassium					
Sodium					
Total bases (Meq./100 gm)	24.54	19.22	8.97	23.27	22.16
C.E.C. (Meq./100 gm)					
% base saturation					
Phosphorus (available)					
P-retention (%)					
Conc. HCl Extractable (ppm)					
Phosphorus	202	156	140	137	112
Potassium	3100	3450	3650	5300	3800
Calcium	520	40	200	40	<20
Magnesium	1941	1593	2767	2755	2624
Iron					
Aluminium					
Group III elements	16.7	19.6	19.8	20.5	15.6
Sulphates (Morgan's)					
Nitrogen (%)	0.35	0.16			
Organic Carbon (%)	4.13	1.39			
C/N Ratio.	12	9			

Table 10: Analytical data, Semongok Series (Profile 3)

Profile 4.

Soil Group: Red-Yellow  
Podsollic

Parent material: Weathered  
Cretaceous shale and conglomerate (?)

Family: Semongok

External drainage: Rapid

Series: SEMONGOK VARIANT

Vegetation/Land Use: Secondary forest

Phase: --

Altitude: c. 130 feet above sea level

Location: Semongok  
Agricultural Station, rentis  
13b, peg 7.

Rainfall: c. 160 inches (?)

Rainfall Class (Mohr): I

Latitude: 1° 23' N

Lab. Nos: S 2634 - S 2637

Longitude: 110° 20'

Field Nos: F 1 - 4

Site: Middle slope of steeply  
rolling topography

Date sampled: 31. 8. 63

Slope: 20°

- 0 - 3 inches Dark grey (10YR 4/1) clay loam. Dry. Medium granular structure. Soft. Many roots and rootlets. Porous. Distinct wavy boundary. (S2634).
- 3 - 19 " Yellow (10YR 7/6) clay, with many distinct fine light grey mottles. Moist. Very weak coarse subangular blocky structure. Firm. Few rootlets. Porous. Diffuse irregular boundary. (S2635).
- 19 - 34 " Yellow (10YR 7/6) clay, with many distinct fine light grey mottles. Moist. Very weak coarse subangular blocky structure. Firm. Few fine quartz gravel. No roots seen. Diffuse irregular boundary. (S2636).
- 34 - 60 " Light grey (10YR 7/1) clay, with profuse distinct fine to coarse yellowish red mottles. Moist. Structureless. Firm. Many fine quartz gravel and few small and medium quartz pebbles. No roots seen. Slightly porous. (S2637).

Laboratory number	2634	2635	2636	2637
Upper depth of horizon (ins.)	0	3	19	34
Lower depth of horizon (ins.)	3	19	34	60
Horizon				
<u>PHYSICAL</u>				
Coarse earth (%)				
Fine earth				
Very coarse sand (%)				
Coarse sand (%)				
Medium sand (%)				
Fine sand (%)				
Very fine sand (%)				
Sand (%)				
Silt (%)				
Clay (%)				
<u>CHEMICAL</u>				
pH (H <sub>2</sub> O; 1:2.5)	3.7	3.7	3.9	3.9
CaCO <sub>3</sub> (%)				
Exchangeable (Meq./100 gm)				
Calcium				
Magnesium				
Potassium				
Sodium				
Total bases (Meq./100 gm)				
C.E.C. (Meq./100 gm)	17.54	17.24	12.14	14.5
% base saturation				
Phosphorus (available)				
P-retention (%)				
Conc. HCl Extractable (ppm)				
Phosphorus	127	70	60	45
Potassium	2150	2700	3050	5200
Calcium	350	170	70	0
Magnesium	2174	1456	2330	2396
Iron				
Aluminium				
Group III Elements	14.4	17.8	21.0	22.4
Sulphates (Morgan's)				
Nitrogen (%)	0.28	0.06		
Organic Carbon (%)	3.70	0.36		
C/N Ratio.	13	6		

Table 11: Analytical data, Semongok Variant (Profile 4)

Profile 5.

Soil Group: Red-Yellow  
Podsollic

Parent material: Weathered cretaceous  
shale, sandstone and conglomerate.

Family:

External drainage: Rapid

Series: Unnamed.

Vegetation/Land Use: Rasam, simpor and  
scattered trees.

Phase:

Altitude: c. 180 feet above sea level

Location: Semongok  
Agricultural Station, rentis  
42, peg 9 $\frac{1}{2}$ .

Rainfall: c. 160 inches (?)

Latitude: 1° 23' N

Rainfall Class (Mohr): I

Longitude: 110° 20'

Lab. Nos: S2779 - S 2782

Site: Upper slope to  
summit of moderately rolling  
topography.

Field Nos: G288 - G291

Date sampled: 3. 9. 61

Slope: 5°

0 - 6 inches Yellowish brown (10YR 5/4) sandy loam. Dry. Fine subangular blocky structure. Hard. Many roots and rootlets. Porous. Indistinct wavy boundary. (S2779)

6 - 17 " Yellow (10YR 7/6 - 7/8) sandy loam, with few faint fine pale yellow mottles. Moist. Medium and coarse subangular blocky structure. Firm. Few large angular fragments of weathered fine-grained conglomerate and sandy shale. Few rootlets. Porous. Distinct wavy boundary. (S2780).

17 - 38 " Brownish yellow (10YR 6/6) sandy clay loam to sandy clay. Moist. Coarse subangular blocky structure. Firm. Few large fragments of weathered conglomerate and sandstone. Few small fragments of weathered shale. No roots seen. Porous. (S2781).

38 - 47 " As above, with few distinct fine and medium pale yellow and yellowish red mottles. (S 2782).

