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PROCEEDINGS OF

THE FOURTH INTERNATIONAL FORUM ON SOIL TAXONOMY AND AGROTECHNOLOGY TRANSFER

BANGKOK, THAILAND

THE DEPARTMENT OF LAND DEVELOPMENT THAILAND
THE SOIL MANAGEMENT SUPPORT SERVICE U.S.A
THE AGENCY FOR INTERNATIONAL DEVELOPMENT U.S.A.
1983

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7 - 24 February 1983

Bangkok Thailand

THE DEPARTMENT OF LAND DEVELOPMENT THAILAND

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1984

THE FOURTH INTERNATIONAL FORUM ON SOIL TAXONOMY AND AGROTECHNOLOGY TRANSFER

Proceedings of A Forum Held In
BANGKOK THAILAND

CO-SPONSERED BY

THE DEPARTMENT OF LAND DEVELOPMENT, THAILAND
AND
SOIL MANAGEMENT SUPPORT SERVICE, USA

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PREFACE

The Forum on Soil Taxonomy and Agrotechnology Transfer is the fourth in the series of training activities organized by the Soil Management Support Services. The first three were held in Fiji, Morocco and Cameroon. The purpose of the Forum is to train soil scientists in this system of soil classification and enable them to use the system for making and interpreting soil surveys. Although the Forums focus on Soil Taxonomy, each Forum is unique in a sense as each in addition, attempts to address concerns specific for the country or region.

The Fourth Forum in Thailand devoted considerable time to selected crops of the region. We were fortunate to obtain the assistance of some of the leading experts on these crops and their lectures and accompanying discussions were a positive contribution to the Forum.

The program of the Forum is given at the end of the Proceedings. Lectures dealing with Soil Taxonomy have been omitted as they have been published elsewhere and only the guest lectures are included in this Proceedings.

Hari Eswaran
Program Leader, SMSS

PART 1

INTRODUCTORY PAPER

WELCOME ADDRESS

Anunt Komes

Director-General of the Department

of Land Development, Bangkok

Mr. Chairman, Excellencies, Distinguished guests, Distinguished lecturers, Participants, Ladies and Gentlemen.

On behalf of the Organizing Committee I have the great honour of extending a warm welcome to everyone during the inauguration of the Fourth International Forum on Soil Taxonomy and Agrotechnology Transfer.

Almost a decade has passed since soil survey has been carried out under the responsibility of the Land Development Department. A large amount of soil information has been collected and used by at least 73 organizations including both government agencies, private firms and academic institutes. Although a systematic evaluation of the impact of soil surveys on development schemes has not been conducted a certain unspoken feeling of the planners and agriculturists for the need of soil information for their work has been a good indicator of its usefulness. Many new land reclamation projects such as acid sulphate soils, peat soil and saline soils and other retarded areas have been initiated as a result of the soil survey descovery. Up to now we have produced two general soil maps (scale 1 : 1,000,000) of the country. The first one was prepared by Dr.F.R. Moormann and Dr.Santhad Rojanasoonthon with assistance from the Soil Survey Division. The second one was revised by the staff of the Soil Survey Division using the Soil Taxonomy for the mapping units. We felt that the Soil Taxonomy was applicable in Thailand, however certain modifications and adjustments had to be made to suit our conditions and the soil surveyors technical background. Beside those two maps we have also published 38 provincial and 285 ad hoc soil survey reports.

We are certainly proud of our past accomplishments but we also have been looking ahead for furthur improvements of the quality of our products in which a good classification system, accurate delineation of soil boundaries, and precise land evaluation methods are involved. In addition we are concerned about the way of conveying this information to other people of different backgrounds.

The Soil Management Support Service (SMSS) proposed to organized the Fourth International Forum on Soil Taxonomy and Agrotechnology Transfer in Thailand. We immediately excepted the proposal because it parallels our goals.

Distinguished guests and participants, we all realize that the transfer of agricultural research findings and experiences between countries or regions will have a better chance of succeeding if the transfer is made between similar soils. Soils which belong to the same categories of classification set forth in the U.S. Soil Taxonomy will help planners in transfering technology from one region to another. To achieve this goal, a national soil survey based on a comprehensive soil classification system is necessary. I have learned that the "Soil Taxonomy" classification system is admirably suited for the purpose of technology transfer between different regions, because the system is categorically complete and has strictly defined criteria at all classes and category levels.

I wish to express my sincere gratitude to all participants, the distinguished lecturers form Indonesia, Malaysia, the Philippines, the People Republic of Vietnam, the United States of America and from Thailand, who have shown a keen interest in the Forum and have contributed to it greatly. Particularly, I wish to express my sincere thanks to the Soil Management Support Service of the United States Department of Agriculture for being the co-hosts of the Forum.

Distinguished participants, during the course of the Forum, I hope you will have sufficient time to discuss and to exchange ideas and experiences among each other and with the distinguished lecturers

who have a thorough understanding and a greatdeal of experience in soils and soil classification and soil survey interpretation for specific uses.

I am confident that in your deliberations you will bring your vast experience, expertise and ability together to help suggest practical measures for solving various problems pertaining to soil classification and its application in agriculture, particularly in finding ways to increase cooperation amongst various countries in terms of effective technology transfer.

In conclusion, I wish all the participants a pleasant stay in the capital city of Bangkok and the other cities that you will visit during the Forum. I am also confident that the good spirit of cooperation and friendship amongst the participants will always prevail.

Thank you.

OPENING REMARKS

Hari Eswaran

National Coordinator, International Soils Programs, Soil Management Support Service, USDA

Your Excellancy Chuan Leekpai, the Minister of Agriculture of the Kingdom of Thailand, Ambassador Dean, Ambassador of the United States distinguished quests, ladies and gentlemen.

Agricultural development efforts throughout the world, and more specifically in the less developed countries (LDC's) calls for more and accurate information on soils and land use. The urgency for such information is highlighted by the different scenarios that have been developed with respect to feeding the world's population in the next few decades. The recent inflationary trends in world economics, arising partly through price hikes in oil, is probably one of the contributributory forces for less developed country governments to seek self-sufficiency in food and fibre production at a rate faster than in previous decades. As a result many LDC's realize that they cannot wait for local research efforts to provide answers for their pressing needs.

In addition, as all of you know, money particularly for research is becoming tighter and we as scientists are constantly fighting an uphill and many times a losing battle, with our administrators to try to get more money for our research programs. The ASEAN countries are in a sense more fortunate than-some of the African, Asian and Pacific countries, where coupled with a constraint on money there is also insufficient trained personnel to undertake to necessary research for sustaining agricultural productivity in the country.

Clearly we have to look for other mechanisms to maintain the high standards of research and to fulfill our responsibilities to society. Many countries now realize that they cannot wait for local research efforts to provide answers for their pressing needs and

technology transfer is the immediate and urgent requirement.

To solve some of these problems, the U.S. Agency for International Development (AID) has embarked on a program of agro-technology transfer. Agro-technology transfer is the taking of an agricultural innovation from its site of origin to another site where it is likely to succeed. Agrotechnology transfer does not imply that research is no more needed. In fact as a result of agro-technology transfer, research becomes more specific and better conceived. It is a most cost-effective way of research and it ensures that mistakes are minimized and successes are maximised.

The three projects of AID.....the Benchmark Soils Project (BSP), the Soil Management Support Services (SMSS) and the International Benchmark Soils Network for Agro-technology Transfer (IBSNAT), are all committed to this concept and are working towards developing an international network of collaborating countries. For the moment, we are concerned mainly with horizontal transfer which is transfer between countries or experimental stations and not with vertical transfer which is the transfer of information from experimental stations to the farmer and which is essentially a national responsibility.

For scientists of all countries to communicate effectively and for horizontal transfer to work, it is imperative that a common scientific language be used. We believe that Soil Taxonomy, the US. system of soil classification, is ideally adapted for this purpose and apart from its scientific quality, its increased use in many countries of the world has established it as the defacto international classification system.

The present Forum is the fourth in the series organized by SMSS and its collaboraters. We had the first one in Fiji, the second in Morocco and the third in Cameroon. We have planned for the Vth in Papua New Guinea, and the VIth in Costa Rica.

Your Excellancy, Thailand is not new to us and for some reason everybody wants to come to Thailand. In 1978, we had the 2ndInterna-

tional Soil Classification Workshop in Malaysia and Thailand. We are indeed very grateful to the Land Development Department and particularly to its Directer General, Mr. Anunt Komes and the Director of Soil Survey Division, Dr. Samarn Panichapong for being willing to host this Forum. The past meetings which Samarn and his crew have organized have proved to be unqualified successes and we have no doubt that this will be similar.

We are also very fortunate in having a very illustrious and world renowned group of lectures. We have Professor Van Wambeke, Professor of Tropical soils of Cornell University, New York; Prof.Ikawa, Professor of Soil Genesis and Classification of the University of Hawaii, Prof. Beinroth; Professor of Soils at the University of Puerto Rico; Prof. Vo Tong Xuan, Prof. at Cantho University, Vietnam; Mr. Purnell, of FAO : Prof. S. Paramanathan, Professor of Soil Genesis at University Pertanian, Malaysia, and Dr. Mausbach of the USDA Soil Survey Laboratory, and a number of distinguished scientists from the ASEAN countries and particularly from Thailand.

Your Excellency, we are indeed grateful to your hospitality and we can assure you that all the time and money put into this Forum will be beneficial to all.

Thank you.

OPENING REMARKS

H. Ikawa

International Benchmark Sites Network for Agrotechnology Transfer

His Excellency, The Minister of the Ministry of Agriculture and Cooperative; Mr. Director General of the Department of Land Development; Dr. Samarn Panichapong of the Soil Survey Division, Ladies and Gentlemen. I wish to thank the organizing committee for the opportunity to participate in this most important forum on soil classification. This morning, my presentation will be in behalf of Dr. Fred Beinroth of Puerto Rico on the research project called the International Benchmark Sites Network for Agrotechnology Transfer, IBSNAT, for short. Before that, however, the talk will be on the research project called the Benchmark Soils Project (BSP) because this project is related to IBSNAT.

For those of you who are not familiar, the University of Hawaii has a research project called the Benchmark Soils Project (BSP). This project was started in 1974 with funds from the U.S. Agency for International Development (U.S. AID) under the leadership of Dr. Leslie D. Swindale, who is today the Director of the International Crop Research Institute for the Semi-Arid Tropics (ICRISAT). The University of Puerto Rico also had a similar project and when we refer to the BSP, we are usually talking collectively about the projects of both Hawaii and Puerto Rico. The BSP is also a cooperative project with the countries of Cameroon, Indonesia, Philippines, and Brazil through Puerto Rico.

The goal of the BSP is to increase food production in the tropics, and the aim of the project is to test the hypothesis that if soils have similar classification, agrotechnology can be transfered between similar soils; that is, soils that are classified according to the soil family category of Soil Taxonomy. As the project comes to a

close in May, 1983, we do find indeed that agrotechnology transfer can take place between soils that have similar classification. More information will be provided when Dr. Beinroth and I report on the activities and findings of the BSP during the latter part of the forum.

Anyway, as the project comes to a close, the question that was frequently asked was, "Will the BSP continue in some other form ?"

As early as 1978, the preliminary results of the BSP indicated that agrotechnology transfer was likely to take place in similar soils. Meetings in 1978 and 1980, therefore, focused on how agrotechnology transfer should take place, and as a result of the meetings, the project called the International Benchmark Sites Network for Agrotechnology Transfer (IBSNAT) was formulated.

With such an introduction, may I now tell you something about IBSNAT ? First of all, IBS in IBSNAT stands for International Benchmark Sites rather than International Benchmark Soils because the 1980 meeting at the FAO headquarters in Rome decided that it was more than soil that was involved in these kinds of network. The network was to include not only soils but also the knowledge of crops and climate. The idea is that in evaluating soils or lands for specified purposes, for example for crop production, one must match the crop requirements with the soil characteristics as well as the climatic environment.

The goal of IBSNAT is also to increase food production not only in the tropics but also in the subtropics. The goal of IBSNAT is further to maximize successes and to minimize failures in agrotechnology transfer.

There are already a number of international agricultural centers and a large number of national agricultural research stations seeking ways to increase food production. The aim of IBSNAT, therefore, is to develop, through collaboration, a prototype network of these international and national agricultural research stations to facilitate agrotechnology transfer. IBSNAT is again funded by the U.S. AID and it is headed by Dr. Goro Uehara of the University of Hawaii and aided by

Dr. Beinroth of Puerto Rico and Dr. Hari Eswaran of the Soil Management Support Services, SCS, USDA.

These investigator are now contacting the various international and national centers for collaboration and for the development of the agrotechnology transfer network.

The mains objectives of the project are :

1. to develop and validate performance prediction model for important crops of the tropics and subtropics.
2. to design a methodology for determining the minimum data sets required for effective transfers of agrotechnology.
3. to devise a prototype communication system for the transnational technology at a scientific level (horizontal transfer).

Again, the idea is that for successful transfer of technology, one must understand the land use requirements and the soil and land characteristics including the climatic characteristics. In this instance, requirements of crops, such as sorghum and wheat, maize and soybeans, cassava and potatoes, and so on including cotton must be known. Some of these studies are going on at the international and national research centers or stations, and it is from these centers or stations that basic information such as crop perfomance must be derived. Soils of these research sites must also be mapped characterized, and classified, and weather data must be collected and studied. The first activity of the project is, therefore, one of data generation.

As the data are generated, crop growth simulation models must be developed and tested for the major crops of the tropics and subtropics. The second activity of the project is, therefore, one of data management.

There is tremendous amount of information that can be collected in fulfilling these two activities. To facilitate this work,

an ICRISAT-IBSNAT-SMSS Symposium on "Minimum Data Sets for Agrotechnology Transfer" is to be held at ICRISAT in Hyderabad, India, in March, 1983. It will be the first of a series of annual meetings in which collaborating scientists will plan and work together.

In summary, IBSNAT is an outgrowth of the BSP of the Universities of Hawaii and Puerto Rico. Funded by the AID, IBSNAT, together with the SMSS, is a collaborative endeavor. The aim is to consolidated a group of international and national agricultural research centers into a prototype network. The purpose is to develop, validate, and utilize a scientific methodology for the effective transfer of agrotechnology among and within countries of the tropics and subtropics. The goal of IBSNAT is to maximize successes and to minimize failure in the transfer of high-perfomance cultivars and the technology to exploit their genetic potential in the tropics and subtropics.

Thank you.

OPENING ADDRESS

His Excellency Chuan Leekpai

Minister of Agriculture and Cooperatives

Your Excellency Mr. Ambassador, Distinguished Participants, Ladies and Gentlemen,

I deem it a real pleasure and a rare privilege to participate in the Opening Ceremony of the Fourth International Forum on Soil Taxonomy and Agro-technology Transfer this morning. On behalf of the Royal Thai Government and the Ministry of Agriculture and Cooperatives, as well as on my own behalf, allow me to take this first opportunity to extend to all the Distinguished Participants our very best wishes and a warm welcome to Bangkok, the venue for the Forum. In this respect, I consider it a great honour for Thailand to have been selected as host country for another academic conference, this time, concerning soil which is generally accepted by one and all as a most important natural resource for mankind as well as the fundamental of most agricultural development programmes. I sincerely hope, therefore, that the Director-General of the Department of Land Development, together with his officials, will do their utmost to render all facilities to the Forum and its Participants throughout your stay in Thailand.

From the report of the Director-General, it is most gratifying to hear that a great deal has been accomplished by scientists, both local and abroad, in the field of soil taxonomy. And yet, to my understanding, much is still left to be desired. I am very pleased, therefore, that the agenda for this Forum aim at improving the soil survey methods as well as at promoting technology transfer among soil scientists themselves, as well as from scientists to planners, administrators, and finally to extension officers. For the ultimate value of soil information lies in its application by other disciplines for the benefit of the people as a whole. I sincerely hope also that this Forum will provide a traditional atmosphere of lively discussions among

the instructors and participants and that the outcome will offer new directions for more positive results for soil resource inventory, evaluation and agro-technological transfer.

May I also express here, on behalf of the nations taking part in this Forum, our deep appreciation for all the assistance and support form the Soil Management Support Service of the United States Department of Agriculture. Our profound appreciation is also extended to all instructors who have spared their time to be here and to share their vast experiences and expertise with their fellow scientists present at the Forum.

I wish you all every success in your endeavour and have the honour to declare open the Fourth International Forum on Soil Taxonomy and Agro-technology Transfer.

Thank you.

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PART 2

SOILS OF THE ASEAN REGION

PHYSIOGRAPHY, GEOLOGY AND CLIMATE OF THAILAND

Lek Moncharoen

Soil Correlator, Soil Survey Division Department of Land Development, Thailand

INTRODUCTION

The Kingdom of Thailand is located centrally in the Indochinese Peninsular of Southeast Asia, between 5°40' and 20°30' north latitude and 97°70' and 105°45' east longitude. The total area of the country is 518,000 square kilometers (approximately 200,000 square miles). The longest north-south span is about 1,620 km (1,000 miles) and the widest part is 750 km (500 miles) from east to west. It has common frontiers with Laos on the north and east, with Burma on the north and west and with Cambodia on the south and east. Peninsular Thailand is bounded on the south by Malaysia (Figure 1).

The preliminary figures of the official 1979 census indicated a Thailand population of 46,140,000 which signified a relatively high increase of 3.2 percent per year for the last decade. The 1,960 population was only 26,258,000 (Thailand, Central Statistic Office, 1962). The present population density is 89.8 per km^2 (per mi^2). About 70 percent of the population is engaged in certain forms of agriculture, predominantly as rice farmers.

PHYSIOGRAPHY

Moormann and Rojanasoonthon (1966) proposed a broad physiography of Thailand to include six regions namely the Central Plain, the Southeast Coast, the Northeast Plateau, the North and West Continental Highlands and Peninsular Thailand. These regions are shown in Fig. 1.

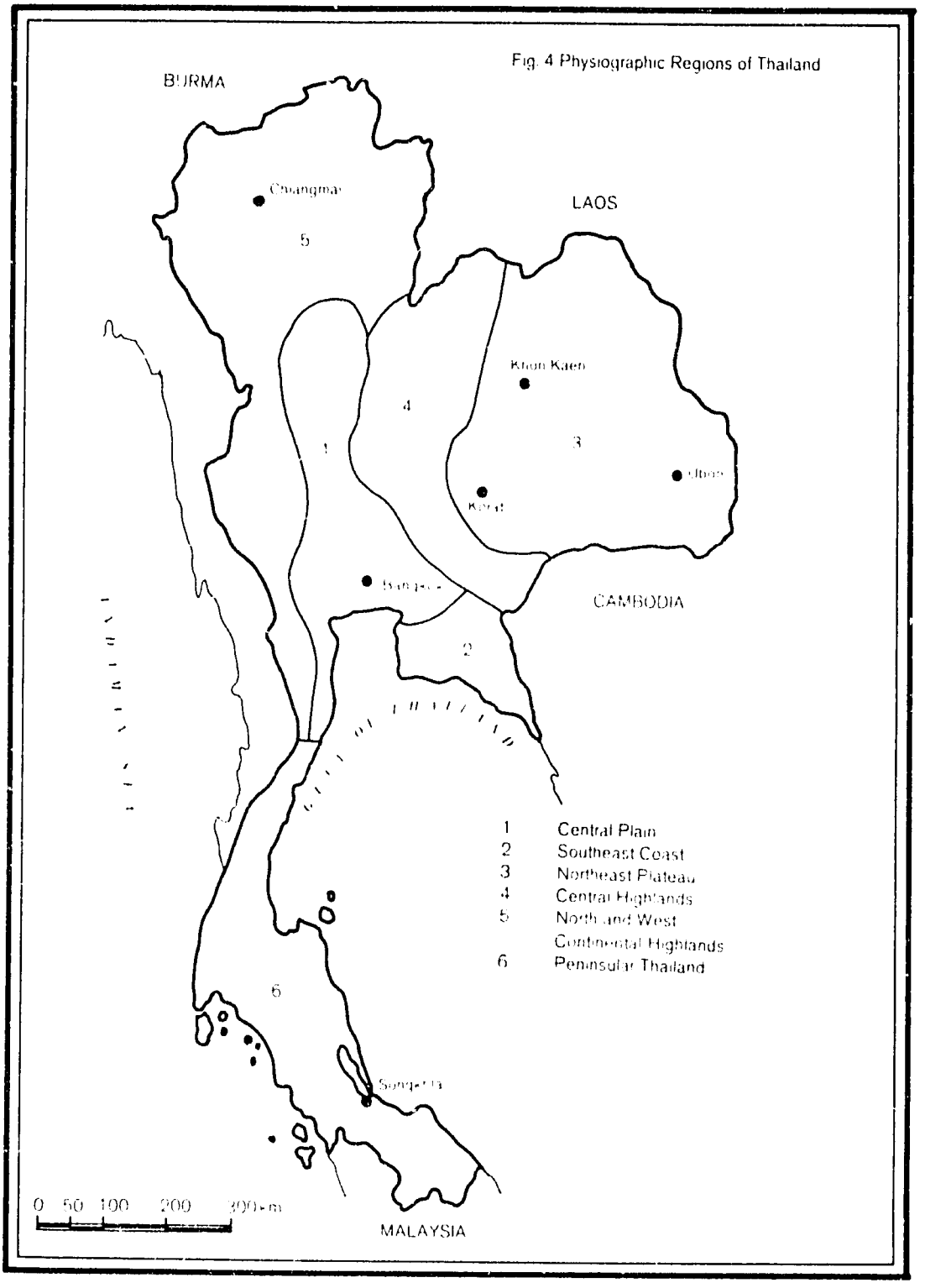


Fig 1 Physiographic Regions of Thailand

(After Moormann and Rojanasoonthon, 1972)

The Central Plain is a large low lying flat terrain, less than 100 m in elevation and extending from the gulf of Thailand approximately 450 km to the north. It occupies approximately 61,478 square km (about 12 % of the country).

The Southeast Coast is bordered on the north by mountains, on the south and west by the gulf of Thailand and on the east, by the Banthad range, which is the site of the Thai Combodian border. The region occupies an area of approximately 22,714 square Kilometres (4.5 % of the country). The eastcentral part of the region includes dissected highlands which are a continuation of the Cardaman mountains of southwest Cambodia. Quaternary sediments surround these highlands mainly in the western and southern part of the region. Shallow alluvial terraces are observed in the north part of the region. The rock types are mostly granite and fine-grained sedimentary rocks.

The northeast Plateau is composed mainly of broad terraces of the Mekong river and its tributaries, the materials of which are derived from sandstone. Three important terrace levels have been recognized by Moormann and they are catchment areas of the Mun and Chi River system.

The Central Highland has a complex physiography, that includes hill, plateaux, peneplains and valleys. This landscape is mainly over basic rocks or transported material of basic origin. Representative rock types are andesite, basalt, limestone and shale.

The West and North Continental Highlands is subdivided into two subregions, i.e. the Northern Hills and Valleys the Western Mountains. The Northern Hills and Valleys is a region of parallel north-south oriented ridges, altenating with elongated intermontane basins which harbour four major rivers namely the Ping, Wang, Yom and Nan rivers. In the Western Hills subregion is mainly of steepland and the dominant rock types are basic.

Peninsular Thailand is composed of a series of north-south parallel mountain ranges. On the west coast the hill ranges extend to

the seashore or beyond, forming strings of islands in the Andaman Sea. The alluvial plains and terraces are small and narrow. On the east coast the zone of terraces and plains is larger.

The most comprehensive attempt at classifying Thailand's landforms (Schotten and Siriphant 1973) can be seen in fig. 2. The following is an abbreviated account of landform types of Thailand according to the nomenclature of these authors.

1. Beach and Dune Formations-they are found along shores of coast-lines. They sometimes grade landward into a terrace landscape. Their relief is undulating with slopes ranging from 2 to 4 %.

2. Active and Former Tidal Flats of Recent Marine and Brackish Water Deposits-they are found extensively in the southern Central Plain along the Gulf of Thailand. They are also found locally on the eastern shore of the peninsular region.

3. Former Tidal Flats of Older Brackish Water Deposits-these areas occupy a large area in the southern part of the Central Plain.

4. Flood Plains of Recent River Alluvium-they can be seen along all major rivers. They are quite flat.

5. Low Alluvial Terraces of Semi-Recent and Old Alluvium-they occur extensively in all parts of the country, usually flat.

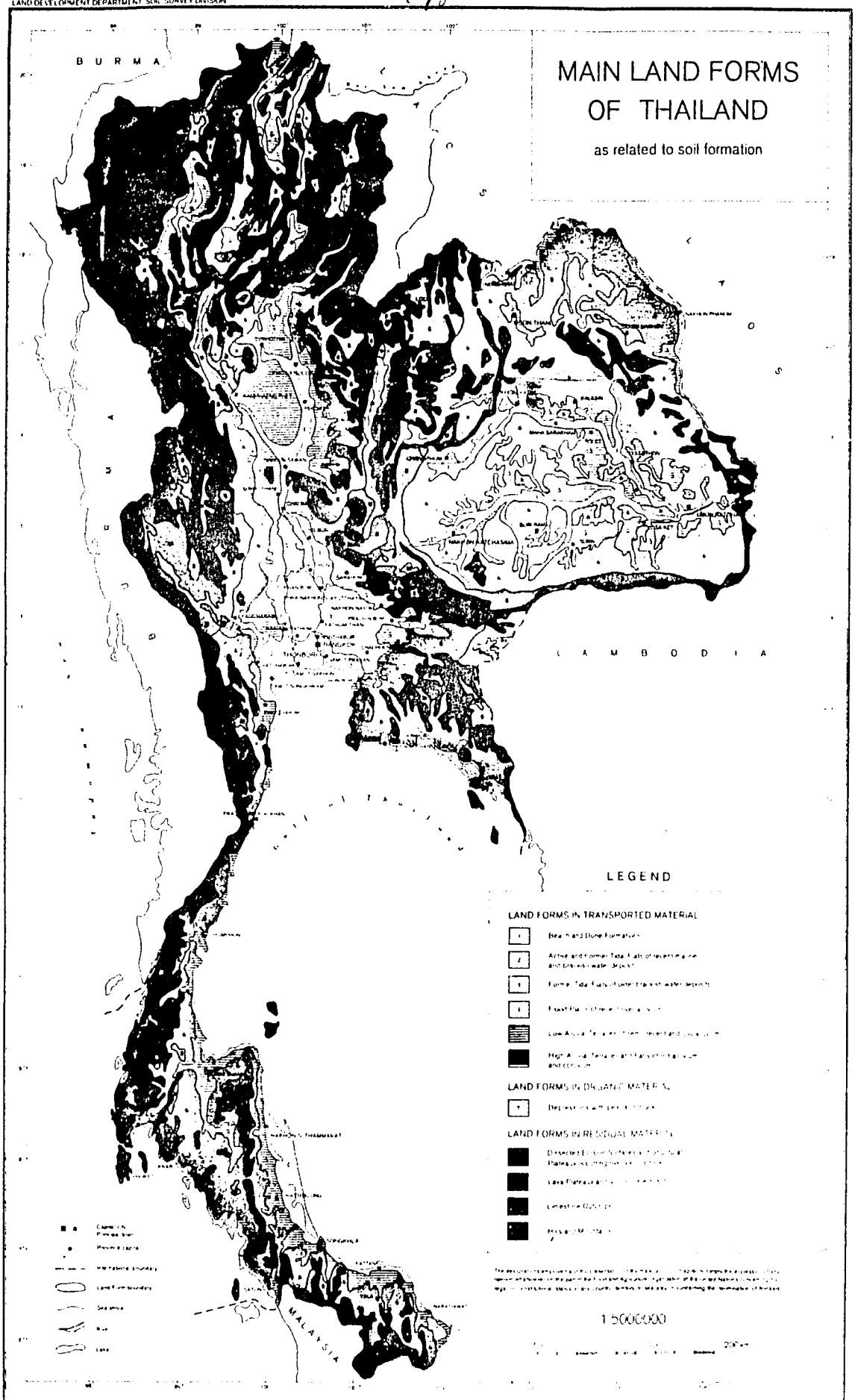
6. High Alluvial Terraces and Fans of old alluvium and colluvium-they are found frequently in positions above low terraces. Generally, the relief is undulating to rolling, with 2-16 % slope. They are especially significant on the Northeast (Khorat) Plateau.

