COOPERATIVE RESEARCH PROGRAMME NO. 27
TROPICAL ENVIRONMENTAL DATA (TREND)
ECOSYSTEM STUDY OF TROPICAL DRY-EVERGREEN FOREST

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EARTH SCIENCES LABORATORY, U.S. ARMY NATICK LABORATORIES (NLABS)

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APPLIED SCIENTIFIC RESEARCH CORPORATION OF THAILAND

in collaboration with
DEPARTMENT OF METEOROLOGY, OFFICE OF THE PRIME MINISTER
ROYAL FOREST DEPARTMENT, MINISTRY OF AGRICULTURE
DEPARTMENT OF RICE, MINISTRY OF AGRICULTURE
DEPARTMENT OF LAND DEVELOPMENT, MINISTRY OF NATIONAL DEVELOPMENT
KASETSART UNIVERSITY
MALITARY RESEARCH AND DEVELOPMENT CENTER, MINISTRY OF DEFENCE
SEATO MEDICAL RESEARCH LABORATORY

RESEARCH PROJECT NO. 27/1
DESCRIPTION OF TROPICAL DRY-EVERGREEN FOREST ECOSYSTEM

REPORT NO. 1
DETAILED SOIL SURVEY OF THE NORTH-EASTERN PORTION OF ASRCT SAKAERAT EXPERIMENT STATION (AMPHOE PAK THONG CHAI, CHANGWAT NAKHON RATCHASIMA)

BY
F. BOS
VICHIT THUNDUAN

ASRCT, BANGKOK 1968
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F O R E W O R D

This report has been prepared by survey teams from the Soil Survey Division, Department of Land Development, Ministry of National Development as a contribution to ASRCT Cooperative Research Programme No. 27: Tropical environmental data (TREND). Technical supervision and co-ordination of the survey was provided by Dr. F.R. Moorman, FAO, and Mr. Santhad Rojanasoonthon, Kasetsart University. Two teams undertook the field work, one led by Mr. Vichit Thunduan, DLD, and the other by Mr. F. Bos, FAO.

The research is being conducted pursuent to ARPA Order 917 under the management of the Earth Sciences Laboratory, U.S. Army Natick Laboratories (NLABS), Natick, Massachusetts, U.S.A. Dr. Lester W. Trueblood is Director of the Earth Sciences Laboratory. Dr. Paul Dalrymple serves as Project Supervisor, Mr. Frank Barnett as Project Manager, and Mr. George Immisch as Deputy Project Manager.

The research programme is being carried out by the Applied Scientific Research Corporation of Thailand through its Environmental and Ecological Research Institute in collaboration with other agencies of the Thai Government: the Department of Meteorology (Office of the Prime Minister); the Royal Forest Department and the Department of Rice (Ministry of Agriculture); the Department of Land Development (Ministry of National Development); the Kasetsart University; and the Military Research and Development Center (Ministry of Defence); and with the SEATO Medical Research Laboratory.

DETAILED SOIL SURVEY OF THE NORTH-EASTERN PORTION OF ASRCT SAKAERAT EXPERIMENT STATION (AMPHOE PAK THONG CHAI, CHANGWAT NAKHON RATCHASIMA)

By F. Bos* and Vichit Thunduan+

I. INTRODUCTION

A detailed survey of the soils of an area of about 15 km^2 in the north-east portion of the ASRCT Sakaerat Experiment Station was undertaken to provide soils data for an interdisciplinary study of a humid tropical forest environment.

Technical supervision and co-ordination of the survey was provided by Dr. F.R. Moorman, FAO, and Mr. Santhad Rojanasoonthon, Kasetsart University. The field work was undertaken by two teams from the Soil Survey Division, Department of Land Development, Ministry of National Development, each led by one of the authors, and covered the period of 18 April to 14 June 1967. This report and its accompanying maps have been prepared using the services of the Department of Land Development.

<u>Location and maps</u>

The survey area is in the ASRCT Sakaerat Experiment Station, an area of about 80 square kilometres dedicated by the Council of Ministers as a forest reserve for scientific purposes. It is situated at approximately 14°30'N, 101°55'E and lies on Route 304 connecting Nakhon Ratchasima and Chachoengsao, about 60 km south of Nakhon Ratchasima. It appears on the 1:250,000 map ND 47-8 and on the 1:50,000 maps 5354 I and II prepared by the U.S. Army Map Service.

