13.

(Am 1)

| Daripada | |
|---|---|
| Tempat | |
| Tarikh | |

PERKARA

| KERTAS₂ YANG BERKENAAN | MINIT² |
|---|---|
| | CONTENTS. |

1. THE GENERALIZED SOIL MAP OF WEST MALAYA. BY. LAW WEI MIN. (with Map)
2. ACID SWAMP SOILS AND PROBLEMS IN THEIR UTILIZATION - BY K. KANAPATHY
3. SUBSIDENCE IN THE RECLAIMED HULA SWAMP AREA OF ISRAEL - BY D. SHOHAM & I. LEVIN.
4. PRACTICAL ASPECTS OF LAND SYSTEM SURVEYS IN NEW GUINEA. BY - H.A. HAANTJENS.

# THE GENERALIZED SOIL MAP OF WEST MALAYSIA

by

LAW WEI MIN
Department of Agriculture
West Malaysia

## 1. INTRODUCTION

The systematic reconnaissance soil survey of West Malaysia initiated in the early nineteen-fifties was completed by the end of the year 1967. During the progress of the survey, attempts were made to produce soil maps of the country (1, 2, 3) but because of the incomplete coverage, inferences were made using the aid of topographical and geological maps in the areas not surveyed at that time. The 1968 Reconnaissance Soil Map of West Malaysia (4) represents the completed survey. During the same period attempts were also made to classify the soils (1, 5, 6, 7, 8, 9) with earlier attempts dating back to the early years of this century (10, 11, 12, 13, 14, 15, 16, 17, 18, 19, 20, 21).

This is an attempt to group the vast array of soils that have been mapped to-date, at soil series level, into Great Soil Groups commonly in use in this part of the world (1, 6, 22, 23, 24, 25, 26). The Great Soil Groups are essentially those of Baldwin et al (27), revised by Thorp & Smith (28). No attempt has been made to follow the new names recommended in the World Soil Resources Report No. 33 (29) so that a general uniformity can be maintained.

This paper is based on the work carried out by the Department of Agriculture, and information has been drawn freely from published and unpublished reports and papers ([redacted]). This paper also represents the final phase of the ambitious project of completing the first ever stock-taking of the soil resources of the country. Information thus gathered has been put to very good use in accelerating the rate of development of agriculture in West Malaysia, with rapid expansion in the acreages of forest lands being cleared for agriculture by the Federal Land Development Authority, other State agencies and private developers.

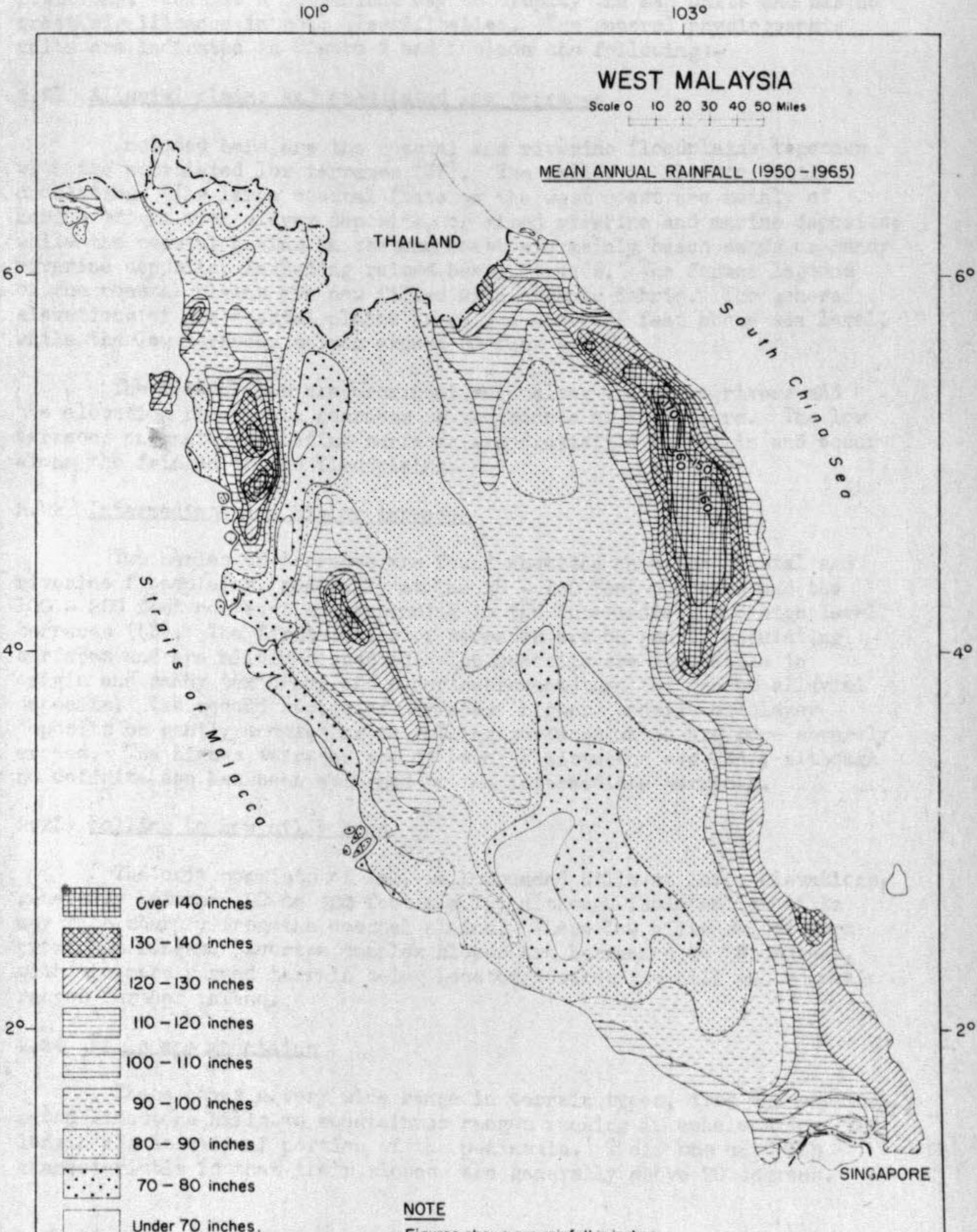
## 2. GENERAL ENVIRONMENT

West Malaysia consists of the southern extension of the peninsula from Thailand and covers an area of approximately 50,840 square miles (131,676 square kilometers). The area lies between the latitudes 1° 15' and 6° 45' N. and longitudes 100° 5' and 104° 20' E.

### 2.1 Climate

The annual mean temperatures in the lowlands (below 500 feet above sea level) is ± 3° F of 80° F., with annual mean humidity at 85% and varying between 55% and 70% by day and rising above 95% by night (30). The mean annual rainfall ranges from below 70 inches to well over 160 inches (31, 32) (Figure 1). "Dry spells" are only experienced in the northeast and northwest, with the rest of the country having a fairly evenly distributed rainfall. The dominant influence of the climate on the soils formed in the country is the intense weathering and leaching, with the majority of soils having low cation exchange capacities, exchangeable cations and base saturation percentages.

FIGURE I


101°
103°
WEST MALAYSIA
Scale 0 10 20 30 40 50 Miles
MEAN ANNUAL RAINFALL (1950 - 1965)
THAILAND
South China Sea
Straits of Malacca
SINGAPORE
6°
4°
2°
Over 140 inches
130 – 140 inches
120 – 130 inches
110 – 120 inches
100 – 110 inches
90 – 100 inches
80 – 90 inches
70 – 80 inches
Under 70 inches.
NOTE
Figures shown are rainfall in inches
101° E. of Greenwich
103°

## 2.2 Physiography

The map units are grouped according to their general physiographic positions. This is a convenient way to display the map units and has no great significance in soil classification. The general physiographic units are indicated in Figure 2 and include the following:-

### 2.21 Alluvial plains and associated low terraces

Included here are the coastal and riverine floodplains together with the associated low terraces (33). The relief is flat to gently undulating. The large coastal flats on the west coast are mainly of marine origin with clayey deposits, or mixed riverine and marine deposits; while the coastal plains on the east coast are mainly beach sands or sandy riverine deposits, including raised beach strands. The former lagoons of the coastal plains are now filled with organic debris. The general elevations of the coastal plains is seldom above 35 feet above sea level, while the low terraces seldom exceed 50 feet a.s.l.

The floodplains are prominent only along the large rivers and the elevation rises with nearness to the source of the rivers. The low terraces on gently undlating surfaces are fluviatile in origin and occur along the fringes of the floodplains.

### 2.22 Intermediate and higher terraces

Two series of terraces are found abutting onto the coastal and riverine floodplains, generally at the 20 - 150 feet contours and the 100 - 250 feet contours corresponding to the intermediate and high level terraces (33). The first series of terraces are on gently undulating surfaces and are mildly dissected. The deposits are fluviatile in origin and sandy textured, and older (subrecent) than the recent alluvial deposits. The second series of terraces (higher) consist of clayey deposits on gently undulating to rolling surfaces which are more severely eroded. The higher terraces are of Lower Pleistocene age (34), although no definite age has been assigned to the intermediate terraces.

### 2.23 Rolling to low hilly land

The unit consists of low, well rounded hills at lower elevations, generally between 150 to 500 feet a.s.l., although isolated low hills may rise sharply from the coastal plains. These low hills seldom form prominent ranges. Average complex slopes are between 6 to 20 degrees, with the more rugged terrain being located towards the hill and mountain ranges further inland.

### 2.24 Hills and mountains

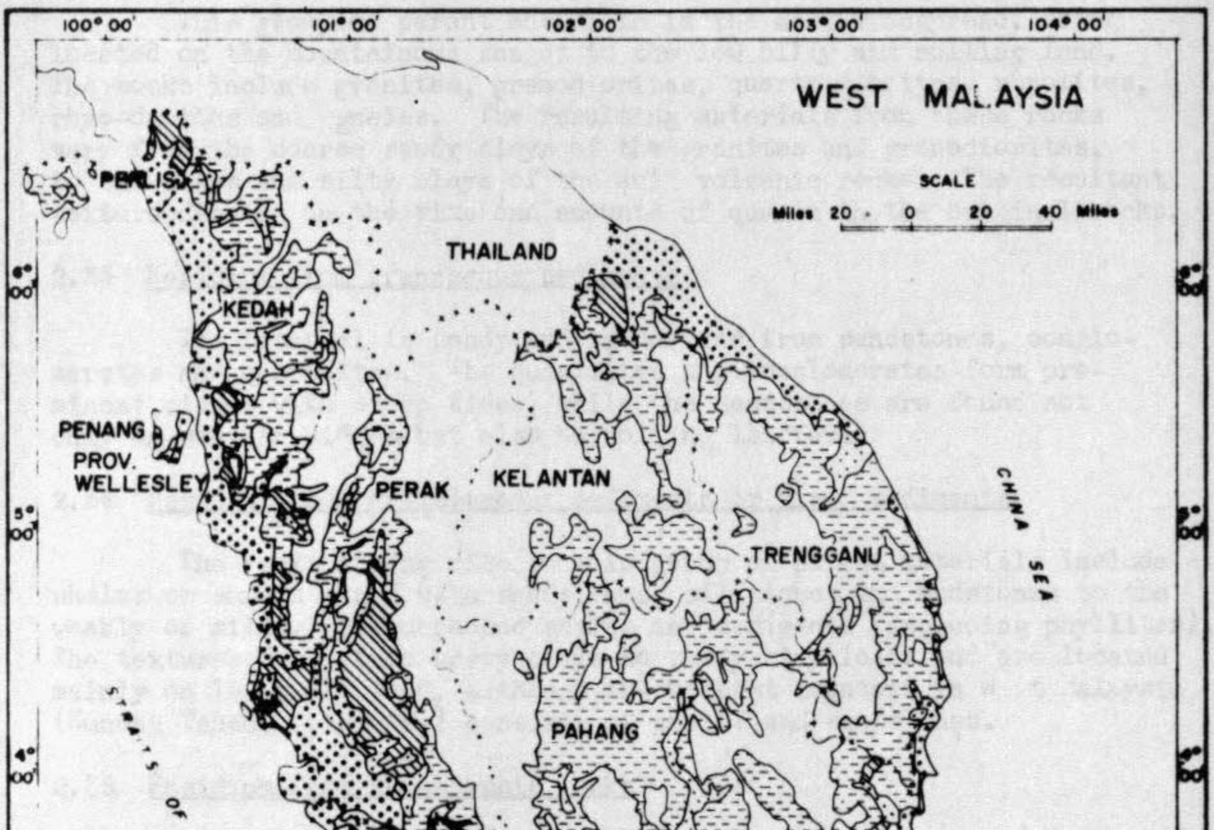
These cover a very wide range in terrain types, from the vertically sided limestone hills to mountainous ranges running in echelons down the length of the central portion of the peninsula. Their one unifying characteristic is that their slopes are generally above 20 degrees.

## 2.3 Parent materials

The parent materials of the soils can be divided into two main groups. The alluvium consists of materials that has been transported and deposited elsewhere, and the residium (together with colluvium) consists of the weathered mantle overlying the geological

.../3

FIGURE 2



WEST MALAYSIA
SCALE
Miles 20 0 20 40 Miles
100° 00'
101° 00'
102° 00'
103° 00'
104° 00'
6° 00'
5° 00'
4° 00'
3° 00'
2° 00'
PERLIS
KEDAH
PENANG
PROV. WELLESLEY
PERAK
KELANTAN
THAILAND
TRENGGANU
CHINA SEA
STRAITS OF MALACCA
PAHANG
SELANGOR
NEGRI SEMBILAN
MALACCA
JOHORE
GENERAL PHYSIOGRAPHY
COASTAL PLAINS AND LOW TERRACES 0–50 FEET
FLOOD PLAINS AND LOW TERRACES 0–250 FEET
INTERMEDIATE AND HIGHER TERRACES 20–250 FEET
ROLLING TO LOW HILLY LAND 100–500 FEET
HILLS AND MOUNTAINS OVER 500 FEET

formations. Subdivisions are as follows:-

2.31 Residium from basic and intermediate igneous rocks

The parent materials from these rocks are limited to the rolling to low hilly land and isolated hills. The rocks include basalt, dolorite (and/or gabbro), andesite etc. The materials derived from these rocks are mainly clayey with very little silt and sand.

2.32 Residium from acid to intermediate igneous rocks

This group of parent materials is the most widespread, being located on the mountainous ranges to the low hilly and rolling land. The rocks include granites, granodiorites, quartz diorites, rhyolites, rhyo-dacites and gneiss. The resulting materials from these rocks vary from the coarse sandy clays of the granites and granodiorites, to the clays and silty clays of the acid volcanic rocks. The resultant texture depends on the size and amounts of quartz in the original rocks.