7. Landforms of Organic Matter-there are peat and muck deposits, usually form in depressions, found especially in Peninsular, Thailand.

8. Landforms in Residual Materials-they are found throughout the country, mostly adjacent to hills and mountains, bordering alluvial terrains, and they have been observed to form on nearly

MAIN LAND FORMS OF THAILAND

as related to soil formation



all rock types in Thailand.

9. Lava Plateau and Volcanic Remnants-these landforms are not especially common in Thailand. Slopes may be as great as 16 %.

10. Limestone Outcrops-since limestone weathers exclusively by chemical solution its outcrops produce craggy vertical sided forms of distinctive appearance. They are found everywhere but on the Northeast Plateau.

11. Hills and Mountains-these landforms occur throughout the country with the exception of Northeast Plateau and most of Central Plain. They are formed on many different kinds of rocks and usually have a North-South trend. Slopes generally exceed 20 %.

GEOLOGY

In general, the geology of Thailand is diverse lithologically and stratigraphically. The most widely accepted geologic history is as follows. N.B. most of the points made here are still the subject of some controversy.

Thailand has a Precambrian basement complex, exposed mainly in the west, that is unconformably overlain by sediments & metasediments ranging from Cambrian to Triassic in age. Most of these sediments are thought to be geosynclinal. The depositional high point occured during the Silurian-Devonian when north-south trending paired geosynclines were thought to have developed. During the lower Carboniferous an orogeny deformed to have and metamorphosed older sediments. The Triassic had major granitic and similar igneous rock intrusions. Contemporaneously, or slightly later, major volcanism (possibly an Island Arc system) occured. Continental shelf followed by marine sedimentation lasted until the upper Triassic when it is thought that another orogeny occured. Stable conditions prevailed from the Jurassic to the Tertiary, characterized by continental deposits. Orogenic activity was renewed in the Tertiary with the uplift of the Khorat plateau

accompanied by volcanic activities throughout the area. Sedimentation occured in isolated structural basins, particularly the Central Plain.

Stratigraphy : Although the stratigraphic nomenclature for Thailand has not been firmly established, the following system is probably most widely known. See the map also for particular lithologies. (Fig. 3).

Tarutao (Cambrian)-Coarse shallow-water shelf deposit, mainly sandstone and metamorphosed quarzite. Mainly found in western mountain, Eastern Gulf and Southern peninsular.

Thung Song (Ordovician)-some elastic shallow water shell deposits, but predominantly limestone. Found in some areas as Tarutao, Also metamorphosed.

Tanaosi (Silurian, Devonian, Lower Carboniferous (?))

Made up of lower Kanchanaburi and upper Kaeng Krachan formations Diverse, but principally clastic rock types mainly geogynclinal in origin. Highly folded and metamorphosed to greenschist facies (low grade) in many places. Extensive everywhere but on the Khorat Plateau.

Ratchaburi (Permian)-diverse clastic marine sediments. Know mainly in Western Thailand.

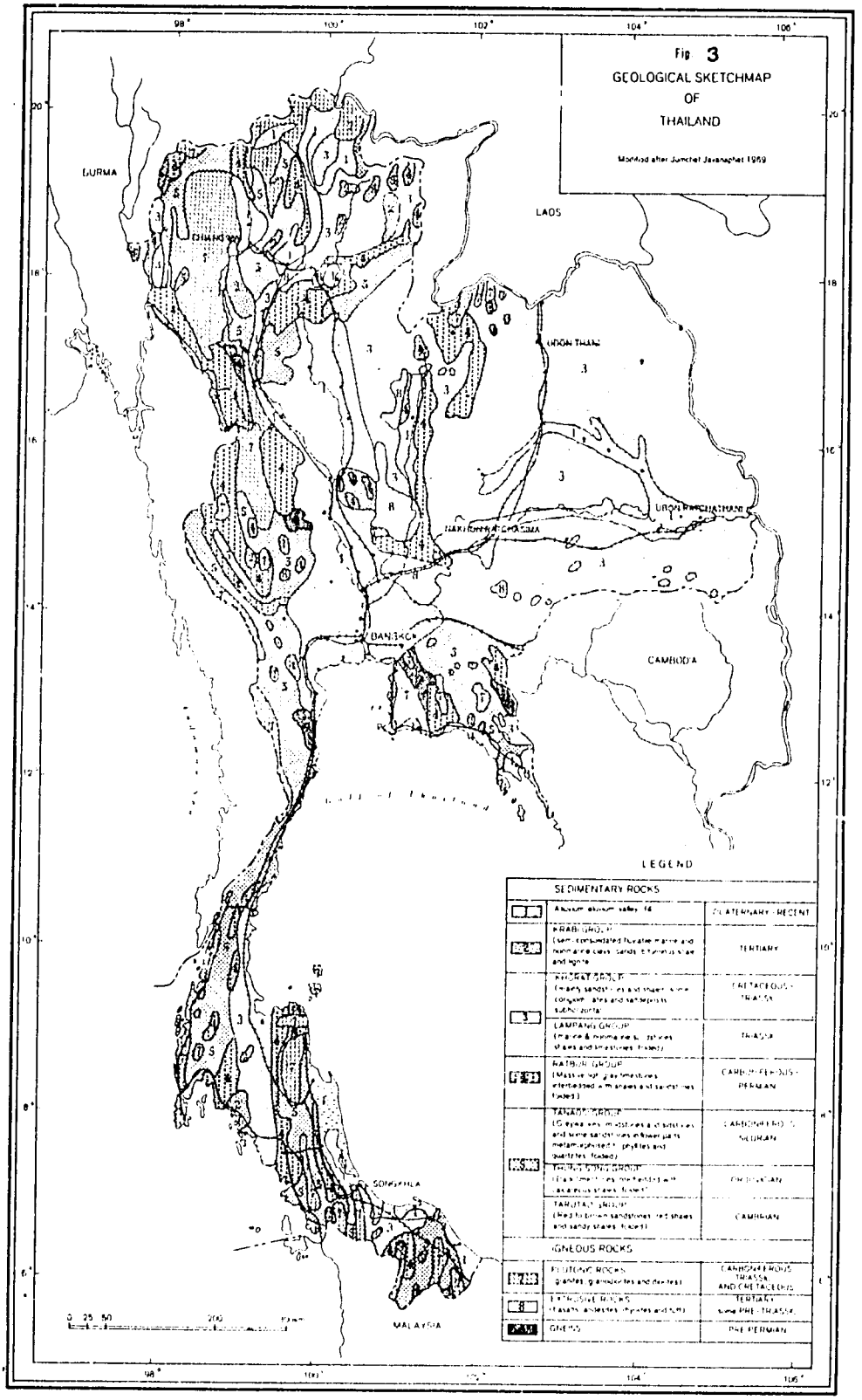
Khorat (Triassic, Cretaceous)-principally clastic sediments (redbeds). Continental especially alluvial in origin. Found on Khorat Plateau.

Krabi (Tertiary)-many clastic rocks, also lignite deposits. Seen in isolated basins throughout Thailand.

Igneous Rocks

Granite is the most common igneous rock in Thailand and has intruded in the Carboniferous, the Triassic-Jurassic, and the Cretaceous-Tertiary. Ultramafic and mafic plutonic rocks are far less common and volcanic rosks occur interbedded with sediments from the

DEPARTMENT OF LAND DEVELOPMENT



SOIL SURVEY DIVISION

geosynclinal sequences. They also occur as flows, plugs and pyroclastic rocks from Carboniferous through Quarternary times. The sapphire and ruby places in Thailand are associated with the basalts of the Chanthaburi and Kanchanaburi areas.

Metamorphic rocks

Precambrian (?) para and orthogneisses are found widely but not extensively throughout Thailand as part of the basement complex. They have been metamorphosed to the amphibolite (medium to high grade) facies and are of diverse rock types including calc-silicate rock, marble, quartzofeldspathic gneisses, quartzites and also interlayered granite and pegmatite. They have undergone many changes and as a result are structurally complex.

Metasedimentary rocks of the greenschist facies (Low grade) are very extensive in Thailand. They occur from the Cambrian to at least the Devonian. They are usually highly folded and include argillites, phyllites, metavolcanics, quartzites and states derived from geosynclinal sediments. Contact metamorphic aureoles occur around many granite plutons particulary those of the Cretaceous-Tertiary. Dynamic metamorphism is also common but not extensive.

CLIMATE

Climatological conditions

Thailand has a climate dominated by the monsoon. The country's generalized climatic data is summarized in table 1. Most of Thailand can be classified as Tropical Savannah (Koppen 'Aw') with the exception of the south-east and Southern Peninsular, where Tropical Monsoon ('Am') predominates, and the Northern Mountain areas where higher altitudes produce a climate classed as Humid Subtropical ('Cw'). Annual temperature ranges are small throughout the country (26° - 28°C) excepting in the north at high altitudes where the range is wider. Isohetal and mean annual temperature map of Thailand are shown in fig. 4.

Table 1. Generalized climatic data for the six physiographic regions of Thailand.

	Central Plain	Southeast Coast	Northeast Plateau	Central Highlands	North and West Continental Highlands	Peninsular Thailand	
						West coast	East coast
Annual rainfall(mm)	1220-1592	1312-4456	1089-2163	1352	1045-1744	2177-5106	1018-2568
Annual mean humidity (%)	64-74	74-78	68-73	70-73	71-75	77-83	78-82
Annual mean temperature (°C)	27-29	27	26.7-27	26-28	24-28	27	27-28
Absolute maximum temperature (°C)	39-44	38	42-43	41-43	40-43	35.5	38-39
Absolute minimum minimum temperature (°C)	5-12	9	2-4	2-7	2-6	19	14-18

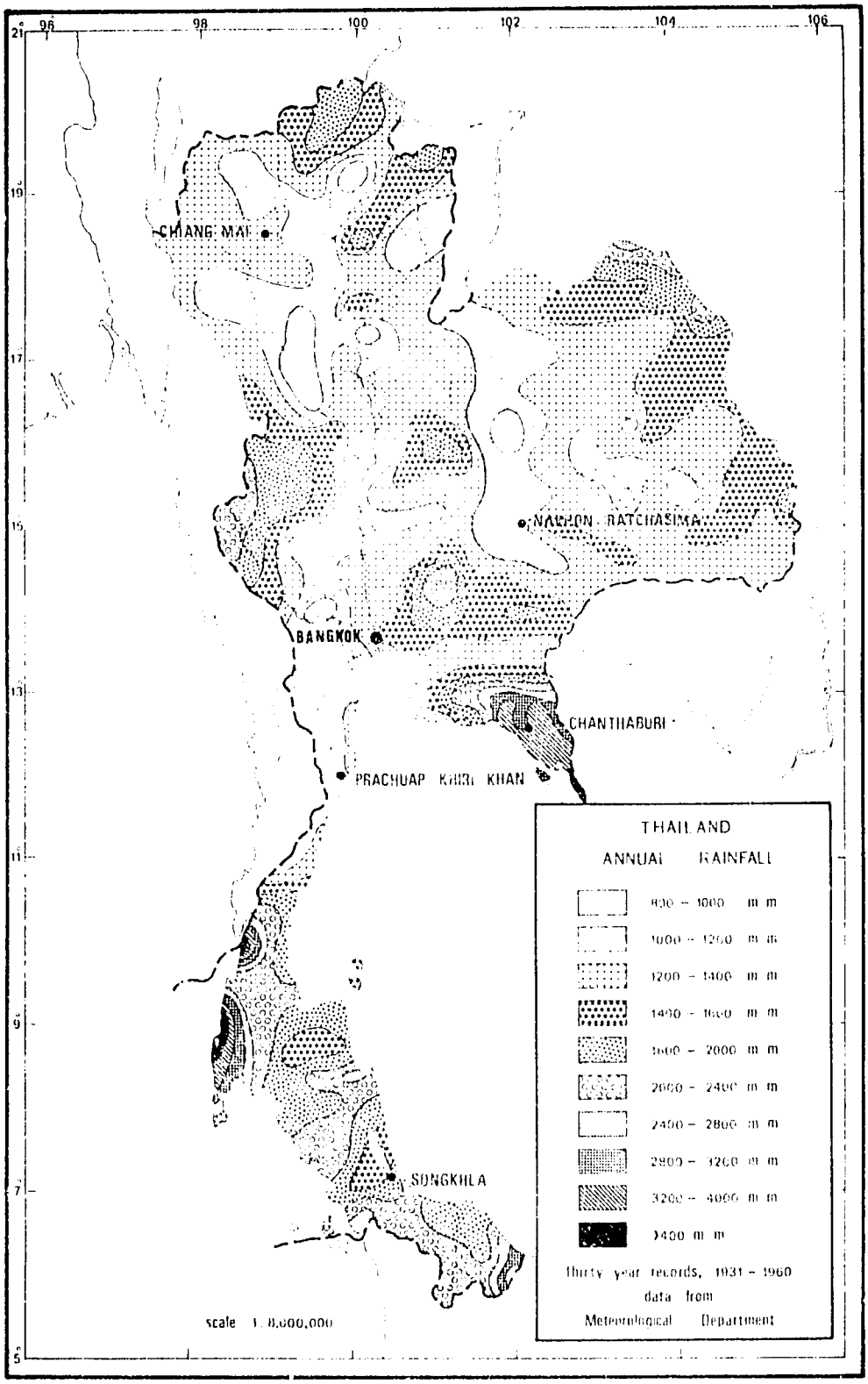


Fig 4 ISOHYETAL MAP OF THAILAND

(After Royal Thai Survey Division, 1969)

Thailand's climate has three main seasons; a rainy season from May to October, a cool, dry one from November to February, and a hot dry period from March to May. The south and south eastern coast, however, do not experience a pronounced dry season. Generally speaking, April is the hottest month and the coolest month is January.

Soil Climate

Soil climate in terms of soil moisture and temperature regimes are very significant criteria for the classification in Soil Taxonomy System. Moncharoen (1980) established the soil moisture regime map of Thailand for use in soil classification and mapping as shown in fig. 5. The method consisted of classifying the daily moisture records from 17 sites of 8 selected areas according to the Soil Taxonomy and identifying the influencing factors for each site. The soil moisture regime map was compiled from the interpretation of influencing factors from climatelogical data, a landuse map, a isohyetal map and a topographic map. Information from field observation for the areas which data was not available was also refered to. From the study, five soil moisture regimes were recognized in Thailand, namely the aquic, ustic, udic, peraquic and perudic moisture regimes. The distribution of each soil moisture regime is shown in the map.

The aquic moisture regime dominantly occur in rice paddies which cover low lying land throughout the country. The peraquic moisture regime occupies the tidal flat and swamp areas dominantly along the gulf of Thailand. The udic moisture regime dominates the Southern Peninsular where the total number if rainy days exceeds 150 days and the total amount of rainfall exceeds 2,000 mm per year. In the North and West Continental High lands where there is hills overgreen vegetation and elevation ranges from 1,000 to 1,600 meters above sea level lies the udic moisture regime. From field observation, in areas above 1,600 metres are expected to be of perudic moisture regime. The rest of the areas are classified under the ustic moisture regime.

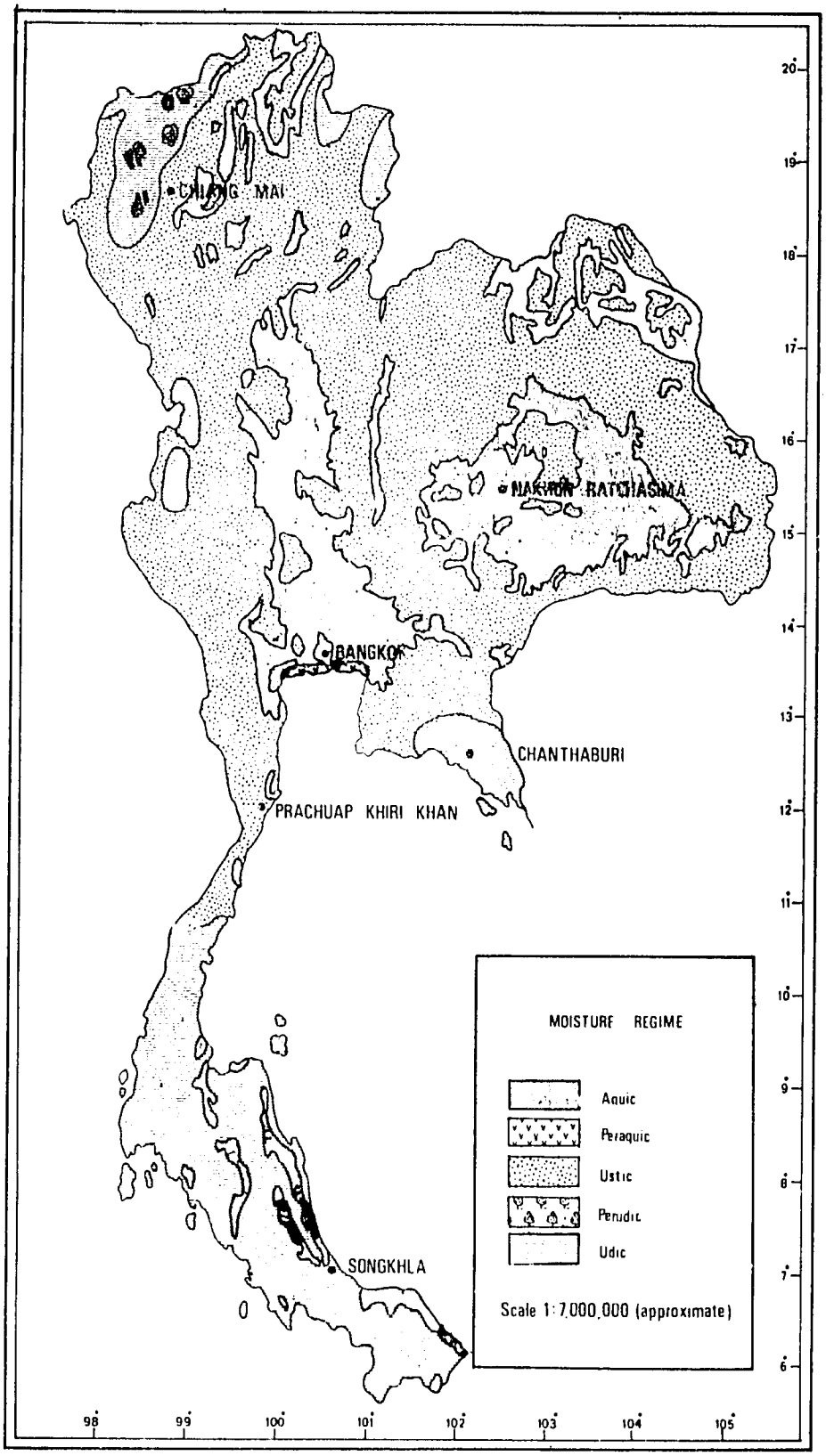


Fig 5 INFERRED SOIL MOISTURE REGIME OF THAILAND

Soil temperature regime

In 1969, O.W. Rice used Moisture-strength data (for a depth of 16.5 inches) to predict the soil temperature regimes in Thailand. It appears that most soils in Thailand fall into the isohyperthermic class and that a significant number of soils with impeded drainage are classified as hyperthermic. A comparison of air and soil temperature differences in the dry season with the rainy season shows that in the rainy season temperature differences were not related to soil drainage conditions. In the dry season, the poorly drained paddy fields clearly had larger positive temperature differences. However, informations about soil moisture regimes should be confirmed since the 16.5 inch depth is short of the control section as defined in the Soil Taxonomy.

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SOILS OF THAILAND

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INTRODUCTION

Thailand lies in the tropical zone of Southeast Asia between approximately 5° and 21° latitude North and approximately 98° and 106° longtitude East. The main part of the country is bordered on the west and north by Burma and on the east by Laos and Cambodia; a southward extension, Peninsular Thailand, stretches to the Malaysian border between Burma and the Andaman Sea on the West and the Gulf of Thailand on the east. The total land area of the country is 513,985 square kilometers, about three-fourths the size of Texas or approximately equal to the size of France.

According to Moormann and Rojanasoonthon, 1972, the country is divided into 6 principal physiographic regions, namely : Central Plains, Southeast Coast, Northeast Plateau, Central Highlands, North and West Continental Highlands, and Peninsular Thailand. This regional division was mainly based on types of landforms soil parent material, (parent rocks) vegetation, and climatic conditions. These factors are more or less directly related to soil characteristics/properties as well as to degree of soil profile development.

Thailand has a monsoonal climate. In most of the country, three major seasons can be recognized : a) the cool season from November through February, b) the hot season from March to May and c) the rainy season from May through October, during the southwest monsoon. On the southeast coast of Peninsular Thailand, the rainy season last through December.

Most of Thailand has an average annual rainfall from 1,100 to 1,500 mm. Major high rainfall zones are Peninsular Thailand and the Southeast Coast which has an average annual rainfall of more than 2,000 mm. and up to 4,000 mm. in some area. The low rainfall zone is found in the rain shadow of the western continental highlands which the average annual rainfall is less than 1,100 mm.

Temperatures in Thailand show slight variantions with the seasons. In the lower elevations, the minimum temperature occurs during the cool season; mean monthly temperatures for January range from 26°C to 28°C for most of the country. For the hot season month of April, the average temperatures are from 28°C to 32°C, and during the rainy season, the values are intermediate. Peninsular Thailand shows even less variation, with the mean monthly temperature remaining between 26°C and 30°C throughout the year. Temperatures in the highlands of the North are lower due to the altitude.

According to O.W Rice, 1969, soil temperature studies indicate that the majority of the soils of Thailand can be expected to fall in the isohyperthermic class; but that a significant number of soils with impeded drainage or perhaps other soils at high elevations would fall in the hyperthermic class.

Soil moisture regimes are an important element for soil classification, particularly at the suborder level. An attempt has been made to estimate soil moisture regimes in Thailand based on the combination of the fallowing factors; physiographic position of soils, groundwater table levels, submerged conditions, soil drainage classes, amount and distribution of rainfall, and vegetative cover. Based on these factors, three classes of soil moisture regimes can be recognized in Thailand : 1) the aquic moisture regime dominantly occurs in low lying areas used for rice cultivation in the country. Soils are saturated by ground water or by impounded water for at least six months of the year and are indicated by wetness characteristics in the profile. The drainage classes would be somewhat poorly drained, poorly drained,

and very poorly drained; 2) the udic moisture regime dominantes in the upland soils of Peninsular Thailand and the Southeast Coast regions where the rainfall is high and well distribution throughout tne year. The udic moitsture regime is also recognized in areas of high altitute in the North Continental Highlands with elevation exceeding 1,000 m above sea level with land areas that are covered by evergreen forest;and 3) the ustic moisture regime which is dominantly found in the upland soils of the Northeast, North, Upper Central Plains and Central Highlands of the country. These soils are used for upland crop production without irrigation water and under natural forest covers.

The seasonal variation in rainfall strongly influences the moisture regime of the soils, with the exception of those which have a continuously high ground water tables or which are irrigated throughout the year. Soils dry out to a considerable depth for period of more than 60 consecutive days, except soils in the low lying areas and in the south and southeast where the soils remain moist at relatively shallow depths throughout the year. Vegetation and agriculture follow this pattern, with no annual crops being grown in the dry season, unless irrigated.

HISTORY OF SOIL SURVEY AND CLASSIFICATION IN THAILAND

In Thailand, soil survey and classification was introduced in 1935 by Dr.R.L. Pendleton, and American Soil Scientist, who came to Thailand as an advisor in agriculture and soil technology to the Department of Agriculture and Fisheries. Dr. Pendleton and his colleague, Dr. Sarot Montrakun were instrumental in promoting interest in the study of soil as a science. Soil courses including soil survey and classification were taught at Kasetsart University as early as 1943 and since 1956 students have been able to major in soils science.

The first general soil map of the country was prepared and published at a scale of 1 : 2,500,000 in 1953 by Dr. Pendleton and his colleagues. The soil units shown on the map were limited, commonly

called "soil series". These soil units were by no means to be considered as "soil series", as defined in the Soil Survey Manual, USDA handbook No. 18. Rather, these units are broad generalizations, usually on the level of the great soil group, or of the association of two or more of such groups. In modern soil classification, such soils would not be named after a type location, but be given the name of relevant great soil group or groups.

In 1967, the general soil map of Thailand was prepared and published at a scale of 1 : 1,000,000 and 1 : 2,500,000 by Dr.F.R. Moormann and S. Rojanasoonthon. The map units were based on the soil classification outlined by R. Dudal and F.R. Moormann, "Major Soils of South-East Asia". The legend by Pendleton and Sarot provided an important body of knowledge on the soils of Thailand when Dr. Moormann and Rojanasoonthon developed the map units for the second general soil map of the country.

Since 1970, the Soil Survey Division of the Department of Land Development has adopted the "Soil Taxonomy of the National Cooperative Soil Survey" developed by the soil survey staff of the U.S Department of Agriculture. All soil series established in the country were placed into soil families using this classification system. Thai Soil Scientists have thought that the "Soil Taxonomy" classification system is admirably suited for the purpose of technology transfer among different regions. Because the system is categorically complete and has strictly defined criteria at all classes and category levels, a revision of the general soil map by Dr. Moormann and Rojanasoonthon was done by the correlation staff of the Soil Survey Division. The revised map was published at a scale 1 : 1,000,000 in 1979. The soil units shown on the map were great groups and associations of the great group of Soil Taxonomy. In order to increase efficiency of applications of the map and report for project development planning, particle size classes defined for soil family differentiation was used to modify the great groups shown on the map. The idea is that the particle size class affects many soil properties, for instance, it affects water

retention, cation exchange capacity, and engineering properties of soils. The description of each great groups existing in Thailand, also shown on the general soil map, 1979, is given below.

SOIL TAXONOMY GREAT GROUPS OCCURING IN THAILAND

A total of thirty nine great groups have been recognized in Thailand to date. In future this number can be expected to increase as more intensive studies are made of the soil population. A summary of the thirty nine great groups are presented below together with the sub-groups.

ORDER ALFISOLS

1. NATRAQUALFS

Gray and mottled Alfisols that have a natric horizon. Ground water is perched above the natric horizon at one period during the year and the soil is saturated during the rainy season. If undisturbed, these soils have a thin A_1 horizon overlying a thin albic horizon which in turn overlies the natric horizon. If ploughed the two upper horizons and the upper part of the natric horizon may be mixed. Only the Typic subgroup has been found to date.

Soils of this great group are mainly used for paddy rice cultivation during the rainy season and no cultivation takes place in the dry season due to the shortage of water and severe salinity problem. They occur in moderate extent in the Northeast and in a small extent in the Western part of Central Plain of the country.

2. TROPAQUALFS

Gray and mottled Alfisols of Tropical regions with less than 50 percent (by volume) of plinthite in all subhorizons to 125 cm and no plinthite that forms a continuous phase within this depth. Subgroups recognized in Thailand are Typic, Abruptic, and Aeric. They are well suited soils for paddy rice production and occur in a moderate

extent in the country.

3. HAPLUSTALFS

Soils of this great group are relatively thin, reddish to brownish Alfisols with an ustic moisture regime. They are mainly developed on relatively recent erosoin surfaces or deposits and have thin and moderately thick argillic horizon. The distribution of clay content in the argillic horizon decreases from the maximum by 20 % or more with in a depth of 1.5 m from the surface, in case of soils with a thick solum. Subgroups recognized in Thailand are Typic, Lithic, Oxic, Udic, and Ultic. They are mainly suited for upland crop production, except for the Lithic subgroup. Such crops are corn, sugar cane, sorghum, cotton and others. Sugar cane and corn in particular grow well on the Udic Haplustalfs and Ultic Haplustalfs. Lack of soil moisture for crop production during the dry season is a main limitation for ultization of these soils in Thailand.

4. PALEUSTALFS

They are thick, reddish or red Alfisols developed on old surfaces with an ustic moisture regime and have an argillic horizon in which the percentage of clay does not decrease from its maximum by as much as 20 percent of that maximum within a depth of 1.5 m from the surface and no plinthite forms a continuous phase or constitutes more than 50 percent of the matric of the argillic horizon within 1.25 m of the surface. The argillic horizon has no lithic or paralithic contact within 1.5 m of the surface. Subgroups existing in Thailand are Arenic, Phodic, and Ultic which are mainly used for upland crop cultivation. They are moderately suited for cassava and kenaf production in Northeast Thailand.