Laboratory number	2779	2780	2781	2782
Upper depth of horizon (ins.)	0	6	17	38
Lower depth of horizon (ins.)	6	17	38	47
Horizon				
<u>PHYSICAL</u>				
Coarse earth (%)				
Fine earth				
Very coarse sand (%)				
Coarse sand (%)				
Medium sand (%)				
Fine sand (%)				
Very fine sand (%)				
Sand (%)				
Silt (%)				
Clay (%)				
<u>CHEMICAL</u>				
pH (H <sub>2</sub> O; 1:2.5)	3.6	4.0	4.1	4.0
CaCO <sub>3</sub>				
Exchangeable (Meq./100 gm)				
Calcium				
Magnesium				
Potassium				
Sodium				
Total bases (Meq./100 gm)				
C.E.C. (Meq./100 gm)	8.37	6.13	7.35	9.18
% base saturation				
Phosphorus (available)				
P-retention (%)				
Conc. HCl Extractable (ppm)				
Phosphorus	102	100	120	127
Potassium	850	1000	1250	2175
Calcium	90	100	10	75
Magnesium	371	503	407	1087
Iron				
Aluminium				
Group III Elements	7.5	12.0	14.9	17.2
Sulphates (Morgan's)				
Nitrogen (%)	0.13	0.05		
Organic Carbon (%)	1.71	0.55		
C/N ratio.	13	11		

Table 12: Analytical data, Unnamed soil (Profile 5).

Profile 6.

Soil Group: Red-Yellow  
Podsollic

Family: Semongok

Series: SEMONGOK

Phase: Shallow

Location: Semongok  
Agricultural Station,  
near rentis 41, peg 20.

Latitude: 1° 23' N

Longitude: 110° 20' E

Site: Middle Slope of  
steeply rolling topography.

Slope: 20°

Parent material: Weathered Cretaceous  
Shale.

External drainage: Rapid

Vegetation/Land Use: Tall grasses and  
scattered trees.

Altitude: c. 130 ft. above sea level.

Rainfall: c. 160 inches (?)

Rainfall class (Mohr): I

Lab. Nos: S 2670 - S 2675

Field Nos: 01 - 6

Date sampled: 29. 8. 63

0 - 2½ inches Brown to dark-brown (10YR 4/3) fine sandy loam, with many faint fine and medium yellow, pale brown and light grey mottles. Dry. Medium to coarse subangular blocky structure, breaking to coarse granular. Hard. Many roots and rootlets. Occasional small pieces of charcoal. Porous. Distinct smooth boundary. (S2670).

2½ - 5 " Yellowish-brown (10YR 5/6) fine sandy clay, with many faint fine light yellowish-brown mottles. Moist. Weak coarse subangular blocky structure, breaking to coarse granular. Firm to very firm. Occasional to rare rootlets. Very rare small fragments of slightly weathered grey shale. Porous. Distinct irregular boundary. (S 2671).

5 - 22 " Yellowish-brown (10YR 5/6) fine sandy clay, with many distinct, fine to coarse, grey, yellow and reddish-yellow mottles. Moist. No structure seen. Firm. Abundant large and small subangular fragments of dark grey slightly-weathered shale, cleaving with difficulty. Occasional to rare rootlets. Slightly porous. Distinct irregular boundary. (S 2672).

22 - 53 " Large angular and subangular fragments of dark grey slightly weathered shale in a matrix of dark grey (10YR 4/1) clay. Laminar iron accumulations in some shale fragments, rarely associated with incipient manganese/iron concretions. No rootlets. Slightly porous. Distinct irregular boundary. (S 2673: 22 - 39"; S 2674: 39 - 53").

53 - 74. " Dark-grey to light-grey shale, cleaving to angular fragments. Pale yellow and yellowish red alteration colours along main cleavage lines, with occasional thin bands of iron accumulation. (S 2675).

Laboratory number	2670	2671	2672	2673	2674	2675
Upper depth of horizon (ins.)	0	2½	5	22	39	52
Lower depth of horizon (ins.)	2½	5	22	39	52	74
Horizon						
<b>PHYSICAL</b>						
Coarse earth (%)						
Fine earth						
Very coarse sand (%)						
Coarse sand (%)						
Medium sand (%)						
Fine sand (%)						
Very fine sand (%)						
Sand (%)						
Silt (%)						
Clay (%)						
<b>CHEMICAL</b>						
pH (H <sub>2</sub> O; 1:2.5)	4.2	4.2	4.2	4.2	4.2	4.2
CaCO <sub>3</sub> (%)						
Exchangeable (Meq./100 gm)						
Calcium						
Magnesium						
Potassium						
Sodium						
Total bases (Meq./100 gm)						
C.E.C. (Meq./100 gm)	22.34	24.43	23.82	23.77	22.03	24.07
% base saturation						
Phosphorus (available)						
P-retention (%)						
Conc. HCl Extractable (ppm)						
Phosphorus	245	137	145	132	127	136
Potassium	2700	2550	5850	4500	2750	4700
Calcium	680	90	50	50	60	20
Magnesium	2456	1677	2713	2690	2576	3486
Iron						
Aluminium						
Group III Elements	18.1	18.0	22.8	18.9	17.3	23.7
Sulphates (Morgan's)						
Nitrogen (%)	0.37	0.15				
Organic Carbon (%)	5.30	0.41				
C/N Ratio.	14	27				

Table 13: Analytical data, Semongok Series (Profile 6)

Profile 7.

Soil Group: Reddish-Brown  
Lateritic.

Parent material: Weathered  
quartz diorite

Family:

External drainage: Rapid

Series: PANTIS

Vegetation/Land Use: Mature Rubber

Phase: Moderately well-drained

Altitude: c. 150 feet above sea level.

Location: Semongok  
Agricultural Station, rentis  
11, peg 4 $\frac{3}{4}$

Rainfall: c. 160 inches (?)