2.33 Residium from arenaceous sediments

The material is sandy and is derived from sandstones, conglomerates and quartzites. The quartzites and conglomerates form prominent ridges with steep sides, while the sandstones are found not only on similar ridges but also on rolling landform.

2.34 Residium from argillaceous sediments or mixed sediments

The rocks giving rise to this group of parent materials include shales or shales mixed with sandstones, siltstones and mudstones to the weakly or mildly metamorphosed shales and sediments (including phyllites). The textures range from heavy clays to sandy clay loams and are located mainly on low hilly land, although the highest mountain in West Malaysia (Gunong Tahan, 7,186 ft.) consists of shales and sandstones.

2.35 Residium from metamorphic rocks

The parent materials are derived from quartz-mica schists to hornfels and more basic schists, and the texture depends on the composition and graininess of the original rocks, with the more basic schists giving rise to more clayey parent materials. The terrain ranges from low hills through steep-sided foothill ranges to the mountain ranges.

2.36 Residium from calcareous sediments

These are derived from residium and colluvium from the numerous limestone hills, and are of very limited occurrence. They are found only in the vicinity of the base of limestone hills; the numerous but rather narrow valleys in between the limestone hills, may be filled with colluvium and alluvium, with limestone boulders outcropping above the generally flat surfaces.

2.37 Older alluvium

The older alluvium is limited to the areas immediately adjacent to the low hills near the coastal areas in the south of the peninsula ; the northeast and certain inland areas, but is generally between the 100 to 250 feet contours (34), although some are located at higher elevations

.../4

inland (35). The texture varies widely, ranging from sandy loam to coarse sandy (and/or gravelly and even bouldery) clay. The majority of the older alluvium are in the vicinity of granitic masses although sedimentary provenance cannot be ruled out.

2.38 Subrecent alluvium

The subrecent alluvium is limited in distribution to areas abutting onto the coastal and floodplains. The surfaces are gently undulating and only weakly dissected, and the materials are essentially sandy although the provenance is uncertain.

2.39 Recent alluvium

These sediments are limited to the coastal and fluvial floodplains, and the surfaces of these deposits vary from gently undulating to flat or even depressional. The riverine and marine alluvia dominate these surfaces with lacustrine deposits being of limited occurrence. The fresh water alluvium varies greatly in texture, being sandy on the levees of the rivers and more clayey in the backwater lagoons, especially if it occurs on the larger floodplains. It is even more mixed in smaller floodplains. The marine and brackish water clays are limited to the coastal strip, while the beach sands are generally more common in the east coast. The marine clays which are predominant on the west coast are dominated by montmorillonite (8).

## 2.4 Vegetation and land use

More than two-thirds of the country is still covered by one of the richest flora in the world. This vast acreage has been diminishing rapidly during the last decade because of rapid agricultural development. Wyatt-Smith (36) has divided the forest into 3 major groups namely:-

I - Lowland (dryland) vegetation
II - Hill and mountain vegetation
III - Swamp and low-lying vegetation.

The lowland vegetation is dominated by Dipterocarp and Shorea species but includes a multitude of species and is limited to elevations below 1000 feet. Above this elevation is the hill and mountain vegetation on the central forest ranges. The vegetation consists of hill, upper Dipterocarp and montane oak going up to 5000 feet, with mountane ericaceous forests above the level. The swamp and low-lying vegetation is dominated by:-

i) marine alluvial (mangrove) swamp forests on the muddy shores, lagoons and estuaries of tidal rivers

ii) fresh-water alluvial swamp forests on semi-permanent to temporarily submerged non-acid fresh water

iii) peat swamp forest evolved in permanently water-logged and anaerobic conditions, with limited species

iv) riparian forests as strips along the estuaries, rivers and streams throughout the country.

.../5

Only broad relationships have been drawn between soils and vegetation types. This is due mainly to the lack of correlation studies on soils and forest types.

Of the one-third of the country which is cultivated, the Present Land Use Survey of the country by interpretation of the complete set of aerial photographs taken in 1966, will bring out the location and acreages of different crops grown in West Malaysia (37, 38, 39, 40, 41). Emphasis has always been on padi cultivation in the lowlying areas, with rubber and oil palm dominating the dryland crops on the upland areas. This pattern is slowly changing with emphasis being shifted to diversification of crops to broaden the economic base of the country. This is possible through related studies on soils and crop performance.

## 3. SOILS

The soils in West Malaysia have been identified and mapped at the series level in reconnaissance surveys. The main mapping units in these surveys are associations of series, convenient landform units and other groupings. Phases and variants (colour) have also been established. The soils here are grouped at the level of the Great Soil Groups. Brief descriptions of the groups are given and the diagnostic characteristics outlined. Separation into groups is based mainly on physical features of the soils, while the chemical properties are so close that separation is not very effective (26). This emphasizes the intense weathering and leaching processes in the hot, humid environment of this country in which the dominant clay in the soils (apart from the young marine clays) is kaolinite (6).

### 3.1 Regosols

Regosols are formed on beach and dune sands, along or near the coastline, usually in elongated ridges. There is very little or no profile development apart from the humiferous surface layer resting immediately on the yellowish or brownish sands. The textures vary from fine sand to coarse sand. On the older beach ridges, a weakly developed eluvial horizon is evident beneath the humiferous surface layer. This forms the first stage in the development of the sand podzols which are so prominent on the older raised beaches along the east coast. Regosols may also be found on sandy subrecent deposits. These are loamy sand or sands with no horizon differentiation.

### 3.2 Alluvial soils

Alluvial soils are developed on recent alluvium deposited by rivers in flat to undulating floodplains and associated low terraces. These soils do not show prominent profile development apart from the humiferous surface layer. Only well drained and imperfectly drained soils on the alluvial deposits are included here.

These soils on recent riverine sediments vary in texture in relation to distance from the river bank, being sandy on levees of larger rivers and clayey in backwater basins. The soils on levees are well drained showing yellowish or brownish colours with mottling only at moderate depths. Those in the basins are generally imperfectly drained with prominent mottling, but no gley layer is found within 20 inches (50 cm) from the surface. Soils on the associated low terraces, especially in the east coast, show a similar sequence as above, the

.../6

better drained members being sited on slightly higher levels, the imperfectly drained members on the lower slopes and the gleyed members in depressions.

3.3 Gley soils

The gley soils are gleyed to varying degrees because of the presence of a high watertable or a perched watertable. Due to reduced conditions, peaty accumulations overlying the mineral layers may be as much as 10 inches thick.

Gley soils are developed in low-lying areas on recent alluvium of bottom lands and basins, marine sediments (mainly clays) and subrecent alluvium. The dominant feature is the presence of the gley horizon indicated by moist colours of low chromas, prominent mottling along root channels or structural faces; or bluish or greyish colours which may change on exposure to air. They gley soils are poorly to very poorly drained for most part of the year. Those on recent alluvium are weakly structured or massive in the subsoils.

Gley soils on the marine alluvium under tidal influence are saline, showing a humiferous surface layer resting on the gleyed clay. Intermixed with these "Saline Gley Soils" are areas of gley soils with high acidity (below pH 3.5) or containing sufficient sulphide compounds (or elemental sulphur) to cause acidification of the soils on oxidation to pH ($H_2O$) less than 4 within auger depth. These acid sulphate soils are also in large areas in depressions of the coastal plains, in locations which have allowed the accumulations of the required amounts of sulphides.

Drained soils on marine clays show a prominently mottled subsurface layer with well developed fine structures. The underlying B horizon is gleyed with mottles along structural faces. The B horizon is usually strongly developed coarse blocky, and overlies the completely reduced massive, sticky parent clay. The less acid members of the gley soils on marine clays are the most fertile soils in the country, with the clay fraction dominated by montmorillonite. Second generation rubber are still producing very well with minimal fertilizer applications. Oil palm is producing well over 12 tons of fresh fruit bunch a year. The acid members are the acid sulphate soils. These problem soils require special techniques in amelioration to bring them into agricultural production. The best use to which these soils can be put have been found to be wet padi with adequate lime and water control (fresh water).

Gley soils on the subrecent alluvium are poorly drained with weakly developed to massive (and compacted) subsoil horizons. Colours are grey or light yellowish brown, and textures vary from sandy loam to clay.

Separation into humic Gley and Low Humic Gley soils is possible. Humic gley soils have a dark coloured top layer with organic content of more than 1.5%, and moderate base saturations. This would limit the Humic Gley soils to those on the marine clays along the west coast and in valley bottoms of limestone areas. The Low Humic Gley soils are on the recent alluvium (fresh water and marine) and subrecent alluvium. Texture varies but is generally sandy loam, loam, clay or silty clay. The colours are generally grey or light yellowish brown, with mottling limited to the root channels or ped surfaces. The majority of the soils cultivated with wet padi in flat to low-lying areas are low humic gley soils.

.../7

3.4 Podzols and Groundwater Podzols

These soils are characterized by a bleached Ae* horizon overlying a humus and/or iron B at depths varying from 20 inches to 50 inches from the surface. The best developed podzols are on the old raised beaches along the east coast. These are sandy, and the spodic B varies from a weakly, darkly stained layer to a compacted & well cemented layer.

Podzols are also found on granitic materials above 5000 feet a.s.l. i.e. in mountainous areas. These have a thick layer of mor overlying a distinct, bleached Ae and rests on a darkly stained spodic B. Beneath is the mottled layer.

3.5 Red Yellow Podzolic soils

This group is widely distributed, occurring on undulating to steep terrain. These soils are formed on a wide range of parent materials including acid igneous rocks, sandstones, shales and older alluvium. The Red Yellow Podzolic soils show distinct horizon differentiation. The eluvial A/illuvial B relationship is more distinct in the heavier textured members than in the lighter textured ones. Colours range from yellowish brown to reddish yellow to yellowish red, depending on the parent rocks. Structures in the B horizons vary from weak subangular blocky to strong subangular blocky, and the degree of development of the structure is directly related to the increase in clay content. Consistence is friable in the lighter textured members and firm in the heavier textured members. Laterized fragments of parent rock may occur as a distinct band in the B horizon or overlying the variegated C (plinthite).

3.6 Yellow Grey Podzolic soils

This group is formed mainly on shales, siltstones or interbedded shale and sandstones, although members have been found on rhyolites acid granites and subrecent alluvium. Colours are generally pale yellow to grey. Horizon differentiation is more distinct in the clayey members and less so in the sandier members. The Ae/Bt relationship is not very distinct. The heavy members may not have a very distint textural B and more often than not the B is indicated by darker, stronger or redder colours, with moderate to strong clayskins. Structures are moderate to strong blocky or even prismatic. Consistence is firm to very firm (and compacted) in the subsoils.

3.7 Reddish Brown Lateritic soils

These soils are formed on residial materials from intermediate igneous rocks, shales or schists. The profile is characterized by a weak Ae/Bt horizon sequence, with weak to moderate clayskins. The colours are strong brown to yellowish red or reddish brown. Textures are clay loam to clay; the consistence is friable in the upper portions of the profile and firm at depth.

The soils on intermediate igneous rocks have moderate to strong, medium to fine subangular blocky structures.

---

*Horizon designation as in 'Soil Survey Manual for Malayan Conditions ' by M.L. Leamy & W.P. Panton 1966.

.../8

The aggregates are stable and in the darker coloured members resemble the stable aggregates of the Latosols. However, with the distinct Bt horizon (8) these soils are put into the group. The soils derived from shales have less well developed and coarser structures, and the aggregates are less stable. Some of the paler coloured soils derived from shales can be grouped with the Red Yellow Podzolic soils.

### 3.8 Reddish Brown Latosols

These soils are formed on the deeply weathered basalt over rolling to hilly terrain. The profile is deep and uniform, showing very little horizon differentiation. Colours are reddish brown to dark brown. The texture is generally heavy clay, but because of the strong granular and strong medium and fine subangular blocky structures, and friable to very friable consistence, the field texture tends to be loamy. The aggregates are very stable. Pores are abundant. The upper portions of the profile tend to dry out in the drier months. Laterite may be present but generally below 5 feet from the surface and are bouldery. The clay is dominated by kaolinite.

### 3.9 Red Yellow Latosols

Like the Reddish Brown Latosols, these soils are deep and friable, showing very little horizon differentiation. Colours are generally yellowish red to dark red, although some members may be only strong brown. Textures are clays or heavy clays, and although the top layers may contain less clay than the underlying horizons, no horizon can be designated as a textural B (Bt). Structures are moderate to strong granular, and medium and fine, subangular blocky. Laterite nodules may form a band at depths below 5 feet from the surface. These soils are formed on andesites and mafic schists, over rolling to hilly terrain. Included in this group are the yellowish brown, friable sandy loams to sandy clay loams with weak horizon differentiation developed on subrecent alluvium.

### 3.10 Laterites

These soils are dominated by the presence of iron-rich concretions and/or nodules and fragments within 20 inches from the surface. The laterite may be massive especially on the upper slopes. The concretions can occur as a distinct band or spread throughout the profile. As a band it is generally more than 20 inches thick. The laterite soils are formed on shales, phyllites and schists on undulating to hilly terrain.

The thin topsoil is friable, brown to greyish brown loam or clay loam, with strong fine structures. The laterite-free subsurface horizon is usually a strong brown to reddish brown clay loam to clay, with moderate medium subangular blocky structures and friable consistence. The laterite concretions constitute more than 50% in weight. It is generally noticed that concretions and nodules occurring in the upper parts of the profile are well rounded and smaller in size compared to those occurring lower down in the profile which are larger and more angular. The variegated clay is beneath the laterite horizon.

### 3.11 Lithosols

Very little detailed studies have been made of the soils in this group, because of the low agricultural potential. Lithosols are

.../9

generally found on steep to very steep slopes on a very wide range of parent materials. They are usually associated closely with more mature profiles on similar parent materials.

The thin humiferous top layer overlies a very weak or incipient B horizon, which is generally very stony. The C horizon and/or rock is reached within 10 inches from the surface.

The lithosols occur in close associations with the Red Yellow Podzolic soils, Yellow Grey Podzolic soils, Red Yellow Latosols. Lithosols formed on shales and sandstones generally rest on the parent rocks. Those formed on granites and associated rocks have very deeply weathered C horizons even on very steep slopes. Often 'core boulders' are found 'hanging' in the C horizons. Boulders are sometimes found on the surface of these soils.

The colour range is very wide, depending on the parent rock. On acid igneous rocks and sandstones, the colour ranges from yellow, yellowish brown to yellowish red. On shales the colour range is even wider; being pale yellow on iron-poor shales; yellow to strong brown on redder shales and yellowish red to dark red on ferruginous shales; and grey to dark grey on carbonaceous shales. Texture depends on the parent rocks and ranges from sandy loam to clay.