ORDER ENTISOLS

5. FLUVAQUENTS

Wet Entisols, primarily of flood plains and deltas that have

either fine or coarse stratifications that reflect deposition of sediments under changing currents and shifting channels. The sediments are relatively high in organic carbon at depth compared with many other wet mineral soils. Organic carbon content decreases irregularly with depth below 25 cm or remains above 0.2 percent to a depth of 1.25 cm. They have no sulfidic materials within 50 cm of the mineral surface and have textures finer than loamy fine sand in some or all subhorizons below the Ap or 25 cm; whichever is deeper, and above 1 m.

Subgroups recognized in Thailand are Thapto-Histic Tropic and Tropic which are partly used for rice cultivation and the rest are under mangrove forests.

6. HYDRAQUENTS

Wet, primarily clayey Entisols of tidal marshes that are permanently saturated with water. Hydraquents have never been dried and consequently the bulk densities are low and the water content is high. Colors are usually bluish gray to greenish gray, and change to shades of brown if exposed to air. They have no sulfidic materials within 50 cm of the mineral surface and have n-values of more than 0.7 and at least 8 percent clay in all subhorizons between 20 and 50 cm of the mineral surface. Because the water content is high, the soil strength is low, which is commonly too low to support grazing animals. Currently, Hydraquents in Thailand are mainly covered by mangrove forest, and some are used for aquaculture and salt making pans.

No subgroups have been developed.

7. SULFAQUENTS

Wet Entisols that have appreciable amounts of sulfides close to the mineral surface, and few or no carbonates. They are largely restricted to coastal marshes where the waters are brackish, and to the tidal marshes at the mouths of rivers, unless the water sediments are rich in carbonates. Sulfaquents are permanently saturated with water at or near the surface and many are nearly neutral in reaction.

If drained the sulfides oxidize and the soils change rapidly to Sulfaquepts. They have sulfidic materials within 50 cm of the mineral surface and have a very low loading-capacity. The n-value is usually more than 1 in all subhorizons below 30 cm from the surface. Only the Typic subgroup has been recognized in Thailand.

The Sulfaquents commonly are not used for crop cultivation in Thailand. They have potential for aquacultural development. A small percentage have been developed for coconut plantations, but they produce poor yields.

8. TROPAQUENTS

Permanently warm and wet Entisols with mottled gray colors and occurring in low lying areas of intertropical regions. They have n-value of 0.7 or less or have less than 8 % clay in some subhorizon between 20 and 50 cm from the mineral surface. They have an organic carbon content that decreases regularly with depth below 25 cm and reaches levels of 0.2 % or less within a depth of 1.25 m.

The Tropaquents in Thailand are partly used for rice cultivation which produces poor yields. They have potential for aquaculture development like brackish water fish and shrimp cultures.

9. USTIFLUVENTS

Brownish to reddish colored Entisols formed in recent water deposited sediments with an ustic moisture regime. They occur on levees, flood plains and fans of rivers and streams and are normally subject to periodic flooding during the rainy season. They have no mottles with chromas of 2 or less within 50 cm of the surface. The subgroups recognized in Thailand are Typic and Aquic. They are well suited for garden crops and some fruit trees. Some are used for paddy rice production and produce moderate yields.

10. QUARTZIPSAMMENTS

Freely drained Entisols predominantly composed of quartz sands. They may be white or stained with shades of brown, yellow or red and occur on late pleistocene and younger surfaces. In some places a spodic horizon may underlie white sands but occurring so deep that it is not practical to determine its presence, the important property of such soils being that the first 2 m or so have uncoated quartz sand. The sand fraction of Quartzipsamments is more than 95 % quartz, zircon, tourmaline, rutile, or other normally insoluble crystalline minerals that do not weather to liberate iron or aluminium.

The subgroups recognized in Thailand are Typic, Spodic, and Ustoxic, they are used mainly for cassava, sugar cane and coconut cultivation, particularly in areas with an udic moisture regime. Hoever, they produce relatively low yields.

11. USTIPSAMMENTS

Freely drained Entisols that have an ustic moisture regime. They are predominantly sandy soils where the sand fraction is less than 95 % quartz, zircon, tourmaline, rutile or others. There are no distinct or prominent mottles to a depth of 1 m and they are not saturated with water within 1 m of the surface in most years. Only the Typic subgroup is recognized in Thailand and is sometimes used for cassava cultivation., The majority is covered by low open dipterocarp forest. Ustipsamments have low potential for crop cultivation, because they have very low fertility and are sensitive to erosion.

ORDER HISTOSOLS

12. TROPOFIBRISTS

Tropofibrists is the only great group of Histosols recognized in Thailand. They occur in a small extent in Peninsular Thailand and in very small pro-portion in the Southeast coast and are found in coastal swamps and closed to depressions of intertropical areas.

They have very low potential for agricultural development. Under the present conditions, only a small percentage fo these soils are used for crop cultivation, particularly for submerged rice.

ORDER INCEPTISOLS

13. SULFAQUEPTS

Inceptisols developed from brackish water sediments with poor or very poor drainage, and ground water stands close to the surface at some period during the year but not every season; or are artificially drained. Sulfaquepts are acid sulphate soils that have been drained and oxidized at some time. They are extremely acid and toxic to most plants, occurring in drained coastal marshes near the mouths of rivers that carry sediments free or low in carbonates. They are mostly dark gray and have straw yellow (jarosite) mottles, i.e, a sulfic horizon within 50 cm of the surface. They are used for paddy rice cultivation and produce low yields due to extreme acidity and are toxic to rice plants.

14. TROPAQUEPTS

Wet Inceptisols that have little or no plinthite. They are mostly gray at the surface and mottled with depth. The ground water fluctuates, but stands relatively high throughout much of the year, or the soil has been artificially drained. They have less than 15 % saturation with sodium in the upper 50 cm or have saturation that is constant or increases with depth below 50 cm. They have no sulfic horizon with an upper boundary within 50 cm of the surface.

The subgroups recognized in Thailand are Typic, Aeric, Sulfic and Vertic. They occur very extensively in former tidal flats and flood plains of rivers, particularly in the central plain of Thailand. They are mostly suited for paddy rice production and produce rather high yields compared to other paddy soils in the country.

15. HALAQUEPTS

Wet Inceptisols that are sodic and in place saline with shallow ground water and a season with little rain when capillary rise and evapotranspiration brings sodium or salts to or near the surface. They do not have a salic horizon that persists throughout the year but salt efflorescence is common on the surface in dry season. Halaquepts are normally gray and mottled to or near the surface. Sodium saturation is 15 % or more in half or more of the upper 50 cm and decreases with depth below 50 cm. They have no plinthite that forms a continuous phase or constitutes more than half of the matrix within 125 cm of the surface. Only the Aeric subgroup is recognized in Thailand.

Halaquepts are partly used for paddy cultivation, but they produce very poor yields. Most of them are left abandoned. Salt making by evaporation also takes place in areas of Halaquepts in the Northeast.

16. DYSTROPEPTS

Brownish to reddish, more or less freely drained Inceptisols that are acid and are formed from acid rocks or under high rainfall, or both. Base saturation is less than 50 % in some subhorizons between 25 cm and 1 m or between 25 cm and a lithic, paralithic or petro-ferric contact shallower than 1 m.

The subgroups recognized in Thailand are Oxic, Ustic, Ustoxic and Aquic. They are mainly used for upland crop cultivation and rubber tree plantations in areas with an Udic moisture regime.

17. USTROPEPTS

Brownish to reddish, more or less freely drained Inceptisols. They are rich in bases, having a base saturation (by NH_4OAc) that is 50 % or more in all subhorizons between 25 cm and 1 m. They have a CEC (by NH_4OAc) of 24 meq/100g clay or more in all horizons above a lithic contact or 1 m. They have no lithic contact within 50 cm of the surface. A calcic horizon or secondary lime occurs below the

cambic horizon. Only the Typic subgroup is found in Thailand. They are suited for upland crop production. Such crops are corn, sorghum, cotton, soybean, castor bean and others.

18. EUTROPEPTS

More or less freely drained Inceptisols that are rich in bases, having 50 % or more base saturation (by NH_4OAc) throughout all subhorizons between depth of 25 cm and 1 m. They are derived from transported materials from granitic origin. The cambic horizon occurs relatively deep in the profile, usually below 80 cm of the surface.

Eutropepts in Thailand are currently used for cassava and sugar cane production mostly and produce moderate yields, but farmers apply both chemical and organic fertilizers because soils are sandy in the upper 50 cm of the profile.

ORDER MOLLISOLS

19. HAPLAQUOLLS

Naturally wet Mollisols that have dominant low chromas and commonly have a cambic horizon with olive hues and high contrast mottles below a black epipedon that is less than 60 cm thick. They have no calcic horizon with its upper boundary within 50 cm of the surface. The content of organic carbon decreases regularly with depth and reaches a level of 0.3 % or less within 125 cm of the surface. They have no histic epipedon and no lithic contact within 50 cm of the surface. They usually contain many crystals of gypsum in the lower A and upper B horizons.

Haplaquolls in Thailand occur on former tidal flats and are derived from calcareous sediments. They are used for paddy rice production and produce high yield. In places, they are used for garden crops and vegetable growing, but soils have been artificially drained by making elevated beds. They were mapped in the Southern part of The Central Plain region. Only the Vertic subgroup is recognized in Thailand.

20. CALCIUSTOLLS

More or less freely drained Mollisols that have a calcic or petrocalcic horizon and that are often calcareous in all overlying layers. They have no argillic horizon above the calcic or petrocalcic horizon. The calcic horizon has its upper boundary within 1 m of the soil surface and there is no lithic contact within 50 cm of the surface or petrocalcic horizon with its upper boundary within 1 m of the surface. Cracks do not open 1 cm or more wide at depths of 50 cm or more and there are no mottles within 75 cm of the surface due to segregation of iron or manganese.

The only one subgroup recognized in Thailand is Typic. They are usually cultivated for upland crops such as corn, sorghum, cotton, and beans. They are moderately to well suited for these crops and found mainly in the Central Highlands of the country.

21. HAPLUSTOLLS

More or less freely drained Mollisols that have a cambic horizon or only slightly altered parent materials below the mollic epipedon. They are developed from basic igneous rocks (basalt) and have no calcic or gypsic horizon with an upper boundary within 1 m of the surface unless some part of an overlying horizon is free of carbonates.

Subgroups recognized in Thailand are Typic, Lithic, and Vertic. They are moderately suited for upland crops production, such crops are corn, sorghum and soybeans. They are mainly found in the Central Highlands and Northern regions.

ORDER OXISOLS

22. HAPLUSTOX

Red or dark red Oxisols that are dry in all parts of the moisture control section for extended periods, but are moist for at least 90 days in the rainy season. They have no mottles with chromas

of 2 or less accompanied by red or dark red mottles within 125 cm of the surface. They have less than 5 % plinthite by volume in all subhorizons within 125 cm of the surface. They have an oxic horizon with texture of clay that extends to 125 cm or more below the surface. Structure in the oxic horizon is weak and base saturation is less than 50 %. They are derived from igneous rocks (basalt and andesite) and occur in teh southern part of Northeast Thailand.

Haplustox Soils are used for upland crop production, such crops are cassava, corn, pepper and some are cultivated with fruit trees. They are moderately suited for these crops. Lack of soil moisture during the dry season is the main limitation.

23. HAPLORTHOX

Red or dark red Oxisols occur in areas with an udic moisture regime in the Southeast coast of Thailand. They are derived from igneous rock (basalt) and occur on the plateau of the lava flow land form. They are quite similar to Haplustox in general appearance, except for the moisture regime. Only the Typic subgroup has been found to date.

They are mainly used for fruit tree and rubber tree plantations and produce relatively high yields.

ORDER SPODOSOLS

24. TROPAQUODS

Spodosols of wet places with a fluctuating ground water table. They have formed almost exclusively from sands that are virtually devoid of any weatherable minerals. They have no albic horizon with any subhorizon so strongly cemented that a dry fragement will not slake when immersed in water. They have no more than 75 cm of a sandy epipedon (loamy fine sand or coarser) overlying the spodic horizon. The spodic horizon has 0.6 %oor more organic carbon in the matrix of the first 30 cm, or an upper part of the spodic horizon that has 2.3 %

or more organic carbon in the upper 2 cm that is continuous or is present in more than 90 % of each pedon. The spodic horizon has some part that has a ratio of free iron to carbon of less than 0.2.

Only the Entic subgroup is recognized in Thailand. Soils of Tropaquods are found in a small extent in the Northeast, where the average annual rainfall is around 2,000 mm. They are normally not used for cultivation, but a small percentage are cultivated to upland crops such as cassava and kenaf. They produce very poor yield.

25. TROPOHUMODS

More or less freely drained Spodosols that have a large accumulations of organic carbon relative to iron in some or all parts of the spodic horizon which has 0.6 % or more organic carbon in the weighted average of the matrix of the upper 30 cm. There is no more than 75 cm of a sandy epipedon overlying the spodic horizon and there are no characteristics associated with wetness.

Tropohumods in Thailand are found in the Peninsular and Southeast coast regions where the moisture regime is udic. They are poor soils for upland crops, and some are cultivated to coconut.

ORDER ULTISOLS

26. PALEAQUULTS

Ultisols, either saturated with water at some period or artificially drained, that have characteristics associated with wetness. They have thick, mottled, gray argillic horizons or have small amounts of plinthite in the argillic horizon, or both. Weatherable minerals are virtually lacking in the fine sand through coarse silt fractions. The argillic horizon has a clay distribution such that the percentage of clay does not decrease from its maximum by as much as 20 % of that maximum within a depth of 150 cm from the soil surface.

The subgroups recognized in Thailand are Typic and Aeric. They are found very extensively in Thailand and are mostly used for

paddy rice production. Yields vary from place to place dependent on rainfall and irrigation facilities provided. However, they are moderately suited for rice cultivation.

27. TROPAQUULTS

Tropaquults are either saturated with water at some period or artificially drained, they have characteristics associated with wetness. They have a mottled, gray argillic horizon with little or no plinthite and have either or both 10 % or more weatherable minerals in the 20 to 200 micron fraction in teh upper 50 cm; or have an argillic horizon with a clay distribution such that the percentage of clay decreases from its maximum by 20 % or more of that maximum within a depth of 150 cm from the surface and the subhorizon in which the clay percentage decreases has less than 5 % plinthite by volume, and few or no skeletans. Only the Typic subgroup is recognized in Thailand. The occur in a small extent in Peninsular Thailand and they are derived from local alluvium of granitic origin. They are used for submerged rice cultivation and produce moderate yields.

28. PLINTHAQUULTS

Ultisols, either saturated with water at some period or artificially drained, that have characteristics associated with wetness and occurring mostly in intertropical areas. They have plinthite that forms a continuous phase or constitutes more than half of the matrix of some subhorizon within 125 cm of the surface. Subgroups found in Thailand are Typic and Oxic. They are used for submerged rice cultivation and produce relatively low yields.

29. PALEHUMULTS

More or less freely drained, humus rich and reddish Ultisols wtih thick argillic horizons and few weatherable minerals in the 20 to 200 micron fraction. They have 0.9 % or more organic carbon in the upper 15 cm of the argillic horizon and typically have a CEC of more than 24 meq/100 g clay in the major part of the argillic horizon.

They have less than 5 % plinthite by volume in all horizons within 150 cm of the surface and have hues redder than 10 YR in all parts of the upper 75 cm that have moist color values of 4 or more if there are high chroma mottles within this depth and if hues become redder with depth within 1 m of the surface.

Only the Orthoxic subgroup is recognized in Thailand and occurs in the Northern part of the country, particularly in hilly and mountainous areas. They are suited for upland croup cultivation if proper soil conservation measure are installed.

30. PALEUDULTS

More or less freely drained, humus poor Ultisols with thick argillic horizons and small amounts of plinthite at depth, occurring in areas with an udic moisture regime. Weatherable minerals are virtually absent and the clay activity tends to be low and in many cases within the range of Oxisols. The argillic horizon has a clay distribution such that the percentage of clay does not decrease from its maximum by more than 20 % of that maximum within 150 cm of the soil surface, or the layer in which the percentage of clay decreases shows skeletans on ped faces or has 5 % or more plinthite by volume.

The subgroups recognized in Thailand are Typic and Rhodic. They occur extensively in the Peninsular and Southeast Coast regions of the country and are mostly used for rubber tree plantation and fruit trees.

31. TROPUDULTS

More or less freely drained Ultisols that either have an argillic horizon that is only moderately thick or there are appreciable amounts of weatherable minerals in the 20 to 200 micron fraction of the argillic horizon, or both. They have no plinthite that forms a continuous phase or constitutes more than half of the matrix of any subhorizon in the upper 125 cm. of the soil. There is only the Typic subgroup recognized in Thailand.

Tropudults have a moderate potential for agricultural use and currently, they are occasionally used for rubber tree plantations.

32. PLINTHUDULTS

More or less freely drained Udults that have plinthite that forms a continuous phase or constitues more than half the matrix of some subhorizon in the upper 1.25 m of the soil. They occur in Peninsular Thailand and the Southeast Coast and are mainly used for rubber tree plantations which produce low to moderate yields.

33. PLINTHUSTULTS

More or less freely drained Ultisols where plinthite forms a continuous phase or constitutes more than half of the matrix within some subhorizon in the upper 125 cm of the soil.

No subgroups were developed in the Soil Taxonomy; but Typic and Aquic subgroups have been tentatively proposed in Thailand. The aquic subgroup being like to Typic except that ground water occurs at depth at some time of the year and there are low chroma mottles in the horizon that are or were saturated. They are found extensively in Northeast Thailand.

Plinthustults in Thailand have low potential for agricultural use, because they are shallow to a layer of lateritic gravel which impedes root penetration and they dry out deeply during the dry season. The best use of these soils is pasture development that keeps them under natural forest.

34. PALEUSTULTS

Paleusults are more or less freely drained soils that have thick argillic horizons and few weatherable minerals in the 20 to 200 micron fraction. Small or moderate amounts of plinthite may occur at depth but plinthite does not form a continuous phase or constitute more than half of the matrix in any subhorizon within 125 cm of the surface. Clay distribution in the argillic horizon is such that the

percentage of clay does not decrease from its maximum by more than 20 % of that maximum with 150 cm of the surface.

Soils of Paleustults are found very extensively in Thailand, particularly soils occuping the middle and high terraces of Northeast at Northern regions. Some of them are formed in situ on the dissected erosion surface. They are moderately suited for many upland crop production like cassava, sugar cane, kenaf, tobacco, watermelon etc. Main limitations for use are insufficient soil moisture for cultivated crops during the dry season and during dry-spells and being sensitive to soil erosion, particularly soils on rolling and hilly terrains. Low fertility status is another problem.

35. HAPLUSTULTS

More or less freely drained Ultisols that have a thin or moderately thick argillic horizon with a clay distribution such that the percentage of clay decreases from its maximum by more than 20 % of that maximum within 150 cm. In places, the argillic horizon has 10 % or more weatherable minerals in the 20 to 200 micron fraction of the upper 50 cm. They have a moist color value of 4 or more in some part of the epipedon, or have an argillic horizon that has a dry color value of 5 or more in some subhorizon or a moist color value of 4 or more.

Subgroups recognized in Thailand are Ustoxic and Petroferric. They are poorly suited for agricultural use, particularly Petroferric Haplustults because they are very shallow to a layer of semi-consoli dated and/or consolidated laterites. In places lateritic sheets are exposed at the surface. The Ustoxic Haplustults are relatively sandy and occury on rolling topography and are sensitive to erosion if they are cultivated with upland crops without installation measures of soil erosion control.

ORDER VERTISOLS

36. CHROMUDERTS

Vertisols that are usually moist in some part and have cracks that open and close one or more times during most years, but that do not remain open for as many as 90 cumulative days. Chromuderts have readily visible colors. Many are brownish throughout but hues may range from olives to reds. Color values are less than 3.5 when moist and less than 5.5 when dry throughout the upper 30 cm or more in more than half of each pedon. Low chroma mottles are normal in the lower horizons because aeration is very poor when the cracks are closed. However, they typically lack distinct or prominent mottles within 50 cm of the surface in more than half of each pedon. Only the Aquentic subgroup is recognized in Thailand and they are cultivated to paddy rice which produces relatively high yield.

37. PELLUDERTS

Pelluderts are usually moist in some part and have cracks that open and close one or more times in most years, but do not remain open for as long as 90 cumulative days. They are usually gray to black in all subhorizons in the upper 30 cm in more than half of each pedon. Color values are typically less than 3.5 ehen moist and less than 5.5 when dry throughout the upper 30 cm in more than half of each pedon.

The Typic and Entic subgroups are found in Thailand. They are used for submerged rice cultivation which procuces high yields compared to rice grown on other paddy soils in the same region.

38. CHROMUSTERTS

Vertisols that have cracks that open and close more than once in most years and that remain open for between 90 and 150 cumulative days but that are closed for at least 60 consecutive days. Chromusterts have readily visible colors in the matrix of some subhorizon in the upper 30 cm or in more than half of each pedon. They typically have color values of less than 3.5 when moist and less than

5.5 when dry throughout the upper 30 cm clay skins on ped faces in soils with a prismatic or blocky structure do not have color values lower than the matrix within 1 m of the surface.

The Typic subgroup is only one recognized in Thailand. They are upland soils which are moderately suited for upland crop production.

39. PELLUSTERTS

Vertisols that have cracks that open and close more once in most years and that remain open for between 90 and 150 cumulative days, but that close for at least 60 consecutive days. Pellusterts are dominantly gray to black in all subhorizons throughout the upper 30 cm in more than half of each pedon. They typically have color values of less than 3.5 when moist and less than 5.5 when dry throughout the upper 30 cm in more than half of each pedon. Low chromas, except for some high chroma mottles, generally extend to considerable depth.

Subgroups recognized in Thailand are Typic and Udic. They are used for both submerged rice and upland crop production which produce high yields. Moisture stress is a main limitation for crop cultivation, especially during the dry season. They are well suited for rice cultivation.

CONCLUSION

A basic knowledge of soils and soil problems in the country is important for planning and carrying out agricultural development programs such as fertilizer trials, soil and water conservation treatments and other land development projects. Therefore, soil survey and classification will provide such soil resources information to planners who have need of them. The findings of soil survey and classification will be more or less useful to users dependent on many factors. Such factors are intensity of the survey, soil mapping units (category of classification), accuracy of the soil map, and the users themselves. However, the findings of soil survey and classification should be in simplified forms that could be understood by non-soil scientists,

soil survey interpretation is necessary for this purpose. Soil Scientists must help planners or users to interpret soil resource data to help serve their purposes the best way possible.

Additionally, the transfer of agricultural research data and experience between regions will have a better chance of succeeding if the transfer is made to similar soils. Soils which belong to the same categories of classification set forth in the Soil Taxonomy will help planners to transfer agrotechnology from one region to another. To achieve this goal, the Soil Survey Division of Thailand, Land Development Department has adopted the U.S. Soil Taxonomy since 1970 and has applied it to Thai Soils. The reason being that the Soil Taxonomy provides a comprehensive classification system which groups soils with similar physical and chemical properties that affect their behavior and use. Those properties are useful in interpreting soil surveys for agricultural and non agricultural uses.

The classification of soils at the great group level of the Soil Taxonomy places soils together based on similarities in kind, arragement, and degree of horizon expression, similarities in soil moisture and temperature and in base status. These properties are useful to planners for evaluating soil or land use potential for uses in general or on a broad scale. A more detailed type of development planning should be based on lower levels of classification i.e. soil family and series.

In order to effectively transfer agrotechnology and experience between members of the ASEAN countries, the author suggests that each country should develop general soil maps in which map units used are the same as the Soil Taxonomy classification system. The great group level would be an appropriate unit for this type of map.

SOILS OF MALAYSIA

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1. INTRODUCTION

The need for a soil survey prior to land development was recognized in Malaysia in the early part of this century. In these early days most of the soil surveys carried out were of an ad hoc nature. These were carried out before rubber, tea or coffee was planted. In the 1950's the Government decided to carry out a quick systematic inventory of the soil resources of the country. This marked the begining of systematic soil surveys in Malaysia. From this begining, soil surveys have played an important and dominant role in guiding agricultural development in the country.

2. SCALES OF SOIL SURVEYS

Depending on the kind of information required, soil surveys have been carried out using three scales in Malaysia.viz. Reconnaissance, Semi-Detailed and Detailed. These scales and their intensity of examination are summarised in Table 1.

2.1 Reconnaissance Soil Survey

Reconnaissance Soil Surveys are used to determine the broad soil pattern of large areas. In such a survey, traverse lines (rentises) are usually spaced at 3 to 5 kilometres (2-3 miles) intervals and soil examination made every 400 metres (20 chains) along each traverse line. Any timber track or other tracks, roads etc. are also examined and the map then produced by extrapolation between the traverse lines with the help of geological and forest maps. The mapping units are usually soil associations or soil complexes, e.g.

TABLE 1 : TYPES AND SCALES OF SOIL SURVEYS

Type of Survey	Scale of Base Maps	Spacing of Examination	Area Covered by Each Examination	Mapping Unit	Scale of Soil Map	Approximate cost[a] $ ha^{-1} ($ ac^{-1})
Reconnaissance	1 : 63,360	3-5 Km x 400 m (2-3 mls x 20 ch.)	128 ha (320 ac)	Soil Association Soil Complex	1 : 253,440 1 : 500,000	$ 3.75 ($ 1.50)
Semi-Detailed	1 : 25,000	800 x 200 m (½ mls x 10 ch)	16 ha (40 ac)	Soil Series	1 : 25,000 1 : 63,360	$ 22.50 ($ 9.00)
Detailed	1 : 5,000	200 x 200 m (10 x 10 ch)	4 ha (10 ac)	Soil Series Type Variant Phase	1 : 10,000 1 : 5,000	$ 3.75 ($ 1.50)

[a] Cost excludes salaries of permanent staff and is based on current rate of Wages for casual labour.

Malacca-Durian-Batu Anam Associations. The scale of the final map is either 1 : 253,440 (4 miles to an inch) or 1 : 500,000 (7.89 miles to an inch). The advantages of this type of survey is that it is comparatively cheap and the area can be surveyed very quickly. With a reconnaissance soil map, it is possible to mark out areas having a high potential for development, and areas with soils which are relatively uniform can often be developed without further surveys. The reconnaissance soil survey would also identify areas marginally suited for agricultural development. The disadvantage with the reconnaissance soil map is that the maps produced are not very reliable and cannot in many cases be use for detailed planning. Thus for example, in an area mapped as the "Malacca-Durian-Batu Anam Association", the percentage of the area covered by the Malacca Series, a poor soil within that mapping unit, cannot be ascertained. Consequently, the reconnaissance soil map should never be used to determine the crop suitability of an area. The reconnaissance soil survey costs approximately $ 3.75 per ha or $ 1.50 an acre.

2.2 Semi-Detailed Soil Surveys

Semi-detailed soil surveys are carried out in areas which have been identified from the reconnaissance soil survey to have potential for agriculture development. These surveys are carried out by having auger examination points every 200 metres (10 chains) along traverse lines spaced at 800 metres (½ mile) interval. Soil pits are also dug and examined every 800 metres (½ mile) along each traverse line. The final soil map is produced on a cale of 1 : 63,360 (1 inch= 1 mile) or on a scale of 1 : 25,000 (2½ inches= 1 mile). The mapping units used are often soil series, phases or variants but if the soil pattern is complex soil associations may also be used. This type of survey is obviously more costly and time consuming. However such maps are mandatory before an area can be cleared for development. Such maps can be utilized for detailed land development planning. Soil suitability and soil capability and crop suitability maps should only be based on such maps. Such maps could also be used by agronomists to

determine which soil types are dominant in an area and therefore which soil type should be experimented with. Although the experimental sites should not be sited using these maps such maps could be used with greater confidence than the reconnaissance soil maps. The semi-detailed soil survey costs approximately $ 22.50 cents/ha or $ 9.00/ac.