Rainfall Class (Mohr): I

Latitude: 1° 23'N

Lab. Nos: S2498 - S 2502

Longitude: 110° 20'E

Field Nos: N1 - 5

Site: Summit of steeply  
rolling topography.

Date sampled: 8.8.63

Slope: 2°

- 0 - 3 inches Dark greyish brown (10YR 4/2) loam to clay loam. Moist. Medium and coarse granular structure. Friable. Many rootlets. Porous. Distinct wavy boundary. (S2498).
- 3 - 14 " Light olive brown (2.5Y 5/6) clay. Moist. Coarse subangular blocky structure, breaking to fine and very fine subangular blocky. Friable to firm. Rare charcoal fragments. Few rootlets. Porous. Distinct wavy boundary. (S2499).
- 14 - 31 " Olive yellow (2.5Y 6/6) clay. Weak very coarse subangular blocky structure, breaking easily to very fine subangular blocky. Firm. Few rootlets. Porous. Indistinct smooth boundary. (S2500).
- 31 - 52 " Olive yellow (2.5Y 6/6) clay. Moist. Weak very fine subangular blocky structure. Friable to firm. Few small and medium fragments of well-weathered rock. No roots seen. Porous. Indistinct smooth boundary. (S2501).
- 52 - 73 " Olive yellow (2.5Y 6/6) clay, with few distinct medium red mottles. Moist. Fine and very fine subangular blocky structure. Firm. Many small and medium fragments of red, pink and yellow weathered rock. No roots seen. Porous. (S2502).

Laboratory number	2498	2499	2500	2501	2502
Upper depth of horizon (ins.)	0	3	14	31	52
Lower depth of horizon (ins.)	3	14	21	52	73
Horizon					
<b>PHYSICAL</b>					
Coarse earth (%)					
Fine earth					
Very coarse sand (%)					
Coarse sand (%)					
Medium sand (%)					
Fine sand (%)					
Very fine sand (%)					
Sand (%)					
Silt (%)					
Clay (%)					
<b>CHEMICAL</b>					
pH (H <sub>2</sub> O; 1:2.5)	4.6	4.8	4.8	5.1	5.0
CaCO <sub>3</sub> (%)					
Available (Morgan's; ppm)					
Calcium	219	0	10	10	10
Magnesium	50	0			
Potassium	38	13			
Sodium					
Total bases (Meq./100 gm)					
C.E.C. (Meq./100 gm)	12.84	7.16	6.97	7.31	7.76
% base saturation					
Phosphorus (available)					
P-retention (%)					
Conc. HCl Extractable					
Phosphorus	230	115	115	116	151
Potassium	550	550	525	425	500
Calcium	200	40	40	130	100
Magnesium	839	1545	1228	1299	1521
Iron					
Aluminium					
Group III Elements	25.3	28.5	33.6	37.3	37.1
Sulphates (Morgan's)					
Nitrogen (%)	0.26	0.06			
Organic Carbon (%)	0.80	0.92			
C/N Ratio.	31	15			

Table 14: Analytical data, Pantis Series (Profile 7)

Profile 8.

Soil Group: Reddish-Brown  
Lateritic

Parent material: Weathered quartz diorite

Family:

External drainage: Moderately rapid

Series: PANTIS

Vegetation/Land Use: Secondary forest

Phase: Moderately well-drained.

Altitude: c. 80 feet above sea level.

Location: Semongok Agricultural  
Station near rentis 10, peg 7.

Rainfall: c. 160 inches (?)

Latitude: 1° 23' N

Rainfall Class (Mohr): I

Longitude: 110° 20'E

Lab. Nos: S2664 - S2668

Site: Lower slope of  
steeply rolling topography.

Field Nos: M1 - 5

Date sampled: 7. 8. '64.

Slope: 4°

- 0 - 4 inches Greyish brown (10YR 5/2) loam, with few faint medium yellowish brown mottles. Dry. Fine and very fine subangular blocky structure. Very firm. Few rootlets. Few small fragments of weathered rock. Porous. Distinct wavy boundary. (S2664).
- 4 - 12 " Light olive brown (2.5Y 5/6) clay, with few faint fine yellowish brown mottles. Moist. Weak medium subangular blocky structure. Firm. Few rootlets. Many stone-size spheroidal pieces of well-weathered rock, easily cut with a spade. Porous. Distinct smooth boundary. (S2665).
- 12 - 26 " Olive yellow (2.5Y 6/6) clay. Moist. Weak medium subangular blocky structure. Firm. Rare rootlets. Few small angular fragments of weathered rock. Porous. Distinct smooth boundary. (S2666).
- 26 - 36 " Olive yellow (2.5Y 6/6) clay. Moist. Weak fine subangular blocky structure. Firm. Very rare rootlets. Few small angular fragments of weathered rock. Slightly porous. Indistinct wavy boundary. (S2667).
- 36 - 52 " Olive yellow (2.5 Y 6/6) clay. Moist. Weak coarse subangular blocky structure. Firm. No roots seen. Many small and large fragments of reddish yellow and large fragments of reddish yellow and greenish grey weathered rock. Slightly porous. (S2668).