The base documents for the survey are airphotos flown in 1967, with an approximate scale of 1:25,000, enlargements from these photos at approximately 1:12,800, and a topographic map prepared in 1967 by the Royal Thai Survey Department by photogrammetric compilation from these airphotos. Comparison of this topographic map with the above-

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mentioned 1:50,000 maps indicates that its scale is 1:9,200 if the scale of the 1:50,000 maps is correct. Based on this comparison, the enlargements of the airphotos have a scale of 1:11,700. These corrected scales were found to harmonize with observations in the field using surveying instruments. The scale of the accompanying maps is 1:20,000.

The grid points on the topographic maps are in accord with the Universal Transverse Mercator grid, zone 47, and the co-ordinates in this system are marked in the margins of the maps. For the purposes of the present survey, a new grid system was introduced based on the same kilometre grid points. The new grid was based on intervals of 500 m, capital letters A to L being used for east-west grid lines, starting with A at the south corresponding to the Mercator grid co-ordinate 1602.000 and advancing to the north with L corresponding to 1607.500, and numbers 0 to 12 being used for north-south grid lines, starting with 0 at the west corresponding to 812.000 and advancing to the east with 12 corresponding to 818.000.

In this way the survey area is divided into squares of 25 hectares and any section can be located by a simple designator; thus, for example, the Kasetsart University Forestry Station is situated in square F 10.

Working methods

A preliminary airphoto interpretation was made to outline the major topographical land forms and to roughly delineate the major vegetation (i.e. open dipterocarp forest, dry-evergreen forest, and secondary vegetation of clearings), in the expectation that differences in vegetation might indicate differences in soils.

In the field, a first reconnaissance survey was made during which various soils were studied in borings and profile pits and during which a first working legend was established. Relationships between soils, topography, parent material, and vegetation were observed.

Thereafter, a systematic survey of the area was undertaken. Borings were carried out to a depth of approximately 100 cm. The major characteristics of most of the soils studied were noted, e.g. slope, stoniness, depth, horizons, texture, colour, pH, presence of concretions, mottling, etc. The borings were made in well determined locations along the trails, as well as along a number of compass traverses cut through the forest and the secondary vegetation of the clearings.

Based on the data obtained in this survey, the working legend was revised and refined. The last stage of the field work has been to delineate the units so defined, and to carry out intermediate borings where necessary.

Five profiles in representative sites were described and sampled in detail; four profile descriptions are given at the end of the report. Observations of the parent rock were made in the survey area and in the adjacent area to the south, notably along the alignment of Route 304 which is now under construction.

II. RELATED ENVIRONMENTAL DATA

Physiography

Sakaerat Experiment Station is situated in the south-eastern part of the central highlands near their transition to the north-east (Khorat) plateau. From the cuesta-like highlands south-west of the survey area, at a maximum elevation of 762 metres, a broad, flat, slightly to moderately dissected surface slopes gently north-eastward into an alluviated valley at an elevation of about 250 metres. Map interpretation of the regional topography suggests strongly that the surface may represent the north-eastern limb of a breached anticline.

The survey area occupies the north-easterly part of this surface, with highest elevation (650) in the south-west and lowest elevation (250) in the north-east. The surface can be represented as a series of tilted steps resulting from block-faulting of the limb of the anticline. The steps are found at elevations of about 390, 470, and 530 metres.

Dissection of the surface has resulted in two big valleys and their side valleys. The larger valley to the south and east contains Route 304 and the only perennial stream, the Huai Nam Khem. It has escarpments on both upper sides, the footslopes being less steep and covered with colluvium. East of the Kasetsart University Forestry Station, the escarpment reaches the road (square F 11). Near the point where the entrance road to the Sakaerat Experiment Station leaves Route 304 (east of G 12), the north-eastward dipping rocks are covered by alluvial terrace sediments. The side valleys run almost east and west.

The second valley (from E0 to J9) is roughly parallel to the first in its southern part but later (north of the living quarters area) it enters another shallow valley running east and west. The second valley contains the bed of the Huai Hin Fon Mit, the other major drainage of the area, which flows only in extended periods of rain. This valley is not as deep as the first and has less steep slopes. It has side valleys running in different directions.

Airphoto interpretation indicates the existence of some stream-cut terraces halfway up the escarpment of the first valley, covered with colluvium.

From the geomorphic point of view, it appears that the strong north-eastward-orientated drainages throughout the Sakaerat Experiment Station area and along the entire range of hills flanking it to the north-west and south-east were initially formed as consequent streams downslope from a high divide, coincident with the axis of the above-mentioned hypothetical anticline. Decomposition and erosion of apparently weaker rocks in the core of the anticline resulted in the beheading of these drainages. This is supported by the fact that many of the existing streams are distinctly underfed and many drainageways are abandoned, some of them at the very southernmost edge of the cuesta.