2.3 Detailed Soil Survey

Detailed soil surveys are currently only carried out in areas whcih are already under agriculture. These surveys are special purpose surveys carried out to monitor the fertility status of the soils. The soil fertility officers use the maps of land development schemes for example, to determine their foliar and soil sampling blocks in their advisory services. In addition to the Department of Agriculture, some of the other agencies, such as RRIM, FELDA and the private estate agencyhouses also carry out such surveys. However, it is uncertain if all their scales of survey and examination are comparable to that being done by the Department of Agriculture.

Since detailed soil surveys are carried out in developed areas, the free traversing technique is used. However, a density of examination of 200 metres by 200 metres grid pattern (10 chains x 10 chains) is maintained. The resultant soil maps are produced at a scale of 1 : 10,000 (1 inch = 16 chains) or at 1 : 5,000 (1 inch = 8 chains). The mapping units used are soil series, phases, variants etc. The cost of such a detailed survey is difficult to assess as it depends on the complexity of the soils, accessibility etc. However, it is estimated that the cost is about $ 3.75 per ha or $ 1.50 ac.

2.4 Ad Hoc Survey/Inspections

In addition to the three types of surveys described above, the National Soil Survey also carries out ad hoc surveys and inspections. The scale of such surveys in between that of a reconnaissance surveys and a semi-detailed survey. Such surveys are not planned in advance, but are carried out as and when a request is

received from any land develpment agency, such as the SEDC, FELCRA, FELDA, etc. In such surveys, the main objective is to produce a crop or soil suitability map without producing a soil map. Almost all land development schemes opened by government agencies are first cleared by the National Soil Survey prior to their development. It is hoped that through this process, a proper land utilization policy can be maintained. However, it must be emphasised that the role of the Department of Agriculture is merely that of providing basic technical information. The final decision whether the land is opened for agriculture is left to the State Government or Agency as other factors such as economics etc. have also to be considered.

The titles of most agricultural lands often specify the type of crop which the landowner must plant. If however, the landowner wishes to change his title to a new crop or if the wishes to apply for a replanting grant of loan from RISDA or form a bank, he has to first obtain a Soil Suitability Certificate from the Department of Agriculture. To do this, he has to provide four copies of a map of his property showing the area to be replanted and the crop to be planted. The area is then visited and examined by a staff member of the National Soil Survey and a soil suitability map produced. The map is then certified by both the soil surveyor and Director-General of Agriculture or his representative and two copies of the Soil Suitability Certificate returned to him. For the inspection and certificate, an nominal fee is charged as follows :-

> $ 100.00 for the first 40 ha (100 ac.) or part thereof $ 10.00 for every additional 40 ha (100 ac) or part thereafter.

2.5 Progress of Soil Surveys

The progress of soil surveys of the agriculturally suitable land in Malaysia is summarised is Table 2. It should be noted that the slope limit used in Peninsular Malaysia is 20° while that used in Sabah and Sarawak is 35°.

Table 2. Progress of Soil Surveys.

Category \ Region	Peninsular Malaysia	Sabah	Sarawak	Malaysia
Total Land Area	13.2 Mill.ha.	7.4 Mill.ha	12.2 Mill. ha.	32.8
Steepland Mining Land and Urban Land	5.1 Mill.ha.	N.A	8.5 Mill. ha.	N.A
Area Suitable for Agriculture	8.1 Mill.ha.	N.A	3.7 Mill. ha.	N.A
Progress of Recce Survey	100 %	100 %	100 %	100 %
Progress of Semi-Detailed Survey	30 %	10 %	15 %	
Progress of Detailed Survey	5 %	2 %	2 %	

As it can be seen from the above table the Reconnaissance survey of the whole country is complete. In Peninsular Malaysia this was completed in 1967, in Sabah 1974 and in Sarawak in 1980. The semi-detailed survey has however been rather slow. This semi-detailed scale is often used to open up land for development. However in spite of this slow progress land development has continued using the Ad Hoc Soil Surveys.

3. Soil Classification

Of the ten order recognized by the Soil Taxonomy, nine are present in Malaysia (Table 3.). The only order that is absent is the ARIDISOLS. The soils found in each order is discussed briefly. The discussion

presented here is only based on experience in Peninsular Malaysia.

3.1 ENTISOLS

The Entisols are the soils that have little or no pedogenic development. Four sub-orders of Entisols are found in Malaysia. The AQUENTS occur along the west-coast of Peninsular Malaysia. These areas which are still inundated by sea water are sometimes sulfidic. Aquents also occur in fresh-water or brackish areas adjoining. The peat swamps. These areas due to the difficulty of drainage remain uncultivated. Recent sandy deposits which occur as beach ridges along the east-coast are PSAMMENTS. These soils if they are near the coast are Quartzipsamments and have been planted with coconuts and cashew. Occassionally some soils on the beach ridges which have a spodic below 2 meters are also placed into this Great Group. The levees of major rivers consists of recent alluvial deposits of the Tropopsamments and Tropofluvents. The Orthents only occur as shallow soils on steep rides. The different soil families of Entisols mapped to date in Peninsular Malaysia are shown in the Table 3.

3.2 INCEPTISOLS

Only two sub-orders of Inceptisols occur to date in Malaysia. The AQUEPTS which are extensive along the west coast are by far the most important. These soils were formed by the drainage of the coastal marine and brackish water deposits-by the construction of a coastal bund. These soils include Sulfaquepts and Tropaquepts which have been cultivated to oil palm, coconut, cocoa, rubber and rice. The other group of Inceptisols occurs mainly along the levees of the major rivers. These soils have weak structural development and are used mainly for housing and mixed horticulture. Some tobaccoo is also often grown on these soils.

3.3 VERTISOLS

The Vertisols have to date only been found in the north-western coastal plain where rice is cultivated. This part of the

country has an udic moisture regime that is marginal to ustic. The classification of these soils into Vertisols is questionable but these soils have cracks and slickensides but due to double cropping of rice with irrigation the cracks are difficult to see except in the dry season. Only one Great Group-Pelludert has been identified to date.

3.4 MOLLISOLS

Only one soil has been mapped are Mollisol in Peninsular Malaysia. This soil an Argiudoll is developed over some migmatites and are localized in extent. In Sabah another Mollisol has been reported over coral reef limestone. It is possible that some Mollisols occur as shallow soils over limestone rock in Peninsular Malaysia but these have never been mapped as these limestone outcrops form sheer cliffs.

3.5 ALFISOLS

The Alfisols are also of very localized extent in Peninsular Malaysia. A Duraqualf has been mapped in isolated pockets over rhyollitic tuffs. These soils being impervious are used for wetland rice. Another soil used for rice on the east coast is Tropudalf which is characterized by the presence of large manganese concretions. This soil is planted with rice in the rainy season and tobacco in the dry season.

3.6 ULTISOLS

The Ultisols form one of the major groups of soils found in Malaysia. They occur on undulating to rolling terrain where sedimentary and igneous rocks with low to moderate amounts of iron occur. Ultisols are also common on the recent, sub-recent and older alluvia which form gently undulating to level topography between the upland areas and the coastal plains. Only three sub-orders of Ultisols have been mapped to date in Peninsular Malaysia. The Aquults occur in the low lying poorly drained areas of the recent and sub-recent terrace alluvia. The Humults are localized soils which occur on steep areas which have yet to be mapped. The Udults are by far the most important

group of soils. Plinthudults occur over iron-poor shales and on imperfectly drained subrecent terraces. Rhodudults are localized soils which are developed over tuffaceous materials. The Paleudults and Tropudults are more extensive occuring over granites, shales, sandstones, reworked lateritic soils, and terrace alluvia. These Ultisols are the major soils on which oil palm, rubber and fruit trees are grown.

3.7 OXISOLS

Oxisols have to date in Malaysia been only mapped over iron-rich parent materials such as serpentinite, basalt, andesite, schist and ferruginous shales. Only one sub-order-ORTHOX has been identified to date. Only one soil has been mapped as a Gibbsiorthox. This soil only occurs in the southern part of Peninsular Malaysia where the soil moisture regime is perudic. The Acrorthox and Haplorthox Great Groups seems to be more related to the iron-content and is often reflected in the differences in colour. The Acrorthox is often much redder. These Oxisols are mainly planted with rubber but where the rainfall distribution is good, oil palm has also been planted on these soils.

3.8 SPODOSOLS

Spodosols occur at two localities in Malaysia. At high altitudes where the temperature regime is isothermic Tropaquods occur. Spodosols also occur on the sandy beach ridges found on the east coast. These Tropohumods depending on the depth and cementation of the spodic have been planted with coconuts, cashew and tobacco.

3.9 HISTOSOLS

Histosols form another important group of soils which have been considered to be problem soils. No detailed work has been carried out on these soils but Troposaprists, Tropohemists and Tropofibrists occur. In some areas Sulfihemists and Sulfohemists also have been mapped.

4. PROBLEMS WITH THE USE OF SOIL TAXONOMY

In the classification of the soils mapped in Peninsular Malaysia at family level only a few examples of soil series are given. The classification given for some soils is only tentative and the data is incomplete. This classification also does not include many soils which many be found in areas more than 20° slopes. However in applying Soil Taxonomy to the soils in Peninsular Malaysia a few problems were encountered and these will be highlighted here.

4.1 Distinction of Agrillic/Oxic Horizons

This problem ha. been faced by many workeres in many parts of the World. In Malaysia a rather pragmatic approach is used. If a soil is weak structured and friable it is often mapped as an Oxic horizon even if some patchy coatings occur. Similarly if the soil has strong structures, relatively high silt content and is not so friable it would be normally mapped as an argillic horizon.

4.2 Cambic Horizon

In the definition of the cambic horizon, it the organic carbon content is $>$ 0.2 % at a depth of 1.25 m the horizon is excluded from the cambic horizon. Many soils show mottles and good structures fail to meet this requirement. Hence this organic carbon criterian is not used in Malaysia.

4.3 Sulfuric Horizon

If a soil has jarosite mottles and a low 'n' value the horizon is mapped in the field as a sulfuric horizon. If however the sulfuric horizon occurs below 100 cm the soil is mapped as a non acid sulfate soil i.e. Typic Tropaquept. In soil Taxonomy the limit for Sulfic Tropaquepts is the presence of sulfuric horizon between 50 and 150 cm.

4.4 Depth of Spodic Horizon

In Soil Taxonomy if the spodic horizon occurs within

2 metres the soil is mapped as = Spodosol. The limit used in Malaysia is one metre.

5. GENERAL COMMENTS

If must be emphasised that the classification given in this paper is only tentative as field data has been used. The lack of proper data has hampered work in improving the classification. The soil series in Peninsular Malaysia are currently being redefined using the badic principles of the Soil Taxonomy. It is hoped that by the end of this years a better picture of the soils is obtained.

TABLE 3. SOIL FAMILIES IN PENINSULAR MALAYSIA

ORDER	SUB-ORDER	GREAT GROUP	SUB-GROUP	FAMILY	SOIL SERIES
ENTISOLS	AQUENTS	SULFAQUENTS	TYPIC	very fine, mixed, isohyperthermic	KRANJI, MERBOX
			TYPIC (HISTIC)	very fine, mixed, isohyperthermic	LINAU
		HYDRAQUENTS	TYPIC	very fine, mixed, isohyperthermic	BAKAU, PIANDANG
		FLUVAQUENTS	TROPIC	very fine, mixed, isohyperthermic	KUALA KEDAN, LUBOX ITEX
	PSAMMENTS	QUARTZIPSAM-MENTS	TYPIC	coated isohyperthermic	BAGING
			TYPIC	uncoated isohyperther-mic	JAMBU (deep)
		TROPOPSAMMENTS	TYPIC	coated, isohyperthermic	ROMPIN.SG.BULOH
	FLUVENTS	TROPOFLUVENTS	AQUIC	fine loamy, siliceous, isohyperthermic	TELAGA
	ORTHENTS	TROPORTHENTS	LITHIC	fine loamy, siliceous, isohyperthermic	KEDAH, KEKURA
INCEPTISOLS	AQUEPTS	SULFAQUEPTS PLACAQUEPTS	TYPIC	very fine, mixed, isohyperthermic	PARIT BOTAK, SEDU ULU KALI

ORDER	SUB-ORDER	GREAT GROUP	SUB-GROUP	FAMILY	SOIL SERIES
		TROPAQUEPTS	TYPIC	very fine, mixed, isohyperthermic	BRIAH, BERNAM, KANGKONG
			AERIC	very fine, mixed, isohyperthermic	SELANGOR, SABRANG
			SULFIC	very fine, mixed, isohyperthermic	TONGKANG, JAWA
				fine loamy, siliceous, isohyperthermic	CAREY
			OXIC	fine, kaolinitic, isohyperthermic	BINJAI
	TROPEPTS	DYSTROPEPTS	OXIC	fine, kaolinitic, isohyperthermic	TOK YONG, KUAN
				fine loamy, siliceouse, isohyperthermic	PENANBANG
				coarse loamy, siliceous isohyperthermic	TELEMONG
		HUMITHROPEPTS	FLUVENTIC	coarse loamy, siliceous, isohyperthermic	SUBANG
VERTISOLS	UDERTS	PELLUDERTS	TYPIC	very fine, montmorillonitic, isohyperthermic	CHENGAI, KECHAI, KANGAR

ORDER	SUB-ORDER	GREAT GROUP	SUB-GROUP	FAMILY	SOIL SERIES
MOLLISOLS	UDOLLS	AGRIUDOLLS	TYPIC	fine, mixed, isohyperthermic	BENTA
ALFISOLS	AQUALFS	DURAQUALFS	TYPIC	fine loamy, mixed, isohyperthermic	HALU
	UDALFS	TROPUDALFS	TYPIC	fine, mixed, isohyperthermic	LUNDANG
ULTISOLS	AQUULTS	PALEAQUULTS	OXIC	very fine, kaolinitic, isohyperthermic	JABIL, SOGO-NANA
		TROPAQUULTS	OXIC	fine, kaolinitic, isohyperthermic	HUTAN, CHERANG HANGUS
			AERK, OXIC	fine, kaolinitic, isohyperthermic	TEPUS
	HUMULTS	TROPOHUMULTS	ORTHOXIC	fine, kaolinitic, isohyperthermic	RINGLET
	UDULTS	PLINTHUDULTS	ORTHOXIC	fine, kaolinitic, isohyperthermic	LOK YANG, ASAHAN, LUOOK KIAT
		PALEUDULTS	TYPIC	very fine, kaolinitic, isohyperthermic	LANCHANG, CHAT LANCHANG
				fine, kaolinitic, isohyperthermic	BUNGOR, RENGAM

ORDER	SUB-ORDER	GREAT GROUP	SUB-GROUP	FAMILY	SOIL SERIES
				fine-loamy, kaolinitic, isohyperthermic	SERDANG, KENAHANG
				clayey-skeletal, kaolinitic, isohyperthermic	BESERAM, GAJAH MATI
				clayey over clay-skeletal, kaolinitic, isohyperthermic	TAUY
		RHODUDULT	ORTHOXIC	clayey, kaolinitic, isohyperthermic	JERA
		TROPUDULT	ORTHOXIC	clayey, mixed, isohyperthermic	DURAIAN, BUKIT TEMIANG
				clayey, kaolinitic, isohyperthermic	KULALI, CHEMPAKA, TAMDIN
				fine-loamy, siliceous, isohyperthermic	NAMI
				clayey-skeletal, mixed, isohyperthermic	POKOK SENA, PADANG BESAR
				clayey over clayey-skeletal, mixed isohyperthermic	CHUNGLOON
			AQUOXIC	clayey, mixed, isohyperthermic	BATU ANAM, LATING

ORDER	SUB-ORDER	GREAT GROUP	SUB-GROUP	FAMILY	SOIL SERIES
OXISOL	ORTHOX	GIBBSIORTHOX	TYPIC	clayey, skeletal, oxidic isohyperthermic	MASAI
		ACRORTHOX	HAPLIC	clayey, oxidic, isohyperthermic	JERANGAU, SEGAMAT, KUANTAM
		HAPLORTHOX	TYPIC	clayey, oxidic, isohyperthermic	TANGGA
			TROPEPTIC	clayey, oxidic, isohyperthermic	MUNCHONG, KATONG
				clayey-skeletal, oxidic, isohyperthermic	MALACCA
				clayey-skeletal, kaolinitic, isohyperthermic	LAMBAK
SPODOSOLS	AQUODS	TROPAQUODS	AERIC	coarse-loamy, siliceous, isohyperthermic	TANAH RATA
		TROPOHUMODS	AQUIC	sandy, siliceous, isohyperthermic	RHU TAPAI
			TYPIC	sandy, siliceous, isohyperthermic	RUDUA

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PART 3

SOIL-CROP RELATIONS

SOME NOTES ON THE FAO-ECOLOGICAL ZONES STUDIES

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SUMMARY

FAO has developed methods for evaluating the suitability of land in order to predict future conditions for the purpose of planning improved land use which is beneficial to the user and can be sustained without damage to the environment.

Using the same principles, complex methods were developed to assess the productive potential of the developing world's land resources. A special climatic inventory was developed relating thermal regimes and lengths of growing period to crop requirements. This was superimposed on the soil map of the world to produce a mosaic of tens of thousands of agro-ecological land units. The potential yields of the major food crops in each of these land units, at three input levels, were compared with the food requirements of the existing and projected populations. Thus it was possible to indicate areas which cannot support their populations and predict which countries and regions will be critical in future.

Recent studies have developed more complex and complete models and methods with computer programmes sufficiently flexible to provide information on various issues, for example, as a basis for planning population activities, judging agricultural investment policies or estimating soil and water conservation needs.

1. Land Evaluation

FAO has for many years been concerned with land development in all its forms. The objectives are to assist in meeting countries' needs for sufficient food and cash crops, to improve the standards of living of the farmers by increased production, while conserving soil

and water resources for future generations, and to provide basic land resource data for planning agrarian reform and other developments designed to help the rural poor.

In order to improve the technology for evaluating the suitability of land for specific agricultural practices, FAO produced, on a basis of international collaboration, a Framework for Land Evaluation (1976) which sets out the principles and guidelines for assessing land suitability. More detailed guidelines are in production (FAO 1983).

In a nutshell the methods advocated comprise the identification of types of land use and their requirements, the description of the land resources in identified land units, and the process of matching the land use to land, to identify the optimum land use for each kind of land with or without land improvements of various kinds. The evaluation must obviously be for specific uses, must take into account the economic and social conditions, and must compare alternative forms of land use in essentially economic terms (though not necessarily with formal economic analysis).

The method with appropriate adaptations has been adopted for surveys at various scales in many countries. At FAO Headquarters it has been used as a basis for global studies of the extent of agricultural land and its suitability for various crops, in the form of the agro-ecological zones project, and the complementary studies of food production and human population supporting activities described below.

2. The Agro-ecological Zones Project

The agro-ecological zones project was developed to answer questions about the developing countries and to serve as a tool for planning land use particularly in critical areas of increasing food shortage. Details of the methods and results have been published by FAO and Higgins. Some questions which needed answers were : how much land is suitable for agriculture, what crops can it produce, what input levels and technology is required, what is the risk of soil

degradation, where can maximum returns be obtained from the inputs, what are the limitations to production increase, where should research concentrate ?

Estimates and opinions have varied enormously in the past. The agro-ecological zones project therefore aimed at a first approximation of the production potential of the world's land resources taking into account the requirements of different crops and different input levels.

The study was based on the 1:5 million scale FAO/Unesco Soil Map of the World on which was superimposed a specially created climatic inventory characterising temperature and moisture regimes matched to crop requirements. The original study was confined to eleven major rainfed crops under two levels of inputs. Later studies have added many more crops, more complex climatological methods, which treat climatic variability in greater detail, have added allowances for non-agricultural land use, fallow periods, irrigated land, grazing land and non-food crops and consider three levels of inputs and technology. Studies being carried out at country level use much more detailed soil maps and climatic information and additional features which are of special local importance, such as hurricanes or widespread flooding.

To summarize the methods very briefly, the climate map divided the developing world into fourteen major climates, based on temperature, subdivided into many hundreds of length of growing period zones. Zones in which moisture conditions permit plant growth for a stated number of days in the year, such as 90-120, 120-150, 150-180 and so on. The constraint-free potential biomass production and hence the yields of the specified crops were calculated for these zones.

The soil map gave information on the soils, topograph, soil texture and various soil phases which affect productivity. The constraints caused by individual soils and phases were fed into the programme. By superimposing the climatic map on the soils map a mosaic of tens of thousands of agro-ecological zones was created. For each

of these a complicated computer programme, designed and run by the International Institute for Applied System Analysis in Vienna, calculated the potential yields for each of the selected major food crops.

The areas of each of the agro-ecological cells was measured. The computer programme can provide the potential production for each of the crops for each individual soil and phase in each growing period zone, in each major climate, and for each country separately. This information is available on request by governments. The programme is quite flexible so that various aggregations of information can be extracted.

3. Population Supporting Capacities.

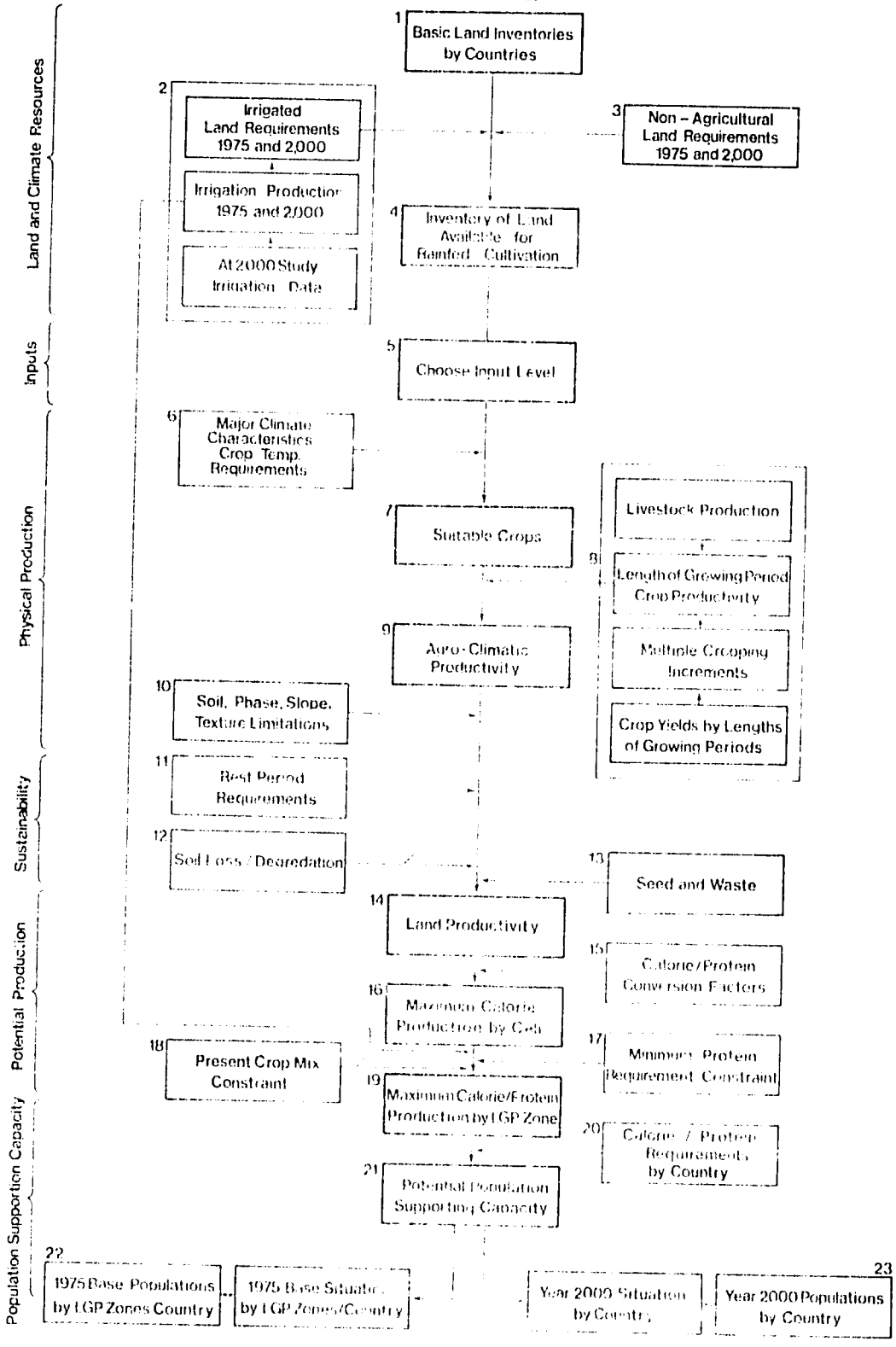
The United Nations Fund for Population Activities supported a project to determine the numbers of people who can be supported by the world's land resources. A more complex development of the agro-ecological zones approach provided the basic data on food producing potential of the world's lands. This is converted to calories and to numbers of people who can be fed. Constraints are included to take account of minimum protein requirements, food preferences and the rate of change to new crops.

The diagram shows the sequences and the main elements in the method. This is not the place to expand on the data requirements, and computational complexities of every step in the method. Many specialists have contributed to the development of the methodology, and it is now in a form in which it can be used at the national level, provide reliable answers and is sufficiently flexible to be used for various purposes. Needless to say improvements can still be made.

The results were compared with 1975 population figures and with projections for populations in the Year 2000 or later years. It is then possible to see which countries have or will have difficulty in feeding their populations. Because of the detailed nature of the

AGRO-ECOLOGICAL ZONES AND POPULATION SUPPORTING CAPACITY

Methodology



base material it is possible to aggregate the results in various ways to indicate where food is short and where it could be produced to meet the shortages.

Thus if there could be completely free transfer of food throughout Africa the continent as a whole could easily feed its projected population. If, on the contrary, each agro-ecological unit had to be self-sufficient in food, very extensive areas, and large numbers of people, would be food deficient. Taking a more realistic scenario, in which food can be freely moved within countries, it becomes clear that at low input levels many countries cannot be self-sufficient in food in the Year 2000, and even with intermediate and high input levels there remain countries which cannot feed themselves. The importance of soil and water conservation measures are clearly brought out,because increased food production based on exploitative agricultural measures leads on quite rapidly to soil degradation and hunger.

4. Food Self-Sufficiency

The methods developed are capable of being used at any scale. Many countries are now beginning to apply them to their own lands. The scale chosen is usually 1 : 1,000,000 or 1 : 500,000 and the models are more complex and use much more detailed information on soils, soil phases, climates and climatic constraints, crops and crop requirements, population data and population projections, and can take account of conflecting uses of land or unequal distribution of land and food supplies.

These inventories which are being technically backstopped by agro-ecological specialist in FAO are expected to provide a valuable tool for planning land development and investment to solve the food supply problems of the developing countries.

5. Conclusions

The agro-ecological zones approach is based on land evaluation principles and concepts developed over the last dozen years

(FAO, 1976). Obviously it is multi-disciplinary. The soil scientist, and soil taxonomy, are very important but other disciplines must play their part in estimating food production, expecially climatologists, botanists, agronomists and economists.

The climatic controls on crop growth are complex. The climatic element in Soil Taxonomy relates to climate effects on soils, which have an indirect effect on crop yields (e.g. weathering, organic matter content etc.). However, it is not likely to be possible to incorporate in soil taxonomy a climatic classification which could indicate crop growth directly.

The world soil map was adequate for this work at world level. The USDA Soil Taxonomy is a useful soils basis for agro-ecological zones at country or more detailed level. Detailed information is usually lacking about the effect on crop yields of individual soil subgroups, let alone families. Therefore it is still usual to use combinations of land qualities to indicate yields rather than taxonomic units, for example, in the Indonesian land evaluation computer system, LECS (Dent and Lambrecht, 1982). Additional and improved information on crop requirements and their relationship to land characteristics and to taxonomic soil units remains a priority requirement for estimating food production potential and for agrotechnology transfer.

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THE INTERNATIONAL BENCHMARK SITES NETWORK FOR AGROTECHNOLOGY TRANSFER

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I. INTRODUCTION

In the next 20 years the world will have to feed two billion more people. Although there exist the land resources and the technology to produce enough food for this anticipated population, there is considerable doubt as to whether the food will be produced where it is needed most and distributed in an equitable manner.