3.12 <u>Organic soils</u>

The organic soils include peats and mucks developed from the organic debris in the low-lying lagoons of the coastal regions. These are mainly woody or forest peats of the wet tropics. Most of the peat are more than 10 feet deep. The peat and mucks are generally very acid and pose special problems to management because of the paucity or non-availability of both major and minor plant nutrients. Once these shortages are corrected the peats and mucks are very good media for shallow rooting crops.

Highland peat has been located in the Cameron Highlands at elevations of above 5,000 feet. These are fibrous peats formed on the debris around the roots of the trees in the montane ericaceous forests.

3.13 <u>Other soils</u>

In addition to the Great Soil Groups outlined above, other soils have also been identified. These are, however, of very limited occurrence and cannot be represented in this map. Among the more important soil groups are:-

3.131 <u>Brown Forest soils</u>

These are juvenile soils formed on residual materials from basic and ultrabasic igneous rocks or calcareous sediments, over hilly to steep terrain. The humiferous top layer overlies the incipient B which has higher clay contents than the underlying C horizon. Colours are either brown or yellowish brown. The A horizon has strong granular structures, but the (B) horizon has weak subangular blocky structures. The pH is generally just above 5, and the base saturation is medium.

.../10

3.132 Red Brown Earths

These soils are formed on residual accumulations of materials formed as a result of weathering of limestones. Hence they are limited to the base of the limestone hills. The red to dark red, friable clay is deep and the moderate fine and medium subangular blocky structures in the textural B may sometimes contain black soft concretions which may be manganese. The terrain is generally undulating, but may also be steep.

4. DESCRIPTION OF THE MAP UNITS

The main mapping units in the reconnaissance soil survey are associations of series and convenient landform units. In these associations the member series may belong to different Great Soil Groups, and although progress was rapid the resultant maps have presented some difficulty in the selection of map units in the Generalized Soil Map. Of necessity, the map units are essentially associations of Great Soil Groups. The name of the unit is taken from the dominant soil group, and the associated soil groups are indicated in the text. In units with the name of two soil groups, the soil pattern is often complex and irregular. When joined by the conjunction 'and' the soil groups are of about equal importance in characterizing the units, otherwise the second name refers to the less dominant soil group. Where necessary additional soil groups associated with these compound units are again indicated in the text.

4.1 Soil of the alluvial plains and low terraces

Unit 1: Regosols and Podzols on beach and dune sands

This unit occurs as a narrow strip of varying width along the whole length of the east coast of the country, with smaller strips along the west coast. The topography is gently undulating. The Regosols are found on the fore beach (yellowish or brownish) or on raised beach ridges (grey to white with the spodic horizon well below 5 feet depth). Podzols are mainly on raised beaches occurring behind the fore beach. The micro-relief consists of low ridges and swales. The Podzols are best developed on the ridges while the depressions are occupied by Groundwater Podzols. Included here are the sands stained with organic matter occurring in depressions with high watertable.

Unit 2: Alluvial soils and Gley soils on recent riverine alluvium

This unit covers the riverine floodplains of the large rivers inland, the coastal plains of the east coast and the coastal plains with mixed or riverine alluvium on the west coast.

The general relief is flat to gently undulating, but micro-relief features has important influence on the soils formed.

In the river valleys, the higher levees are better drained while the lower basins away from the river banks are less well drained. In the upper reaches of the rivers, the basins generally have high watertable. Alluvial soils are found on the levees and better drained sites while Gley soils are located in depressions and smaller river valleys, especially when these valleys are intermittently or permanently waterlogged swamps.

.../11

In the riverine coastal plains, the present day rivers are still depositing materials during floods. The relief is generally gently undulating. Alluvial soils are again found on better drained sites, while the slight depressions are occupied by Gley soils (usually Low Humic Gley soils).

Unit 3: Gley soils with Alluvial soils on recent marine & riverine alluvium, and subrecent alluvium

This unit occurs extensively on the coastal plains on the west coast and to a lesser extent in the estuaries and brackish water regions of the larger rivers in the east coast. The relief is generally flat with only slight depressions.

In the better drained sites of the coastal plains, Alluvial soils are dominant, but the greater portions of these plains consist of Gley soils. Gley soils on the marine alluvium are heavy textured, grey brown or dark grey with mottling along root channels and structural faces; while the Gley soils on the riverine alluvium are yellowish or grey, lighter textured and less prominently mottled.

On the subrecent alluvium, the Gley soils are generally light yellow or light grey, with low organic matter, coarse structured or massive subsoils. These are essentially Low Humic Gley soils.

Unit 3a: Gley soils on marine clays (Saline Gley soils and Acid Sulphate soils)

Along the seaward edge of the coastal plains of the west coast, and the estuaries of the tidal rivers of both the east and west coasts where the vegetation is mangrove swamps, the Gley soils are saline. Intermixed with these 'Saline Gley soils' are Gley soils containing sufficient sulphides to cause acidification of these soils on oxidation to pH less than 4. These are potential acid sulphate soils to distinguish them from those Acid Sulphate soils in which the air-dried samples have pH ($H_2O$) or less than 3.5. These Acid Sulphate soils occur in depressions of the coastal plains, in large areas on the west coast and in smaller areas on the east coast.

Unit 4: Organic soils and Gley soils

This unit occurs as large areas on the coastal plains, generally occupying the basins on the landward edge. These are swampy depressions situated in most cases just above the sea level. The peats are usually thicker in the centre, becoming shallower towards the edges, with mucks and organic clays at the fringes. This unit can also be found in inland waterlogged river basins, in association with the Gley soils.

4.2 Soils of the intermediate and high terraces

Unit 5: Red Yellow Latosols and Regosols on subrecent alluvium

This unit consists of soils formed on the subrecent alluvial terraces with weakly dissected surfaces. The parent material range from loamy sand to sandy clay loam. Soils on the loamy sand parent material are essentially Regosols with yellow and light yellow brown subsoil colours. Soils on the sandy clay loam parent material has developed a B (oxic?) horizon. The colours in the B horizon are yellowish brown to brownish yellow, and structures are weak subangular

.../12

blocky. The low-lying depressions of this terrace are occupied by Gley soils. This unit is quite extensive, occurring just behind the coastal plains along both the east and west coast.

Unit 6: Red Yellow Podzolic soils on older alluvium

This unit is located on undulating to rolling surfaces of the high terraces in the southern end of the peninsular and in the northwest corner. Great difficulty has been experienced in separating these soils from the Red Yellow Podzolic soils on granites at the series level. In the narrow river basins of the high terraces are the Gley soils.

## 4.3 Soils of the rolling to low hilly land

Unit 7: Yellow Grey Podzolic soils with Laterites and Red Yellow Podzolic soils on argillaceous & mixed sediments and acid igneous rocks

This unit occurs very extensively on undulating to hilly land, generally on the fringes of the granitic masses or in between these. The soil pattern is very complicated due to the sharp differences in lithology of the argillaceous and mixed sediments over short distances. It is often difficult to separate the dominant soil group out, let alone separating the different soil series in the soil group. The members of this unit occur in close association as sequences(42), each sequence usually containing only a few members closely related together. The Laterites are commonly associated with the dominant soil group especially when the Red Yellow Podzolic soils on argillaceous or mixed sediments are found amongst them. The pattern is further complicated by the occurrence, although in very limited extent, of Reddish Brown Lateritic soils on the argillaceous sediments.

Unit 8: Red Yellow Podzolic soils with Reddish Brown Lateritic soils on acid to intermediate igneous rocks, arenaceous argillaceous and mixed sediments

This unit is one of the most extensive one, stretching down the whole length of the country. The terrain is generally rolling to hilly, and the unit merges into the shallower soils of the steepland. The greater portion of this unit is formed on igneous rocks, in which the pattern is very simple consisting of the dominant soil group over vast acreages. On the sedimentary rocks, however, the pattern is more complicated, due again, to changes in lithology of the sediments over short distances. The dominant soil group on these sediments generally form the low foothills to the massive granite ranges. The Reddish Brown Lateritic soils are associated with the dominant soil group on both igneous and sedimentary rocks.

Unit 9: Reddish Brown Lateritic soils with Red Yellow Podzolic soils on argillaceous, arenaceous and mixed sediments

This unit occurs on the rolling to hilly land of the low foothill ranges to the granite mountains, or on isolated low hills. The dominant soil group is closely associated with the Red Yellow Podzolic soils on arenaceous and mixed sediments. The unit is more widespread on the western side of the main ranges, and to lesser elsewhere.

.../13

Unit 10: Reddish Brown Latosols on residual materials from basic igneous rocks (mainly basalts)

This unit is limited to a small area near Kuantan, on basaltic flows over low hills. The area is covered by the deep, friable reddish brown clays, but in the valleys, waterlogged conditions has resulted in greyish colour instead of the reddish brown colour of the well drained members on higher sites.

Unit 11: Red Yellow Latosols on residual materials from intermediate igneous rocks and mafic metamorphic rocks

This unit does not occur in very large acreages in continuous blocks, but as areas spread throughout the central portion of the country in which volcanic activity had been widespread. The soils are well developed on the andesitic flows or tuffs, with smaller areas on the mafic schists. Associated with the soil group are the Reddish Brown Lateritic soils on the ferruginous shales or tuffaceous shales. The terrain is rolling to hilly, and occasionally steep.

Unit 12: L erites on residual materials from argillaceous sediments and metamorphic rocks

The unit is very widespread in the northwest corner, but elsewhere occurs in close association with other soils, especially the Red Yellow Podzolic and Yellow Grey Podzolic soils and often in a complex pattern. The terrain is generally undulating to hilly.

4.4 Soils of the hills and mountains (steepland)

The steepland complex of the reconnaissance soil survey maps was not examined in detail because of the low potential for normal agricultural development due to steep slopes and severe soil erosion. Information to date, however, indicates that there are more than one soil group in the steepland complex. The terrain ranges slopes with more than 20 degrees to the almost vertical limestone crags. The following map units are inferences based on our present knowledge of these soils and on information from geological and topographical maps.

Unit 13: Red Yellow Podzolic soils with Lithosols on acid to intermediate igneous rocks

This unit is the largest of the steepland complex, occupying all the prominent granite hills and ranges running the length of the country. Weathering is deep seated on most of these granites, expect on very steep slopes and sharp ridges. The Red Yellow Podzolic soils are dominant and these merge into the Lithosols, the surface of which are littered with boulders.

Unit 14: Lithosols and shallow Red Yellow Podzolic soils arenaceous sediments

The arenaceous sediments in the steepland complex occur as prominent parallel riges or isolated hills with very steep slopes. The soils are generally sandy and colours are yellow, yellowish brown or redder. The dominant soil group is the Lithosols with the shallow Red Yellow Podzolic soils on less steep slopes.

.../14

Unit 15: Shallow Red Yellow Podzolic soils and shallow Yellow Grey Podzolic soils with Lithosols on argillaceous and mixed sediments

The argillaceous and mixed sediments in the steepland complex generally occur as foothills to the main granite ranges or as isolated ranges. The foothill ranges consist of hills with short steep slopes and V-shaped gullies, the tops of which are generally concordant or rise gradually into the higher granite ranges. Gunong Tahan consists of a series of ridges rising from a broad base. Very little is known of the soils on Gunong Tahan. The lower slopes of the foothill ranges consist of shallow Red Yellow Pozolic and Yellow Grey Pozolic soils. Lithosols are generally found to occupy the tops of these hills.

Unit 16: Pozols and Lithosols on acid igneous rocks at elevations of above 5,000 feet

This unit occurs on the main range and the granite range on the east, where the highland peat is abundant. The Podzols are formed as a result of the leachate from the acid peat flowing through the siliceous parent material. The peat has accumulated because of the lower temperatures. Where the slopes are too steep for the peat to accumulate, Lithosols are found on the silicèous parent material.

Unit 17: Lithosols on limestone crags

Where the limestone is not pure, the resultant landform due to subaerial erosion tend to approach the roundness characteristic of the topography of non-calcareous rocks. Pure limestone hills however are usually vertically sided. The relatively rounded limestone hills are covered with denser vegetation on lithosols, while the vertically ided hills have very sparse vegetation on very little soil.

ACKNOWLEDGEMENTS

The permission of the Director of Agriculture, West Malaysia, to prepare this paper and the accompanying map for presentation is gratefully acknowledged. Grateful thanks are due to my colleagues Messrs. Ignatius Wong Fen Thau and K. Selvadurai for valuable discussions and comments, and to the staff of the Soil Science Division for the help rendered.

## REFERENCES


1. Panton, W.P., "The 1962 Soil Map of Malaya", Jour. Trop. Geog. Vol. 18, 1964. pp. 118-124.

2. Ng Siew Kee, "Soils in The Oil Palm in Malaya". 2nd Ed. Min. of Agri. & Co-opt. Malaysia. 1966. pp. 164.

3. Ng Siew Kee, "Soil Resources in West Malaysia" Second Sym. on Sci. & Tech. Res. in Malaysia and Singapore, Uni. of Malaya, K.L. 1967.

4. Law Wei Min & Selvadurai, K, "The 1968 Reconnaissance Soil Map of Malaya" Proc. 3rd. Malaysian Soil Conf., Kuching, 1968. pp. 229-237.

5. Owen, G, "A Provisional Classification of Malayan Soils" Jour. of Soil Sci., Vol. 2, 1951. pp. 20-42.

6. Leamy, M.L., "Soil Classification in Malaya" Proc. 2nd. Malaysian Soil Conf., K.L. 1966. pp. 79-84.

7. Leamy, M.L., "Proposals for a Technical Classification of Malayan Soils" Malayan Soil Survey Report No. 3/1966, Division of Agric., K.L. pp. 62.

8. Ng Siew Kee, "Laboratory Data and Classification of Malayan Soils" Proc. 2nd Malaysian Soil Conf., K.L. 1966. pp. 93-97.

9. Joseph, K.T., "A Scheme for the Classification of Malayan Soils" Proc. 2nd. Malaysian Soil Conf., K.L. 1966, pp. 86-92.

10. Akhurst, G.G. and Haines, W.B. "Descriptions of Soils at the Rubber Research Institute Experimental Station" Jour. of the R.R.I.M., Vol. 3, 1931. pp. 174-181.

11. Barrowcliff, M., "Malayan Rubber and Coconut Soils" M.A.J., Vol. 2, 1931. pp. 328-337.

12. Belgrave, W.N.C., "General considerations on a Soil Survey of Malaya" M.A.J. Vol. 17, 1929. pp. 175-178.

13. Dennett, J.H., "Preliminary results of a soil survey in Selangor" M.A.J. Vol. 17, 1929. pp. 179-187.

14. Dennett, J.H., "The Soils of Cameron Highlands" M.A.J., Vol. 18, 1930. pp. 20-29.

15. Dennett, J.H., "The western coastal alluvial Soils" M.A.J., Vol. 20, 1932. pp. 347-361.

16. Grantham, J., "Some Johore Soils" M.A.J., Vol. 4, 1915. pp. 114-121.

17. " " "Some soils from the Kuala Pilah and Jelubu Districts", M.A.J., Vol. 4, 1915, pp. 243-247.