Laboratory number	2664	2665	2666	2667	2668
Upper depth of horizon (ins.)	0	4	12	26	36
Lower depth of horizon (ins.)	4	12	26	36	52
Horizon					
<u>PHYSICAL</u>					
Coarse earth (%)					
Fine earth					
Very coarse sand (%)					
Coarse sand (%)					
Medium sand (%)					
Fine sand (%)					
Very fine sand (%)					
Sand (%)					
Silt (%)					
Clay (%)					
<u>CHEMICAL</u>					
pH (H <sub>2</sub> O; 1:2.5)					
CaCO <sub>3</sub> (%)					
Exchangeable (Meq./100 gm)					
Calcium					
Magnesium					
Potassium					
Sodium					
Total bases (Meq./100 gm)					
C.E.C. (Meq./100 gm)	12.65	7.85	8.06	8.06	7.10
% base saturation					
Phosphorus (available)					
P-retention (%)					
Conc. HCl Extractable (ppm)					
Phosphorus	90	115	115	80	85
Potassium	650	550	600	600	550
Calcium	130	90	180	50	60
Magnesium	821	1492	1030	1719	958
Iron					
Aluminium					
Group III Elements	21.3	26.9	30.2	32.4	34.0
Sulphates (Morgan's)					
Nitrogen (%)	0.31	0.08			
Organic Carbon (%)	5.56	0.81			
C/N Ratio.	18	10			

Table 15: Analytical data, Pantis Series (Profile 8)

Profile 9.

Soil Group: Low-Humic Gley

Parent material: Recent alluvium

Family:

External drainage: Slow to moderate

Series: ABAT

Vegetation/land use: Young regrowth;  
resam, simpor, Cyperaceae.

Phase: Imperfectly drained.

Altitude: c. 60 feet above sea level

Location: Semongok Agricultural  
Station, rentis 33, peg 2

Rainfall: c. 160 inches.

Latitude: 1° 23' N

Rainfall Class (Mohr): I

Longitude: 110° 20'E

Lab. Nos: S2655 - S2658

Site: Alluvial Flat

Field Nos: K 1 - 4

Slope: <1°

Date sampled: 6. 8. 63

- 0 - 5 inches Yellowish brown (10YR 5/6) loam. Moist.  
Weak coarse granular to fine and medium subangular  
blocky structure. Friable. Few roots and rootlets.  
Porous. Indistinct wavy boundary. (S2655).
- 5 - 14 " Brownish yellow (10YR 6/8) clay with many distinct  
coarse light grey and reddish yellow mottles. Moist.  
Weak coarse subangular blocky structure. Firm.  
Rare rootlets. Porous. Indistinct wavy boundary.  
(S2656).
- 14 - 30 " Brownish yellow (10YR 6/8) clay, with abundant distinct  
medium and coarse light grey and strong brown mottles.  
Moist. Very weak coarse subangular blocky structure.  
Firm. No roots seen. Rare fine quartz gravel and  
very small pebbles. Porous. Distinct irregular  
boundary. (S2657).
- 30 - 50 " Light grey (10YR 7/1) clay, with abundant rusty root  
channels and dark grey staining on main cracks faces.  
Moist. Weak coarse subangular blocky structure.  
Firm. Few light yellow and red patches from weathered  
shale. Slightly porous. (S2658).

Laboratory number	2655	2656	2657	2658
Upper depth of horizon (ins.)	0	5	14	30
Lower depth of horizon (ins.)	5	14	30	50
Horizon.				
<u>PHYSICAL</u>				
Coarse earth (%)				
Fine earth				
Very coarse sand (%)				
Coarse sand (%)				
Medium sand (%)				
Fine sand (%)				
Very fine sand (%)				
Sand (%)				
Silt (%)				
Clay (%)				
<u>CHEMICAL</u>				
pH (H <sub>2</sub> O; 1:2.5)	4.0	3.9	4.0	3.9
CaCO <sub>3</sub> (%)				
Exchangeable (Meq./100 gm)				
Calcium				
Magnesium				
Potassium				
Sodium				
Total bases (Meq./100 gm)				
C.E.C. (Meq./100 gm)	7.96	8.47	15.3	15.2
% base saturation				
Phosphorus (available)				
P-retention (%)				
Conc. HCl Extractable (ppm)				
Phosphorus	80	90	90	75
Potassium	650	900	1500	1000
Calcium	120	110	50	20
Magnesium	317	270	928	264
Iron				
Aluminium				
Group III Elements	2.5	4.1	11.1	4.7
Sulphates (Morgan's)				
Nitrogen (%)	0.16	0.06		
Organic Carbon (%)	3.31	0.36		
C/N Ratio.	21	6		

Table 16: Analytical data, Abat Series (Profile 9)

Profile 10.

<u>Soil Group:</u> Low-Humic Gley	<u>Parent material:</u> Recent alluvium
<u>Family:</u>	<u>External drainage:</u> Slow
<u>Series:</u> DRAS	<u>Vegetation/land use:</u> Simpor with scattered trees.
<u>Phase:</u> Poorly drained.	<u>Altitude:</u> c. 95 feet above sea level
<u>Location:</u> Semongok Agricultural Station, rentis 17b, peg 4	<u>Rainfall:</u> c. 160 inches
<u>Latitude:</u> 1° 23'N	<u>Rainfall Class (Mohr):</u> I
<u>Longitude:</u> 110° 20'E	<u>Lab. Nos:</u> S2659 - S2663
<u>Site:</u> Alluvial flat.	<u>Field Nos:</u> L 1 - 4
<u>Slope:</u> <1°	<u>Date sampled:</u> 6. 8. 63

- |              |   |
|--------------|---|
| 0 - 4 inches | Brown (10YR 5/3) clay loam. Moist. Weak medium subangular blocky structure. Friable. Many rootlets. Few fragments of charcoal. Porous. Distinct wavy boundary. (S2659).   |
| 4 - 12 "     | Brownish yellow (10YR 6/6) clay loam to clay, with abundant prominent medium light grey mottles. Friable. Moist. Weak medium subangular blocky structure. Few rootlets. Porous. Distinct wavy boundary. (S2660) |
| 12 - 21 "    | Light grey (10YR 7/1) sandy clay, with many distinct medium brownish yellow mottles. Moist. Structureless. Firm. Rare rootlets. Slightly porous. Indistinct wavy boundary. (S2661)                              |
| 21 - 34 "    | Grey (10YR 5/1) clay, with few distinct fine and medium brownish yellow mottles. Moist. Structureless. Friable. Very rare rootlets. Slightly porous. Distinct irregular boundary. (S2662)                       |
| 34 - "       | Hard light grey shale, little weathered, coarsely cleaving.   |