Ironically, food shortages of major proportions are expected to arise among the agrarian countries of the tropics and subtropics where the major part of the as yet unexploited or underutilized resources of arable land of the world are located. Advantageously, however, the knowledge about the management of these resources for the production of food and fiber has dramatically increased in recent decades through the work of the national and international agricultural research centers. But the work of these research centers becomes meaningful only when the results can be effectively conveyed to the ultimate user--the farmer-- in all areas where they are environmentally and sociologically applicable. It is distressing, therefore, that the development of operational methodologies for the efficient diffusion of agroproduction technology has lagged behind the knowledge generation

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process. Research and development efforts relative to the transfer of agrotechnology must consequently be augmented so that the existing and rapidly expanding knowledge base can be shared by many users in the countries of the Third World. This is particularly crucial for countries which lack the capital and human resources to set up national research programs or cannot delay their agricultural development until their own research has yielded implementable results.

In the context of this perspective, the International Benchmark Sites Network for Agrotechnology Transfer, IBSNAT, has been established to develop and test a methodology for intergrating scientific and technological knowledge of agricultural production into systems that optimize resource management and facilitate the transfer of technology in the tropics and subtropics.

IBSNAT is an outgrowth of the Benchmark Soils Project of the Universities of Hawaii and Puerto Rico and has had a long gestation period. The idea of the network was first discussed at a workshop on "Operational Implications of Agrotechnology Transference Research" held at the International Crops Research Institute for the Semi-Arid Tropics (ICRISAT) in October 1978. Another milestone in the project development was an international panel consultation on the "Strategy for Land Evaluation and Agrotechnology Transfer in the Tropics and Subtropics" which was hosted by FAO in Rome in March 1980. IBSNAT has recently been funded, in part, by the United States Agency for International Development (AID) under a nine-year contract with the University of Hawaii.

The University of Hawaii will serve as the coordinating entity and as a catalyst for IBSNAT. The ultimate success of the project, however, will depend on the aggregate research output resulting from the concerted efforts by the various collaborators who in their entirety form IBSNAT. Through the aspired synergistic collaboration of institutions from many countries, IBSNAT holds the promise of emerging as a major scientific endeavor of multidisciplinary nature

and international scope of consequence to the agricultural development in the lower latitudes.

The purpose of this paper is to give an overview of IBSNAT and its underlying rationales. As the project has only been effective for a short time, complete operational details have not been finalized and this discussion will, therefore, be confined to the overall project design. We want to make it clear at the outset, however, that IBSNAT concerns primarily the transfer among countries and between regions within countries, i.e. horizontal transfer. The diffusion of technology to farmer fields, i.e. vertical transfer, has been deliberately excluded from the scope of IBSNAT. Consequently, this paper will address mainly horizontal transfers which should not be construed to imply that the crucial importance of vertical transfers is not recognized.

II. PROJECT RATIONALES

A. Approaches to Agrotechnology Transfer

Uehara (1981) defined agrotechnology transfer as the taking of an agricultural innovation from its site of origin to a new location where it is likely to succeed. How, then, are the innovations transfered from one location to another ?

Most commonly transfer of agrotechnology occurs through trial and error, but there also exist scientific approaches. Swindale 1981), 1981), drawing in part on the work of Nix (1968, 1980), has identified three different, but not mutually exclusive, models.

1. Simulation models

Simulation models employ systems analysis to reduce the complex system into a number of simpler components and to identify the linkages between them in an attempt to mimic the behavior of the complex system (Nix, 1980).

Inherently simulation models should provide the best methodology for agrotechnology transfer. But the incompleteness of of scientific knowledge, particularly relative to the cause and effect relations that control genotype-environment interactions, and the complexity of the models themselves have been barriers to their use. The difficulty to achieve the multidisciplinary collaboration that is clearly required to develop the models may have been a further detriment (Swindale, 1980).

As Nix has pointed out, however, the development of simulation models is essential to identify the "minimum data set" needed for the adequate interpretation and extrapolation of experiment results. This minimum data set consists of a cultivar-specific, balanced set of soil-crop-weather-management data and is, in turn, a key prerequisite for technology transfer via simulation models.

2. Statistical relationships

In this approach correlations and multiple linear regressions are used to relate crop yields to input and resource variables. This site-factor method is widely used, but works better with interpolations rather than extrapolations and thus appears to be of limited value for intercountry transfers (Swindale, 1980).

3. Analogue transfer

Soil and climate classifications are used in this method to identify analous areas. The assumptions are (i) that the taxa of the classification schemes stratify the environment with sufficient precision to ensure successful transfers, and (ii) that all occurrences of a defined class have similar production potentials and responses to management. While in general, multi-attribute schemes of agroclimatic classification are of limited value in the analogue transfer of technology (Burgos, 1968), soil classifications have been more successful. The U.S. system, Soil Taxonomy (Soil Survey Staff, 1975), is particularly suited for this purpose as it incorporates both soil

and climate and thus stratifies the agroenvironment into distinct niches of agroproduction (Beinroth, 1983).

Transfer by analogy is also implied in the concept of benchmark soils advanced by Kellogg in 1961 (Kellogg, 1961). As currently defined, a benchmark soil is an important soil selected for intensive study and complete characterization because it occupies a key interpretative position in the classification and/or covers large areas (Miller and Nichols, 1980). A benchmark soil represents a reference site from which research results can be extrapolated to other areas with similar characteristics.

B. Role of Soil Classification in Agrotechnology Transfer

Soil scientists have long assumed that soil classification, in conjunction with soil surveys, provides an adequate basis for the transfer of pedologic knowledge and agronomic experience. Many authoritative statements can be found in the literature which allude to this conjecture. In the foreword of the FAO-Unesco Soil Map of the World (FAO, 1974), for example, it is stated that one of the objectives of the map was "to supply a scientific basis for the transfer of experience between areas with similar environments....(because)..... with the tremendous amount of knowledge and experience gained in the management and development of different soils throughout the world, the hardship perpetuated in some areas by methods of trial and error is no longer justified". And Smith (1965) pointed out that "we make the basic assumption that experience with a particular kind of soil in one place can be applied to that particular kind of soil wherever it exists if consideration is taken of any climatic differences".

The stated assumptions and the transfer hypothesis implied therein were subjected to a thorough scientific test in the Benchmark Soils Project (BSP) of the Universities of Hawaii and Puerto Rico whose primary objective was to test the transferability of agroproduction technology on the basis of soil families as defined in Soil Taxonomy. The results of the BSP (Benchmark Soils Project, 1982a and

1982b) show that Soil Taxonomy taxa allow to predict crop production potential and management requirements in qualitative terms and that, logically, the specificity of predictions increases with decreasing categoric levels. The extensive experimental and statistical work conducted by the BSP also showed that fertilizer response and crop yields can be predicted with considerable accuracy at the family level if additional site factors are taken into consideration (Benchmark Soils Project, 1982a).

The importance of this provisio has also been emphasized by Smith (1981) who, in his last technical paper, wrote that "soil interpretations at any categoric level nearly always require an additional step of reasoning which includes the relation between the potential use being considered and the soil properties. This requires knowledge of soil and non-soil factors that cannot be inferred from the classification".

C. Ecosystems Approach to Agrotechnology Transfer

In the light of the preceding, it should be obvious that a quantitative model of agrotechnology transfer must necessarily be more complex than the somewhat simplistic approach of analogue transfer that was tested by the BSP. The intricacy of the transfer process clearly calls for a holistic approach that should be based primarily on concepts of transfer by simulation.

Central to this approach is the realization that in successful transfers the characteristics and requirements of cultivars must be compatible with the environmental conditions at the new site. This implies (i) quantitative knowledge of the cause and effect relations between the soil, agroclimate and management practices on the one hand, and crop requirements and performance on the other hand, and (ii) quantitative knowledge of certain environmental parameters of the transfer site.

The transfer model of IBSNAT has essentially four components:

1. Data base generation through site characterization, field experiments and growth chamber studies;

2. Data base management, particularly the development of computerized data bases which contain (a) pedon data, (b) climatic data, and (c) crop growth and development data collected in field and growth chamber studies;

3. Development of computer simulation models which employ the data bases above to produce predictions of crop growth and yield; and

4. Verification of predictions, adaptations of transferred technology, and diffusion of technology.

III. IBSNAT's GOAL AND OBJECTIVES

The goal of IBSNAT is to maximize successes and to minimize failures in the transfer of high-performance cultivars and the technology required to exploit their genetic potential.

The principle objectives of IBSNAT are :

1. To develop and validate performance prediction models for important crops of the tropics and subtropics;

2. To design a methodology for determining the minimum data sets required for the effective transfer of agrotechnology; and

3. To devise a prototype telecommunication system for the transnational exchange and diffusion of agroproduction technology at a scientific level.

IV. MAJOR IBSNAT ACTIVITIES

A. Network Establishment

IBSNAT will consolidate a group of collaborating agricultural research centers in a prototype network for the purpose of generating the data base for the development of crop performance prediction models and testing their validity. This worldwide cluster should initially comprise about 20 actively cooperating National and International Agricultural Research Centers and Regional Research Organizations that are willing to financially and technically support the research effort and whose stations represent the dominant agroecological zones and the major kind of soils of the tropics and subtropics. Examples of the three kinds of desired collaborators are the Centro Nacional de Investigaciones Agropecuarias (CENIAP) of Venezuela, the International Crops Research Institute for the Semi-Arid Tropics (ICRISAT) in India, and the Arab Center for the Studies of Arid Zones and Dry Lands (ACSAD) in Syria, respectively.

B. Data Generation

Data for IBSNAT will come from detailed soil, climate and site characterization, and agronomic research. The latter will be conducted using especially designed experiments conducive to creating the data base needed for establishing the relationships between soil, climate and other site characteristics and crop requirements and performance under various levels of management inputs. This research should elucidate the genotype-environment interactions and will provide the data base that will enable the data analyzers to model agricultural production and management systems.

In the course of field experimentation it will be essential to collect balanced sets of soil-weather-crop-management data that monitor the whole crop system and facilitate the identification of minimum data sets. Data compilation should be characterized by a wide range and a high precision, accuracy and frequency of measurements and observations.

The crops currently under consideration for model development and/or validation include cacao, cassava, coffee, cotton, groundnuts, maize, pigeon peas, plantain, potatoes, rice, sorghum, soybeans, and wheat. Other root crops may be added. To the extent feasible, it is planned to grow all crops under study at all appropriate sites of the network. This will allow to establish the boundary conditions of environmental crop requirements under a wide range of soil and climatic situations.

Not all of the crops mentioned will require the same amount of research. User-oriented models for maize and wheat, for example, are already available for field validation. For some of the crops growth chamber studies are contemplated to complement the field experiments.

C. Data Management

In recent years scientist in many countries have developed models to simulate various agricultural processes. One of the most comprehensive operational models has been devised by scientists of the USDA Agricultural Research Service working, in collaboration with the USDA Soil Conservation Service, in Temple, Texas. This model is called the Erosion-Productivity Impact Calculator (EPIC) and is designed to simulate the long term change in yield resulting from changing soil properties due to wind and water erosion. The eight major components of EPIC include hydrology, weather, erosion, nutrients, plant growth, soil temperature, tillage, and economics. By simulating the interactions of these components, the EPIC model can produce long term estimates of soil depth, soil nitrogen and phosphorus levels, crop yield trends, and the affect of erosion on soil loss and yield.

Other important models developed at Temple simulate grain yields of maize and wheat for a single growing period. The major inputs of these models include daily weather, water holding capacity of the soil, soil fertility, applied fertilizer, and crop cultivar. The interactions of these components result in predicted dates of plant

development stages, leaf area, and dry matter and grain yields.

Recognizing the immense potential of simulation models, the USDA is currently developing a general agricultural management model called Agricultural Land Management Alternatives with Numerical Assessment Criteria, ALMANAC. This model is a synthesis of the models mentioned above.

ALMANAC is designed for use in decision making and in research. It allows decision makers to evaluate the effects of various management options. It simulates the effects of different tillage practices on soil physical and chemical properties and the effects of various conservation practices such as terraces and wind breaks on wind and water erosion, and it simulates different irrigation techniques and the effect of water tables and impermeable layers on root and crop growth. ALMANAC also simulates nitrogen and phosphorus fertility and their effect on crop growth. The versatility of ALMANAC allows comparisons among crops with different nutrient requirements, among soils with different native fertilities, and among sites with different weather characteristics.

Individual farmers can use ALMANAC to plan their farm operation to increase profit, conserve soil, and provide a cleaner environment. Watershed and river basin mangers will find ALMANAC quite useful for determining optimal management for large areas. And ALMANAC will be useful at regional and national levels for making policy decisions.

In addition to decision making capabilities at various level, ALMANAC also provides two modes of operation for long and short term assessments. Short term or within growing season decisions are facilitated by simulating crop growth at weekly intervals during the growing season. Early in the season such decisions are based mainly on probabilities of weather conditions for the remainder of the season. Decisions become clearer, however, as the crop grows simply because observed conditions are substituted for uncertain conditions at each weekly simulation run.

Long term decisions are based on computer simulations for 25 to 100 years. These simulations provide probability distributions that can be used for (i) making annual decisions like crop varieties and fertilizer rates, or (ii) making long term decisions like structural measures for erosion control. The long term simulations are also essential in studying the effects of erosion on productivity because erosion can be a relatively slow process.

The soil, weather and crop data generated by the IBSNAT collaborators will be used to adapt ALMANAC to the agroenvironmental conditions of the tropics and subtropics. In the modelling process it will be attempted to relate crop performance to named kinds of soil, following the criteria and nomenclature of Soil Taxonomy. This approach is based on the realization that the numberical value of an individual soil parameter is meaningful only in relation to other soil properties and that the effect of a given parameter on soil behavior varies with the taxonomic class of a soil.

The final model must be operational and user-oriented and must allow long term predictions and assessments. To meet these requirements, it must employ minimum data sets that are devoid of non-essential information. This implies, in turn, that the data base must be compiled, analyzed and interpreted in a way that is compatible with the model. If this is assured, computers can perform the complex task of matching crop requirements with the site factors at the transfer location in a fast and sophisticated way. For example, using historical weather data for a 20 year period, a weather simulator can predict 50 years of statistically similar weather. On the basis of this and other site factors critical for a specific land use, the model should be able to predict crop yields, or any other output, and display it as a frequency distribution for a 50 year period. This will allow the user to judge the risk associated with unfavorable weather conditions. It may be of interest to note that present computer technology permits to operate such simulation programs at the speed of one second computer time per crop year, or less than one minute for a 50 year run.

The simulation models will be experimentally validated at IBSNAT collaborator sites and observed discrepancies will provide useful feedback for refining the basic model. It is also planned to test the sensitivity of the model by using only Soil Taxonomy-derived data for various categoric levels. The purpose of that study is to determine how accurate crop performance predictions are if they are based only on the information contained, by definition, in the name of a taxon and on the covariant accessory properties.

D. Information Dissemination

As this aspect will become more important in the later stages of the project, particulars have not been developed at this time. It is clear, however, that all of the data collected at the IBSNAT sites will, with the permission of the responsible institution, be available to other members of the network. It is also intended to develop a user-friendly query-response interface program for minicomputers through which the data base and computing capacity of a mainframe computer can be accessed.

E. Symposium on Minimum Data Sets for Agrotechnology Transfer

IBSNAT's first major activity will be an international symposium on "Minimum Data Sets for Agrotechnology Transfer". This symposium is co-sponsored by ICRISAT, IBSNAT and the Soil Management Support Services (SMSS) of the USDA and will be held at ICRISAT in Hyderabad, India, from 21 to 26 March 1983. Participants at the symposium will be mainly the data generators representing the agricultural research centers collaborating with IBSNAT and data managers. The purpose of the symposium is to reach a consensus among the collaborating institutions, agencies and organizations regarding the crops to be studied, the kind and design of the field experiments to be conducted, the nature and magnitude of the soil, weather, management, and crop phenological data to be collected and to discuss data processing, analysis and interpretation, and dissemination of information.

The symposium will provide a forum for the participants to create a network that functions for the mutual benefit of all collaborating institutions. It will also allow the collaborators to actively participate in the planning and design of IBSNAT. The ICRISAT symposium will be the first in a series of meetings designed to convene the collaborators periodically to report progress on attainment of network objectives and to plan future work.

V. IBSNAT LINKAGES

By intent and design, IBSNAT depends heavily on the cooperation of experts in many fields and efforts will therefore be made to enlist the best available individual talents and institutions in this joint endeavor.

IBSNAT will be able to draw on the expertise and institutional capabilities of other AID-supported projects, notably the Soil Management Support Services of the USDA Soil Conservation Service and such programs as the Soil Management Collaborative Research Support Program (CRSP) or TROPSOIL, the Nitrogen Fixation by Tropical Agricultural Legumes project (NIFTAL), and the International Soybean Program (INTSOY).

Mutually beneficial linkages are anticipated with FAO, the International Fertilizer Development Center, the National Oceanic and Atmospheric Administration of the U.S. Department of Commerce, the Foreign Agricultural Service of the USDA, the Federal Institute for Geosciences and Natural Resources of West Germany, and others.

VI. CONCLUSION

IBSNAT's main premise is that agrotechnology transfer can be achieved by simulating the performance of cultivars and management practices at the transfer site. To demonstrate the feasibility of this approach, IBSNAT will consolidate a cluster of national and international agricultural research centers into a prototype network for the

purpose of developing, testing and utilizing a scientific methodology for the effective transfer of agrotechnology that is based on a systems approach and computer simulation techniques.

While simulation models have long been considered the conceptually best approach, various constraints have prevented their use in the past. Advances in crop modelling, however, coupled with advances in computer technology, now make such an approach entirely feasible. Huge amounts of data can now be processed quickly and translated in a purposeful way into user-oriented formats.

At the end of the nine-year project, the prototype IBSNAT network should transform into expanding and self-sustaining networks. At that time, each participating country should have the capability to screen large numbers of technologies and cultivars relative to their suitability for transfer to various agroecological zones of the country. The screening of technologies and cultivars by computer simulation cannot replace field research, but it enables the user to identify the technologies which, through a minimum of adaptive research, can be tailored to local conditions with a high probability of success.

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LAND EVALUATION FOR LAND USE PLANNING: PRINCIPLES AND CONCEPTS

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Introduction

As more demands are made on the use of the land for specified purposes, land use planning becomes more than ever an important function. One of the processes in determining the suitability of land in land use planning is land evaluation. The purpose of this paper is to describe the principles and concepts of land evaluation in relation to land use planning.

Land evaluation, according to FAO (1976), is defined as, "the process of assessment of land performance when used for specified purposes, involving the execution and interpretation of surveys and studies of landforms, soils, vegetation, climate and other aspects of land in order to identify and make a comparison of promising kinds of land use in terms applicable to the objectives of the evaluation".

Some of the aims in land evaluation, furthermore, are to study or to determine (1) how the land is used currently and how its management can be improved; (2) what are the alternative uses of the land, uses which are economically and socially relevant with sustained production or benefits; and (3) what recurrent and non-recurrent inputs are necessary in the land use and what are the outputs or benefits.

Principles

Certain principles are recognized in land evaluation. As listed by FAO (1976), these principles are :

1. Land suitability is assessed and classified with respect to specified kinds of uses.

This principle recognizes that a given land use has specified requirements and that land suitability is related to the characteristics or qualities of the land. An alluvial floodplain with impeded drainage is cited as possibly being highly suitable for rice cultivation but not so for many other kinds of agriculture. In the Netherlands, the peat areas are suited for pasture but not for orchards, and in lands devoted to orchards, in certain areas with high water table, pears may be more suited than apples because the former appears to be more tolerant of the wetter soil environment.

2. Evaluation requires a comparison of the benefits obtained and the inputs needed on different types of land.

Suitability for a specified use requires the comparison of the required inputs with the outputs in terms of yield or benefits. For example, in comparing the different types of the land, the highest yield may not necessarily denote the best suitability because net labor productivity must also be considered.

3. A multidisciplinary approach is required.

Land evaluation includes some form of socio-economic considerations. Thus, depending on the nature and extent of participation, a land use feasibility team, for example, should include not only the soil scientist, agronomist, or others in the physical and biological science, but also the economist and the sociologist.

4. Evaluation is made in terms relevant to the physical, economic, and social context of the area concerned.

In addition to the physical environment such as climate, factors such as the availability of capital, availability and cost of labor, standard of living, and nearness to market must be considered. Again, the "Framework" (FAO, 1976) cites as an example how non-mechanized rice cultivation requiring large amounts of low-cost

labor can be unrealistic in a country with high labor costs.

5. Suitability refers to use on a sustained basis.

This principle is associated with land use and its impact on environment. Immediate benefits of land use should carefully be weighed against long term land degradation such as those brought about by soil erosion or soil toxicity.

6. Evaluation involves comparison of more than a single kind of use.

Comparison of alternative uses of land, of farming systems, or between crops is made to determine suitability. Such comparison is necessary to recognize the more beneficial use of the land.

Levels of Intensity and Approaches

The activities and methods of land evaluation are related to the intensity of the survey and to the approaches of evaluation. The three levels of intensity of survey are reconnaissance, semi-detailed, and detailed, and they go from the broad inventory of resources and development possibilities at regional and national scales for planning purposes to the detailed planning and design or advice of projects with more economic considerations. The approach in land evaluation is either the two-stage or the parallel approach. In the former, qualitative land evaluation, the first stage, is followed by quantitative economic and social analysis, the second stage. In the latter approach, physical land evaluation goes concurrently with the economic and social analysis. Of the two approaches, the two-stage approach appears to be more common.

Basic Concepts

The main concept in land evaluation is to match the requirements of land use with the qualities of the land. To understand this concept more fully, the following discussion is made.

According to Beek (1979), land evaluation is a study of the land use system, and this land use system, in turn, is a study of two components : (1) the kinds of land use in relation to (2) the land mapping unit.

In reference to the first component, land use can be described in either a major or a detailed way. Major kinds of land use are associated with qualitative or reconnaissance land evaluation studies, while the detailed kinds, called land utilization types, are those associated with quantitative studies. An example of a major kind of land use is "rainfed agriculture" or "irrigated agriculture". An example of a land utilization type is "irrigated field maize, with moderate capital resources, with moderate to high labor intensity, using small to moderate-size, power-operated machinery, applying high technology and maintaining near-optimum management of fertilization, drip-irrigation, control of weeds, pests, and disease, and control of land degradation, and located on an experiment station of 2 to 5 ha with easy accessibility to water, power, and labor source". An example of the crop requirement associated with the above land utilization type is shown in Tables 1 and 2.

The major kind of land use, therefore, is only a generalized description, while the land utilization type is a precise definition with specific requirements of land use. As illustrated, some of the key attributes of these requirements are the kind of produce or goods, intensity of capital or labor, kind of technology used, scale of management or operation, and so on.

The second component of the land use system is the land mapping unit, and associated with this unit are land characteristics and land qualities. The basic unit under study, therefore, is the land and it includes not only soils but also climate, vegetation, relief, hydrology, and other land-related factors.

Land characteristics include the soil properties and other features such as slope angle and biomass vegetation. Land qualities,

on the other hand, are the result of the interactions of two or more land characteristics. Some examples of land qualities that are related to crop productivity are moisture availability, nutrient availability, such as phosphorus availability, oxygen availability in the root zone, and workability of the land. For phosphorus availability, examples of interacting characteristics are soil pH, amount of kind of soil minerals, availability of native phosphorus, and so on.

Finally, the method of land evaluation is relating the specified types of land use, the land utilization type, to the land mapping units. The use requirements of the land utilization types are compared or matched with the land characteristics and the land qualities of the land mapping units. A land suitability classification is then derived to show the assessment of a given land for a defined use based on present condition or after improvements.

Summary

The term land evaluation has been defined and the principles and concepts of land evaluation have been presented. In land evaluation, assessment is made of the performance of the land when used for specified purposes. The system of land evaluation is the land use system which is a study of the land utilization type in relation to the land mapping unit and the evaluation is the matching of the requirements of the land use with the qualities of the land. Land suitability is then determined when the land qualities of the land mapping unit are used to meet the requirements of the specified types of land use as described by the land utilization type.

Table 1. Some Requirements of Maize (Rainfed Cultivation).

Requirements	Optimum	Marginal	Range
Slope (percent)	0 - 8	8 - 15	
Soil depth (cm)	50	10 - 50	
Soil Drainage class	moderately well drained to well drained	-	imperfectly drained to somewhat excessively drained
Soil Texture class	silt loam to clay loam	-	sandy loam to montmorillonitic clay
Inherent fertility level	-	moderate	-
Salinity (mho/cm)	0 - 4	4 - 6	-
pH (1:2.5)	5.5 - 8.2	-	5.2 - 8.5
$CaCO_3$ (percent)	0 - 15	15 - 25	-
Gypsum (percent)	0 - 0.2	0.2 - 2.0	-

Source : Prepared from Report on the Agro-ecological Zones Project, Vol.1, Methodology and Results for Africa (FAO, 1978, Table 4.1).

Table 2. Photosynthesis Characteristics and Other Information of Maize.

Characteristics	Crop Adaptability	
	Group III	Group IV
Photosynthesis pathway	C_4	C_4
Temperature response of photosynthesis :		
Optimum temperature	30 - 35°C	20 - 30°C
Operative range	15 - 45°C	10 - 35°C
Radiation intensity at maximum photosynthesis	1.0 - 1.4 cal $cm^{-2}min^{-1}$	
Maximum net rate of CO_2 exchange at light saturation	70 - 100 mg $dm^{-2}h^{-1}$	
Maximum crop growth rate	30 - 60 g $m^{-2}day^{-1}$	40 - 60 $gm^{-2}day^{-1}$
Water use efficiency		
Days to maturity/growing period		
Early cultivar	80 - 100	110 - 130
Medium cultivar	110 - 130	140 - 160
Late cultivar	-	170 - 200
Grain formation period	Last third period in crop's life	
Photoperiodic sensitivity of flowering	Day neutral	
Major climatic division for rainfed production	Tropical lowland, humid and seasonally arid, altitude of less than 1,500 m; sub-tropical, summer rainfall, warm growing period with mean temperature 20°C.	Temperate; tropical highland, altitude of more than 1,500 m; sub-tropical, summer rainfall, cool growing period with mean temperature 20°C.

Source : Prepared from Report on the Agro-ecological Zones Project, Vol. 1, Methodology and Results for Africa (FAO, 1978, Tables 3.3 and 3.4).

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CHARACTERISTICS AND POTENTIAL PRODUCTIVITIES OF SOME MAJOR CASSAVA SOIL IN THAILAND

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As a world crop, cassava ranks sixth in importance. The exact center of origin is not known but is often ascribed to the Brazilian Amazon region. Archaeological evidence has shown that it was grown by pre Inca civilizations some 4,000 years ago. However, it was only about 300 years ago that it was introduced to Africa, and more recently into Asia. In Thailand, cassava had been first introduced from Indonesia and thereafter from Malaysia. The original planting areas were in Rayong and Cholburi provinces in which cassava has been cultivated continuously for more than 30 years. However, as recognition as being a promising crop, more recently, this plant has migrated and is grown almost throughout the country.

In the tropics, cassava has come to be regarded as the fourth most important crop which produces enormous energy, staple food and income for 750 million people. In 1980, the total production was estimated at 122 million tons with 38 percent of production in Africa, 36 percent in Asia and 26 percent in America. Among about 90 countries which cultivated this crop, six leading producers are Brazil Indonesia, Nigeria, Zaire, Thailand and India (table 1). Except Thailand which exports most of its production to Europe, generally, most of the global tonnage of this starchy root are locally consumed as human food. Recently, demand for use as a source of substrate for

producing fuel alcohol has grown remarkably. High potential use for industrial purposes has aroused great interest during the past few years.

Botanically, taxonomists classify cassava (Manihot esculenta Crantz) into Family Euphorbiaceae, Subdivision Angiospermae, Class Dicotyledonae and Order geraniales. This shrubby perennial species possess high adaptibility to grow under a large diversification of soils and climates. Cassava has been grown in areas between latitudes 30°N and 30°S and on land elevation from seas level to as high as 2,000 meter above sea level. It can be grown on any area where the atmospheric temperature and amount fo annual rainfall are in the range of 10-35°C and 500-5000 millimeters respectively. Furthermore, this crop also possess high adaptability to grow on a wide range of soil pH, i.e, within the pH values from 4 to 8. However, cassava does not perform well on saline soils, gravelly or stony soils and also on poorly drained soils.