Geology

A recent geological reconnaissance of the Sakaerat Experiment Station* indicates that its entire area appears to be underlain by sandstone of the Phra Wihan formation of the Khorat group to a maximum thickness of 1,025 metres. This has a regional strike NW-SE and

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* Report No. 2 on Research Project 27/1, "Reconnaissance geological survey of the ASRCT Sakaerat Experiment Station, (Amphoe Pak Thong Chai, Changwat Nakhon Ratchasima) by Amorn Methikul and Montri Silpalit. (In preparation).

dips 2^{o}-7^{o} north-eastward into the Khorat basin. It lies conformably upon the purplish siltstone, micaceous sandstone, and conglomerate of the Phu Kadung formation of the same group (seen as an outcrop about 5 km south of the Station in a road-cut of Route 304). The Phra Wihan formation was overlain conformably by the Phu Phan formation of the Khorat group but has now been removed in the Station area, although a thickness of 22 metres of this conglomeratic sandstone caps Khao Khabut Hill about 7 km north-north-east of the Station.

In the survey area parallel, almost vertical joints trending north-south are common in stream beds. Small anticlinal folds are exposed in the Huai Hin Fon Mit and its tributary, Huai Hin Poeng. Fractures are relatively uncommon and there is no evidence of major disturbance of the strata. Sandstones of the Phra Wihan formation appear whitish grey when fresh, weathering to gray-brown, yellow-brown, or red with flecks of altered mica and iron stains showing on exposed surfaces. More than 90 per cent of the constituent minerals is angular to subangular quartz, the remaining minerals including hematite, magnetite, leucoxene, muscovite, sericite, zircon, chlorite, and a little feldspar. The texture is clastic and the granular minerals are well sorted. Cementing materials are cherty, siliceous, or ferruginous.

The percentage of deposited impurities and the degree of oxidation of the iron-bearing minerals are the cause of the primary colour differences in the sandstone. Epigenetic solution of these minerals in certain parts of the sandstone results in iron concentration along fissures. Lighter coloured parts in the sandstone indicate places from which minerals have been transported, and red bands and crusts show the areas of enrichment. A two-coloured sample examined under the microscope showed a much lower content of white micas in the light part than in the red part, and the light part was more porous.

The sandstone is thick bedded and fine to coarse grained, with some conglomeratic layers and lenses. The weathered outcrop rocks of the escarpment show cross-bedding and ripple marks. Cross-bedding is of the compound foreset type common in deltas, the upper ends of the foresets being truncated and overlain by new beds of similar nature dipping in the same or in different directions. Some clay balls of less than 5 cm diameter are intercalated. With this kind of sedimentation, colours, and lack of fossils, these sediments are comparable with the "red beds" of Europe and America.

Passing from east to west, interbedding of shales is encountered to an increasing extent. Reddish brown shale fragments are found in borings from the subsoil, mostly mixed with lateritic concretions or pieces of weathered sandstone. Higher clay percentages and yellower colours in the soil indicate the presence of shales and/or siltstones, and these are often found only in small patches. In one area in the west (squares B2, B3 and C2), these features occur on a B slope without boulders (other B slopes in dry evergreen forest usually have a stoniness of 1), and it is concluded that there was a fairly high percentage of shale at this place.

Climate

The survey area has a tropical savannah climate with annual rainfall of about 1,500 mm falling almost wholly in the period April to October.

Vegetation and land use

The natural vegetation of most of the survey area is dense dry evergreen forest, except for the north and north-east sections where an open dry dipterocarp forest occurs. The boundary between these two forest types is sharp and can easily be located on the map by airphoto interpretation (see Map 3). The relationship between these vegetation types and the soils is discussed on pages 14 and 15.

There are many clearings cut for shifting cultivation in the area, especially in the flatter parts. Most of them are covered with secondary vegetation (particularly alang alang, *Imperata cylindrica*, and sugarcane grass *Saccharum spontaneum*). The most important of the dry upland crops that have been grown are castor bean, maize, banana, tobacco, chilli, and jackfruit.

III. SOILS

Morphometric legend (Maps 1 and 2)

The standard survey of soil series and phases, commonly used in the soil surveys of DLD, proved to be inadequate for the detailed survey required in this study. The soil series as used in Thailand are too broad in scale to describe the soil variations, and, furthermore, such series have not yet been fully elaborated for the hilly and mountainous parts of Thailand. A more complex morphological legend was therefore established, which distinguishes the soil variations found in the area, with particular reference to depth of soil, surface stoniness, and slope.