Laboratory number	2659	2660	2661	2662	2663
Upper depth of horizon (ins.)	0	4	12	21	34+
Lower depth of horizon (ins.)	4	12	21	34	
Horizon					
<b>PHYSICAL</b>					
Coarse earth (%)					
Fine earth					
Very coarse sand (%)					
Coarse sand (%)					
Medium sand (%)					
Fine sand (%)					
Very fine sand (%)					
Sand (%)					
Silt (%)					
Clay (%)					
<b>CHEMICAL</b>					
pH (H <sub>2</sub> O; 1:2.5)	3.9	4.0	4.1	3.3	3.2
CaCO <sub>3</sub> (%)					
Available (Morgan's; ppm)					
Calcium	666	582	312	354	447
Magnesium	200	112	75	181	562
Potassium	56	38	26	128	88
Sodium					
Total bases (Meq./100 gm)	15.3	10.61	6.32	24.95	23.50
C.E.C. (Meq./100 gm)					
% base saturation					
Phosphorus (available)	6	1	tr	tr	9
P-retention (%)					
Conc. HCl Extractable (ppm)					
Phosphorus	140	155	80	80	240
Potassium	1000	1500	1350	5075	4550
Calcium	370	460	340	310	660
Magnesium	59	946	815	2198	6313
Iron					
Aluminium					
Group III Elements	8.2	13.1	8.9	11.4	23.4
Sulphates (Morgan's)					
Nitrogen (%)	0.32	0.13			
Organic Carbon (%)	4.55	2.64			
C/N Ratio.	14	20			

Table 17: Analytical data, Dras Series (Profile 10)

Profile 11

Soil Group: Low-Humic Gley

Parent material: Recent (?) alluvial clays (deposited on older alluvial sands)

Family:

Series: EMBANG

External drainage: Very slow

Phase: Very poorly-drained.

Vegetation/Land Use: Old fallow after wet padi now buffalo rough grazing land.

Location: Semongok Agricultural Station, rentis 5, peg 0

Altitude: c. 60 ft. above sea-level

Rainfall: c. 160 inches (?)

Site: Alluvial flat.

Rainfall Class (Mohr): I

Slope: <1°

Lab. Nos: S2638 - S2642

Field Nos: G1-5

Date sampled: 30. 6. 63

- 0 - 4 inches Very dark greyish-brown (10YR 5/2) fine sandy loam. Moist. Structureless to weakly very coarse subangular blocky. Friable. Few roots and rootlets. Porous. Distinct smooth boundary. (S2638)
- 4 - 10 " Light grey (10YR 7/1) sandy clay loam. Few to many rusty root channels. Moist. Structureless to weakly very coarse to coarse subangular blocky. Friable. Few rootlets. Porous. Indistinct wavy boundary. (S2639).
- 10 - 22 " Light grey (10YR 7/1) sandy clay loam to clay. Many rusty root channels. Moist. Structureless to weakly coarse subangular blocky. Slightly firm. Very rare rootlets. Porous. Indistinct wavy boundary. (S2640)
- 22 - 35 " Light grey (10YR 7/2) sandy clay loam to clay, with few faint fine brownish-yellow mottles. Few rusty root channels. Moist. Structureless. Firm. Very rare rootlets. Porous. Distinct wavy boundary (S2641)
- 35 - 48 " Light brownish-grey (10YR 6/2) medium and coarse sand, Moist. Structureless. Slightly firm. Many large and small fragments of decomposing wood. No roots seen. Porous. (S2642).

Laboratory number	2638	2639	2640	2641	2642
Upper depth of horizon (ins.)	0	4	10	22	35
Lower depth of horizon (ins.)	4	10	22	35	48
Horizon.					
<b>PHYSICAL</b>					
Coarse earth (%)					
Fine earth					
Very coarse sand (%)					
Coarse sand (%)					
Medium sand (%)					
Fine sand (%)					
Very fine sand (%)					
Sand (%)					
Silt (%)					
Clay (%)					
<b>CHEMICAL</b>					
pH (H <sub>2</sub> O; 1:2.5)	4.3	4.1	4.0	4.0	4.1
CaCO <sub>3</sub> (%)					
Available (Morgan's; ppm)					
Calcium	291	125	250	666	686
Magnesium	0	0	0	0	0
Potassium	10	15	18	28	13
Sodium					
Total bases (Meq./100 gm)					
C.E.C. (Meq./100 gm)	4.49	3.26	5.70	5.38	4.39
% base saturation					
Phosphorus (available)	7	2	1	tr	1
P-retention (%)					
Conc. HCl Extractable (ppm)					
Phosphorus	70	70	70	60	35
Potassium	650	650	1100	1150	750
Calcium	370	160	340	760	720
Magnesium	186	138	599	467	174
Iron					
Aluminium					
Group III Elements	1.4	2.3	5.0	4.7	5.4
Sulphates (Morgan's)					
Nitrogen (%)	0.13	0.04			
Organic Carbon (%)	1.91	0.25			
C/N Ratio	15	6			

Table 18: Analytical data, Embang Series (Profile 11)

Profile 12.