In spite of being long forgotten crop of the tropics, cassava has until very recently been recognized as a sort of botanic marvel. The miracle of this crop for subsistence farmers is its highly efficient carbohydrate production under harsh conditions. This crop can grow and sustain in poor soils while many other staple crops do not. In addition, as compare to many other crop species, cassava appears to be more tolerant to drought and insect pests. All of such the marvellous advantages are most suited to poor farmers. Especially to those who live on poor, exhausted soils which are located under erratic rainfall areas. Besides, most subsistence farmers could hardly efford to obtain chemical fertilizers and pesticides for their selected crops. Under such of the most trying circumstances, cassava is the better choice.

In Thailand, cassava has been recently established as one of the most important commercial crop. As shown in table 2, the exported values of cassava products in year 1980 was accounted for the second largest as compared to other four main economic crops. Regarding the

acreage and production, except in year 1979, total production of fresh root as well as the total planted area has been increased gradually from year 1976 to 1981 (table 3). The total productions were increased from 10.2 to 17.7 million tons whereas planted areas were raised from .69 to 1.27 million hectare. In year 1981, the distribution of total acreage under cassava as well as the production by regions are given in table 4. As seen, the bulk of cassava growing areas of the country are located in the northeast and the southeast. In the northeast alone, about 758,000 hectares which accounted for nearly 60 percent of the total acreage of this crop are under cassava. Moreover, planted areas and production from these two regions accounted for 90 and 89 percent of total respectively. Regarding the distribution by province and the inhabitants involved, it has been reported that areas of field soils under cassava has been found in 33 provinces. The population which is involved in this sort of farming has been estimated at about 8 millions or about 17 percent out of the toal population of the country.

Important Factors Affecting Growth and Yields.

According to the results obtained from numerous studies, it is obvious that from amongst the factors influencing cassava growth and yield, amount and distribution of rain, weeds and soil fertility are likely to be the most important. Problems with the amount and distribution of rain however, are not as severe as one would expect, fortunately this is because most farmers start planting cassava at the beginning of the rainy season or otherwise adjust their planting scheme properly. Besides, it so happens that this crop is quite tolerant to drought. Problems with rainfall, therefore, seem to be reduced to a certain extent.

As has already been mentioned, weed competition in cassava is very detrimental to cassava. Especially during the early stages of plant growth before it has formed a closed canopy. For a normal cassava plant, a closed canopy could be fully form within 2-3 months after

planting. Therefore, the fundamental principle involved in weed control in cassava is to keep the field free of weeds for the first 3 months after planting. To give one example on the suppressing effect of weed infestation, data obtained by Duangpatra in 1982 (table 6) demonstrated that in either fertilized or unfertilized soils, by average, controlling weeds during the first 4 months after planting resulted in an increase in fresh root yield in as much as about 500 percent. Existed evidences as such indicated that without weed elimination, cassava growing is not worth the risk.

The last prime factor which markedly influences cassava growth and yield is the fertility of soil as a natural growth medium. Generally, in the case of Thailand, numerous studies indicate that most soils under cassava are poor in its native fertility. Most cassava soils are light in its texture and also highly erodible (Figure 3). Regardless of climatic influences, such light texture and easily erodible soils more or less resulted in the existence of large variation in production stability of cassava fields in the bulk of the growing area (Figure 2). More discussions on the characteristics of some important cassava soils in Thailand will be made in the later part. Nutrient requirements of cassava.

Unlike many other crop species, one unique characteristic of cassava that makes it most suitable to subsistence farmers is its adaptability to grow and produce some acceptable amount of edible roots in poor, exhausted soils. Apparently, poor soils in this sense mean any soil which is low in plant nutrients. The high ability of cassava to sustain its growth in low fertility soils is dependent on the genetic adjustability to maintain the proper balance between the amount of dry plant weight and the average nutrient concentrations in the total plant. As a matter of fact, the total nutrient requirements for any crop depends on the total dry weight of the plant and the average concentration of that nutrient element throughout the plant needed to secure that yield. Under certain conditions, the total requirements for any nutrient element vary with the level of yield

which is affected by limited environmental growth factors or interacting factors. Under favorable conditions, total nutrient requirements rise in order to secure a higher yield. On the contrary, poor growth affected by any factor or stress factors also limit nutrient requirements.

Generally, the level of nutrient concentrations in cassava vary with plant parts and growth stages. According to data in the literature, nutrient concentrations in several parts of plant at 2-5 months of age is shown in table 7. As seen, it is noted that the highest concentrations ranges of each elements found in various plant parts are as follows i.e., N in leaves, P in stem and K, Ca and Mg in the petioles. Comparatively, it is noted that all nutrient concentrations in roots are at the lowest range. Such evidences indicated that at this growth stage, plant parts above ground need large amount of nutrients for active top growth. As such, for more effective use of fertilizers, high requirement for N, K, Ca from among all essential macronutrients and Fe, Mn, Zn from among five minor elements has to be taken into considerations.

In addition to different levels of nutrient concentrations in various plant parts, data given by Asher (1980) on the total nutrient requirement of cassava plant are also shown in table 8 and 9. As seen in table 8, the approximate amounts of each element required to produce a 30 tons per hectare of root harvest is in the order of K $>$ N $>$ Ca $>$ P, Mg $>$ S for micro-elements and Fe $>$ Mn, Zn $>$ B and Cu for micro-elements. From such, it is evident that, cassava has a relatively large requirement for K and N whereas the requirement for P is much less. The amount of uptake for Fe is also high as compare to other micronutrients on the list. Such approximate values for total N and K uptake however, is appreciably high as compared to data obtained by Sittibusaya and Saitapakdee (1975) (table 9) in which under six different field soils, N, P and K removal accounted for only 73, 31 and 72 kg/ha respectively. Indeed, differences in the amount taken up is depend largely on variety, the fertility status of soil and also the

amount of dry matter accumulations in the plant.

Being one of the most important economic crops, cassava has long been blamed as being a lousy crop by sucking out large quantity of soil nutrients and thus brought about rapid depletion in the fertility of land. However, experimental evidences indicates that nutrient removal by cassava is not as high as those occur with most of all other important crops. As shown in table 10 in one example, at normal average yield per hectare, cassava appears to remove less N (30.2 kg/ha) and P (6.1 kg/ha) than those of rice, corn and sugar cane. On the contrary however, it is also seen that cassava remove K in relatively plentiful quantity i.e about 3 to 6 times higher than those of corn and rice respectively. Cassava therefore, may be regarded as a monster which robs large amounts of K from the soil. But it is not justifable however, to condemn this crop as to cause the immense decline in N and P fertility of the soils. Instead, it has much ample reasons to imply that the most severe casualties which result in marked exhaustion of soil fertility is its severe erosion that occurs year after year without appropriate protection measure. Illustration in figure 2 fairly well support the foregoing statement. As a matter of fact, it is not uncommon that any crop that yields well particularly on unfertilized poor soil, will deplete the nutrient reserves in that soil. To maintain the productivity, appropriate soil and fertilizer management has to be done.

Distribution and Characteristics of Cassava Soils.

From a total area of upland soil which has been estimated at about 38 million hectares, total acreage of land suitable for growing upland crops accounts for about 15 million hectares. From this bulk of land, most varieties of field crops including cassava have been grown by the majority of farmers who live on soils existing on middle to high terrace landforms. According to Monchareon*, it has been been reported that from this 15 million hectares of land, approximately

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*Lek Monchareon, Soil Survey Division, Department of Land Development, Personal Communications.

0.8, 2.9 and 11.3 millions hectares has been estimated to class into sandy, clayey and loamy soils respectively. From this, it is seen that the most suitable upland soils are light in texture and consequently, possess good drainage properties in most areas where it is found.

Base on the U.S. Soil Taxonomy System, most cassava soils in Thailand has been found to belong to 4 orders namely the Ultisols Entisols, Inceptisols, and the Oxisols, Among these, the Ultisols are by far the most predominate. By estimation, from a total of 15 million hectares, only 4 phases of the Ultisol great group, namely the loamy Paleustults, clayey Paleustults, loamy Haplustults and clayey Haplustults occupy about 8.5 million hectares or account for about 56.8 percent. Generally, 7 great groups of soils have been found to exist in the cassava regions namely the Paleustults, Plinthustults, Haplustults, Haplustox, Rhodustults, Dystropept and Quartzipsamments.

The most common soils under cassava in the northeast are Korat, Warin, Yasothon and Satuk soil series. Among these, Korat soil series is by far the most predominant, being represented in as much as about 80 percent of the total acreage, (table 11). These four soils have similar epipedon characteristics . The only soil property which seperates these soil series, is the color of the sub-soils. Generally, these deep profile soils have sandy loam surfaces and sandy clay loam sub-soil texture. Some other characteristics are; strong to slight acidity, moderate to well drained and relatively low native fertility.

In the southeast, important soil series which occupy vast areas are the Pattaya, Sattahip, Mapbon and Huaipong series. Among these, Sattahip soil series occupies the highest acreage (46.1 %) follow by Huaipong (28.3 %), Mapbon (22.3 %) and Pattaya (3.3 %) (table 12). These soils have somewhat different profile textures. The Pattaya series has a sandy texture whereas Sattahip and Mapbon series have a generally sandy loam or even sandy clay loam texture.

Generally, these three Entisol soils show little or no profile development. Drainage classes vary from moderately well-drained to excessively drained. Some other characteristics are slightly acid soil and very low to low plant nutrient availabilities. For Huaipong soil series, the following characteristics are observed, the texture varies from sandy clay loam to sandy clay, well-drained, medium to slightly acid and the general fertility is better than the other two series by being more productive as indicated by soil test values and also by crop performances.

General physical and chemical properties of some major cassava soil series existed in most provinces in the northeast and southeast, data was obtained from the Soil Survey Division, DLD and has been modified by extracting and recondensing it into tabulated form as shown in table 13. Although data of this type can be notoriously unreliable, general range means obtained give some broaded ideas. By considerations with the data given in table 14, it is observed that most cassava soils are characteristically low in organic matter contents, in available P and also contain low to medium levels of an available K. Apparently, this data tends to show that cassava soils exist in the majority of provinces in each region and are poor in native fertility. Being generally sandy in texture and also low in the cation exchange capacity values, as such, native or applied nutrients could not be retain long in these soils. For Huaipong soil however, it is seen that the general fertility is relatively higher than the other soils. This soil contains medium levels of organic matter, medium levels of available P and K and also possess greater capacity to retain nutrients as indicated by the CEC values. This is probably due to the higher content of clay & clay mineralogy.

Fertilizations and Management of Cassava Soils.

As has already been indicated, most soils of the cassava region are relatively non fertile especially with respect to the availability fo primary nutrients. Under such conditions, the use of fertilizer to obtain high yields is essential, particularly when the

value of cassava roots are attractive. However, precise fertilizations is not depend solely on the nature of soil itself. In fact, several other factors are involved such as climate; plant cultivars, cultural practices and also the technical know how of the user.

Since 1954, numerous fertilizer trials has been carried out in either farmers'fields or in the regional research stations. Presently, after almost 30 years of experimentations, hundred of well documented results give some similar highlights i.e. cassava grown on most field soils showed large response to nitrogen fertilizers.generally, the response to this nutrient is invariably high especially in sandy quartzipsamments soils whereas the response in the soils of the Ultisol great groups are slightly lower. In most soils, in comparing to that of N, the response to P and K are appreciably smaller in which the magnitudes of response to all these three primary elements are in the order of N>P>K. In fact, the response to P and K are not consistent and frequent lack of response is observed even in soils of low soil test values. In spite of rainfall which markedly influences the nitrogen response, studies suggest that the response to P and K has been largely dependent on the contents of these elements in the soils. Consequently, well correlated soil test values then could be used to predict the status of P and K availabilities in particular soils.

To look into some of the experimental results, data given in tables 15 to 20 demonstrate the individual responses of cassava to levels of applied fertilizers in different soils. As seen in the tables, it is evident that the maximum yield obtained are variable with soils and rates of each nutrient added. As shown in tables 15, 17 and 19, maximum yields were obtained from applying N, P_2O_5 and K_2O at the rates of 150, 100 and 200 kg/ha respectively. Doses of added fertilizers which give maximum response however, are much lower. As seen in tables 16, 18 and 20, the maximum response in term of yield increase per unit of applied nutrient are 50, 50 and 50 to 100 kilograms

of N, P_2O_5 and K_2O per hectare respectively. The results obtained therefore reveal that any fertilizer rate which produces the highest yield does not necessarily give the maximum responses. Additionally, data present in tables 15 to 20 also suggested that, in most cases, the magnitude of responses to applied fertilizers in 4 soils are similar. In other words, fertilizer rates suitable for any soil series would be also applicable to all other soil series especially for those soils of similar surface texture. Apparently therefore, fertilizer recommendations would be probably applicable not only for individual soils, but also for group of soils of similar characteristics. Regarding this prospect, more intensive research needs to be done.

For cassava income, since maximum net profit, in this case, is largely dependent on the fertilizer cost to product price ratio, practically therefore, the optimum rates for fertilizer recommendations should be considered on the basis of the economical point of view. Presently, in Thailand the official rates of fertilizer recommended by the Fertilizer Board Committee, Ministry of Agriculture and Cooperatives are based and separated by two groups of soil textural class. The first group, for sandy to sandy loam soils, low and high recommended rates are 94-94-94 and 188-188-188 kg/ha of N-P_2O_5- K_2O respectively. For the second group, 50-50-50 and 94-94-94 kg/ha of N-P_2O_5- K_2O has been recommended for sandy loam to sandy clay loam soils.

In Thailand, after long and intensive studies, it has been suggested that the best time to apply fertilizers to cassava is to split the application by applying the first half at planting time and the another half at about 1 to 2 months after planting. For the application methods, it has been recommended that the fertilizer materials be placed locally near each plant stand and cultivate it into the soil few inches deep. Generally at planting time, fertilizer broadcasting for cassava is not recommended. Being a wide row spacing plant, broadcasting fertilizer materials would create severe weed problems, especially the infestation of weed between the plant stands.

Very little information exists as to the best mixed fertilizers grades to apply to cassava. As known, different grades of mixed fertilizers contain unequal amounts and ratios of plant nutrients. When applied to soil, the differences in such, may more or less, influence cassava growth and yields. In two consecutive trials conducted by Duangpatra during crop years 1981 to 1982 (table 21), it was observed that from among four grades of mixed fertilizer used, generally, the impact of fertilizer sources on root yields were not large. Regardless of soil type however, the overall average values tend to suggest that fertilizer grades which contain relatively high N proportions seemed to perform better than the fertilizer grades which contain lower N contents. On the contrary, the variations in the amount of P and K present in mixed fertilizers are not of considerable importance. Apparently, from these experiments, the ratio of each of N, P and K in mixed fertilizers suitable for cassava seem to be in the order of N > K > P. To confirm this however, more intensive investigations have to be carried out.

Eventhough cassava grown on soils of similar characteristics show similar trends of response to fertilization, the magnitude of response in different soils or even in soils of similar surface textures are varied as shown in table 22. As seen, it was noted that two soil series belonging to the great group Quartzipsamments namely the Sattahip and Pattaya series showed very high response to fertilization. The response in other soils however, are much lower. Apparently, the evidence as such seems to indicated that, at least, the two Ultisol soil series namely Warin and Korat are more fertile than those of the Quartzipsamment soils as indicated by percent and rank of response.

As has already been indicated, most cassava soils are light and or even loose in its texture. Such properties create some problems in that such soils possess low capacity to retain nutrients. Besides, as most cassava soils are light and are found on hilly land, the prime causes of the soil fertility depletion is the severe loss of soil mass,

particularly by sheet erosion and also by clay shift.

To improve the productivity of these exhausted cassava soils as well as to get good crop yields, appropriate management of soils and plants should be practiced. According to Sittibusaya (1980), the following measures has been suggested;

1. Avoid planting cassava on too steep of slopes. If planting has to be done. It is suggested to plant cassava along the contour lines or in otherwords, planting against the slope.

2. It is recommended that for every another year at least, any type of annual legume plant, preferably of some economical importance, be intercropped between cassava rows. At maturity, legume plant residues should be incorporated into the soil.

3. To fertilize the soils, the quantity of applied fertilizers should be based on either the official recommendations or the fertility status of the soils and also the climatic conditions. Generally, high levels of complete mixed fertilizers (94-94-94 kg/ha of N-P_2O_5- K_2O) is recommended, especially in soils which have been cultivated with cassava for long periods without fertilization. In more fertile soils, only half of that dose is required.

4. At harvest, it is suggested that only roots be removed and taken away from the field. There after, the remaining plant tops and residue should be ploughed into the soil.

5. Planting operations should be timed properly, especially when the soils have adequate moisture. Good germinations of cuttings in the first stages is a very important start for a sucessful cassava crop.

6. Weeds should be eliminated especially during the first 3 months after planting. Without this, cassava growing is not profitable.

7. After 3 to 4 years of continuous cropping, soil samples have to be properly collected for chemical anlaysis. Actually, rates of fertilizer used during the previous years may have to be change due to the residual accumulations of an applied fertilizers.

In addition to the foregoing, it is also recommended that any forms of organic fertilizers such as manures or compost be applied solely or together with chemical fertilizers. For a long run, the influence of added composts or manures would be of some benefit to cassava. Some data on the results which support the said statement are given in table 23.

SUMMARY

As a staple crop, cassava (Manihot esculenta Crantz) has been grown in about 90 countries and apparently could be regarded as one of the most important food crops in the world. In Thailand this crop has been grown in almost every region and the commercial importance is second only to rice.

Prime factors which affect cassava growth and yield are moisture, weeds and the fertility of the soil. Among these, weeds and the soil fertility problems are among the most important. Regarding the nutrient requirements, it has been realized that cassava needs large amounts of N and K. However the uptake of nutrients is not as high as to condemn this plant as being a soil depleting crop. In fact, the prime cause of soil fertility exhaustions is the enormous loss of soil mass that occurs mainly by sheet erosion and also by clay shift.

Generally, most cassava soils can be classified into two orders namely the Ultisol and the Entisol. Among these, the Ultisol soils are by far the most predominant. At the lower categories, most great groups of soils under cassava are the Paleustults and the Quartzipsamments. Soil series most common to cassava regions are Korat, Yasothon, Warin, Huaipong, Sattahip and Pattaya.

As most cassava soils are light in texture and also low in fertility, for a good cassava crop, fertilizer has to be applied to these soils. Generally, it has been observed that from among all primary nutrients, nitrogen has been found to be the most deficient.

To improve the productivity of the soils as well as to get a good cassava crop, Appropriate management of soils and plants should be practiced.

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Table 1. World production of cassava in 1980.

Country	Area (x 1000 ha)	Production million tons	Production % of total	Yield (t/ha)
Brazil	2,056	24.5	20.1	11.9
Thailand	1,015	13.5	11.1	13.3
Indonesia	1,420	13.3	10.9	9.7
Zaire	1,880	12.5	10.2	6.6
Nigeria	1,200	11.0	9.0	9.2
India	370	6.5	5.3	17.6
Tanzania	940	4.6	3.8	4.9
Viet-Nam	480	4.0	3.3	8.3
33 Countries in Africa Producing less than 4 million tons	3,247	18.7	15.3	5.7
N. C America	160	1.0	0.8	6.4
9 Countries in South America Producing less than 4 million tons	554	6.0	4.9	10.8
10 Countries in Asia Producing less than 4 million tons	556	6.3	5.1	11.3
Oceania	20	.22	0.2	11.1
Total	13,925	122.1		

Source : FAO Production Yearbook, 1980.

Table 2. Planted area, production and exported values of some major crops of Thailand, year 1980.

Crops	Planted area (million hectare)	Production (million ton)	Exported value (million Baht)
Rice	9.61	17.4	19,508
Cassava	1.16	16.5	14,796
Sugar-cane	.47	19.8	2,975
Maize	1.43	3.0	7,201
Rubber	1.54	.46	12,351

Source : Office of Agricultural Economics, Agricultural Statistics No. 150.

Table 3. Planted area, production and average yield of cassava in Thailand, year 1976-1981.

Year	Planted area (million hectare)	Production (million ton)	Average Yield (t/ha)
1976	.69	10.2	14.8
1977	.85	11.8	13.9
1978	1.16	16.4	14.1
1979	.84	11.1	13.2
1980	1.16	16.5	14.2
1981	1.27	17.7	13.9
Average	.99	13.9	14.0

Source : Office of Agricultural Economics, Agricultural Statistics No. 150.

Table 4. Planted area, production and average yield of cassava by regions in Thailand, crop year 1981.

Region	Planted area (1,000 hectare)	Production (1,000 ton)		Average Yield (t/ha)
North	47	708		15.1
Northeast	758	10,045		13.2
Central	15	220		14.9
West	59	962		16.3
Southeast	391	5,808		14.8
South	-	-		-
Total	1,270	17,744	Average	13.9

Source : Center for Agricultural Statistics, Office of Agricultural Economics, Report No. 160/1981.

Table 5. Climatological data for 10 provinces in the Northeast* and all provinces in the Southeast of Thailand (Average of 30 years from 1951-1980).

Region	Province	Mean Rainy Day Per year	Mean Rainfall (mm./year)	Mean Temperature (°C)
Northeast	Nong Khai	122	1628	26.3
	Loei	131	1236	25.8
	Udon Thani	121	1496	26.1
	Sakon Nakhon	125	1498	26.5
	Mookdaharn	119	1524	26.6
	Khon Kaen	107	1197	27.0
	Roi Et	107	1408	27.0
	Ubon Ratchathani	124	1588	27.0
	Surin	120	1298	27.2
	Chaiyaphum	106	1218	27.4
	Nakhon Ratchasima	117	1137	26.4
	Range	106-131	1137-1628	25.8-27.4
	Mean	120	1384	26.7
Southeast	Prachin Buri	140	1997	28.4
	Chachoengsao	75	1307	27.9
	Chonburi	128	1348	27.9
	Rayong (Sattahip)	103	1917	27.9
	Chanthaburi	171	2977	26.5
	Trat	122	3862	27.3
	Range	75-171	1307-3862	26.5-28.4
	Mean	123	2235	27.6

*Northeast comprises 17 provinces.

Source : Soil Survey Division, Department of Land Development.

Table 6. Influence of weed infestations and fertilizer rates on the fresh root weight of cassava grown on Sattahip soil series, Chonburi province, Wet season, 1981, (Duangpatra, 1982).

Rates of Mixed Fertilizer grade 15-15-15 (kg./ha)	Fresh Root Weight (t/ha) 1/ Wo	2/ Wh	3/ Wh+c	Average	Relative Yield (%)
0	2.4	17.8	13.9	11.4	100
625	4.6	26.4	28.7	19.9	175
1250	7.9	33.8	32.5	24.7	217
Average	4.96	26.0	52.0		
Relative Yield (%)	100	524	505		

1/ No weed control

2/ Handweeded

3/ Handweeded + Chemical treatments

Table 7. Critical levels in upper leaves and nutrient levels of several plant parts of the cassava (Howeler, 1978)

Element	Upper leaves Range	Upper leaves Critical level*	Lower leaves	Petioles	Stems	Roots**
	- % -		- % -	- % -	- % -	- % -
N	5-6	5.7	5	1.2-2	.6	.25-.7
P	.3-.5	.4	.2-.3	.12-.2	.35-.5	.08-.12
K	1.2-2		.7	1.5-3.0	1-2	.5-1
Ca	.6-1.5		1.4	1.5-3.0	.4-.8	.05-.12
Mg	.25-.5		.15-.4	.3-.5	.15-.4	.13-.14
S	.3-.4	.32		.13-.15		
	µgm/g	µgm/g	µgm/g		µgm/g	µgm/g
B	15-15					
Cu	6-12					2-10
Fe	60-200				45	25-400
Mn	50-500		500-1000			
Zn	40-100	35-50				10-60

*Uppermost fully expanded leaf blades of cassava of 2-5 months of age

** Roots with peel

Table 8. Approximate amounts of each element required to produce a thirty tonnes/ha crop of cassava (Asher *et al* 1980)

Macronutrients	Total amounts required for a 30 t/ha Root harvest (kg)				
	Roots	Stems	Leaves	Petioles	Total
K	76	76	23	25	200
N	38	30	81	15	164
Ca	9	28	19	24	80
P	10	15	5	1	31
Mg	9	10	7	5	31
S	6	-	6	1	13
Micronutrients*					
Fe					3.6
Mn					1.35
Zn					1.35
B					.45
Cu					.14

* Calculated from concentrations in total plant

Table 9. Total nutrient uptake of cassava grown on different soil series (Sittibusaya and Saitapakdee, 1975).

Soil series	Yield (t/ha)		Nutrient removal (kg./ha)			
	Top	Roots	N	P	K	Total
Sattahip	18.6	35.3	88.3	50.5	97.3	217.4
Pattaya	13.1	21.5	59.1	36.1	77.2	172.4
Huaipong	27.8	38.2	98.4	19.4	114.2	232.1
Korat	12.9	23.1	56.7	45.9	36.9	139.7
Yasothon	17.2	41.5	77.9	39.6	44.2	162.7
Warin	19.0	30.8	56.1	15.1	62.6	133.8
Average	18.1	31.7	72.7	31.4	72.1	

* Leaves + petioles + stems

Table 10. Nutrients removal of rice, corn, sugar-cane and cassava (Rojanaritpichate, 1976, Sanchez, 1976)

Crop	Yield (t/ha)	Nutrient removal (kg/ha)		
		N	P	K
Rice (grain)	1.5	35.0	7.0	10.0
Corn (grain)	1.98	42.4	7.3	19.3
Sugar-cane (stem)	43.4	85.6	10.4	87.2
Cassava (fresh root)	14.7	30.2	6.1	59.9

Table 11. Acreage of some major soil series for cassava planting in each province in the Northeast (ha)

Province	Soil series				Total
	Korat	Warin	Yasothon	Satuk	
Kalasin	271,578	20,413	17,155	6,239	315,384
Khon Kaen	218,287	3,885	34,942	50,449	307,563
Chaiyaphum	84,804	111,444	9,739	4,833	210,820
Nakhon Phanom	237,094	2,125	-	-	329,214
Nakhon Ratchasima	138,546	151,598	70,039	109,497	469,668
Buri Ram	287,245	12,719	21,624	84,104	405,692
Maha Sarakham	119,108	3,066	4,283	9,617	136,074
Roi Et	225,991	-	2,911	-	228,901
Loei	3,742	-	-	902	4,644
Si Sa Ket	199,372	43	821	4,020	204,257
Sakon Nakhon	281,672	-	503	-	282,175
Surin	193,195	20,403	12,900	15,559	242,156
Nong Khai	37,266	5,663	-	17,083	60,012
Udon Thani	432,280	6,863	21,454	9,675	470,273
Ubon Ratchathani	667,450	438	5,009	-	672,897
Total	3,487,630	338,660	201,380	312,078	4,339,712
% of total*	80.4	7.8	4.6	7.2	

* % of total area of 4 major soil series

Source : Soil Survey Division, Department of Land Development.

Table 12. Acreage of some major soil series for cassava planting in each province in the Southeast (ha).

Province	Soil series				
	Huaipong	Mapbon	Pattaya	Sattahip	Total
Chanthaburi	25,442	-	-	248	25,690
Chonburi	-	16,745	2,649	46,733	66,127
Chachoengsao	-	1,658	-	9,147	10,805
Rayong	17,931	15,824	2,389	14,695	50,839
Trat	146	-	117	-	263
Total	43,519	34,227	5,155	70,823	153,724
% of total*	28.3	22.3	3.3	46.1	

* % of total area of 4 major soil series.

Source : Soil Survey Division, Department of Land Development.

Table 13. Physical and chemical characteristics* of some major cassava surface soils (0-30 cm) in the Northeast and Southeast regions of Thailand.