Depth of soil

The depth of the soil was taken as the depth which could be penetrated by an auger. Intervention of bedrock or of an impermeable layer of lateritic concretions or stones often set the depth of penetration, but if none of these obstructions were met, borings were continued to a depth of 100 cm.

It was not possible to map units with exactly the same depth of soils throughout since considerable variations were encountered. Thus, in flat parts with soils generally of the same depth, there were patches with shallow soils and even rock outcrops. Similarly, along the escarpment where there are predominantly rock outcrops and shallow soils, there are patches with deep soils where washed down soil material has accumulated. Accordingly, four classes have been distinguished based on the predominant depths of soil:-

- d: predominantly deep soils (more than 60 cm), sometimes with dense concretions at less than 60 cm.
- m: predominantly medium deep soils (30-60 cm), frequently with dense concretions at less than 60 cm.
- m/s: predominantly medium deep and shallow soils mixed.
- s: predominantly shallow soils (less than 30 cm).

Surface stoniness

Surface stoniness has been divided into four classes, according to the extent to which the surface of the ground is covered by boulders, stones,and rock outcrops:-

0: no or very few boulders and/or rock outcrops.

1: few boulders and/or rock outcrops.

2: many boulders and/or rock outcrops.

3: bouldery and/or rocky land.

An estimate was made of the percentage of the surface of the ground covered by boulders, etc., in these classes by measuring some representative sites. In this way it was estimated that the classes covered the following limits:-

0: less than 0.02 % boulders, etc.

1: 0.02 to 0.2 % boulders, etc.

2: 0.2 to 10 % boulders, etc.

3: more than 10 % boulders, etc.

Again considerable variation occurs within each area and mapping units have been designated on the basis of the predominant class in the area.

Slope

Since very little flat land (slope less than 2 %) occurs in the survey area, this slope class has not been indicated separately. Three classes were distinguished as follows:-

A: slope from 0-10 % (flat to sloping).

B: slope from 10-20 % (moderately steep).

C: slope more than 20 % (steep to very steep).

For most observation sites, slopes were measured. However, the cartographic delineation of the slope class areas is based on the topographic map, where the distance between the 10-metre contour intervals was systematically measured and interpreted in terms of the above-mentioned slope classes (measured on 1:10,000 scale map):-

Distance more than 1 cm	=	A-slope
Distance from 0.5-1 cm	=	B-slope
Distance less than 0.5 cm	=	C-slope

Simplification had to be applied because not all minor incidents of slopes can be indicated on the map.

Interrelation of mapping elements

In the survey area, these elements are interrelated, and not all possible combinations occur. Soils of the d-class are situated on flatter land (A- or B-slope) and have 0 stoniness; m-soils occur on all slopes, but their stoniness does not exceed 1; m/s-soils also occur on all slopes, but their stoniness is either 1 or 2; and s-soils on C-slopes all have stoniness 3. (It is noted that s-soils on slopes A and B occur only in areas with open dipterocarp forest - see Map 3.) These limitations reduce the possible 48 combinations to an occurrence of only 20.

Colluvial foot slopes

Where a complex of various morphometric soil units occurs on colluvial foot slopes, this is marked CC. This unit has been added because of the occurrence of many different morphometric units within short distances at these locations.

Other elements

Special characteristics, of incidental importance and applicable to some soils only, are:-

M: mottled and grey colour throughout; poorly drained soils.

m: weak mottles in the subsoil; moderately well to imperfectly drained soils.

y: hue of the soil is 7.5 YR or more yellow.

r: hue of the soil is 5 YR or more red.

C: presence of a layer with abundant concretions at less than 60 cm, with a minimal layer thickness of 10 cm.

These elements imply some characteristics occur. (Element M has been also included in the detailed map (Map 1).

All special characteristics of the morphometric symbol are written below the bar. Thus d0A/ym is a deep soil with little surface stoniness, on flat to gentle slope, with a yellow, somewhat mottled subsoil (i.e. moderately well drained Red-Yellow Podzolic soil on materials derived from shales).

Great soil groups and soil series (Map 3)

The majority of the soils belongs to the Red-Yellow Podzolic great soil group (tropustults,according to the 1967 revision of the 7th Approximation). The situation can be summarized as follows:-

Red-Yellow Podzolic soils (tropustults). This is the dominant great soil group of the area, occurring in all topographic positions on materials derived from both sandstone and shale. Soil series included are:-

Ky: Khao Yai series, covering the deep soils (dOA and dOB), occurring in the dry-evergreen forest.

Ml: Muak Lek series, covering the deeper soils on shale-derived material (dOA/my), differing from the Ky series in the yellow colour and presence of mottles.