Soil Group: Parent material: Old alluvium  
Family: External drainage: Very slow  
Series: TAPAH Vegetation/Land use: Low kerangas scrub; buffalo rough grazing land.  
Phase: -Poorly drained. Altitude: c. 60 ft. above sea level  
Location: Semongok Agricultural Station, near rentis Rainfall: c. 160 inches (?)  
Latitude: 1° 23'N Rainfall Class (Mohr): I  
Longitude: 110° 20' Lab. Nos: S2941 - S2946  
Site: Alluvial flat Field Nos: S374 - S379  
Slope: < 1° Date sampled: 21. 4. '64

- 0 - 6 inches Very dark grey (10YR 3/1) fine sandy clay loam. Moist. Structureless. Friable. Many roots and rootlets. Porous. Indistinct wavy boundary. (S2941)
- 6 - 20 " Dark to very dark grey (10YR 3/1 - 4/1) fine sandy clay loam. Moist. Structureless. Friable. Occasional roots and rootlets. Porous. Distinct wavy boundary. (S2942)
- 20 - 40 " Light brownish grey (10YR 6/2) coarse sandy loam, with many rusty root channels. Moist. Structureless. Friable. Very rare rootlets. Porous. Distinct wavy boundary. (S2943).
- 40 - 50 " Dark greyish brown (10YR 4/2) coarse sand. Moist. Structureless. Loose. No roots seen. Porous. Diffuse wavy boundary. (S2944).
- 50 - 65 " As above with many medium and large fragments of rotting leaves and wood. Distinct irregular boundary. (S2945).
- 65 - 75 " Olive grey (5Y 5/2) clay, with very rare black and dark brown stains and small fragments of rotting wood. Moist. Structureless. Firm. (S2946).

Laboratory number	2941	2942	2943	2944	2945	2946
Upper depth of horizon (ins.)	0	6	20	40	50	65
Lower depth of horizon (ins.)	6	20	40	50	65	75
Horizon						
<b>PHYSICAL</b>						
Coarse earth (%)						
Fine earth						
Very coarse sand (%)						
Coarse sand (%)						
Medium sand (%)						
Fine sand (%)						
Very fine sand (%)						
Sand (%)						
Silt (%)						
Clay (%)						
<b>CHEMICAL</b>						
pH (H <sub>2</sub> O; 1:2.5)	4.5	4.6	4.3	5.0	4.9	4.5
CaCO <sub>3</sub>						
Exchangeable (Meq./100 gm)						
Calcium						
Magnesium						
Potassium						
Sodium						
Total bases (Meq./100 gm)	5.86	3.53	3.37	2.06	3.93	
C.E.C. (Meq./100 gm)						
base saturation						
Phosphorus (available)						
Retention (%)						
conc. HCl Extractable (ppm)						
Phosphorus	104	76	57	46	46	70
Potassium	480	460	380	200	260	400
Calcium	0	24	132	48	168	1474
Magnesium	950	900	1200	1000	1050	1000
Iron						
Aluminium						
Group III Elements	1.04	1.14	3.42	1.86	2.08	32.04
Sulphates (Morgan's)						
Nitrogen (%)	0.20	0.14	0.02			
Organic Carbon (%)	2.11	1.55	0.15			
C/N Ratio.	11	11	8			

Table 19: Analytical data, Tapah Series (Profile 12)

Profile 13.

Soil Group:

Parent material: Old alluvium

Family:

External drainage: Very slow

Series: TAPAH

Vegetation/Land use: Short grassland with scattered trees; Buffalo grazing area.

Phase: Poorly drained

Location: Semongok  
Agricultural Station, near  
rentis 13, peg 11.

Altitude: c. 65 ft. above area level

Rainfall: c. 160 inches (?)

Latitude: 1° 23'N

Rainfall Class (Mohr): I

Longitude: 116° 20'E.

Lab. Nos: S2481 - S 2485

Site: Alluvial flat

Field Nos: B 1 - 5

Slope: < 1°

Date sampled: 17.7.63

- 0 - 4 inches Dark greyish-brown (10YR 4/2) fine sand. Moist. Structureless. Loose. Few roots and rootlets. Very porous. Distinct wavy boundary. (S2481)
- 4 - 10 " Dark brown (10YR 3/3) medium sand. Moist. Structureless. Loose. Rare rootlets. Very porous. Distinct wavy boundary. (S2482).
- 10 - 21 " Greyish-brown (10YR 5/2) coarse sand. Few rusty root channels. Moist. Structureless. Friable. Porous. Indistinct wavy boundary. (S2483).
- 21 - 32 " Brown (10YR 5/3) medium sand, with many distinct medium light grey and dark brown mottles. Moist. Structureless. Friable. Few fine quartz gravel. No rootlets. Porous. Sharp smooth boundary. (S2484).
- 32 - 43 " Dark grey (10YR 4/1) silty clay. Wet. Structureless. Slightly sticky. Plastic. Abundant small dark yellow and dark grey fragments of well-weathered shale, crumbling easily. Slightly porous. Water-table at 38 inches.

Laboratory number	2481	2482	2483	2484	2485
Upper depth of horizon (ins.)	0	4	10	21	32
Lower depth of horizon (ins.)	4	10	21	32	43
Horizon					
<b>PHYSICAL</b>					
Coarse earth (%)					
Fine earth					
Very coarse sand (%)					
Coarse sand (%)					
Medium sand (%)					
Fine sand (%)					
Very fine sand (%)					
Sand (%)					
Silt (%)					
Clay (%)					
<b>CHEMICAL</b>					
pH (H <sub>2</sub> O; 1:2.5)	4.8	4.9	4.8	4.5	3.5
CaCO <sub>3</sub> (%)					
Available (Morgan's; ppm)					
Calcium	125	21	21	21	239
Magnesium	6	0	0	0	206
Potassium	25	0	25	25	25
Sodium					
Total bases (Meq./100 gm)	3.92	1.29	3.10	6.92	23.33
C.E.C. (Meq./100 gm)					
% base saturation					
Phosphorus (available)					
P-retention (%)					
Conc. HCl Extractable (ppm)					
Phosphorus	45	17	30	18	115
Potassium	500	575	800	950	4000
Calcium	120	120	140	240	420
Magnesium	0	0	264	353	2929
Iron					
Aluminium	1.2	1.3	3.6	2.1	11.7
Group III Elements					
Sulphates (Morgan's)	0.11	0.01	0.02	0.29	0.10
Nitrogen (%)	1.91	0.40	0.44	1.39	1.46
Organic Carbon (%)	17	40	22	5	15
C/N Ratio.					