Region	Soil Series	pH	O.M %	P (ppm)	K (ppm)	B.S %	CEC (me./100g)	Texture	Drainage**
Northeast	Korat	5.0-6.0	0.5-1.0	2-6	20-60	35-75	3-5	Sandy loam	MW
	Yasothon	5.0-6.0	0.5-1.0	2-6	30-60	35-75	2-5	Sandy loam	W
	Warin	4.5-6.5	0.5-1.5	3-10	20-60	35-75	3-5	Sandy loam or Loamy sand	W
	Satuk	4.5-6.5	0.5-1.5	2.5-6	30-90	35-75	2-6	Sandy loam	MW to W
	Range mean	4.8-6.3	0.5-1.3	2.3-7	25-68	35-75	2.5-5.0		
Southeast	Sattahip	5.5-6.5	.5-1.0	4-7	20-60	35-75	2-4	Sand or Sandy clay loam	W
	Mapbon	5.5-6.5	1.0-2.0	4-10	60-80	60-75	2-5	Sandy loam	W
	Huaipong	4.5-6.0	1.5-3.0	10-20	60-80	25-30	3-10	Sandy clay or Sandy clay loam	W
	Pattaya	4.5-5.5	0.3-1.0	3-6	10-40	50-70	2-5	Sand	E
	Range mean	5-6.2	.8-1.8	5.3-10.8	38-65	43-63	2-6		

Source : Modified from data from Soil Survey Division, Department of Land Development.

* The most probable range found in samples collected from the majority of provinces in each region.

** MW = moderately well drained, W = well drained, E = excessively drained.

Table 14. Soil test values and the categories of the fertility levels of cassava soils (Sittibusaya, 1980).

Soil fertility level	Soil test values			
	pH	Organic matter %	Available P (ppm)	Available K (ppm)
Low	<4.9	<1.5	<8	<40
Medium	5.0-5.9	1.6-3.0	9-30	41-100
High	6.0-7.0	> 3.0	>30	>100

Table 15. Fresh root yields* as affected by various levels of applied-N in some major cassava soil series (t/ha) (Sittibusaya et al, 1976)

N-levels (kg./ha)	Soil series				
	Sattahip	Huaipong	Korat	Yasothon	Average
0	16.1	23.8	29.4	28.0	24.3
50	18.9	27.4	36.4	29.5	28.0
100	19.1	27.3	40.2	32.7	29.8
150	19.3	28.8	43.1	31.4	30.7
200	17.8	27.8	42.4	30.8	29.7
Average	18.2	27.0	38.3	30.5	

Table 16. The magnitude of response** in term of kilogram of fresh root yield increase per kilogram of applied N (recalculated from data given in table 15).

N-levels (kg./ha)	Soil series				
	Sattahip	Huaipong	Korat	Yasothon	Average
0	-	-	-	-	-
50	55	71	140	30	74
100	30	34	107	47	55
150	21	33	91	23	42
200	8	20	65	14	27
Average	28.5	39.5	100.8	28.5	

* Underlined means indicated maximum yield.

** Underlined data indicated maximum response.

Table 17. Fresh root yields* as affected by various levels of applied-P in some major cassava soil series (t/ha) (Sittibusaya et al, 1976)

P_2O_5 -levels (kg./ha)	Soil series				
	Sattahip	Huaipong	Korat	Yasothon	Average
0	17.0	22.4	37.0	25.9	25.6
50	18.6	27.9	39.1	30.6	29.0
100	19.3	29.3	38.5	31.5	29.7
150	17.9	28.4	38.2	33.9	29.6
Average	18.2	27.0	38.2	30.5	

Table 18. The magnitude of response** in term of kilogram of fresh root yield increase per kilogram of applied P_2O_5 (recalculated from data given in table 17).

P_2O_5 - levels (kg./ha)	Soil series				
	Sattahip	Huaipong	Korat	Yasothon	Average
0	-	-	-	-	-
50	31	110	35	93	67
100	23	69	11	55	39
150	6	5	5	53	17
Average	20	61	17	67	

* Underlined mean indicated maximum yield.

** Underlined data indicated maximum response.

Table 19. Fresh root yields* as affected by various levels of applied - K in some major cassava soil series (t/ha) (Sittibusaya et al, 1978)

K_2O -levels (kg/ha)	Soil series			
	Sattahip	Korat	Yasothon	Average
0	31.7	28.1	23.8	27.9
50	-	41.9	25.0	33.5
100	33.4	45.0	27.5	35.3
200	34.6	45.6	28.8	36.3
400	-	46.3	28.1	37.2
Average	33.2	41.4	26.6	

*Underlined mean indicated maximum yield.

Table 20. The magnitude of response* in term of kilogram of fresh root yield increase per kilogram of applied - K (recalculated from data given in table 19).

K_2O -levels (kg/ha)	soil series			
	Sattahip	Korat	Yasothon	Average
0	-	-	-	
50	-	275	25	150.0
100	17	169	38	74.7
200	14	88	25	42.3
400	-	45	11	28.0
Average	15.5	144.3	24.8	

* Underlined data indicated maximum response.

Table 21. Two years average (first and second crops)[1/] on the effect of mixed fertilizers on the fresh root weights of cassava grown on different soils (t/ha) (Duangpatra, 1981, 1982).

Fertilizer grades	Soil series group A [2/]				Soil series group B [3/]				Overally Average
	Warin	Yasothon	Sattahip	Average	Huaipong	Chalong	Korat series	Average	
0-0-0	22	22	21	21.7	11	16	13.5	37	21.5
10-10-10	32	30	27	29.7	16	19	17.5	35	26.5
10- 5-15	33	28	27	29.3	15	20	17.5	36	26.5
14- 8- 8	36	27	27	30.0	14	19	16.5	40	27.2
15- 5-10	35	29	28	30.7	16	20	18.0	38	27.7
Average	31.6	27.2	26.0		14.4	18.8		37.4	

1/ The combined results of the 1979 - 80 and 1980 - 81 trials (two consecutive crops grown on each soil series).

2/ Group of soil series which showed marked responses to fertilizations.

3/ Group of soil series which showed slight responses to fertilizations

Table 22. Fertility levels of some important soil series as indicated by magnitude response of cassava to fertilization (Kurmarohita and Sittibusaya, 1978).

Soil Series	No. of Replications	Year	% Response	Rank
Warin	6	1976-77	12	1
Huaipong	14	1968-70	16	2
Korat	4	1976-77	27	3
Yasothon	4	1976-77	28	4
Sattahip	82	1968-70	41	5
Pattaya	25	1968-70	52	6

Table 23. Influence of garbage compost and incorporated plant residues on fresh root yield of cassava (t/ha) (Sittibusaya, 1980).

Treatment	Crop Year 1975	Crop Year 1976	Crop Year 1977
Check (No fertilizer)	28	10	8
NPK*	29	18	20
NPK + GC**	29	19	23
NPK + CPR***	26	21	23
CPR	30	17	15

* Applied each of N, P_2O_5 and K_2O equally at 50 kg/ha.

** Garbage compost, applied yearly at 12.5 t/ha.

*** Cassava top, cut above ground level and incorported into the soil before each planting.

USE OF SOIL SURVEY AND FERTILITY EVALUATIONS IN HEVEA CULTIVATION

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Hevea traditionally was cultivated in the equatorial region in the zone lying between 10°N and 10°S of the equator with the major production being within 6°N or S of the equator. The concentration in this location was because these areas provided the accepted ideal environmental conditions with mean annual temperatures of 28°C ± 2°C and a good rainfall of about 2000-4000 mm distributed throughout the year in about 100-150 rainy days. In addition, the soils were relatively deep with satisfactory pH conditions (pH 3.8-6.0) with optimum being about 4-5.5.

However, with the increasing demand for natural rubber, countries outside the hitherto conventional zones are beginning to establish rubber. For example, rubber plantations are being established even at latitudes of 23° - 24°N and in latitudes 20° - 21°S. Further, even within the traditional rubber growing countries, due to an increase in competition for land by other crops, example, rice, oil palm, cocoa, grain cereals etc., rubber is being relegated more and more to the marginal environmental and soil conditions. Thus for optimum management, there is a greater need to understand and appreciate the relationships between productivity and the soil and climatic environment. This paper therefore considers such relationships and the use of soil survey classification in such management practices.

Effect of Climate on Hevea

Temperature The main factor involved is climate with uniform temperature with an annual mean of 24° - 27°C which is generally considered to be favourable for growth and productivity. Variations from this

have been found to affect growth. In Malaysia, the mean temperature is about 26.7°C, while the mean minimum is rarely less than 22°C. On the other hand, in Bangladesh for example, the minimum temperature in 3 months of the year, i.e. December to January can be as low as 18°C. This has been shown to result in increase in the unproductive phase from the normal 5 to 6 years experienced in Malaysia to about 7 to 8 years in Bangladesh (Pushparajah, 1981). Further, Dijkman (1951) showed that for every 0.5° drop in temperature as a result of increase in altitude, the period of immaturity could be increased by 3-6 months.

Rainfall : Though the ideal climatic rainfall is accepted as being 2000-4000 mm per year, rubber has been successfully grown even at rainfall of up to 1500-1600 mm.

In addition however, rainfall can also have an adverse effect on productivity of rubber by interfering with tapping, i.e. exploitation of the tree for latex. Nevertheless, based on Malaysian experience, growth of rubber can be affected if the moisture deficit period extends from 3-4 months (Pushparajah and Haridas, 1977). Yield of rubber need not be adversely affected if the dry season coincides with wintering (Pushparajah, 1981). However, excess rain could interfere with tapping.

Relative humidity : Relative humidity which to an extent is influenced by the rainfall distribution, can affect performance of rubber. Rubber has been successfully grown in areas where relative humidity fluctuates between 65 % to over 90 %. However, the occurrence of high humidity regimes while having beneficial effects on one side, could have deleterious effects through its influence on disease infection etc.

Wind velocities : Generally, it is an accepted fact that extremely high wind velocities, e.g. in excess of 30 in per second, could cause damage to any tree crop. On the other hand, particularly for rubber, depending on the type of clonal material, wind damage by trunk snap could occur even with relatively low wind velocities. At times, particularly on the shallow soils, such wind damage could be in the form of uprooting during gusts of wind of even 10 m per second. Tree

losses of up to 15 % by such uprooting have been reported (Chan & Pushparajah, 1972).

Sunshine : Rubber is grown in areas with 1800 hours to 2800 hours of sunshine per annum. As *Hevea* is not photoperiodic, the day length does not appear critical.

Effect of Soil on Rubber

This would generally include altitude, topography, soil depth and physical and chemical characteristics of the soil.

Altitude : Rubber has generally been established on altitudes of up to 200 m. Dijkman (1951) reported that in Java (Indonesia), rubber had been established up to elevations over 600 m. He showed that for increase in elevation over the base of 200 m, the period of immaturity could be increased by about 5 to 6 months from each 200 m increase in elevation. This poor performance has been ascribed as being due to the drop in temperature at higher altitudes. Similarly, Wright (1912) quotes that rubber had been somewhat successfully cultivated in Sri Lanka at altitudes of 678 m where the temperature was about 23°C.

Sope : Slope has been shown to influence the productivity of rubber even when all other conditions remain similar (Chan et.al. 1974) (Table 1). The influence of slope was ascribed to the possible influence on the moisture retention. It must be emphasised however that the work reported by Chan et.al. only extended up to slopes of 26° and in areas where terracing had been carried out. However, there is no information on slopes greater than 25° expected to indicate from field observations that as the slope increases beyond this, the yield of rubber gets less.

Soil depth : Rubber needs a deep soil for firm anchorage. Thus a shallow soil would not enable anchorage resulting in losses of tree by uprooting. Chan and Pushparajah (1972) showed that over a period of 12 years from planting, about 13 % of the stand of trees of RRIM 600 and heavy canopied clone was lost by uprooting. Thus even within

TABLE 1. EFFECT OF SLOPE, DEPTH AND TEXTURE* ON *HEVEA*

Soil classification at lower category					Relative	Leaf nutrient content	
Slope %	Drainage	Depth (cm)	Texture: Top soil	Texture: Subsoil	Yield (%)	N	K
		a) Effect of Slope					
3 - 5	well drained	0 - 25 HLP	clay	clay	100	3.11	1.40
5 - 8	- do -	- do -	- do -	- do -	106	3.10	1.46
12 - 26	- do -	- do -	- do -	- do -	113	3.17	1.53
		b) Effect of depth					
8 - 12	well drained	0 - 25 HLP	clay	clay	100	3.23	1.32
- do -	- do -	25 - 50 HLP	- do -	- do -	124	3.20	1.68
		c) Effect of texture					
0 - 1	well drained	> 125	sandy clay loam	sandy clay loam	100	3.19	1.37
- do -	- do -	- do -	- do -	sandy clay	109	3.29	1.47
0 - 1	well drained	> 125	sandy clay loam	sandy clay	100	3.11	1.22
- do -	- do -	- do -	sandy clay	clay	118	3.23	1.44

*After Chan & Pushparajah (1972)

a given soil series, yield differences of up to 24 % were observed on an oxisol where the soil depths of 0-25 cm and 25-50 cm was considered; the deeper soil area giving a higher yield (Table 1). In this case, the soil depth referred to depth of the lateritic concretionary area.

Similarly, where the depth of the soil was influenced by the water-table, large differences were also observed. In such instances, the yield of rubber in areas with soil depth to water-table being 50 cm, was 971 kg per ha which was about 20 % lower than in areas where soil depth on similar soil and location was up to 100 cm. In the latter, mean annual yield was 1190 kg. per ha.

Texture : Chan et.al. (1974) showed that the productivity of rubber increased with increasing clay content from a textural range of sandy clay loam to sandy clay in the top soil and sandy clay to clay in the subsoil (Table 1). Yield increases of up to 18 % were observed. Such influences of texture was also reflected in leaf nutritional status of the rubber. Further, Pushparajah et.al. (1977) have demonstrated that the texture of the soil could have a large influence on the losses of N and K fertilisers, particularly during the times of the intense monsoonal rains.

Soil moisture conditions : The adverse influence of soil moisture on rubber could be due either to excessive drainage or poor drainage. Pushparajah and Haridas (1977) showed that during moisture deficit periods, growth of rubber was adversely affected. The response to overcoming the moisture deficit was larger in sandy textured soils than in the clay textured soil during the period of low precipitation. Haridas (1980) showed that the efficiency of water used was better at 1 bar and 0.3 bar than at 0.1 bar moisture and he further showed that in rubber, plants were capable of accumulating dry matter at moisture levels of soil below the upper limits of available water. He however demonstrated that the evapotranspiration as measured over a period of 2 years was equivalent to about 4.4 mm per day which closely followed the mean daily potential evaporation.

Impeded drainage or higher water-table was also shown to adversely affect growth and productivity of rubber (Chan and Pushparajah, 1972).

Chemical parameters : The major nutrient needs of *Hevea* are for nitrogen, phosphorus, potassium and magnesium.

Tan (1972) showed that for nitrogen, the total nitrogen as determined by Kheldjal method, gave the best relationship between soil N and leaf nutrient status of *Hevea*. However, he could not relate such N levels in soil to responses. Pushparajah and Tan (1979) found that this was so because the type of cover present had a major influence on N responses.

For phosphorus, Owen (1951) found that Bray and Kurtz method of ammonium fluoride extraction for P gave a good indication of the availability of P for *Hevea*. Lau et.al. (1973) while confirming this, showed that the double acid extraction (sulphuric and perchloric) was also a good indicator for *Hevea*. However, though a level of about 20 ppm NH_4F/HCl extractable P (i.e. available P) was considered to be a satisfactory level, Pushparajah found that there were other factors influencing this level. A response to P was obtained in an area where "available P" was 13 ppm but not where it was 5 ppm. This was ascribed to the role of organic matter; the latter area having high % C ($>$ 2.0 %) and the former having about 1.0 % C.

Guha (1963) showed the relationship between 6N HCl extractable K (total K) and leaf K in a number of survey samples collected from commercial plantations not using fertilisers or using limited amount of fertilisers. Later, Lau et.al. (1972) considered the relationship of soil and leaf K values in some fertiliser trials and found that in addition to "Total K", exchangeable K was correlated to leaf K and yield of *Hevea*; the relationship with exchangeable K being more evident within a soil series. However, K being more evident within a soil series. However, Pushparajah (1977) found that as a general rule, "Total K" was a better indicator and responses was limited where 6N

HCL K was $>$ 2.0 m.eq. per 100 g in the top soil.

Response to Fertilisers

Pushparajah and Guha (1968) in reviewing a number of fertiliser trials according to Great Soil Group, showed a relationship between responses and soil indices. Subsequently, Pushparajah (1977) re-assessed the information by considering the soil units under the Taxonomic System. The main findings were :

Soil Unit	Likely response to
Poorly drained, fine clayey, mixed, acid soils from marine alluvial parent material-a Sulphic Tropaquept	Nitrogen only
Well drained, clayey-skeletal, kaolinitic soils from granite - a Paleudult	N, K and Mg and to P in new areas
Well drained, clayey, kaolinitic soils derived from basalt-Haplic Acrothox	K and to N in the early stages of growth
Somewhat excessively drained, fine loamy, siliceous derived from sandstone-Typic Paleudult	N, P, Mg and at times to K

However, the responses were often inter-dependent, i.e. response to N was dependent on K; that for Mg dependent on K and vice-versa.

On such considerations, the following categorisation of potential nutrient availability (Table 2) are projected.

TABLE 2. CATEGORISATION OF POTENTIAL NUTRIENT AVAILABILITY FROM 0-30 CM

Nutrient	Category of amount of nutrient			
	Low	Medium	High	Very High
C %	< 0.5	0.51-1.50	1.51-2.50	> 2.50
N %	< 0.10	0.11-0.20	0.21-0.30	> 0.30
NH_4F/HCl P (ppm)	< 10	11-20	21-30	> 30
Double Acid P (ppm)	< 250	251-350	351-500	> 500
6N HCl K (m.eq. %)	< 0.50	0.51-2.00	2.01-4.00	> 4.0
6N HCl Mg (m.eq. %)	< 0.75	0.76-3.00	3.01-8.00	> 8.0
C.E.C	< 5	5-10	11-16	> 16

Soil Suitability and Productivity

The climate, external and internal characteristics of the soil has an influence on the productivity of the soil. Chan and Pushparajah (1972) based on a survey, related yields of commercial plantings of *Hevea* to soil series. The yields were consistent with soil physical properties. Yields were highest on soils with good physical properties and lowest on those with poor properties.

Later, Chan et.al. (1975) attempted to quantify the various soil and physiographic parameters. Of these, the desired characters were : soil depth (>100 cm), well drained (Class D), good aeration, good structure, absence of peat or acid sulphate, texture with >35 % clay and slopes of < 9°. Each character was given equal weightage. This was subsequently modified by Pushparajah (1977) who included water availability and chemical parameters in addition to a few external factors. Subsequently, Yew (1982) added further refinements including the incorporation of climatic indices. The desirable characters and the ranges of the limitations are given in Tables 3 to 6. are self

After Yew (1982)

TABLE 3. CRITERIA FOR ACIDITY INDEX

Parameter	Range of limitations			
	Nil	Minor	Serious	Very serious
pH	4.3 - 4.6	> 4.6 - 5.0 < 3.9 - 4.3	> 5.1 - 6.0 > 3.5 3.9	> 6.0 < .3.5
Acid sulphate	Absent in 150 cm from surface	> 100 cm from surface < 25 cm thick	> 50 - 99 cm from surface > 25 cm thick	< 50 cm from surface > 25 cm thick

TABLE 4. CRITERIA FOR GRADING INTERNAL SOIL FACTORS

Parameter	Range of Limitation			
	Nil	Minor	Serious	Very Serious
Texture	Equal proportions of silt, clay & sand	Loam (>50-70% sand) Clay (>50-70% clay) Silty clay (>50-70% silt+clay)	Very sandy (>70-90% sand) Very clayey (>70-90%clay) Very silty clay (70-90% silt +clay)	Sand (>90% sand) Clay (>90% clay) Silty clay (>90% silt+clay)
Effective depth	> 150 cm	149 - 100 cm	99 - 50 cm	< 50 cm
Stoniness of subsoil	Almost absent	<50%	50 - 70%	> 70%
Internal Drainage (USDA)	Well drained (Class D)	Moderately well drained (Class C)	Imperfectly drained (Class B)	Poorly drained (Class A)
Available water (cm/m)	> 150	149 - 100	99 - 50	< 50
Permeability	Moderate	Moderately slow or moderately rapid	Slow or rapid	Very slow or very rapid
Erodability (USDA class)	Slightly erodable (1)	Moderately erodable (2)	Readily erodable (3)	Very readily erodable (4)

After Pushparajah (1977)

TABLE 5. CRITERIA FOR GRADING EXTERNAL FACTORS

Parameter	Range of limitations			
	Nil	Minor	Serious	Very Serious
Slope (%)	0 - 8	8 - 16	16 - 32	>32
Susceptibility to flooding	Nil	For few hours	For <3 days	For >3 days
Pest characteristics	Absence of Peat	Peat >50 cm from surface; <25 cm thick	Peat 25-50 cm from surface; 25-50 cm thick	Peat <25 cm from surface; >25 cm thick

After Pushparajah (1977)

TABLE 6. CRITERIA GRADING FOR SUITABILITY OF CLIMATE

Parameter	Degree of Limitation			
	Nil	Slight	Moderate	Severe
Temperature °C				
- Mean	25.0 - 28.0	22.0 - 24.9	21.9 - 20.0	19.9 - 18.0
- Daily Maximum	29.0 - 34.0	28.9 - 27.0	26.9 - 24.0	23.9 - 22.0
- Daily Minimum	>20.0	19.9 - 19.0	18.9 - 17.0	16.9 - 15.0
Mean rainfall (mm/year)	>2000	1750 - 2000	1500 - 1749	1250 - 1499
Dry season (months)	>1.0	1.1 - 2.0	2.0 - 3.0	>3.0
Rain interference (days)	< 30	31 - 60	61 - 90	>90
Sunshine (h/year)	> 2100	1800 - 2100	1400 - 1799	1000 - 1399
Maximum wind speed (m/sec)	<7.0	7.1 - 14.0	14.1 - 21.0	21.1 - 30.0

evident. These include climate, acidity, external and internal factors of soils. The gradings and the eventual suitability indices have been shown to be related to actual yields obtained in the field.

Management of Soils

Generally, most of the soils under rubber have low contents of the major nutrients required by rubber. However, generally physical characteristics have a major role and thus greater emphasis is placed on physical properties. Further, in soils with good physical properties, proper agronomic inputs (viz. covers, fertilisers etc.) lead to good yields (Table 7).

TABLE 7. SCOPE FOR IMPROVEMENT OF YIELD[a]

Input	Yield (kg/ha/year)-mean over 4 years	
	Haplorthox	Sulfic Tropaquept
Poor inputs	1214	760
Good inputs	2106	985
Difference	892	225

(a) For clone RRIM 600; After Chan & Pushparajah (1972)

The scope and details for management of the commoner soils derived on granite, sedimentary and older alluvial parent materials have been detailed by Chan et.al. (1973), while those for alluvial soils have been reported by Noordin and Pushparajah (1981).

In addition, the assessment of fertiliser needs of *Hevea* in relation to nutrient contents of soils has been detailed elsewhere (Pushparajah, 1977 and Pushparajah & Chew, 1979).

Use of Soil Taxonomy

Due to the large variability in soils, there is a consequent wide fluctuation on the inputs of management and fertilisers required for *Hevea*. Detailed trials unden each situation would be the theoretical ideal for assessing the actual needs. However, this is impractical. Thus there is a need for adapting and transfering the knowlege gained from the limited experimental areas to the large sector of commercially established plantations. The soil taxonomic classification system has been found to be useful in such technological adaptations.

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A-PROPOSED RICE PRODUCTION PHILOSOPHY

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ABSTRACT :

In order to propose a philosophy of rice production in developing countries, a case study of Thailand is used as a model. The reviews of information collected ideas of importance to rice in Thailand, the rice cultivation at present and suitability of paddy soils. Development of important technologies in the country reveal that : a lack of ownership of land, poor seasonal distribution of farm labour utilization, inability to accept new technologies because of too limited total irrigated area, and lack of capital are the major problems. These problems bring about minimum input, followed by poor grain yields, poverty of the farmers and the country. The philosophy proposed aims at solving the four basic problems by these four hypothesises : (1) Utilization of the most suitable paddy soils efficiently in the decreasing order of suitability, along with reformation and consolidation of the land would be the most socio-economically feasible justification; (2) Better distribution of small farms by family; (3) Utilization of suitable rice varieties and proper cultural practices locally tested,would be the most appropriate technology, and (4) Financial support for better rice production for the poorest people but the biggest group of the rice farming population. Strategy for reaching these hypothesises is proposed and discussed.

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The author feels that this proposed philosophy might be applicable to other developing rice producting countries.

I. Importance of Rice

Rice is the primary food staple for billions of people (Brady, 1978). To Thailand, it is the most important carbohydrate source, major occupation of her population and chief agricultural product export of the country.

It is estimated that in average, we consume 148 kg of milled rice or 224 kg of paddy per head per year. In 1979, when our population was about 46.14 million, about 12 million tons of paddy or about 71 % of total paddy produced was consumed, used as seed and added to the government stock.

Table 1 presents changes of income and export of agricultural products during 1969 to 1979. In 1969, almost 40 % of total agricultural income, which accounted for 34.4 % of the national income, was that of the paddy produced. Enormous added value from rice milling and domestic trading, though information is not available, should be expected. As the result of the National Socio-economic Planning, national income jumped from 104,581 to 454,700 million baht or a 335 % increase, though contribution of agriculture to Thailand's economy during 1967-1979 has been a 327 % increase or from 35,970.1 to 153,762.7 million baht comparing with a 335 % increase of the national income, rice is still a major source of foreign currencies for the agricultural sector. Table 2 illustrates the importance of rice with respect to area utilized, compared with other land utilization for crop production in Thailand. This table clearly demonstrated that wetland rice is the most important crop of the country because it occupies 63 % of the total farm holding land. If 63 % of the farm households : as the area implied, 2.8 million households or 19.3 million persons are directly involved in rice production.

Table 1 : Income and export of agricultural products of Thailand in 1969 and 1979.

Agricultural Product	1969				1979			
	Income		Export		Income		Export	
	x 10^6B	Index	x 10^6B	Index	x 10^6B	Index	x 10^6B	Index
Total	35,970.1	100	11,111.6	100	153,762.7	100	68,334.7	100
Rice	13,732.0	38.2	2,966.9	26.7	35,328.7	230	15,875.5	23.2
Food crops	4,265.3	11.9	3,085.5	27.8	19,879.6	12.9	23,087.9	33.8
Oil crops	1,493.5	4.2	225.2	2.0	3,354.6	2.2	828.1	1.2
Fiber crops	1,906.6	5.3	956.3	8.6	2,369.3	1.5	1,319.4	1.9
Textile materials	-	-	133.0	1.2	-	-	2,152.8	3.2
Other cash crops	1,460.4	4.1	205.3	1.8	29,326.3	19.1	3,863.4	5.7
Rubber	2,248.8	6.3	2,663.3	24.0	7,673.2	35.0	12,681.6	18.6
Animals + products	4,005.6	11.1	213.9	1.9	35,299.9	23.0	1,704.0	2.5
Animal feeding	-	-	50.3	0.5	-	-	1,361.9	2.0
Fishery products	4,798.0	13.3	314.2	2.8	11,708.0	7.6	5,020.1	7.3
Forestry products	2,059.9	5.7	296.7	2.7	8,823.1	5.7	440.0	0.6
National	104,581	290.7	14,100.8	126.9	454,700	295.7	106,336.5	155.6

Sources : Division of Agricultural Economics (1974) and Office of Agricultural Economics (1980).

Table 2 : Distribution of land utilization for agriculture and estimated paddy farmers in 1978.