Ty: Tha Yang series, covering all soils with a stoniness of 1 or higher.

Reddish Brown Lateritic soils (rhodustults). Some of the soils may belong to this great soil group, i.e. those on somewhat richer shales. However, their occurrence is incidental, and the soils observed appear to be transitional to the Red-Yellow Podzolic soils. The closest series equivalent would be Trat series (Td).

Low-Humic Gley soils (tropaquults). These soils were found in a few poorly drained depressions. No series equivalent can be given at this time.

Soil series descriptions

Khao Yai series (Ky). These are the deep soils in the morphometric units dOA and dOB, and occur only on shallow slopes in the dry-evergreen forest where the flatness and vegetation prevent erosion of the top soil.

In the forest, the soil is covered by 2-3 cm of leaf litter. The A horizon has a thickness of 20 cm in the lower sites and 10 cm in the higher sites, and is differentiated into a humiferous A_1 (1-4 cm thick) and a paler, leached A_2. The Bt horizon usually contains concretions as the lower levels and may change to a B/C horizon before a depth of 100 cm is reached.

The texture does not vary much throughout the area. In the A horizon the texture varies between fine sandy loam and loam. The B horizon consists of sandy clay loam with sandy clay loam to clay at the deeper levels. Weak and distinct clay skins are found in the B horizon.

The colour varies and depends largely on the quantity of iron in the parent material. Normally, the colour of A_1 is brown (7.5 YR 4/4), but it varies between dark reddish brown (5YR 3/4) and dark yellowish brown (10 YR 4/4). The A_2 has the same hue as A_1, but with a higher value and chroma, the usual colour being strong brown (7.5 YR 5/7). The B horizon has a redder hue than the A horizon, the usual colour being yellowish red (5 YR 4/6-8). Soils with deviating colours are marked on Map 2, and the others conform to the colours described here.

Soil pH is slightly acid in the topsoil to acid in the subsoil; it varies in the horizons between the following limiting values: A_1 5.5 - 6.5, A_2 5.0 - 5.5, B_t 4.5 - 5.0. The only exceptions are recently burnt clearings where the upper few centimetres of the top soil are neutral or even slightly alkaline. Soils of the series are well drained.

"Concretions" may be found at depths of more than 60 cm. This term covers small amounts of sandstone gravel and shale fragments of the same size and colour as well as true concretions. The latter are rounded and red in colour, with an average diameter of 1 cm but sometimes with pieces up to 4 cm diameter, and consist of hard, dark red, concentric lateritic layers, usually with a core of red sandstone (in which case they are called pseudo-lateritic concretions).

An example of a red coloured member of the Ky series, which is possibly a transition to the Trat series (Reddish Brown Lateritic soil), is described in Appendix I.

Khao Yai series, shallow phase (Ky-sh). Mediumly deep soils m0A and m0B belong to this series, which differs from the Ky series only in the depth of soil (between 30 and 60 cm) and/or the occurrence of concretions within the first 60 cm. All other properties such as colour, texture, etc. are the same as those of the Ky series.

Muak Lek series (Ml). This series covers the soils of the morphometric group d0A/my. They consist of colluvium and residuum derived from shales and sandstone, and occur only occasionally. The major differences from the Ky series are the yellow colour and the presence of mottles.

The genetic soils horizons are about the same thickness as in the Ky soils of the lower sites, i.e. with an A horizon of about 20 cm. The texture is somewhat more clayey than that of Ky soils and distinct clay coatings occur in the B horizon. Weak mottles usually occur in the subsoil as a result of imperfect drainage.

The colour of the A_1 horizon varies between very dark greyish brown (10 YR 3/2) and dark yellowish brown (10 YR 4/4). The A_2 has higher values and chromas and is yellowish brown (10 YR 5/4-7). The B horizon has the same or a redder colour and varies between yellowish brown (10 YR 5/4-8) and strong brown (7.5 YR 5/6-8). Soil pH is slightly acid in the topsoil and acid in the subsoil. Sometimes "concretions" are present in the lower subsoil, most of them being more or less weathered shale fragments.

An example of the Muak Lek series is described in Appendix II.

Muak Lek and Khao Yai association (Ml/Ky). Soils belonging to this association may have the properties of Ky or Ml or both, and include the morphometric groups d0A/my, d0A/y, d0A, d0B/my, d0B/y, and d0B.

They probably arise from weathering of a mixed parent material. Shales are intercalated in the sandstone as layers and lenses, and weathering can produce patches with Ky properties, with Ml properties, and, where a thin shale layer existed, with a combination of both. Furthermore, heavy rainfall causes transportation of material from the topsoil and this may result in the deposition of topsoil derived from shale on a subsoil with many pseudo-lateritic concretions and pieces of sandstone.