18. " " "Soils of the Sabak District on the Bernam River", M.A.J., Vol. 4, 1915. pp. 298-300.

19. Greenstreet, V.R., "Report on the Soils of Lubok Temang and Cameron Highlands" M.A.J., Vol.10, 1922. pp. 281-283.

20. Hamilton, R.A., "Notes on tropical soils with special reference to Malayan soils for rubber cultivation" Jour. R.R.I.M., Vol. 7, 1936. pp. 27-45.

21. Savage, H.E. and Wilshaw, R.G.H., "An examination of the geology and soils of an area in the State of Perak" Dept. of Agric. Sci. Series, No. 10, 1932.

22. Dudal, R. and Moorman, F.R., "Major Soils of South-east Asia" Jour. Trop. Geog., Vol. 18, 1964. pp. 54-80.

23. Soil Survey Staff, "A Classification of Sarawak Soils" Dept. of Agri. Sarawak, 1966. pp. 45.

24. Thomas, P., and Allen, A.W., "A Provisional Soil Map of Sabah" Dept. of Agric, Sabah, 1966. pp. 30.

25 Moorman, F.R. and Rojanasoonthon, S., "Soils of Thailand "Soil Survey Report No. 72, Min. of National Development. Bangkok, 1968. pp. 43.

26. Ng Siew Kee and Law Wei Min "Pedogenisis and Soil Fertility in West Malaysia" Paper presented at the Bandung Conf. on Tropical Weathring, 1969.

27. Baldwin, M., Kellog, C.E. & Thorp, J., "Soil Classification" in Soils and Man. Year Book of Agriculture, U.S.D.A. 1938. pp. 979-1001.

28. Thorp, J. & Smith, G.D., "Higher Categories of Soil Classification: Order, Suborder and Great Soil Group" Soil Sci., Vol. 67, 1949. pp. 117-126.

29. FAO/UNESO World Soil Resources Report No: 33, "Definitions of Soil Units for the Soil Map of the World" 1968. pp. 72.

30. Dale, W.L., "Surface Temperatures in Malaya" Jour. Trop. Geog., Vol.17, 1962. pp. 57-71.

31. Dale, W.L., "The Rainfall of Malaya, Part I" Jour. Trop. Geog., Vol. 13, 1959. pp. 23-37.

32. Drainage and Irrigation Department, "Rainfall Data 1950-1965" Min. of Agric. & Co-opt. K.L. pp.

33. Gopinathan, B., "Terrace and Alluvial Soils in West Malaysia" Proc. 3rd Malaysian Soil Conf., Kuching, 1968. pp. 45-49.

34. Burton, C.K., "The older Alluvium of Johore and Singapore" Jour. Trop. Geog., Vol. 18, 1964. pp. 30-42.

35. Law Wei Min, "Reconnaissance Soil Survey of the Raub-Temerloh : Jeruntat · Region" Malayan Soil Survey Report 2 /1967. Dept. of Agric. K.L.

36. Wyatt-Smith, J., "A Preliminary Vegetation Map of Malaya with Descriptions of Vegetation Types" Jour. Trop. Geog. Vol. 18, 1964. pp. 200-213.

37. Donaldson, R.D., "The Present Land Use of Malacca" Present Land Use Report No:1, Dept. of Agric., K.L. 1968. pp. 1-11.

38. Donaldson, R.D. & Siew Kam Yew, "The Present Land Use of Negeri Sembilan", PLUR No:2, Dept. of Agric., K.L. 1968. pp. 1-15.

39. Siew Kam Yew, "The Present Land Use of Penang/Province Wellesley" PLUR No:3, Dept. of Agric. K.L. 1969. pp. 1-14.

40. Wong, I.F.T., "The Present Land Use of Selangor" PLUR No: 4, Dept. of Agric., 1969. pp. 1-13.

41. Wong, I.F.T., "The Present Land Use of Johore" PLUR No:5, Dept. of Agric. 1969. pp. 1-18.

42. Law Wei Min & Leamy, M.L., "Factors involved in the Genesis of some shale derived Soils in Malaya" Proc. 2nd Malaysian Soil Conf. K.L. pp. 104-111.


N.B.

M.A.J. - Malayan (Malaysian) Agricultural Journal
PLUR - Present Land Use Report

Soils.

# Acid Swamp Soils and Problems in their Utilization

by

K. Kanapathy
Senior Chemist

## Introduction

The rapid and extreme acidification of certain soils was first noted and studied in Holland as early as 1886 by Van Bemmelen (1). The very low pH of these soils were attributed to very acidic iron and aluminium sulphates and free sulphuric acid formed by the oxidation of iron sulphides. Such soils were known in Holland as "cat clay" a name associated with cat's excrement, a general term of abuse for all kinds of poor soils. In Malaya Dennett (2) in 1933 in his preliminary classification and description of the properties of Malayan soils noted that there are cases of soils which have a pH of 3.5 and less, definitely detrimental to plant growth. He stated that this was due to the presence of free sulphuric acid, formed frequently where there are old 'nipah' stumps and similar vegetation containing amounts of sulphur compounds which are subsequently oxidised. This type of acidity he noted nearly always occurred on coastal alluvials but occasionally have been found in quartzite valley areas.

Wilshaw (3) studied the development of high acidity in certain coastal clay soils of Malaya and he inferred that certain soils developed high acidity on drainage and this had serious effect on the growth of plantation crops. He noticed also that freshly dug lumps of clay from the lower depths darkened rapidly from a light blue-grey to near black colour within a space of a few minutes. He attributed this to the rapid oxidation of ferrous sulphide compounds. He analysed some of the soils especially from lower depths 3 to 4 ft. gave a value of 3 to 4.5 per cent and a pH as low as 1.6.

Coulter, J.K. (4) called the acid soils containing considerable quantities of sulphur as "gelam soils". The name being derived from the "gelam" tree (Melaleuca leucadendron) which is characterised by a bark resembling layers of paper and an essential oil (Cajput oil) which may be distilled from the leaves. According to him at a depth varying from 6 to 24 ins. below the surface "gelam" soils smell distinctly of hydrogen sulphide.

## Occurrence

Acid soils whether known as 'cat clays' or 'gelam' soils are widely distributed in Malaya especially near the coastal areas; for example at Pulau Gadong, Tanjong Minyak and Duyong in Malacca, Paya Besar near Kuantan, Gual Periok in Kelantan, Kuala Nerus and Batu Rakit in Trengganu and in many other areas some small and some large and others still to be surveyed. Apart from the typical acid 'gelam' areas there are soils which are not so acid to make padi growth obviously bad and uneconomical but which reduce the growth and yield of padi to a considerable extent. These soils contain considerable amounts of sulphur at lower depths which limits root penetration. All the acid soils are characterised by the presence of large quantities of sulphur compounds present which increases with depth. Some of the samples analysed by Coulter showed as much as 6.8 per cent sulphur at a depth of 18-36 ins.

2/-

## Formation of Acid 'Gelam' Soils

Since 'gelam' soils are characterised by the large quantity of sulphur contained in them the accumulation of sulphur is at the basis of the formation of such soils. According to Van Beers, W.F.J. (5) the amount of sulphides formed in non-marine sediments is comparatively slight but the sulphur in marine sediments particularly in brackish waters is high. The author has analysed irrigation water and has found that inland waters contain very low quantities of sulphate but on the other hand brackish waters contain a good deal. The source of sulphur therefore is sea water.

The sulphur in brackish water accumulates as sulphide if the environment is highly reducing. Normally iron is present in sufficient quantity in soils to fix the sulphides as iron **sulphides**. Under Malayan conditions organic matter production in the form of plant life is high and this helps to add organic matter to the soil creating reduced conditions. Further organic matter is not completely decomposed under more or less water-logged conditions but tends to accumulate. This produces soils containing not only high amounts of sulphur but also generally rich in organic matter and sometimes highly acid peaty soils.

## Reclamation of Acid 'Gelam' Soils

Since the 'gelam' soils are formed under reductive water-logged conditions which allow the accumulation of sulphur the way to reclaim it is to provide oxidative conditions to oxidise the sulphur to sulphate and wash it out. During the course of this oxidation the soil would become even more acid and would dissolve out the cations like potassium, calcium and magnesium which are already low in such soils. Liming the soil could neutralise the sulphates formed while oxidation is taking place but the formation of calcium sulphate may retard the movement of sulphate since it is only sparingly soluble. In order to study the best method of reclaiming preliminary tank experiments were started by Coulter about 1956.

## Experiment in Tanks and Pots

Tanjong Minyak, Malacca, acid soil was put into concrete tanks 1 square meter in area and 3 ft. deep. One row or tanks had sub-soil alone and another two rows of tanks had top-soil 0-12 ins. These were limed at the rate of 0, 1, 2, 5 and 10 tons per acre and subjected to periods of drying and leaching with tap water and rain. Padi was planted but in most cases it either died or made such poor growth as to produce hardly any yields.

In the later part of 1958 the tank experiments were taken over by the author. It was found that inspite of the liming and leaching the sub-soil was very acid pH 2.0 and the conductivity was high. The tanks containing the top soil alone had improved considerably and without lime the pH was about 3.9. This may be attributed to the leaching by rain and tap water. The tanks that received large quantities of lime showed poor distribution of lime. Thus there were soils which showed a pH of 7.2, 0-4 ins. but only a pH of 4.3 about 12 ins. below. The soils were therefore thoroughly cultivated and heavy dressings of fertiliser in the form of calcium cyanamide, fused magnesium phosphate, potassium carbonate (in place of ash popular with farmers in acid areas), trace elements and in some treatments additonal green matter was added. The yield of padi produced was just as good as those from ordinary soil. The yields from the tanks receiving 2 and 5 tons lime were just as good as that from the 10 tons.

3/-

The tank observations appeared to show that the soil could be improved by drainage alone to a considerable extent. Liming aided in the reclamation but heavy liming resulted in poor distribution of the lime and nutritional troubles which were later diagonised as due to manganese deficiency.

The uptake of manganese in acid water cultures is suppressed probably by the much larger uptake of iron by the plants. In acid soils like the Pulau Gadong soil manganese concentration is also low and this results in large uptake of iron and corresponding low uptake of manganese. The uptake by padi of manganese in the acid Yen Series is also lower than in other normal soils.

An important aspect of acid soils in connection with the growing of padi is the change in acidity due to water-logging. A pot test with padi with 2 ins. of water gave the following results:-

| Time in days | 1 | 12 | 45 | 63 | 80 |
|---|---|---|---|---|---|
| pH | 2.60 | 3.30 | 4.47 | 6.00 | 6.30 |

It appears from this that padi can be grown if there is an assured supply of good water and the soil is water-logged long before the padi is transplanted, liming being unnecessary. It is also not advisable to cultivate the soil but just slash any weeds before transplanting as cultivation would bring up sub-soil containing more sulphur

## Field Experiments

Since tank experiments showed that it was possible to grow padi successfully it was decided to try out on a field scale. The area chosen for the tests was a section of the Pulau Gadong Test Station, Malacca. Of the 18 acres acquired for the tests about 4 acres had grown padi successfully and had obtained yields of only about ½ a ton per acre of padi, rather low. Attempts to grow padi in the rest of the area before had failed completely. Part of this area was so poor and barren that Coulter in 1952 described it as follows.-

> "Pulau Gadong Padi Test Station, Malacca, is an area which was once covered with gelam and gelam still exists in the outskirts of the station. A curious phenomena in certain parts of the station is the occurrence of patches, a few square yards in area which are completely bare of vegetation. The surface of the soil cracks and flakes of a hard scale-like material with a greenish yellow colouring form. The area is practically water-logged, the watertable being within 6 ins. of the surface. Pulau Gadong is an example of a former gelam area with a highly sulphurous and sterile soil."

Such a poor highly sulphurous soil was levelled, drainage greatly improved and lime was applied at the end of September, 1964. In July 1965 the pH of the soils in various plots receiving different quantities of lime were determined.

| Magnesium Limestone powder in tons/acre | 0 | 1 | 2 | 0 | 1.5 | 3 |
|---|---|---|---|---|---|---|
| | pH | pH | pH | pH | pH | pH |
| Fresh top-soil 0-4" | 3.40 | 3.70 | 3.96 | 3.49 | 3.96 | 4.02 |
| " sub-soil 4-10" | 3.40 | 3.47 | 3.44 | 3.39 | 3.28 | 3.42 |
| Dry top-soil 0-4" | 3.44 | 3.68 | 3.82 | 3.48 | 3.83 | 3.99 |
| " sub-soil 4-10" | 3.27 | 3.34 | 3.48 | 3.33 | 3.45 | 3.38 |

4/-

One and two tons of limestone powder were used for plots which were not peaty and 1.5 and 3 tons for peaty plots. Drainage had improved the pH of the soils as a whole but the liming had only effect on the 0-4 ins. of the soil. The limed plots had better weed growth than the unlimed plots. It has been reported that liming has had little effect on this type of soils and this may be attributed either to, too deep sampling of the soil or due to the soil being cultivated and highly sulphurous soils from the lower depths being brought up.

It is probable that most of the plots that received lime could grow padi but unfortunately there was lack of suitable water.

## Water the Key to Reclamation

The lack of suitable water in acid areas is probably the most important problem in the utilization of the areas. Good irrigation water properly applied could help wash out the sulphur compounds. Besides, water-logging the area in time can reduce the acidity making it possible to grow padi or even use it for fish culture.

In the case of Pulau Gadong it was unfortunate that the water available had a pH usually below 3. The commercial limestone powder required to neutralise the water was determined:-

| Limestone powder/water | pH | Conductivity mhos $10^{-6}$ |
|---|---|---|
| 1/100 | 7.40 | 1200 |
| 1/500 | 6.10 | 1200 |
| 1/1000 | 4.85 | 1150 |
| 1/5000 | 3.20 | 1400 |
| 1/10000 | 2.90 | 1600 |
| 0 | 2.75 | 1600 |

As the rate of 1 ton of limestone powder to 1000 tons of water it would require a minimum of 3 tons of limestone for about 30 ins. of water per acre for a crop of padi; granting that the rest came from rain. Apart from the cost, the addition of such large quantities of gypsum and magnesium sulphate would give rise to serious problems. In view of this the idea of growing padi was abandoned.