Table 20: Analytical data, Tapah Series (Profile 13)

Profile 14.

Soil Group: Low-Humic Gley      Parent material: Recent alluvial clays  
Family:      External drainage: Slow  
Series: BURONG      Vegetation/Land use: Short grassland  
with very scattered trees; Buffalo  
grazing area.  
Phase: Imperfectly-drained.      Altitude: c. 65 ft. above sea level.  
Location: Semongok Agricultural      Rainfall: c. 160 inches (?)  
Station, near rentis 13,  
peg 12.      Rainfall Class (Mohr): I  
Latitude: 1° 23'N      Lab. Nos: S 2493 - S 2497  
Longitude: 110° 20'E      Field Nos: D 1 - 5  
Site: Alluvial flat,  
incipient levee      Date sampled: 18. 7. 63  
Slope: < 1°

- 0 - 4 inches      Light grey to grey (10YR 6/1) loam to clay loam.  
Occasional rusty root channels. Dry. Moderate.  
medium to coarse subangular blocky structure. Slightly  
hard. Many rootlets. Porous. Distinct smooth  
boundary. (S2493).
- 4 - 10 "      Brownish-yellow (10YR 6/6) clay loam, with few distinct.  
medium light grey mottles. Moist. Medium to coarse sub-  
angular blocky structure. Friable. Occasional  
rootlets. Porous. Distinct smooth boundary. (S2494)
- 10 - 25 "      Brownish-yellow (10YR 6/8) clay loam to clay, with  
many distinct medium light grey mottles. Moist.  
Weak coarse subangular blocky structure. Firm.  
Occasional rootlets. Porous. Distinct smooth  
boundary. (S2495).
- 25 - 44 "      Reddish-yellow (7.5YR 6/8) clay with scattered small  
patches of light grey coarse sand. Moist. Structureless.  
Firm. Occasional to rare rootlets. Porous.  
Distinct smooth boundary. (S2496).
- 44 - 63 "      Light grey (10YR 7/1) clay, with many distinct medium  
reddish-yellow mottles. Wet. Structureless.  
Slightly sticky. Nonplastic. No rootlets seen.  
Slightly porous. (S2497).

Laboratory number	2493	2494	2495	2496	2497
Upper depth of horizon (ins.)	0	4	10	25	44
Lower depth of horizon (ins.)	4	10	25	44	63
Horizon					
<b>PHYSICAL</b>					
Coarse earth (%)					
Fine earth					
Very coarse sand (%)					
Coarse sand (%)					
Medium sand (%)					
Fine sand (%)					
Very fine sand (%)					
Sand (%)					
Silt (%)					
Clay (%)					
<b>CHEMICAL</b>					
pH (H <sub>2</sub> O; 1:2,5)	4.8	4.8	4.9	4.9	5.0
CaCO <sub>3</sub> (%)					
Available (Morgan's; ppm)					
Calcium	333	73	42	42	2490
Magnesium	56	19	13	0	475
Potassium	25	13	13	25	150
Sodium					
Total bases (Meq./100 gm)	12.49	13.53	10.10	7.56	25.07
C.E.C. (Meq./100 gm)					
% base saturation					
Phosphorus (available)					
P-retention (%)					
Conc. HCl Extractable (ppm)					
Phosphorus	145	99	67	45	23
Potassium	1500	2000	1400	1550	4800
Calcium	480	210	120	40	1880
Magnesium	1168	1599	1048	785	4534
Iron					
Aluminium	10.3	14.1	9.9	9.8	30.6
Group III elements					
Sulphates (Morgan's)					
Nitrogen (%)	0.20	0.12			
Organic Carbon (%)	2.18	1.23			
C/N Ratio	11	10			

Table 21: Analytical data, Burong Series (Profile 14).

APPENDIX I

ANALYTICAL METHODS

Reserve Nutrients (or hydrochloric acid extractable nutrients):

One gm of soil is ignited and then digested with concentrated hydrochloric acid. Phosphorus is determined by the molybdenum blue method using ascorbic acid as the reducing agent. Calcium and magnesium are determined by E.D.T.A. titration after removing the iron and aluminium by precipitating as hydroxides. Potassium is determined in the final solution by flame photometer.

Group III compounds:

The precipitate of hydroxides from the above reserve nutrient determination is ignited and weighed to give the percentage of Group III compounds (mainly iron and aluminium oxides).

Phosphorus retention:

This is the percentage of soluble phosphate retained by 5 gms of soil when 15.5 mgms of a standard phosphate solution are shaken with the soil for 24 hours.

Cation exchange capacity and exchangeable potassium:

N. ammonium acetate is used for leaching the soil. Potassium is determined by flame photometer. Cation exchange capacity is determined by distillation into boric acid.

Available nutrients:

Phosphorus is extracted with 0.03 N. ammonium fluoride and 0.1 N. hydrochloric acid (Bray & Kurtz solution II). Calcium and magnesium are extracted with Morgan's solution.

Carbon:

Walkley Black method.

Nitrogen:

Kjeldahl method.

pH:

Glass electrode method.