A particular characteristic of the Ml/Ky association in the west (squares B2, B3 and C2) is the unusual absence of sandstone boulders on a B slope in dry evergreen forest, which elsewhere has a stoniness of 1. This appears to be associated with a fairly high percentage of shales in this region.

Tha Yang series (Ty). This series includes all soils of stoniness of 1 and higher. It has been divided into two phases to separate the soils of the escarpment from the others. It differs from the Ky series in the shallowness of the soil, the content of boulders and stones at the surface and in the soil, and the occurrence of "concretions" at shallow depths.

The genetic soil horizons of the topsoil have about the same thickness as those of the Ky series. The subsoil changes to a B/C horizon before a depth of 100 cm is reached in the dry-evergreen forest and to a C horizon in the dry dipterocarp forest.

Textures are loamy in the surface layer (sandy loam or loam) and clayey in the subsoil (sandy clay loam, clay loam, sandy clay, or clay).

The colours correspond with the colours of the Ky series, although soils with a yellower hue than the average seldom occur. The colours in the profiles of Appendices III and IV represent the average colours for the Ty series.

Soil pH is slightly acid near the surface and becomes acid in the subsoil.

Soils of the Ty series are well drained. Pseudo-lateritic concretions and sandstone gravel start at different depths, but usually before 20 cm, and increase in size and number with depth. Sandstone boulders are found in the surface and throughout the profile.

Morphological difference between Ty in the dry-evergreen forest and the dry dipterocarp forest are not very obvious. In the dipterocarp forest, soils are generally shallower and more stony, although equally shallow and stony soils exist in the dry evergreen forest. The major difference is in surface stoniness. In the dipterocarp forest, most of the stones are more or less on the surface of the soil, whereas in the dry evergreen forest, stones and rocks are mostly embedded in the soil mass. It is probable that continuous sheet erosion is in progress in the dipterocarp forest with its incomplete ground cover, forming an uncovered "stone pavement", and the shallowness of the soil in the dipterocarp forest may thus be self-perpetuating. The impression is formed also that the surface soil of the dipterocarp forest is somewhat sandier and has a poorer humus type than the surface soil of the dry-evergreen forest. Further study of this is indicated.

The basic ecological reasons for the existence of the two very distinct forest types are not yet clear. Our present thinking is that the soil materials in the area of the dry-evergreen forest, which is found generally on the higher levels of the terrain, are mostly mixed with materials derived from shales, whereas the lower soils under the dipterocarp forest are mostly from more or less pure sandstone. A mineralogical comparison of the soil materials is indicated.

Profile description of Ty soils, one under dipterocarp forest and the other under dry-evergreen forest, are given in Appendices III and IV.

Tha Yang series, sloping phase (Ty-sl). This phase has been introduced to separate the soils of the upper slope of the escarpment, and it includes soils of group s3C. In this region, nearly perpendicular slopes occur at places, with large rock outcrops alternating with steep slopes. The slope is covered with sandstone rock outcrops, boulders, and stones. Predominantly shallow soils occur, although deep soils form in places where soil material can accumulate.

Tha Yang series, colluvial phase (Ty-c). The soils of this phase occur on the lower, less steep slopes of the escarpment and on the stream-cut terraces along the escarpment. This phase has been marked CC (colluvial cpmplex) in the morphometric legend. All soil depths occur in large and small patches, and there are fast changes in stoniness, patches almost without stones and with deep soils changing within a few metres to patches with stoniness 3. The boundary between Ty-sl and Ty-c has been obtained by airphoto interpretation, and lies on the transition between steep and moderately steep slopes.

Low-Humic Gley soils (LHG). These soils are found in a few poorly drained depressions and are formed on colluvium and residuum of sandstone and shale. They are in group d0A/My of the morphometric legend.

All LHG soils are found in clearings. A remarkable feature of the LHG spot at the centre of square H7 is the absence of sugar-cane, which is amongst the usual secondary vegetation of clearings after shifting cultivation. Here the groundwater table is too high to permit the growth of sugar-cane, and the only vegetation subsisting is alang alang.

The genetic soil horizons are: A_1 0-3 cm, A_2g 3-13 cm, B_1tg 13-25 cm, B2tg deeper than 25 cm, and eventually B_2tg/c deeper than 60 cm.

Texture in the A horizon is sandy loam. The illuvial B horizon has a higher clay content, and textures vary between sandy clay loam and clay loam. Mottling is present throughout the profile, or immediately below the surface, and occurs most frequently along root channels and fissures.