## Other Crops

The growing of other crops, especially those which can tolerate acidity, shallow rooting and be adequately supplied by rainfall seems to offer promise. This can only be done after draining the area for some time and liming. However, one method which is usually resorted to is to grow crops on beds made up to more than 2 ft. in height. This helps to oxidise and wash out the sulphur and at the same time keeps the plants above the high watertable and frequent water-logging. Farmers in the Tanjong Minyak acid soil area grow vegetables on high beds and use considerable quantities of ash as fertiliser.

Deep-rooting tree crops cannot be considered as suitable for reclaimed acid areas as it is difficult to remove sulphur compounds from deep layers. As a result tree crops show very poor root system.

## Other Uses

A good method of utilizing acid sulphurous areas seems to be to convert them into fish ponds since the soil is perpetually under water the sulphur is in the reduced form and does not cause acidity. Very good yields of fish have been obtained at the Tropical Fish Culture Research Institute at Batu Berendam, Malacca, in ponds situated in acid soils.

5/-

Summary

1. The presence of acid soils has been noted in Malaya as early as 1933 and the cause has been attributed rightly to the presence of sulphur compounds.

2. The acid soils mostly occur near the coast as they are formed under brackish water containing sulphur.

3. Experiments in tanks showed that small quantities of limestone powder (2 tons/acre) with good drainage could reclaim the soils for padi. Initial heavy fertiliser dressings were required.

4. Test in pots showed that acidity is greatly reduced with prolonged water-logging.

5. Field tests in draining and liming was conducted at Pulau Gadong, Malacca. This showed that lime penetration was very poor.

6. Good water availability and proper application and drainage are key factors in the utilization of acid soils.

7. Shallow rooted acid tolerant crops could be grown without much difficulty in acid areas.

8. Acid areas could be used as fish ponds.

References

1. Van Bemmelen, 1886. "Acid Sulphate Soils" by W.F.J. Van Beers, Wageningen, Netherlands 1962, Bull. 3.

2. Dennett, J.H. 1933. The classification and properties of Malayan soils. M.A.J. Vol. 21, No. 8.

3. Wilshaw, R.G.H., 1940. Note on the development of high acidity in certain coastal clay soils of Malaya. M.A.J. Vol. 28, No.8.

4. Coulter, J.K., 1952. "Gelam" soils. M.A.J. Vo. 35, No.1.

5. Van Beers, W.F.J. 1962. Acid sulphate soils. Wageningen, The Netherlands 1962, Bull.3.

KK/
Chemistry Division,
Department of Agriculture,
Kuala Lumpur.

14th February, 1966.

of Water in Living Organisms. Ed. G.E. Fogg. XIXth Symp. Soc. Exp. Biol., Cambridge, England.

8. Poncelet, L. (1959) Sur le Comportement des Pluviomètres. Publ. A (10). Koninklyk Meteozologisch Instituut van België. Ukkel, Belgium.

9. Raschke, K. (1958) Über den Einfluss der Diffusionswiderstände auf die Transpiration und die Temperatur eines Blattes. *Flora* 146 (4) : 546–578.

10. Reed, H. S. and Hirano, F. (1931) The density of stomata in citrus leaves. *J. agric. Res.* 43 (3) : 209–222.

11. Reynolds, E. R. C. and Leyton, L. (1963) Measurements and significance of throughfall in forest stands. pp. 127–141. *In:* The Water Relations of Plants. Eds. A. J. Rutter and F. H. Whitehead. Symp. no. 3, British Ecol. Soc. Dorking, England.

12. Van Bavel, C. H. M., Newman, J. E. and Hilgeman, R. H. (1967) Climate and estimated water-use by an orange orchard. *Agric. Met.* 4 : 27–37.

13. Watkins, L. H. (1955) Variation between measurements of rainfall made with a grid of gauges. *Met. Mag.* 84 : 350–354.

14. Wilm, H. G. (1943) Determining net rainfall under a conifer forest. *J. agric. Res.* 67 : 501–512.

# SUBSIDENCE IN THE RECLAIMED HULA SWAMP AREA OF ISRAEL

*By*

D. SHOHAM* AND I. LEVIN**

As part of a research program initiated to retard the rate of subsidence in the recently reclaimed swamp area in the Hula Valley of Israel, repeated surveys are taken of the average soil surface elevation in six specific plots. A comparison of results from 1958, 1964 and 1965, and their statistical analysis, showed that the average elevation decreased by approximately 0.60 m during 1958–1964, and by an additional 0.09 m during 1964–1965. The average rate of loss was uniform for both periods, but a difference in the rate was found for points differing in their location (boundary or interior) in the plots. The different distances between the soil and the ground water surface partially explained these differences. The density of the survey grid and accuracy of survey methods were tested and found adequate.

## INTRODUCTION

The Hula Valley is located in the north of Israel, at the lower end of a catchment area roughly ten times its own size. Due to a lava-blocked outlet, the rate of water discharge from the valley is considerably smaller than the rate of inflow through numerous streams. This situation resulted in severe flooding, drainage problems, and the formation of extensive swamps.

In former days, the valley was only sparsely populated and its inhabitants eked out a living at subsistence level. Recently, the swamps were drained, thereby making available 40 km² of newly arable organic soils. This drainage scheme included clearing and lowering of the outlet from the valley, excavating main and secondary channels to convey peak discharge rates through the valley without flooding, and excavating channels to drain the swamps.

The subsidence*** of organic soils as a result of drainage and cultivation is a well known phenomenon (8, 9). The engineers who planned the drainage project of the Hula Valley took into account some subsidence but did not anticipate its magnitude correctly (5).

In 1964, additional flood control measures proved necessary. Consequently, it was feared that subsidence might not be as little as previously thought (6). A research project was initiated to determine the rate of subsidence, to assess the damage

Publication of The Volcani Institute of Agricultural Research, Bet Dagan. No. 1152-E. Received April 1967; accepted Jan. 1968.

* Drainage Division, Water Planning for Israel Ltd., Haifa.

herefrom and, if warranted and economically feasible, to slow it down (3). As part f this project, soil surface elevation surveys of six plots were made in 1964 and 965 and the results compared to the elevations of the same plots measured in 1958. his report deals with the rate of subsidence during this period (1958–1965), and its ossible causes.

## METHODS

Soil surface elevations at points of intersection of a 30 × 30 m grid were obtained 1964 and in 1965 by direct leveling on six plots at the Hula Development Authority IDA) farm. The plots were selected at random in 1958. Elevations were determined y running a closed circuit of levels to B.M. 262/C, located on a culvert at the inter- ection of the Rosh Pinna — Metulla Road with the Meẓudat Jesha Road. The eliability of B.M. 262/C was ascertained by running closed circuits of levels to everal bench marks of the Israel Geodetic Survey. These measurments showed that t has not changed elevation since it was first surveyed in 1932 by the then Department of Surveys of the Government of Palestine. All bench marks so checked, including B.M. 262/C, are located outside the Hula swamp area on shallow terra rosa soil underlain by limestone. Land grading maps of the plots on the HDA farm, which were prepared in 1958, were used to compute subsidence between 1958 and 1964. These maps give soil surface elevation at a grid of 15.0 × 15.0 m before and after the actual grading was done. The elevations given in these maps were also based on a closed circuit level run to B.M. 262/C.

The statistical significance of the following was tested: (*a*) the difference between the average yearly increments in soil surface elevation for all plots for both periods; (*b*) the difference between the results of the computation mentioned when carried out separately for points on the plot boundaries and separately for points interior to the plot boundaries; and (*c*) the regression coefficient of the increment in soil surface elevations as related to the distance from the irrigation ditch at the higher boundary of each plot. To give the proper weight to each survey point, the following weighting factors were used: for points inside the plots, 1.00; for points located on plot boundaries, 0.50; and for points located at the intersection of two boundaries, 0.25.

## RESULTS AND DISCUSSION

The average subsidence in the reclaimed Hula swamp area during the period 1958–1964 was 0.60 m, or an average of 0.10 m per year; for the period 1964–1965 the average subsidence was 0.09 m. The difference in the average rate of sub- sidence between the two periods were not statistically significant. These results are similar to those obtained for drained organic soils located in similar climatic regions (1, 7, 8). Thus the rate of subsidence does not decrease so long as a permanent depth of drainage is maintained, as is actually the practice on the HDA farm.

The density of the leveling grid used, and the degree of accuracy of the leveling, permitted measurements of average subsidence within ±0.01 m. The computed stand-



ard error, indicates that changes in the rate of subsidence of less than 0.03 m/year can not be measured accurately.

It was observed (Table 1) that points on the plot boundaries, when compared with interior points, showed quite different rates of subsidence and a marked difference in the deviation from their respective means. The difference between the interior and boundary areas may be explained, at least in part, by the differences in distances of their respective points from the irrigation ditches. Boundary points are located nearer to the main and secondary irrigation ditches, and consequently closer

TABLE 1

A COMPARISON OF AVERAGE SUBSIDENCE (in meters, ± S. E.) AT BOUNDARY AND INTERIOR POINTS IN SIX PLOTS AT THE HULA DEVELOPMENT AUTHORITY FARM

| *Plot No.* | 1958–1964 | | 1964–1965 | |
|---|---|---|---|---|
| | Boundary points | Interior points | Boundary points | Interior points |
| A 5 | 0.62 (0.03) | 0.80 (0.01) | 0.09 (0.02) | 0.01 (0.005) |
| B 4 | 0.42 (0.02) | 0.56 (0.01) | 0.11 (0.01) | 0.13 (0.006) |
| C 3 | 0.33 (0.03) | 0.53 (0.03) | 0.21 (0.02) | 0.10 (0.010) |
| D 7 | 0.55 (0.04) | 0.68 (0.02) | 0.12 (0.02) | 0.03 (0.006) |
| D 20 | 0.70 (0.04) | 0.88 (0.02) | 0.04 (0.04) | 0.17 (0.020) |
| E 5 | 0.36 (0.02) | 0.56 (0.01) | 0.11 (0.01) | 0.07 (0.003) |

to the free ground water surface. The elevation of the ground water surface decreases from the ditch toward the center of the plot. It has been shown in the literature (1, 4, 7, 8) that loss of elevation in organic soils is directly related to the distance between soil surface and ground water surface. Other factors contributing to the differential subsidence may be the yearly maintenance whereby the dregs scooped from the ditches are deposited on the banks of the ditches, and the method of tillage whereby tillage implements make their turns at the boundaries and thus disturb the soil surface there.

During the period 1958–1964 the subsidence was found to be greater for the interior area than for the boundary area. The reason for this is that in 1958 all plots were graded to a uniform cross-section elevation. Therefore, interior points were farther from the concave (upward) ground water surface than were boundary points. By 1964 the average cross section of the plots had approached a shape similar to that of the ground water surface, i.e., concave upward, probably through the process of differential subsidence. A much smaller difference between the rates of elevation loss for boundary and interior points was therefore expected for the period 1964–1965. Indeed, the analysis of the data for this period failed to reveal any discernible difference between the rates of elevation loss of the two regions.

Points located farther from the main water supply ditch showed a higher rate of subsidence (Fig. 1). This fact may also be related to the increase in the distance

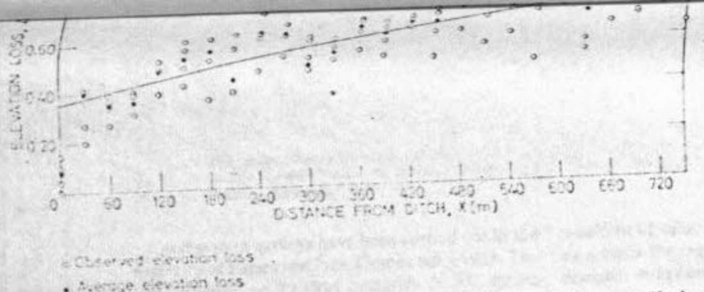



*Fig. 1.* Subsidence (1958–1964) as related to the distance from the irrigation ditch at the higher plot boundary. (Plot D 7)

from soil surface to ground water surface along the longitudinal section of the plots. The main supply ditch carries water almost the whole year round. Even when any specific plot along it is not irrigated at any given time this plot still obtains water from the ditch by seepage. The plots and the secondary ditches drain into a drainage channel at the opposite, lower end of the plot. It may be inferred that both the difference in elevation loss between boundary and interior points, and the increase in elevation loss with the distance from the main ditch, are due to the same cause — the distance between the soil and the ground water table. The maintenance of a water table as close to the soil surface as practicable may be the best way of slowing down subsidence rates of organic soils. In many countries, this is the most common method of maintaining reclaimed organic soil.

## REFERENCES


1. Clayton, B. S., Neller, G. R. and Allison, R. V. (1942) Water Control in the Peat and Muck Soils of the Florida Everglades. *Bull. Fla agric. Exp. Stn.* No. 378.
2. Hald, A. (1952) Statistical Theory with Engineering Applications. John Wiley and Sons Inc., N.Y.
3. Levin, I. and Shoham, D. (1965) Outline of Research Program to Retard the Rate of Soil Surface Elevation Loss in the Reclaimed Hula Swamp. Water Planning for Israel Ltd., Haifa. (Hebrew, mimeo.)
4. Nakamura, I. (1963) Peat bog of Hokkaido and overdrainage. Trans. 5th Congr. I.C.I.D., Tokyo R. 7, Quest. 17.
5. Rendel, Palmer, Tritton Ltd. (1936) Technical Report on Hula Basin: Preliminary Scheme for Reclamation, Drainage and Irrigation. London.
6. Shoham, D. (1964) The Reclaimed Hula Swamp. Drainage Div., Water Planning for Israel Ltd., Haifa. (Hebrew, mimeo.)
7. Stephens, G. C. (1955) Drainage of Peat and Muck Lands. *Yb. Agric. U.S. Dep. Agric.* 1955 : 539–557.
8. Weir, W. W. (1950) Subsidence of peat lands of the Sacramento San Joaquin Delta, California. *Hilgardia* 20 (3) : 1–5.




# THE GROWTH RESPONSE OF CITRUS TO NEMATOCIDE TREATMENTS

*By*

E. Cohn*, W. A. Feder** and M. Mordechai*

Growth of citrus seedlings was determined in 10-liter containers in soil infested with the citrus nematode and other microorganisms, in comparison to soil treated with methyl bromide and DBCP. On seedlings planted nine days after soil treatment, methyl bromide caused a severe setback and DBCP a slight setback in plant growth, which persisted for two years. When seedlings were planted 12 months after soil treatment, rate of plant growth was in the order: methyl bromide-treated > DBCP-treated > untreated. It is suggested that the inconsistent response of adult citrus trees to post-planting DBCP treatment is partly due to a mild inhibitory effect of the chemical on growth which offsets results achieved by nematode control, as well as its inefficacy against secondary microorganisms which invade the root tissue after nematode penetration.