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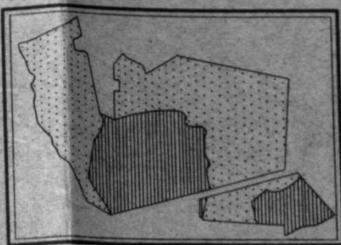
# SEMONGOK AGRICULTURAL STATION AND PROPOSED EXTENSIONS

MAP I

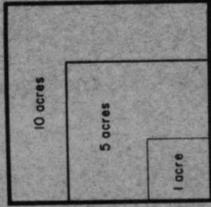
## TOPOGRAPHY



- Fishpond
- Main buildings
- Station and survey boundary
- Main track
- Minor track
- Stream
- Farm line (50')
- Farm line

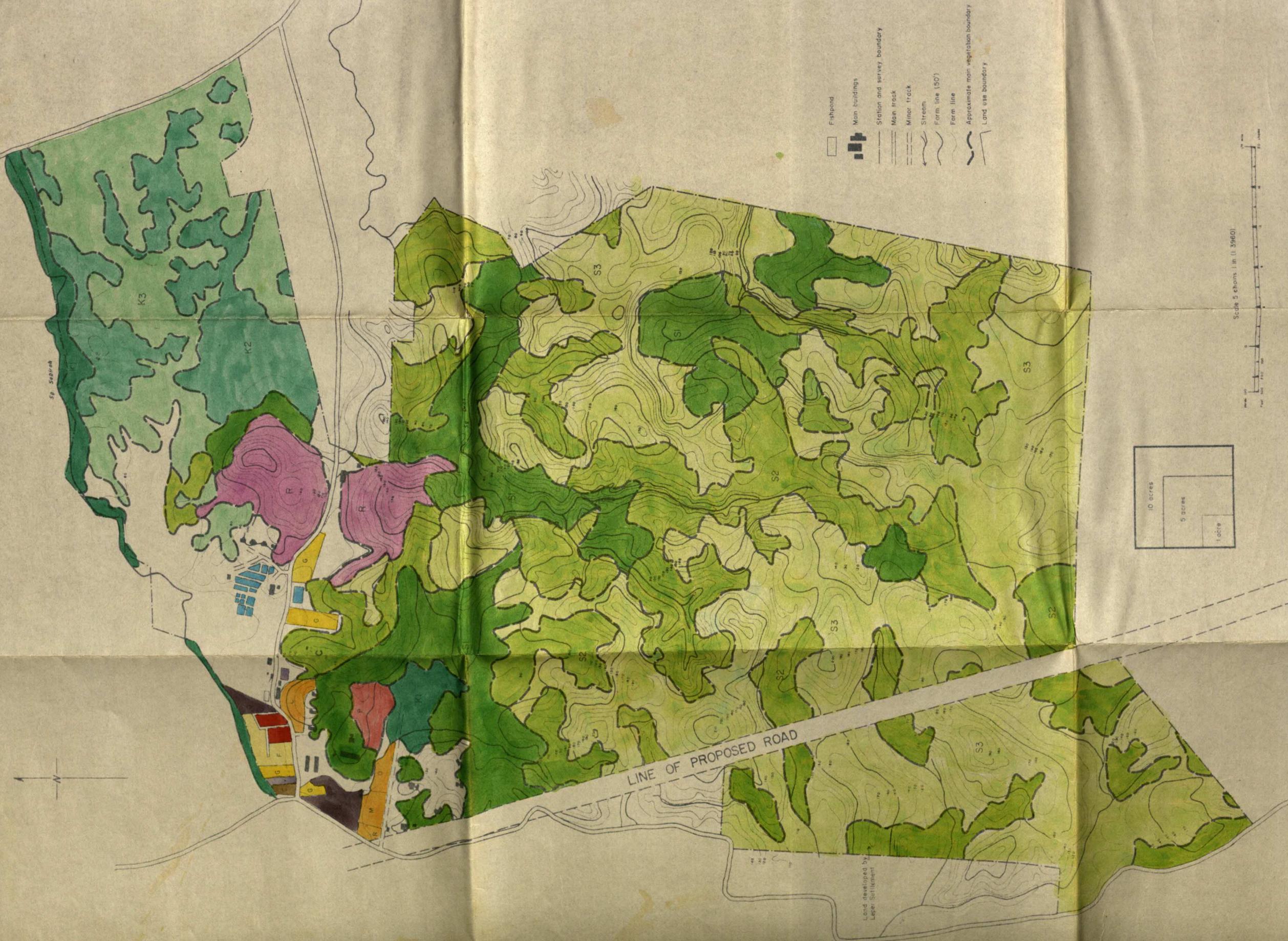


- Farm lines from Land & Survey Dept. plans
- Farm lines interpolated from rentis levelling



# VEGETATION AND LAND USE

AND PROPOSED EXTENSIONS



- Fishpond
- Main buildings
- Station and survey boundary
- Main track
- Minor track
- Stream
- Farm line (50')
- Farm line
- Approximate main vegetation boundary
- Land use boundary

Scale 5 chains 1 in. (1:3960)

Soil Survey Drawing No. 91

Prepared by I. M. Scott

Drawn by H. B. Hafshah

- S1 Forest, including some tall large-crowned trees. Upland and bottomland associations not differentiated
- S2 Low secondary growth with many small trees
- S3 Low scrub, along, resam, etc. Trees few and scattered
- K1 Thin forest cover on swamps and along larger rivers
- K2 Low heath forest (kerangas)
- K3 Sparse heath cover with scattered thicket clumps

- F Fruit trees L - Lime, R - Rambutan, M - Mangosteen, O - Oranger (young)
- G Fruit nurseries, largely rambutan and durian
- V Vegetables
- C Coconut N - nursery, D - Dwarf coconut
- C Coffee
- C Coffee under shade, boundary not drawn

- F Flemingia fallow
- G Improved grasses, many varieties
- R Rubber
- P Recent clearance for pepper
- Waste land around offices and buildings, rough grazing for buffaloes