The dominant soil colours all have a hue of 10 YR, whilst the mottles always have redder hues of 7.5 YR or even 5 YR. The A_1 horizon is dark greyish brown (10 YR 4/2) to dark brown (10 YR 3/3), and the A2 horizon is brown and has a few strong brown (7.5 YR 5/6) mottles. The B horizon is light brownish grey (10 YR 6/2) and has many mottles of the same colour as in the A_2. These colours continue unchanged to depths of more than 100 cm, except near the boundary with surrounding soils where colours of weathering sandstone (e.g. 5 YR 3/4) may occur at depths between 60 and 100 cm.

Soil pH is like the Red-Yellow Podzolic soils, slightly acid in the surface soils and acid in the subsoil.

<u>Soils of the survey area as related to soil conditions in other hilly areas</u>

Soil conditions in the survey area are estimated to be fairly representative of general soil conditions in the hilly parts of southeast Asia, and those of Thailand in particular. The dominant great soil group in the survey area is a Red-Yellow Podzolic soil. This great soil group is also the dominant soil in most hilly terrains of southeast Asia, notably on residuum and colluvium from more or less acid rocks, as there are sandstones, conglomerates, sandy shales, siltstones, complex quartzite-phyllite formations, granites, granitic gneisses, etc. Throughout hilly southeast Asia, the shallow, more or less stony Red-Yellow Podzolic soils dominate strongly, and these shallow soils are amply represented in the survey area. The deeper members occur much less frequently, being confined mainly to peneplained areas, plateaus, and footslopes. In this respect, the survey area is quite representative for the central highlands of Thailand, where such plateaus with deeper soils occur quite extensively. In neighbouring countries, e.g. South Vietnam, such plateau areas with deeper soils are a common, though minor, feature. On the General Soil Map of South Vietnam, the deeper plateau soils are found, among others, in the area of Dalat town (map unit 12).

Further soil studies

It is recommended that further detailed soil studies be made to supplement the observations made in this survey. These should include profile studies in trenches adjacent to the main tower sites with a view to examining micro-spatial variations in the soils at these sites.

A study of the variations in the A_0-A_1 horizons are of particular interest in connection with relationships between forest vegetation and soils. Further spot studies and sampling are needed and it is suggested that laboratory studies be made on the nature of the organic matter (humus) in the A horizons in the dry-evergreen forest, dry dipterocarp forest, and clearings. Mineralogical comparison of soil materials from dry-evergreen forest and dry dipterocarp forest would be valuable.

Further semi-detailed survey of the areas adjacent to the present survey area is recommended. It would be interesting if this could include some of the areas of the various alluvial terraces between the Sakaerat Experiment Station and Pak Thong Chai.

IV. ACKNOWLEDGEMENT

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APPENDIX I

DESCRIPTION OF PROFILE T4
(Map 2, square D4)

Series: *Ky*

Morphonetric symbol: dOA/r

Vegetation: dry-evergreen forest.

Parent material: residuum and colluvium from iron-rich red sandstone.

Drainage: well drained.

Topography: gently undulating plateau.

O_1	2 to 0 cm, leaf litter.
A_1	0 to 2 cm, dark reddish brown (5YR 3/4) fine loam; fine moderate crumb; very friable; many fine interstitial pores; many fine roots; clear, smooth boundary; pH 5.5.
A_2	2 to 9 cm, reddish brown (5 YR 4/5) fine loam; weak fine subangular blocky; very friable; common fine and very fine tubular and very fine interstitial pores; common medium and thick roots; clear, smooth boundary; pH 5.
B_1	9 to 20 cm, red (2.5 YR 4/6) clay loam; moderate to weak fine subangular blocky; friable; weak and patchy clay skins; common fine and very fine tubular and common fine interstitial pores; common medium and thick roots; diffuse, smooth boundary; pH 4.5.
$B_{21}t$	20 to 80 cm, red (2.5 YR 4/6) light clay; moderate fine subangular blocky; friable; distinct and patchy clay skins; common fine and very fine tubular and common very fine interstitial pores; common medium and thick roots; gradual, smooth boundary; pH 4.5.
$B_{22}t$	+ 80 cm same as $B_{21}t$, but with concretions of 1 cm and less, increasing in size and number with depth.

APPENDIX II

DESCRIPTION OF PROFILE T5
(Map 2, square G7)

Series: M1

Morphometric symbol: d0A/my

Vegetation: secondary vegetation after shifting cultivation, alang alang, sugar-cane.

Parent material: residuum and colluvium from shale and sandstone.