## INTRODUCTION

The citrus nematode, *Tylenchulus semipenetrans* Cobb, is a widespread pest in adult citrus orchards in Israel and a recognized factor in the citrus replant problem in the country (4). Experiments have shown that it can be effectively controlled on living trees by soil treatments with the fumigant dibromochloropropane (DBCP) (2, 7). However, tree response to these treatments has not been as uniform as expected, and although increases in yield and tree vigor have been observed following nematocide applications (1, 7), in many cases trees have failed to show improved performance, although satisfactory nematode kill was attained; moreover, a few cases of actual injury to trees as a result of DBCP treatment have been encountered recently. In the present paper, we report results of trials which offer some possible explanations for the inconsistency in the response of citrus trees to post-planting DBCP treatment.

## PROCEDURE AND RESULTS

Sandy loam soil was removed from a 30-year-old citrus orchard which was infested with the citrus nematode. Laboratory examinations revealed also a high incidence of *Fusarium* spp. and unidentified bacteria in the soil. Treatments were carried out on heaped soil with two compounds: the sterilant methyl bromide at a rate of

Publication of The Volcani Institute of Agricultural Research, Bet Dagan. No. 1281-E. Received April 1967; accepted Nov. 1967.

* Div. of Nematology, The Volcani Institute of Agricultural Research, Bet Dagan.

** Fulbright Fellow, 1964; present address: Department of Environmental Sciences, University of Massachusetts, Waltham, Mass., U. S. A.

# PRACTICAL ASPECTS OF LAND SYSTEM SURVEYS IN NEW GUINEA

By

H.A. HAANTJENS

This paper was read at the International Conference on Principles and Methods of Integrating Aerial Survey Studies of Natural Resources for Potential Development, UNESCO, Toulouse, France, September 1964.

Land system surveys have been carried out in the Territory of Papua and New Guinea since 1953. The areas covered up to 1964 comprise 36,500 square miles out of a total land area of 180,000 square miles (Fig. 1).

Land system surveys are designed to yield a maximum of basic information on the physical features of whole regions from a minimum of field data extrapolated with the aid of aerial photographs. This high output of admittedly somewhat tentative information favours the application of these surveys to areas about which little or no systematic scientific knowledge exists. Thus they would be of value in large parts of the humid tropics as a basis for regional development as well as for research in agriculture and many other fields.

Although the methods used in land system surveys are basically the same wherever they are carried out, adjustments are needed to suit the particular conditions of each survey area. Thus it appears useful to give special attention to land system surveys in a humid tropical and generally poorly accessible country like New Guinea, a subject that has only been briefly discussed before (Haantjens, 1961; Mabbutt and Stewart, 1963; Christian and Stewart, 1964, in press).

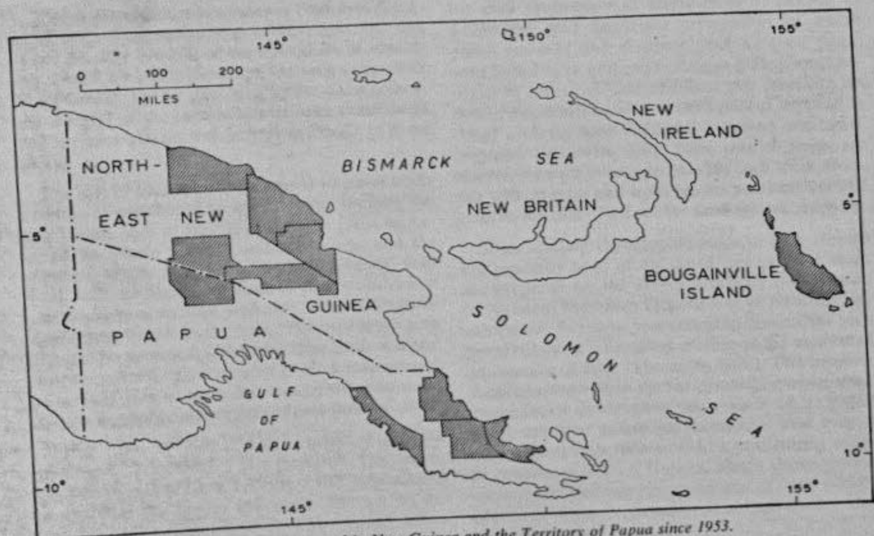



*Fig. 1. Areas surveyed in New Guinea and the Territory of Papua since 1953.*



## THE NATURE OF LAND SYSTEM SURVEYS

The concepts on which land system surveys are based have been discussed by Christian (1952, 1958) and Christian and Stewart (1952, 1964, in press). The outstanding feature of the surveys is that the land forms, soils and vegetation of a region are studied *together* and in relation to lithology and climate, by scientists working as a team and integrating the information obtained in their own disciplines in the description and mapping of land systems.

Team work is probably the most essential aspect of land system surveys. The most efficient way to integrate studies of land form, soil and vegetation is to have scientists examine the same sites at the same time. Even then each member is likely to get a different personal impression of what he has seen, but at least all discussions can be objectively confined to the same facts. The correlative value of such integrated observations made by experts in various disciplines is high. Each team member can concentrate on his own field work, yet discussions with his colleagues will help him in the interpretation of his data and broaden his outlook on the nature of the land surface as a whole.

Team work cannot work if there is too much difference between the professional capabilities of the team members. Not every scientist is temperamentally suited to work in close co-operation with others, especially under the sometimes trying conditions in the field. Apart from being able to make a sound contribution in his own discipline, a scientist selected for team work should have the ability to see the other man's point of view and to keep the various aspects of the survey work in their proper perspective in relations to the overall objective of analysing and describing the complex feature called land.

In C.S.I.R.O. surveys the land system is a complex mapping unit composed of land units which are not individually mappable at the scale of working, but which are associated in such a way as to produce a characteristic pattern on aerial photos. The land system is thus similar in nature to the soil association (Soil Survey Staff, 1951), but unlike the soil units in the soil association, the land unit is not a taxonomic unit.

There are three main types of land system photo patterns:

(1) The truly 'recurring' pattern mentioned by Christian and Stewart (1952), in which the land units making up the pattern occur in a multi-directional arrangement, and will therefore be encountered repeatedly during a traverse in any direction through the land system. Plate 1 is an imperfect example of this situation.

(2) The 'catenary' pattern in which there is a one-directional arrangement of the land units, all of which can therefore be encountered only during traverses in a particular direction through the land system (Plate 2).

(3) The 'irregular' pattern in which the land units apparently occur haphazardly yet form a characteristic association (Plate 3).

In practice few patterns fall wholly into one of these categories. The majority of land systems mapped in New Guinea are mixtures of (2) and (3), many others mixtures of (1) and (3).

The recognition and mapping of land systems is almost wholly based on air photo interpretation, their description largely on the limited data collected in the field. This involves a great deal of extrapolation for which two conditions must be fulfilled. First, the field observation sites must be carefully selected as typical examples of the land units to be examined (see p. 17). Second, there must be reasonable assurance that the photo pattern in the large unexamined portions of the land system is indeed the result of the association of the same land units as those on which data were collected. To this end the photo interpretation and mapping of land systems should be guided by morphogenetic considerations, based largely on geomorphic interpretation both of the land units in the field and of the land unit patterns on the air photos, as well as on interpretation of the correlations between land form, soil and vegetation observations. The application of geomorphic mapping to land system surveys has been more fully discussed by Mabbutt and Stewart (1963).

Morphogenetic mapping and interpretation do not imply that a land system should be genetically simple. Many land systems have a complex morphogenetic history (Plate 1), but this history should

From: The Journal of Trop. Geography
Vol. 22, Dec. 1965

be essentially the same wherever the land system occurs. Variations in photo patterns indicative of differences in morphogenetic history are very important for the location of land system boundaries, because extrapolation across such variations is hazardous. On the other hand, areas with a broadly similar history may still be subdivided into land systems on purely morphological grounds, if this serves a useful purpose.

## SURVEY PROCEDURES

### *Selection and size of survey areas*

Reasons for selecting an area may vary. In New Guinea the selection is usually a compromise between priorities indicated by the Administration and the availability of aerial photographs. Cloudiness may delay photographic coverage of a high priority area for several years. A decision on the location and size of a survey area should be made six to twelve months ahead of the scheduled field work so as to leave ample time for the administrative, logistic and financial preparation of a survey.

The ideal procedure is to survey complete catchment areas or administrative subdivisions, but this is not possible because of the difficulties of obtaining special air photo coverage for such irregularly shaped areas. The air photographs are taken following the grid of the inch-to-a-mile map sheet index and the survey areas thus comprise blocks of these sheets.

The aim of land system surveys is to cover areas as large as possible. The basic factors limiting the size are the need to sample at least the great majority of the photo patterns and land units, and the duration of the field work. In New Guinea, field work must be limited to three to four months in a year because of rainfall, and also to avoid physical and mental fatigue in the team. The maximum area that can be surveyed within this time limit is therefore determined by the number of land units present per unit of area (complexity) and by the number of observations possible per unit of time (accessibility).

Most parts of New Guinea have complicated landscapes. Accessibility is a problem. The survey areas have ranged from 1,850 to 4,700 square miles in size, but the proper minimum size for an experienced team appears to be 2,500 square miles. These areas are much smaller than those that can be covered on, for example, the arid mainland of Australia. With increased accessibility resulting, for instance, from the use of helicopters or the establishment of a road network, it is possible either to increase the size of the area, or to reduce the period of field work. Little is gained by increasing the sampling density beyond a few replications. This will not significantly influence the mapping by photo interpretation and will contribute little to the reliability of the survey.

The total time needed to complete a comprehensive land system survey is fifteen to eighteen months, subdivided into preliminary mapping and survey preparation (two to three months), field work (three to four months) and report preparation (ten to twelve months).

### *Aerial photographs and maps*

Most of the aerial photographs used are taken from an altitude of 20,000 to 25,000 feet resulting in a scale from 1:40,000 to 1:50,000 at sea-level. This small scale provides all the detail required for map production at scales from 1:100,000 to 1:250,000, and facilitates recognition of entire photo patterns and discontinuities between them, which tend to be obscured on large scale photos because of restricted field of vision and emphasis on detail. The small number of such photos required to cover a survey area facilitates mapping and handling and cuts costs, since three sets of prints are needed for each survey to provide each team member with at least half a set for his personal use and reserve the other half set for land system mapping.

Since existing topographic maps in New Guinea are generally poor or out-dated, special base maps are prepared for the survey group by the Division of National Mapping, Department of National Development. In recent years the map lay-out has been prepared using a modified version of the method of adjustment of Jerie (Thomson, 1961). This involves the preparation (with the aid of stereotopes) of small 'preliminary detail plots' at a scale of 1:50,000 which are later assembled to make a base map at the required scale. The method is particularly suited to conditions in New Guinea, where scarce ground control and extreme distortion due to relief present problems in the preparation of normal slotted template assemblies.

*Plate 1. The Abiera land system in the highlands is a good example of a recurring land unit pattern and has a complex morphogenetic history. It consists of lacustrine deposits which were exposed to weathering and subsequently dissected, leaving only remnants of the original surface intact (1). Slumping finally carried more sediment to the valleys than the small streams could cope with. This led to the formation of swampy valley plains (2).*

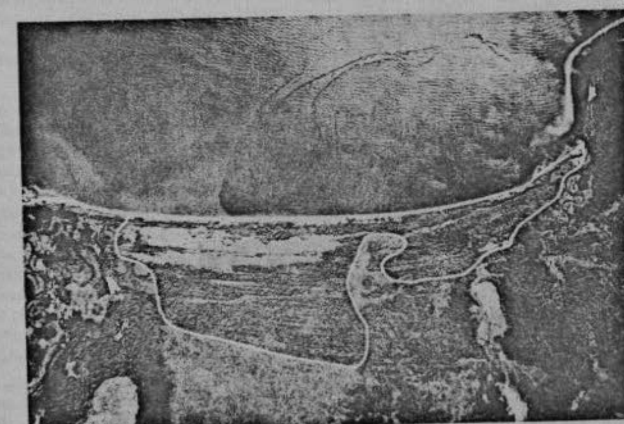


*Plate 2. The catenary land unit pattern is well illustrated in the Pawara land system. There is a land inward succession of a present beach, frontal beach ridge, broad degraded beach ridges and narrow, poorly drained and strongly degraded beach ridges. Only one land unit, the swales, recurs almost throughout the entire land system.*

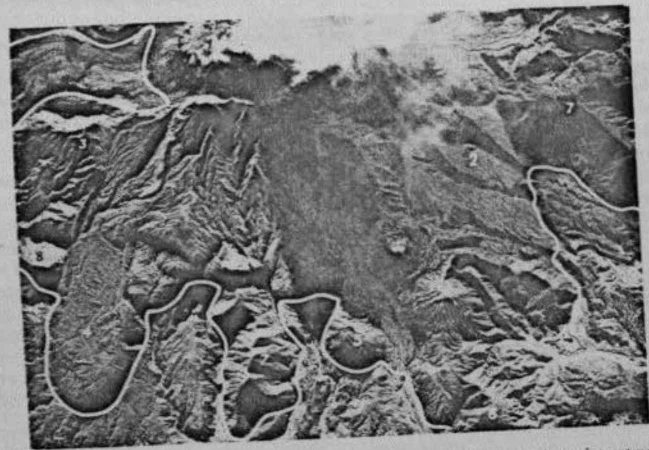


*Plate 3. The summit of Mt. Lamington volcano (Lamington land system) displays an irregular yet very characteristic array of land units: active tholoid (1), ash slopes (2), dissected ash slopes (3), coulees (4), adventive cones (5), dissected cones (6), dissected lava flows and coulees (7), and asymmetrical lava ridges (8). This photograph was taken two years after the 1951 eruption which completely destroyed the forest.*

*Plate 4. These two very similar photographic patterns represent: (a) An uplifted, gently undulating plain of Pleistocene sediments with strongly weathered meadow podzolic soils and short grassland; and (b) a recent flood-plain, with fertile alluvial clay and peat soils and swamp grassland. The water-table is shallow and the plain is inundated for several months each year. The grass vegetation in (a) is man-induced and maintained by burning. In (b) it appears to be natural, although the photograph shows that burning-off is practised even in this swampy environment.*



*Personnel*

A basic team consists of a geomorphologist, a pedologist, and a plant ecologist. A transport officer, who handles the logistic side of the survey in all its stages, acts as an assistant during report preparation and collects general geographic information in the field.

The participation of other scientists in the team, although in some cases desirable, is usually difficult due to the problem of keeping a larger team sufficiently mobile in the difficult terrain, and because they require methods of investigation that do not fit the survey procedures. For instance, most hydrological work needs to be based on data collected over many years. Solid rock geology can be properly investigated only by means of slow traverses along deeply incised river beds, generally avoided by the basic team which is dependent for its observations on more rapid progress across the land. A regional analysis of available climatic data is made for each survey by a climatologist, who co-operates with, but is not a member of, the field team.

Experts in applied fields such as agronomy, soil engineering, land reclamation, etc., are not included in the team. They are concerned with later stages of regional development, and their investigations should use the survey report rather than contribute to it.

However, two other activities have always been a part of the normal survey operations in New Guinea, although they are generally carried out independently because they involve more detailed local investigations. The first consists of plant taxonomic investigations by a systematic botanist or botanical collector. These are aimed at supporting the work of the plant ecologist. The second is a broad examination of the commercial forest resources by a forest botanist, who thus supplements the work of the plant ecologist.

*Survey preparation*

*Preliminary photo interpretation.* Each member of the team familiarizes himself with the area by individual study of the aerial photographs, concentrating on those features that are of particular significance to his own discipline and attempting their preliminary interpretation and classification. A rapid and efficient methods of obtaining a good impression of an area is the use of stereo assemblies in which photographs of successive runs are laid out accurately according to the lines of flight and spaced in such a manner that they can be examined with a pocket stereoscope after photographic reduction of the assembly to one-third of the photo scale.

This phase of individual orientation is followed by the delineation of preliminary mapping units, which serve as a guide for the planning of field traverses and observation sites, as a framework for recording field information and as an aid to final mapping. Preliminary mapping is carried out jointly by the geomorphologist and plant ecologist, with the aid of paired Old Delft scanning stereoscopes. The pedologist usually contributes little to this, but familiarizes himself with the results. The forest botanist compares his own preliminary forest mapping with that of the other scientists.

As stated by Mabbutt and Stewart (1963) the objective is to recognize and interpret whole photo patterns, rather than to analyse these by mapping separate photo elements as in the case of preliminary soil interpretation maps (Vink, 1963). However, the preliminary mapping should be more detailed than the final land system mapping in order to guide field work towards all possibly significant differences in photo patterns.

The interpretation of the photo patterns remains very general at this stage, but is systematically expressed in the symbols used to distinguish between the preliminary mapping units. Examples of such symbols are: F/R$_t$=alluvial fan with tall rainforest; A/R$_i$=alluvial plain with irregular tall rainforest; Mu/LM=mountains of ultrabasic rock with lower montane forest. Detailed descriptions would generally be made obsolete by the information obtained in the field.

One of the problems in preliminary mapping is that different ground conditions may produce almost identical photo patterns (Plates 4 & 5). Interpretation is often possible by studying their relationship to adjacent patterns or on the basis of pre-existing knowledge, but in some cases only field checking can solve the problem.

*Traverse Planning.* The aim of traverse planning is to ensure that the largest possible number of land units is examined in the field, and that observation sites are properly distributed over the preliminary mapping units. To achieve this the survey must be based on existing lines of communication. Cutting cross-country traverses is too slow and can only be done in exceptional circumstances, and over short distances.

The first task is, therefore, to mark on the aerial photos all visible roads, tracks, airstrips and settlements. An experienced interpreter can also plot the most likely position of tracks through densely forested country between villages. The data are augmented and identified by comparison with information on existing maps, in patrol reports and from any other source. The most efficient methods of transportation can now be chosen. These in turn largely determine the logistic preparations required for the survey.

The next step is to plot both this information and the boundaries of the preliminary mapping units on a set of uncontrolled photo mosaics. These are assembled into a rough map of the whole survey area on which the most efficient general traverse lay-out can be established.

In the few areas in New Guinea where accessibility is a minor problem and roads and tracks are clearly visible on the photos, traverses can be planned in detail, including the selection of small sampling areas in the preliminary mapping units (query areas). In most areas there is so much uncertainty about the location of tracks that only a broad outline of the traverse plan can be prepared. Its beginning and end points must be at an airstrip, anchorage or vehicular road-head. The traverse plan itself is based on a weekly module, which facilitates prior distribution of supplies and creates a regular rhythm in survey operations. The spacing of the weekend bases is largely governed by an assessment of the nature of the country to be traversed and by the expected amount of side-tracking needed to reach the preliminary mapping units to be examined during each week.

Traverse planning for surveys based largely on helicopter transport, as in the case of the 1964 survey of Bougainville Island, is concerned with the selection of strategically distributed operational base camps, suitable sampling areas in each preliminary mapping unit and potential landing spots within each of these (R.M. Scott, personal communication).

## Field work

*Field Transport.* Four-wheel drive road transport, outboard motor dinghies and larger craft are the cheapest and most efficient media of transport. They combine speed, versatility and carrying capacity for the party, its indigenous assistants and equipment. The greatest lengths of traverses and the largest number of observations (500 to 1,500) are achieved in surveys based largely on motorised transport. Unfortunately this method cannot be generally used in New Guinea.

In many areas walking and native canoes are, of necessity, the principal if not the only means of communication. Their slowness reduces the length of traverses to at most 600 miles and the number of observations to a maximum of 500. Survey costs tend to increase because of the need to employ large numbers of carriers. On the other hand, walking surveys are more versatile because only few preliminary mapping units cannot be reached on foot or by canoe. They are reliable because they are not held up by mechanical breakdowns and are little affected by adverse weather. They also allow greater flexibility in individual movements and sampling, and bring the party in intimate contact with the terrain.

The merits of helicopter transport can only be fully assessed after the Bougainville survey. However, some experience was gained during a week's trial in 1963. The advantages are the greatly increased speed and comfort in moving between observation sites, the helicopter's suitability for low level aerial reconnaissance and picture taking, and the enormous reduction in time and effort to reach poorly accessible and unpopulated preliminary mapping units; for instance, in swamps with patches of open water, rugged grass-covered hills and alpine environments (Plate 6). Disadvantages appear to be the high cost, the small pay load, the helicopter's dependence on the availability of landing spots (which could be a serious handicap in completely forested country), the relatively great influence of adverse weather conditions, and the rare opportunities to examine ground conditions between preselected observation points.

*Nature of Observations.* Joint observations made on the same spot by all team members are the main objective of the field work. As shown earlier, the system has important advantages, but it has also certain limitations: (1) joint observations take longer than individual ones. Scientists normally require different lengths of time to make their notes. Thus time is lost in waiting for the last man to finish. This may make the slowest observer feel rushed, which may lead to less accurate observations. (2) It is not always possible to select observation sites of equal signifiance to each scientist. Thus joint observations may, on the one hand, prevent visits to certain sites of particular interest to only one of the scientists, and on the other hand, require the presence of one of the team members at sites that are of little interest to him. The latter situation confronts the plant ecologist most often, because many observations must necessarily be made in areas where the natural vegetation has been destroyed by man.



In responsible team work these difficulties may be partly overcome by allowing some freedom of individual movement, provided that all scientists catch-up with each other at each joint observation site.

Some individual observations are desirable in their own right. Brief geological inspections should be made when the traverse crosses streams with rock outcrops. There may also be a case for spending individual effort on a levelling survey, a detailed examination of an important forest type, or an assessment of soil variability in a promising land unit.

Joint observations should refer to areas of land just large enough to measure the slope characteristics and to sample the particular type of vegetation, centred round the soil observation hole. The writer proposes to call such a small homogeneous area a *land element*. From these the land unit descriptions are built up.

The need to cover large areas in a short time prevents the team from making very detailed observations. Soil descriptions have to be based only on auger samples, unless road cuts can be examined. Only the more general characteristics of complicated vegeation types, such as rainforest, can be noted.

*Siting of Observations.* The need for a careful selection of sampling sites should be constantly kept in mind during field work, even though inaccessibility will in some cases force the team to accept the compromise of a second choice. A few atypical observations can be therefore expected.

On surveys where query areas can be selected during the planning stage it will only be necessary during field work to work out the most efficient daily traverses to visit these sampling spots, to find substitutes for those that are much harder to reach than anticipated, and to eliminate some from the programme as experience accumulated during the survey shows their examination to be superfluous.

On the more typical New Guinea surveys where only board traverse outlines can be planned, the choice of observation sites is a matter of continuous planning and improvisation. Although it is not generally possible to alter the basic traverse scheme because the weekly supply depots must be reached on time, the daily traverses can be adjusted at will to suit the local conditions. The adjustments are made by weighing the physical possibilities of access, as gauged from aerial photos and discussions with local inhabitants, against the desirability of reaching certain spots in preliminary mapping units. The traverses can be even more flexible if there is time available for impromptu observations where unexpected changes in ground conditions make this desirable. However, even the most carefully planned sorties can fall short of their objectives, as for instance, when a guide leads the party up the wrong hunting track, a river in flood prevents further progress, or heavy rain makes observations impossible. Such wasted traverses cannot be repeated, but some of the losses can be recouped by imaginative planning later during the survey.

*Recording of Data.* For the joint summarizing of individual notes in the field, the writer recommends the '*element card*' system in which the scientific observations on every land element are summarized on specially printed punch cards. This can be done at the site or in the evening in camp. The latter method is more comfortable and will not use up precious observation time. The objectives of joint descriptions are to evoke discussion on their significance, to build up a feeling of mutual understanding in the team and to preclude later disputes about the correlation of individual field notes. The element card system is commended because the cards can be easily duplicated for distribution as well as to insure against loss; they are easy to handle in the field and form a compact permanent record of all field data, from which varied information can be simply extracted; and they can be easily arranged and re-arranged for various purposes at all stages of report preparation.

The recording of data is restricted to the registration of observed facts and does not include official attempts at classification, grouping and interpretation. Unlike the case of more detailed multi-stage soil surveys described by Vink (1963), map legends and classification systems for land system surveys cannot be gradually built up during the field work, but must be left until *all* relevant data are available for sorting and comparing after the field survey.

*Report preparation*

*Individual Work.* Report preparation starts immediately after the return of the team from the field. Before attempting the final description and mapping of the land systems, the scientists must have an opportunity to assess the significance of their own field observations. This work may involve the sorting out of sample collections and preparing them for analysis or identification, and the classification and interpretation of land forms, soils and vegetation, including an evaluation of their relationships to the preliminary mapping units.

Further periods of individual work are devoted to writing specialist papers in the report. These will alternate with periods of team work on land system descriptions.

*Joint description and mapping of land systems.* This work is concerned with the conversion of the preliminary mapping units into land systems. It involves the grouping of the element cards (or equivalent data) according to land units and land systems and also the partial regrouping and remapping of the preliminary mapping units, based on the better interpretation of the photo patterns as a result of the field observations. Photo patterns that were originally separated are combined when field observations have shown that the variation in pattern is the result of only minor differences in the nature or in the arrangement of the component land units (Plate 7). Only in few cases do field observations show the need for further subdivision by photo mapping of preliminary mapping units.

It is most convenient if the first tentative land unit and land system proposals are made by the team leader. These are then amended during team discussions, when skeleton land system descriptions are drawn up and the need for remapping examined. Remapping may be done jointly by the team, or each scientist may take care of a portion of the area. It will generally indicate the need for further amendments of the land system descriptions. The final results thus emerge gradually from the interaction between description and mapping.

Mapping by photo interpretation is made difficult in New Guinea because minor diagnostic land form features may be concealed below a dense forest cover (Plate 8). Conversely the local destruction of the natural vegetation by man may create differences in the photo pattern that are of no significance to land system mapping (Plate 9).

The problem of dealing with large transitional zone between otherwise distinct photo patterns is solved either by including such zones with the land system to which their pattern is most similar (Plate 10), or by giving such zones separate land system status (Plate 8). In the first case, additional land units are normally required for the land system description.

Final land system descriptions retain some kind of tabular presentation and include a block diagram or plan (Table 1). Minor land units that have no morphogenetic relation to the characteristic photo pattern of the land system (Plate 11), and often consist of unmappable outliers of adjacent land systems, are excluded from the regular description, but may be mentioned as 'inclusions'. The area occupied by each land unit in a land system is a vital but difficult part of the description. Uneven distribution and/or problems in accurate recognition on the photos prevent the application of simple statistical sampling methods. Approximate areas are arrived at by comparing independent estimates made by each team member.

*The survey report.* Land system descriptions form the core of the report, serving as a link between specialist parts dealing with climate, geology, geomorphology, soils, vegetation, forest resources, and land use capability. On the other hand the land system descriptions can be kept brief by referring to the specialist parts for more detailed information. An illustrated general description of the area in the beginning of the report brings all facets of the survey together in one simple overall picture.

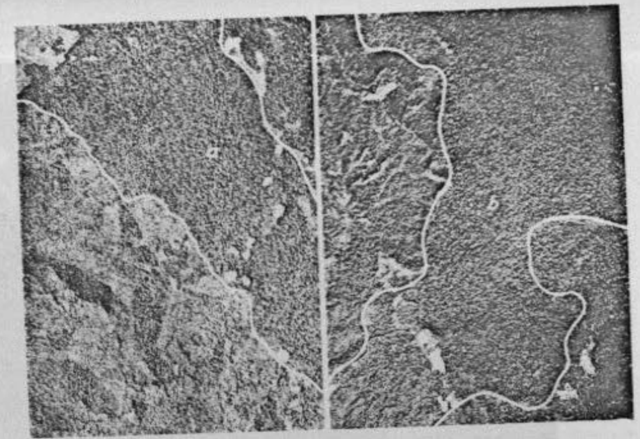


*Plate 5. The interpretation of the forested plain at (a) as a series of coalescing alluvial fans and that at (b) as an ash-covered basalt plateau is virtually impossible from their photographic characteristics alone, but may be deduced at (a) from its position at the foot of a sharp mountain front and at (b) from its association with more clearly recognizable volcanic features and from the sudden deep incision of the major stream.*

*Plate 6. The Wilhelm land system, ranging from 10,000 to nearly 15,000 feet, is characterized by the effects of a late-Pleistocene glaciation and by vegetation of montane beech forest and alpine grassland. Field examination of such photographic patterns is greatly facilitated by helicopter transport. As land system surveys are concerned with the whole of a region, such patterns should not be neglected only because they offer no scope for development.*

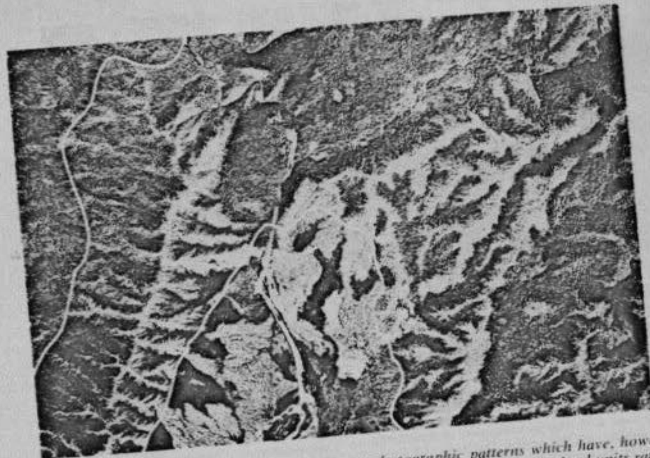


Plate 7. The Arumbai land system includes rather different photographic patterns which have, however, very similar characteristics and are the result of differences in the arrangement of the same recurring land units rather than of significant differences in morphogenetic history. Much of the vegetation consists of eucalypt savanna, which is unusual in New Guinea.