Drainage: imperfectly drained.

Topography: gently rolling on the side of a long slope.

A_1 0 to 4 cm, very dark greyish brown (10 YR 3/2) to brown (10 YR 4/3) fine loam; very weak medium and fine crumb; friable; many fine interstitial pores; organic matter poorly incorporated; common fine roots; clear, smooth boundary; pH 6.0.

A_2 4 to 17 cm, yellowish brown (10 YR 5/4) silt loam; common fine distinct mottling; moderate to weak fine subangular blocky; friable; common fine tubular pores; common fine roots; clear, smooth boundary; pH 5.5.

$B_{21}t$ 17 to 38 cm, strong brown (7.5 YR 5/5) clay loam; common fine faint mottling; moderate to strong fine and medium subangular blocky; slightly firm; distinct clay coatings, movement in pores; many fine tubular pores; few fine roots; gradual, smooth boundary; pH 5.0.

$B_{22}t$ 38 to 62 cm, strong brown (7.5 YR 5/5) clay loam to clay; common, medium faint mottling; moderate to strong fine and medium subangular blocky; slightly sticky, plastic, distinct clay coatings; common fine tubular and interstitial pores; few fine roots; clear, smooth boundary; pH 4.5.

B_3 + 62 cm, multicoloured brownish yellow (10 YR 6/5) and yellowish red (5 YR 5/6) mottled clay; many fine and medium distinct mottles; moderate strong fine and medium subangular blocky; slightly sticky, plastic; distinct clay coatings; many gravels, mostly shale, diameter smaller than 2 cm; few fine roots; pH 4.5.

APPENDIX III

DESCRIPTION OF PROFILE T1
(Map 2, square I8)

Series: Ty

Morphometric symbol: mlA/c

Vegetation: open dipterocarp forest with sparse grass floor.

Parent material: derived from sandstone, rounded gravels in lower profile, sandstone boulders throughout profile.

Drainage: well drained.

Topography: locally undulating in a rolling landscape, saddle between two knolls.

A_1 0 to 3 cm, dark brown (7.5 YR 3/2) loamy sand to sandy loam; weak fine to medium crumb; very friable; many fine interstitial pores; some fine and medium tubular pores; many roots; clear, smooth boundary; pH 5.5.

A_2 3 to 8/11 cm, dark brown to brown (7.5 YR 4/3) sandy loam; very weak fine subangular blocky; very friable; many fine tubular pores; many roots; clear, wavy boundary.

B_1 8/11 to 24 cm, reddish brown to yellowish red (5 YR 4/5) gravelly sandy clay loam; moderate fine subangular blocky; friable, patchy clay coatings; common fine tubular pores; $\pm$ rounded gravels, hard outside, sandstone inside, 3-15 mm diameter; common roots; gradual, smooth boundary; pH 4.5.

B_2t 24 to 40/48 cm, yellowish red (5 YR 4/7), very gravelly (sandy) clay loam; moderate fine subangular blocky; friable to form soil matrix; distinct clay coatings; common fine tubular pores; same gravels as in B_1, but more ($>$ 60%); common roots; broken boundary; pH 4.5.

B & C + 40/48 cm, reddish yellow (7.5 YR 6/7) weathered sandstone, with yellowish red (5 YR 4/7) Bt material in between.

APPENDIX IV

DESCRIPTION OF PROFILE T2

(Map 2, square H7)

Morphometric symbol: mlB/c

Vegetation: dry-evergreen forest, with a distinct forest litter on the surface.

Parent material: residuum and colluvium from sandstone, surface stoniness 1.

Drainage: well drained, after rains moist to about 60 cm.

Topography: rolling, on side of hill, long slope.

A_1 0 to 6 cm, reddish brown to brown (5-7.5 YR 4/3) gravelly, fine sandy loam; strong fine crumb; very friable; many fine and medium interstitial pores; many roots; gradual, smooth boundary; pH 5.5 to 6.

A_2 6 to 20 cm, reddish brown to yellowish red (5 YR 4/5) gravelly fine sandy loam; moderate fine crumb; fine subangular blocky; friable; many fine and medium interstitial and tubular pores; many holes (low bulk density); lateritic gravels, ± rounded, 5-10 mm diameter; also stones and boulders; common roots; gradual, wavy boundary; pH 4.5.

B_2tcn 40/45 to 75, yellowish red (5 YR 4/6) very gravelly clay loam; structure as before; gravels, stones and boulders as B_1; ± 60 % gravels; clear, broken boundary.

C & B_2tcn + 75 cm, very gravelly clay loam with many weathering sandstone stones and boulders.