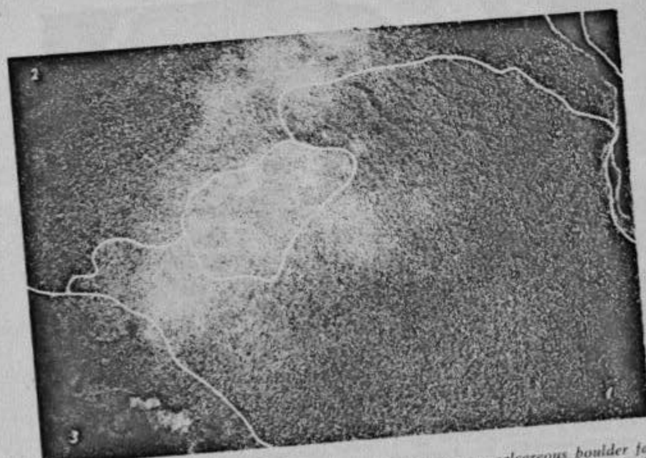



Plate 8. Photo pattern (1) combines features of the undissected, very young, calcareous boulder fans of pattern (2) with those of the dissected, older, deeply weathered mudflow fans of pattern (3). Field observation showed that it also has some unique soil and vegetation features. It was therefore mapped as a separate land system, even though it is in many ways a transitional unit with generally vague boundaries, due largely to the dense forest cover.

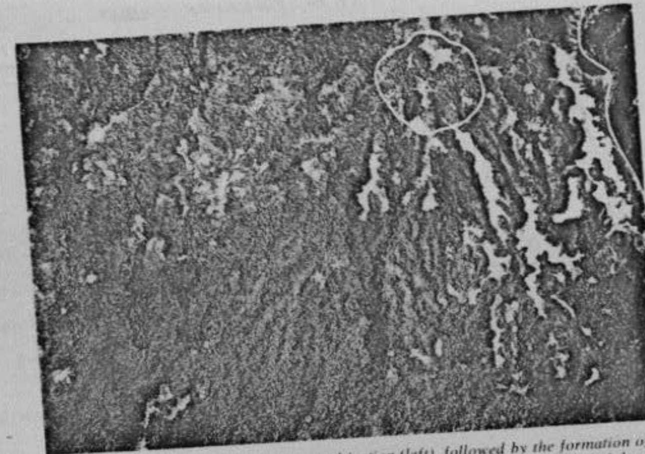


Plate 9. Destruction of rain forest (bottom) by shifting cultivation (left), followed by the formation of man-made grassland (right), creates differences in photographic patterns that are not reflected in differences in inherent land characteristics. Throughout the photograph the Tahma land system consists of low ridges of weathered mudflow material, covered with thick volcanic ash. The intricate vegetation pattern obscures the outline of a distinct volcanic cone (1) forming part of another land system.

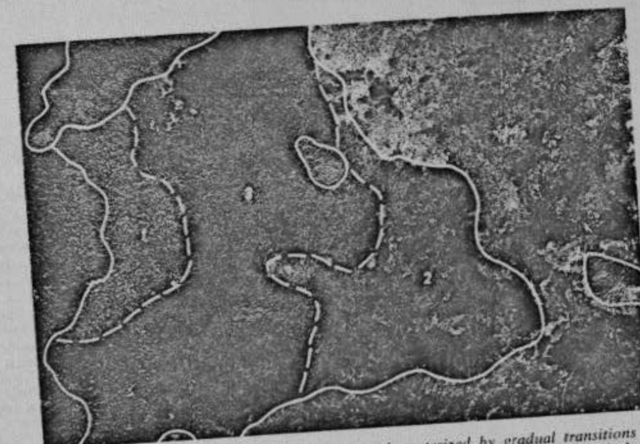



Plate 10. Apart from the hills the photographic patterns are characterized by gradual transitions ranging from tall forest (left) to herbaceous swamp (right). The transitional patterns (1) and (2) have been included with the typical swamp woodland (3) because they resemble it more than they resemble herbaceous swamp or forested flood-plain.

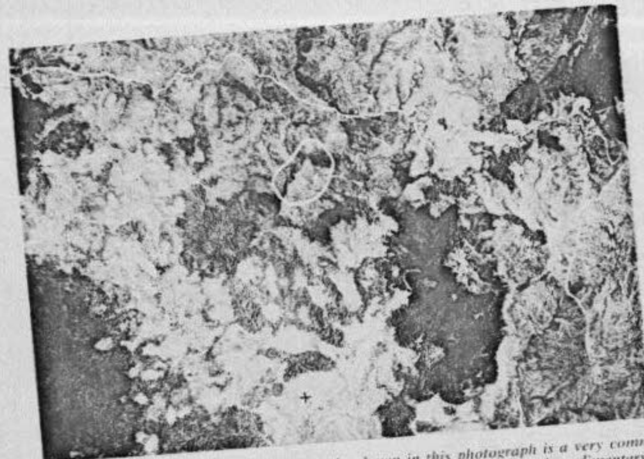


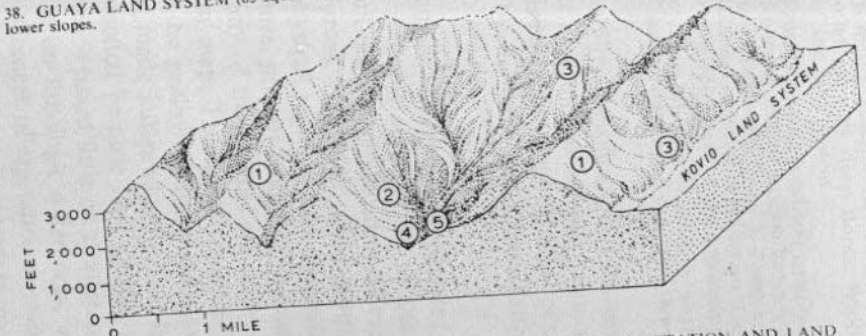
*Plate 11. The irregular, hilly country in sedimentary rocks shown in this photograph is a very common type of landscape both in the lowlands and the highlands. A volcanic neck (1) protruding through the sedimentary strata is a typical example of a foreign inclusion in a land system. The area is at about 5,000 feet above sea-level with shifting cultivation concentrated in valleys and infringing upon the remaining areas of beech forest.*

*Plate 12. Sugar loaf volcanic plateau at 9,000 to 12,000 feet with its characteristic association of little to moderately dissected lava domes and plateaux, and colluviated valleys. It has been mapped as a single land system, notwithstanding the great variation in vegetation which includes lower montane forest, with lower montane grassland and sedges in cold air valleys and swampy areas, and montane forest and alpine grassland on the highest, central dome. These vegetation types can be separately mapped on an independent vegetation map.*



TABLE 1. AN EXAMPLE OF A LAND SYSTEM DESCRIPTION

38. GUAYA LAND SYSTEM (85 square miles). Ash-covered mountain ridges in the north-west, with dissected gentle lower slopes.




SUMMARY OF CORRELATIONS BETWEEN LAND FORMS, SOILS, VEGETATION AND LAND CAPABILITY CLASSIFICATION.

| LAND UNIT NUMBER† | AREA (Sq. Miles) | LAND FORMS | SOILS* | VEGETATION | LAND CLASS |
|---|---|---|---|---|---|
| 1 | 45-50 | Short straight slopes; 30-45° | Kwena, Uoive (16) | *Castanopsis* and lower montane forest, minor secondary forest | VIIe, VIII |
| 2 | 25-30 | Dissected, very long slopes; 15-2° | Kiara (14), Owalama (16) | Mainly foothill forest, some midslope forest | VIe, VIIe |
| 3 | 3-6 | Ridge crests; 0-30° | Kwena (16). Very locally Silimidi (18) | Lower montane, stunted lower montane, *Castanopsis* and midslope forest | VIe, IIIe |
| 4 | 2-4 | Very short slopes; 45-60° | Ondoro (15), probably Kiara (14) | Irregular *Castanopsis* forest | VIII |
| 5 | 1-2 | Alluvial terraces; ½-2° | Gorabunina (6) | Foothill forest | IIIe, VIe |

†Numbers in descriptions which follow below refer to these land units.
*The names in this column refer to soil families and the numbers to great soil groups.

*Altitude*: 900 to 5,500 ft. *Relief*: 800 to 2,000 ft.

*Geology*. ? Late Cretaceous or ? early Tertiary basic-ultrabasic plutonic rocks and Recent andesite ash layers of variable thickness, generally thinning southwards. Recent up-faulting to form block mountains.

*Geomorphology*. Mountain ridges, with sub-accordant crests in the south and prominent lower concave slopes in the north. Recent stream incision working in from the marginal fault scarps has dissected the thick colluvial mantle on the concave slopes. Fine to very fine texture of dissection, and deep mature weathering of bedrock.

Short, very steep, straight slopes (1), with abundant terracettes and local severe slope wash are predominant in the south. They meet in very sharp small steep spurs on the side slopes of the major ridge crests (3) which are convex, and up to 200 feet wide. Northwards, very long concave lower slopes (2) are dissected into a maze of ridges with 100 feet relief and very short, straight-side slopes. Minor alluvial terraces (5) margin the axial streams and are up to 40 feet above them and 200 feet wide. Short, precipitous slopes (4) occur adjacent to incised stream courses.

*Soils*. Mostly deep, acid to weakly acid, moderately weathered, yellow brown ash soils; sandy clay loams and sandy loams with thick dark topsoils on crests and upper slopes (1 and 3), sandy clays with thick dark topsoils and clayey, colluvially mixed soils on lower slopes (2). The latter occur also on precipitous lower slopes (4) together with less colluvial sandy clay loams with thin dark topsoils. The ash soils generally overlie weathering profiles, which appear locally at the surface, giving rise to strongly weathered, very clayey but friable soils. The only profile of this kind observed (3) is a weakly acid strong brown soil, but similar and more acid soils are likely to occur locally, also in land units 1 and 4.

*Drainage Status*. Well drained.

*Vegetation*. Owing to the high altitude the main vegetation types are *Castanopsis* forest and lower montane forest (1, 3, 4). On very steep slopes the forest is open and irregular (1, 4). *Casuarina*, widely scattered or forming a very open er storey, occurs in land unit 4. Mainly foothill forest is found in land units 2 and 5. Old secondary forest with ch *Albizia* is mainly concentrated along larger rivers, especially between Emo and Sirorata and between Gorabuna l Sirorata, often on very steep slopes. Widely scattered high emergent palms to 36 metres in height occur on the tern edge of the land system.

*essment.* Notwithstanding good soil conditions, land use potential is severely restricted by the steep slopes and dense ection, which cause serious erosion hazards and strongly reduce accessibility. Small scale development for tree crops y be possible in land units 2 and 5. These land units, carrying a forest of moderately high stocking rate, would also he most suitable for forest exploitation. Generally speaking, the land system should be kept under protective forest t forms an important part of the catchment area of the Kumusi River.

*lusion.* Very steep low hills of strongly weathered basalt near Sirorata, with shallow weak red strongly acid soils orata, 18) and yellow brown ash soils (Kwena, 16) on crests. *Castanopsis* and midslope forest.

Land capability classification is discussed in the nd system descriptions as well as in a separate apter. It is based on a modification of the system veloped by the U.S. Soil Conservation Service aantjens, 1963).

Apart from the land system map (scale 1 : 250,000), e report contains some or all of the following aps, which may be produced at different scales: rest resources, vegetation, soils, geomorphology, ology, physical regions, land capability groups, imatic zones, present land use, population distri- ution. Many of these maps are derived from the nd system map. The forest resources map is al- ays, and the geological and vegetation maps are metimes, made independently. This latter course recommended because land system mapping in ew Guinea is based little on stratigraphic and not nsistently on lithologic differences, whilst many arked differences in vegetation are not sufficiently gnificant to be used in land system mapping (Plate ).

KNOWLEDGEMENTS

The author gratefully acknowledges the stimulus ovided by Messrs. C.S. Christian and G.A. Stew- t, former and present Chief of the Division of and Research and Regional Survey, in developing s appreciation of the value of land system surveys. hanks are also due to the many colleagues who ith discussion, criticism and co-operation in sur- y teams made this paper possible, and in particu- r to J.G. Speight and R.A. Perry for their helpful criticism in the preparation of the manuscript. Finally, the author wishes to thank the Director, Division of National Mapping, Department of National Development, for making the aerial photographs available for publication.

REFERENCES

Christian, C.S. (1952), 'Regional land surveys', *Journal of the Australian Institute of Agricultural Science*, Vol. 18, pp. 140-146.

——(1958), 'The concept of land units and land systems', *Proceedings of the Ninth Pacific Science Congress 1957*, Vol. 20, pp. 74-81.

——and Stewart, G.A. (1952), *Report on Survey of the Katherine Darwin Region, Northern Territory, 1946* (C.S.I.R.O. Land Research Series No. 1).

——(1964, in press), 'Methodology of integrated surveys', *Proceedings of the U.N.E.S.C.O. Conference on Principles and Methods of Integrating Aerial Survey Studies of Natural Resources for Potential Development.*

Haantjens, H.A. (1961), 'C.S.I.R.O. land surveys in Papua and New Guinea', *Australian Territories*, Vol. 1, pp. 11-17.

——(1963), 'Land capability classification in reconnaissance surveys in Papua and New Guinea', *Journal of the Australian Institute of Agricultural Science*, Vol. 29, pp. 104-107.

Mabbutt, J.A., and Stewart, G.A. (1963), 'The application of geomorphology in resources surveys in Australia and New Guinea', *Revue de Geomorphologie Dynamique*, Vol. 14, pp. 97-109.

Soil Survey Staff (1951), *Soil Survey Manual* (U.S. Department of Agriculture, Handbook 18).

Thomson, W.A. (1961), 'The adjustment of aerial triangulation (planimetry), Part 2. A modified procedure of the use of the Jeric Block Adjustment Method with slotted template layouts', *Cartography*, Vol. 4, pp. 55-59.

Vink, A.P.A. (1963), *Planning of Soil Surveys in Land Development* (Publication 10, International Institute for Land Reclamation and Improvement).