Information	Region				Whole Kingdom
	Northern	N.Eastern	Central	Southern	
A. Land utilization					
Paddy (10^6 ha)	2.55(65.4)	5.69(72.1)	2.71(57.9)	0.77(35.8)	11.72(62.9)
Field crops (10^6 ha)	1.05(26.9)	1.48(18.8)	1.25(26.7)	0.02(0.9)	3.80(20.4)
Fruit & tree (10^6 ha)	0.12(3.1)	0.07(0.9)	0.34(7.3)	1.13(52.6)	1.67(9.0)
Vegetable & flowers(10^6 ha)	0.01(0.3)	0.01(0.1)	0.03(0.6)	<0.01(<0.5)	0.06(0.3)
Others(10^6 ha)	0.17(4.4)	0.63(8.0)	0.36(7.7)	0.22(10.2)	1.38(7.4)
Total holding (10^6 ha)	3.90(100)	7.89(100)	4.68(100)	2.15(100)	18.63(100)
B. Number of household and estimated number involved					
Total household (10^6)	1.15	1.75	0.87	0.61	4.38
Total population (10^6)	8.05	12.25	6.09	4.27	30.66(68.0)
Household for paddy (10^6)	0.75	1.26	0.50	0.22	2.76
Population (10^6)	5.25	8.82	3.5	1.54	19.32(42.8)
Total population					45.1(100)

Table 2 : (Continue)

Note :

1. Northern Region (17 provinces) : Chiang Mai, Chiang Rai, Kamphaeng Phet, Lampang, Lamphun, Mae Hong Son, Nakhon Sawan, Nan, Payao, Phetchabun, Pichit, Phitsanulok, Phrae, Sukhothai, Tak, Uthai Thani and Uttaradit.
2. Northeastern Region (16 provinces) : Buri Ram, Chaiyaphum, Kalasin, Khon Kaen, Loei, Maha Sarakham, Nakhon Phanom, Nakhon Ratchasima, Nong Khai, Roi Et, Sakon Nakhon, Si Sa Ket, Surin, Ubon Ratchathani, Udon Thani and Yasothon.
3. Central Region (25 provinces) : Ang Thong, Ayutthaya, Chachoengsao, Chai Nat Chanthaburi, Chon Buri, Kanchanaburi, Lop Buri, Nakhon Nayok, Nakhon Pathom, Nonthaburi, Pathum Thani, Phetchaburi, Prachin Buri, Prachuap Khiri Khan, Ratchaburi, Rayong, Samut Prakan, Samut Sakhon, Samut Songkhram, Saraburi, Sing Buri, Suphan Buri and Trat.
4. Southern Region (14 provinces) Chumphon, Krabi, Nakhon Si Thammarat, Narathiwat, Pattani, Phangnga, Phatthalung, Phuket, Ranong, Satun, Songkhla, Surat Thani, Trang and Yala.
5. Household of paddy farmers are estimated from relative land utilization in each region.
6. Population of the farmers are estimated from average 7 persons per family.

Sources : Mostly from Office of Agricultural Economics (1980).

II. Rice Cultivation in Thailand

Rice cultivation is linked closely with Thai history and tradition. It is really difficult to trace back when Thai farmers start cultivating rice. In general rice cultivation in Thailand can be subdivided broadly into lowland and upland rice. The former is the most socio-economically important. The lowland rice can be differentiated, based on type of cultivation into broadcasting and transplanting types. The traditional broadcasting types occupied all area of the flood plain especially that of the Central Region. The rice varieties of these area are almost always the floating type. According to the Census of Agriculture (1963) about 1.55 million hectares of the lowland rice was devoted for this broadcasting type, while the transplanting type occupies approximately 2.86 million hectares.

Almost all native rice varieties are photoperiod sensitive and of a short day type. These rice plants will flower only when the daylength of the sunshine is short enough. Based on optimum daylength for flowering, 3 main groups of rice can be subdivided :

(1) Early : These varieties will flower in August and September and will be harvested in September and October;

(2) Medium : These varieties will flower in October and will be harvested in November; and

(3) Late : These varieties will flower and will be harvested later than the medium group.

Based on types of starch, 2 main groups are differentiated :

(1) Non-glutinous rice or normal rice starch is composed of about 30 % amylose and 70 % amylopectin. This type of rice has been cultivated widely in the Central, Southeastern and Southern Regions for both local consumption and international trading;

(2) Glutinous rice or sticky rice starch is composed of amylopectin not less than 90 %. This type of rice has been cultivated mainly in the Northeastern and upper Northern Regions for local

consumption, only some surplus is exported but only to a few countries.

The Rice Division, Department of Agriculture, Ministry of Agriculture and Cooperatives has carried out research and released recommended photoperiod sensitive varieties having good milling and cooking qualities and is well accepted in the world market. Since 1960, intensive breeding programs have been conducted for high yielding, resistance to disease as well as acceptable milling and cooking quality for both nonglutinous (odd number RD's varieties) and glutinous (even number RD's varieties). These RD's varieties have ideal plant types recommended at IRRI, they are short, stiff straw, erect leaves and nonphoto period sensitive. Some of the improved RD's varieties have been well accepted for off-season or dry season cropping, but in the wet or normal growing season both native and official recommended varieties are used. In general, rice cultivated in dry season only receives fertilization. Table 3 presents the irrigation system and some recent information on rice production in both wet and dry seasons in Thailand. The highest land area but the lowest yield of rice in the wet season occurs in the Northeastern Region and markedly influence the national average yield. Since the off season cropping is limited only in the irrigated areas. Irrigation could bring about higher national average yields as presented in Table 4 than in Table 3, however, it is still the lowest among the ASEAN and some selected countries. Besides socio-economic problems, the four basic problems of good crop production are : (1) lack of suitable crop varieties, (2) lack of good irrigation system, (3) lack of good soils and (4) lack of appropriate technology and/or transferring of the technology. The last two technical factors will be emphasized in the following two sections.

III. Suitability of Paddy Soils

Though more than 10 million hectares of land have been used throughout the country, only small portions are the most suited for paddy production. Based on systematic soil surveys of the Soil Survey Division, the Land Classification Division (1972) presented the General

Table 3 : Irrigation system and some important information on rice production in Thailand in 1979.

Information	Region				Whole Kingdom
	Northern	N.Eastern	Central	Southern	
I. Irrigation system					
Irrigation (10^3 ha)	398.4	71.5	966.1	99.7	1,536.1
Storage of water (10^3 ha)	88.2	202.2	145.7	115.8	551.9
Pumping (10^3/ha)	15.3	17.4	11.1	10.6	54.4
Total (10^3/ha)	502.3	219.1	1,122.9	226.1	2,142.4
II. Production, area, yield, average price and values of paddy					
A. Wet season cropping					
Production (10^6 t)	4.28	5.64	3.66	1.09	14.67
Area (10^6 ha)	3.55	5.69	2.71	0.77	11.72
Yield (t/ha)	1.68	0.99	1.35	1.42	1.25
Price (B/t)	2242	2242	2242	2242	2242
Value (10^6 B)	9,595.76	12,644.88	8,205.72	2,443.78	32,890.14
B. Dry season cropping					
Production (10^6 t)	0.24	0.06	1.93	0.03	2.26
Area (10^6 ha)	0.09	0.03	0.55	0.01	0.68
Yield (t/ha)	2.67	2.00	3.51	3.00	3.32
Price (B/t)	2242	2242	2242	2242	2242
Value (10^6 B)	538.08	134.52	4,327.06	67.26	5,066.92

Source : Office of Agricultural Economics (1980)

Note : Number and name of province in each region are the same with that of Table 2.

Table 4 : Paddy yield in kg/ha of Thailand and some selected countries in the last five years (1975-1979).

Country	Year				
	1975	1976	1977	1978	1979
ASEAN					
Indonesia	2,575	2,781	2,794	2,888	2,975
Malaysia	2,625	2,731	2,631	2,575	2,856
Philippines	1,738	1,819	1,962	2,075	2,000
Thailand	1,831	1,844	1,406	1,969	1,819
Others					
China	3,288	3,519	3,494	3,681	3,719
Japan	6,188	5,500	6,169	6,419	6,238
S. Korea	5,325	5,969	6,862	6,769	6,556
U.S.A.	5,119	5,225	4,944	5,025	5,138
World average	2,456	2,450	2,556	2,662	2,612

Sources :

Thailand : Office of Agricutlural Economics (1980)

Other : FAO, Production yearbook 1977 - 1979.

Land Capability Map of Thailand including areas of soil suited for paddy. Detailed descriptions of Soil Suitability Classification are divided into 5 main groups : P-I to P-V; and subgrouping within group P-II to P-V, has been published (Land Classification Division, 1973). The limiting factors and their degrees for each soil suitability group are presented in Table 5. Extents and short descriptions of each group in the 5 socio-economic regions, recently established are presented in Thai by Vijarnsorn (1979) and is illustrated in Table 6. It is clear from this table that Thailand has only 3,866,382 ha or 7.54 % of total area being the best paddy soil and only 10,508,266 ha. being soils suited for paddy, based on their physical characteristics.

The area of each group presented in Table 6 is generally based on physical characteristics as well as climatic factors controlling the moisture regime. Soils in the poorer classes might be upgraded if the limiting factor or factors are eliminated, especially by irrigation or flooding control measures.

In Thailand, all soils of the aquic moisture regime, are paddy soils. Distribution of paddy soils at the Great Group levels in each region is presented in Table 7. In general, P-I group is composed mainly of clayey, Tropaquepts and clayey, Haplaquolls but in the irrigated areas clayey, Tropaqualfs could also be included. Flooding and acidity problems reduce suitability of the clayey, Tropaquepts and clayey Haplaquolls into group P-II. Soils in the loamy, Paleaquults are the major core of group P-III. Poor physical and chemical characteristics as well as topography and very strong acidity are the main limiting factors for the P-IV group. Table 8 sumarizes some edaphic properties of soil series within each Great Group.

Since loamy, Paleaquults dominate other great groups of paddy soils (38 % of total soils suited for paddy), this soil greatly influences the national paddy yield average under the traditional cultivation practices of crop production. The clayey, Tropaquepts, though occupy the second largest area of paddy soil (about 30 %) long

Table 5 : Guidelines for paddy soil suitability grouping (Land Classification Division, 1973)

Limiting factor	P - I	P - II	P - III	P - IV	P -V
Effective soil depth to limiting layer	> 50 cm	> 50 cm	> 25 cm	> 25 cm	-
Texture of surface soil	clay; silty clay; clay loam; silty clay loam; sandy clay	clay; silty clay; sandy clay; silty clay loam; sandy clay loam; clay loam	sandy loam to clay	loamy sand to clay	-
Permeability of subsoil	< 0.5 cm/hr,slow	slow to moderately slow, < 1.5 cm/hr	slow to moderate < 5 cm/hr	slow to moderately rapid; 15 cm/hr. (slow to moderate if well drained)	
Fertility; relative nutrient status	high to moderate	high to moderately low	high to low	high to low	-
Reaction of surface soil layer (dry soil, pH 1:1 H_2O)	5.0 - 7.5	4.5 - 8.0	4.0 - 8.0	3.5 - 8.5	-
Salinity EC5 x 10^6	< 1500	< 2500	< 2500	< 4000	-
Slope	< 1 %	< 2 %	< 3 %	< 5 %	-

Table 5 : (Continue)

Limiting factor	P - I	P - II	P - III	P - IV	P - V
Micro-relief	> 80 % of land is smooth; little leveling required	>80 % of land is smooth; little leveling required	>50 % of land is smooth; moderate leveling may be required	> 40 % of land is smooth. Much leveling may be required	-
Gravel and stone that hinder cultivation	none	none to slightly gravelly	none to slightly gravelly and slightly stony	none to gravelly and slightly stony	-
Risk of damage by water shortage	no damage by water shortage during growing season	Occasional slight damage	moderate damage in <4 years in 10; occasional severe damage	moderate to severe damage <6 year in 10; occassional complete loss	-
Soil drainage class	somewhat poorly to poorly drained	somewhat poorly to poorly drained	somewhat poorly to very poorly drained	well to very poorly drained	
Risk of damage by flash floods, quickly rising water, or saline water	seldom, < 1 in 10 years	occasional moderate damage; < 3 in ten years	moderate damage may be frequent, < 4 in 10 years occasional severe damage	severe damage may be very frequent; < 6 in 10 years	-

Table 6 : Distribution of soils suitable for paddy production in socio-economic regions of Thailand (Vijarnsorn, 1979).

Suitability Group	Description	N. ^thern		North Eastern		Central		Southeastern		Southern		Whole country	
		ha	%	ha	%	ha	%	ha	%	ha	%	ha	%
P-I	Soils very well suited for paddy, having no significant limitations that ristrict their use for wetland rice.	944,916	5.57 (24.44)	1,068,848	6.33 (27.64)	1,282,010	20.30 (33.16)	297,735	8.66 (7.70)	272,873	13.54 (7.06)	3,866,382	7.54 (100)
P-II	Soils well suited for paddy, having slight limitations that restrict their use for wetland rice.	500,790	2.95 (39.19)	251,931	1.49 (19.72)	56,838	0.90 (4.45)	27,504	0.80 (2.15)	440,760	5.72 (34.49)	1,277,823	2.49 (100)
P-III	Soils moderately well suited for paddy, having moderate limitations that restrict their use for wetland rice.	70,572	0.42 (1.45)	3,427,405	20.30 (70.25)	780,573	12.36 (16.00)	436,357	12.69 (8.95)	163,262	2.12 (3.35)	4,878,169	9.51 (100)
P-IV	Soils poorly suited for paddy, having severe hazards or limitations that restrict their use for wetland rice.	20,967	0.12 (4.32)	279,623	1.66 (57.55)	11,999	0.19 (2.47)	10,658	0.13 (2.19)	162,645	2.11 (33.47)	485,892	0.95 (100)
P-V	Soils generally not suited for wetland rice.	15,427,182	90.94 (37.81)	11,857,627	70.22 (29.06)	4,183,898	66.25 (10.25)	2,665,795	77.54 (16.53)	6,668,742	86.51 (16.34)	40,803,244	79.51 (100)
	Total area	16.964,427	100 (33.06)	16,885,434	100 (32.9`)	6.315.318	100 (12.31)	3,438,049	100 (6.70)	7,706,282	100 (15.02)	51,331,510	100 (100)

Note : (1) Total area for P-I, P-II = 5,144,205 ha or 10.03 % of the country.
(2) Total area for P-I, P-II, P-III = 10,022,374 ha or 19.54 % of the country.
(3) Total area for P-IV = 485,892 ha or 0.95 % of the country.
(4) Total area for P-v = 40,803,244 ha or 79.51 % of the country.
(5) Figures in parenthesis under the percent column for each region are percentages of the area for each group.
(6) Southeastern Region has been separated out of the Central. This region has 6 provinces : Chachoengsao, Chanthaburi, Chon Buri, Rayong and Trat and has 3,438,050 ha of region area.
(7) The remaining Central Region has only 19 provinces instead of 25 mentioned in Table 2, the root area of this region become 6,315,316 ha.
(8) The number and name of the provinces of the Northern, Northeastern and Southern Regions are the same as in Table 2. Total areas are 16,964,429 ha; 16,885,434 ha and 7,708,281 ha for the Northern, Northeastern and Southern Region respectively.

Table 7 : Distribution of paddy soils in all socio-economic regions of Thailand (Vijarnsorn, 1979).

Great group	Socio-economic Region										Area in all region (ha)	Relative to the whole country (%)
	Northern Area		Northeastern Area		Central Area		Southeastern Area		Southern Area			
	ha	%	ha	%	ha	%	ha	%	ha	%		
1. loamy, Fluvaquents	-	-	-	-	-	-	-	-	26,979	0.35	26,979	0.05
2. clayey, Fluvaquents	-	-	-	-	-	-	-	-	62,437	0.12	62,437	0.12
3. sandy, Tropaquents	-	-	-	-	-	-	-	-	16,958	0.22	16,968	0.03
4. loamy, Tropaquepts	-	-	-	-	-	-	15,815	0.46	-	-	15,815	0.03
5. clayey, Tropaquepts	556,433	3.28	1,068,848	6.33	949,192	15.03	205,939	5.99	272,873	3.54	3,053,285	5.95
6. clayey, acid, Tropaquepts	-	-	-	-	557,011	8.82	138,210	4.02	31,604	0.41	726,825	1.42
7. clayey, Haplaquolls	-	-	-	-	87,783	1.39	-	-	-	-	87,783	0.17
8. loamy, Natraqualfs	-	-	183,714	1.09	-	-	-	-	36,229	0.47	219,943	0.43
9. loamy, Tropaqualfs	-	-	-	-	51,786	0.82	-	-	-	-	51,786	0.10
10. clayey, Toopaqualfs	388,485	2.29	-	-	245,034	3.88	-	-	-	-	633,519	1.23
11. clayey, Plinthaquults	-	-	-	-	-	-	91,796	2.67	76,466	0.99	168,262	0.33
12. skeletal, Plinthaquults	-		72,269	0.43	-	-	-	-	-	-	72,269	0.14
13. loamy, Paleaquults	70,572	0.42	3,427,405	20.30	59,996	0.95	282,333	8.21	42,241	0.55	3,898,547	7.57
14. clayey, Paleaquults	500,790	2.95	251,931	1.49	56,838	0.90	27,504	0.80	317,451	4.11	1,153,874	2.25
15. skeletal, Paleaquults	-	-	23,640	0.14	-	-	-	-	-	-	23,640	0.05
16. clayey, Tropaquults	-	-	-	-	-	-	-	-	47,483	0.62	47,483	0.09
Total	1,516,280	8.94	5,027,807	29.78	2,007,640	31.79	761,597	22.15	930,082	12.07	10,243,406	19.96

Table 8 : Some chemical properties of the surface (0-30 cm) of paddy soils of Thailand (Vijarnsorn, 1979)

Great group	Soil series	O.M 1/ %	Avail.P 2/ ppm	Avail.K 3/ ppm	pH (1:1)
1. loamy, Fluvaquents	Ts	1.5-3.5	<10	<60	4.5-5.0
2. clayey, Fluvaquents	Ra, Cy	1.5-3.5	<10	<60	4.5-5.0
3. sandy, Tropaquents	Sak, Wn	<1.5	<10	<60	5.5-7.0
4. clayey, Tropaquepts	Bk, Bn, Bp,Cn Cs, La, Pm,Rb Sb, Sin, Ss	1.5-3.5	<10-20	<60- >90	5.5-6.5
5. clayey, acid Tropaquents	Ok, Rs, Tan, Tg	1.5-3.5	< 10	> 90	4.0-4.5
6. loamy, Tropaquepts	Cl, St, Ptg	<1.5	< 10	< 60	4.0-4.5
7. clayey, Haplaquolls	Bl, Dn	1.5-3.5	< 10	> 90	6.0-7.5
8. clayey, Tropaqualfs	Hd, Ms, Na, Np, Ph, Lgu,Kr	1.5-3.5	< 10	60-90	5.5-7.0
9. loamy, Natraqualfs	Nk, Kl	< 1.5	< 10	< 60	6.5-8.0
10. loamy, Tropaqualfs	Cb, Kyo, Sai, Wb	< 1.5	< 10	< 60	5.0-7.0
11. clayey, Paleaquults	Br, Cr, Mn, Nm, Pat, Tt	1.5-3.5	< 10	< 60	5.0-6.5
12. loamy, Paleaquults	Bt, Ko, Lp, Re, Rn, Sng, Su, Hk	1.5-3.5	< 10	< 60	5.0-6.5
13. skeletal, Paleaquults	Nc, Mae	1.5-3.5	< 10	< 60	5.5-6.0
14, clayey, Tropaquults	Sk, Tsl	1.5-3.5	< 10	< 60	5.0-5.5
15. clayey, Plinthaquults	Kl, Kut, Stu	1.5-3.5	< 10	< 60	4.5-5.5
16. skeletal, Plinthaquults	On, Pn, Stn	<1.5	< 10	< 60	4.5-5.5

Note :

1/ O.M. by Walkley-Black method.

2/ Available P by Bray II method.

3/ Available K by 1N neutral NH_4OAC method.

duration of flooding always reduced yield potentials of these areas. The high abundance of the clayey, acid Tropaquepts of the Central Region (27.7 % of paddy soils of this region) and that of the Southeastern Region (18.1 % of the Region's paddy soils) undoubtedly bring about the second rank of the regional average yield mentioned in Table 2. The best average yield of the Northern Region closely relates to the highest abundance of the P-I and the P-I and P-II combined within the region. The highest areas of P-III and P-IV of the Northeastern Region account for the lowest grain yield of the region mentioned in Table 2.

IV. Development of Technologies for Rice Production in Thailand

A. Varietal Improvement

The Rice Division, Department of Agriculture, up to the present has succeeded in rice varietal improvement both by (1) selection for photoperiod sensitive rice or the official recommended varieties, and (2) by breeding for the nonphoto period sensitive one or the R.D.'s varieties (R.D. comes from Rice Division). The number of recommended photoperiod sensitive varieties for the Northern, the North Eastern, the Central including the Southeastern and the Southern Regions are 5, 9, 6 and 4 varieties respectively. These varieties adapt very well for the soil and climatic condition of each region in the wet or normal season. The RD's varieties that can be used both in the wet and dry season cropping in the irrigated areas throughout the country are 1, 3, 5, 7, 9, 11, 21, 23, and 25 for the nonglutionous one.

B. Development of Irrigation Systems

The Rayal Irrigation Department takes responsibility on development of irrigation systems. Though enormous funds, both from the National Budget and International Loans, have been spent, only 2.1 million ha. or 17.9 % of the paddy lands are irrigated. Most of the irrigated areas, however, still have to be supplemented in the

drought period of the rainy season. This irrigation problem undoubtedly has been one of the most important causes of poverty of farmers, because without water, efficient fertilization is impossible. Efficient use of water is now being investigated.

C. Development of Rice Fertilization

The Rice Department, in the past, and Rice Division, at the present, conducted thousands of experiments on fertilizer trials both in the rice experiment stations and in the farmer's fields throughout the country. Table 9 and 10 present summaries of the classical 7 year fertilizer trials in farmer's fields throughout the country during 1958-64 (Suwanwaong et al 1966). Table 9 clearly illustrated that paddy soils of the Northern and the Central regions are deficient in both N and P while that of the Northeastern are deficient in N, P and K. From the information in 1958 and 1959 and other information from experiment stations the research team decided to fix the optimum rates, based on economic return, of P_2O_5 at 25 kg/ha. and they tested 5 levels of N and compared them with 3 other treatments in various locations in each region including the Southern Region during 1960 to 1964. The results are summarized in Table 10. It is very clear from this table that, this field trial experiment is the most reliable because of its low CV (%) for each treatment in all regions, though number of locations are not fixed. The response to N of the recommended nonphoto period sensitive varieties suitable to each region could also be discerned up to the highest dose tested, except for the Southern Region where the maximum dose was at 37.5 kg N. However, according to the authors (Suwanwaong et al, 1966), 12.5 - 25 - 0 kg of N, P_2O_5 and K_2O/ha gave the highest economic return.

It should be also noted here that the average yield of the check plot (0-0-0) in all regions investigated is higher than the average region yield of the wet season crop reported in Table 3. The yield improvement may be explained by (1) all damaged plots either by

Table 9 : Response to fertilizer of suitable native varieties of rice in the farmer's field (Suwanwaong et al, 1966).

Response	$N-P_2O_5-K_2O$ kg/ha	Regions			Average
		Northern	Central	N.Eastern	
Fertilizer trial in 1958					
Location	-	11	35	15	61
Yield(kg/ha)	0-0-0	2325	1850	1450	1875
Response (%)	75-0-0	26.3	35.8	25.9	29.3
"	0-75-0	30.1	27.3	27.6	28.6
"	0-0-75	12.1	16.3	12.5	13.6
"	75-75-0	38.2	59.1	70.2	53.3
"	75-0-75	27.7	39.5	39.6	34.6
"	0-75-75	27.4	37.2	41.4	34.3
"	75-75-75	41.7	62.1	99.1	63.0
Fertilizer trial in 1959					
Location	-	9	53	38	100
Yield (kg/ha)	0-0-0	2394	1775	1138	1769
Response (%)	37.5-0-0	13.5	25.0	26.4	20.1
"	0-37.5-0	10.9	23.9	31.3	19.8
"	0-0-37.5	9.1	17.9	15.3	13.4
"	37.5-37.5-0	29.5	45.4	69.2	43.1
"	37.5-0-37.5	16.2	30.9	45.0	27.2
"	0-37.5-37.5	9.6	28.5	51.6	25.1
"	37.5-37.5-37.5	26.4	50.0	102.2	50.5

Table 10 : Response to fertilizers of suitable native varieties of rice in the farmer's field during 1960-1964 (Modified from Suwanwaong et al. 1966).

$N-P_2O_5-K_2O$ kg/ha	Average Paddy Yield (kg/ha)					Statistics (n = 5)		
	1960	1961	1962	1963	1964	$\bar{X}$	± s	CV(%)
A. Northern Region								
Location	7	16	27	16	31	-	-	-
0-0-0	2750	2556	2469	2519	2500	2559	111	4.4
12.5-0-0	2969	2894	2844	2950	2912	2914	49	1.7
0-25-0	3081	2981	2931	3088	2988	3014	68	2.3
12.5-25-0	3206	3131	3169	3262	3169	3188	49	1.6
25-25-0	3394	3188	3175	3281	3238	3255	88	2.7
37.5-25-0	3444	3250	3338	3425	3356	3342	96	2.9
50-25-0	3494	3356	3319	3525	3350	3409	94	2.7
50-25-0	3738	3388	3469	3525	3450	3514	134	3.8
B. Central Region								
Locations	31	57	40	34	46	-	-	-
0-0-0	1738	1975	2106	2206	2138	2032	185	9.1
12.5-0-0	2338	2300	2362	2462	2456	2384	72	3.0
0-25-0	2162	2362	2412	2575	2538	2410	164	6.8
12.5-25-0	2400	2612	2594	2744	2662	2602	128	4.9
25-25-0	2538	2719	2644	2756	2775	2686	97	3.6
37.5-25-0	2581	2681	2719	2838	2888	2741	123	4.5
50-25-0	2756	2912	2788	2950	2794	2840	86	3.0
50-25-25	2850	2850	2919	3075	2988	2936	96	3.3

Table 10 (Continue)

$N-P_2O_5-K_2O$ kg/ha	Average Paddy Yield (kg/ha)					Statistics (n=5)		
	1960	1961	1962	1963	1964	$\bar{X}$	$\pm$ s	CV(%)
C. Northeastern Region								
Location	32	31	37	32	34	-	-	-
0-0-0	1169	1238	1375	1325	1175	1256	91	7.3
12.5-0-0	1331	1469	1706	1681	1525	1542	155	10.1
0-25-0	1475	1662	1906	1906	1675	1725	184	10.6
12.5-25-0	1706	1938	2019	2062	1900	1925	138	7.2
25-25-0	1838	2075	2188	2156	2019	2055	139	4.5
37.5-25-0	1944	2250	2375	2256	2081	2181	169	7.7
50-25-0	2075	2269	2412	2388	2262	2281	134	5.9
50-25-25	2556	2562	2469	2488	2394	2434	116	4.8
C. Southern Region								
Locations	7	6	11	12	13	-	-	-
0-0-0	2469	1675	1912	2106	1644	1961	341	17.4
12.5-0-0	2588	2044	2219	2438	2100	2278	230	10.1
0-25-0	2719	2406	2494	2644	2569	2566	122	4.8
12.5-25-0	2875	2912	2912	2862	2581	2829	140	5.0
25-25-0	3138	2975	3019	2919	2819	2974	118	4.0
37.5-25-0	3256	2956	3138	2900	2925	3035	155	5.1
50-25-0	3131	2944	3131	2988	2931	3024	101	3.3
50-25-25	3262	2862	3094	3062	3025	3061	144	4.7

flooding or drought are not included; (2) better varieties are used and (3) better cultural practices are used.

After this classical experiment, experiments on sources of N have been studied. According to the Rice Fertilization Research Branch (RFRB, 1978), $(NH_4)_2SO_4$, urea and NH_4Cl gave no statistical difference in efficiency. Questions on whether long term application of these 3 N sources deteriorate paddy soils have been asked. From theoretical points of view either NH_4Cl or $(NH_4)_2SO_4$ are likely to have residual effects of Cl^- from the former or $SO_4^=$ and/or $S^=$ from the latter. These residual anions might change soil chemical environment after long term application. In reality, $(NH_4)_2SO_4$ is more available in the Thai market than NH_4Cl. The adverse effect of $S^=$ reduced from residual $SO_4^=$ of $(NH_4)_2SO_4$ after long term application has been tested at Suphanburi and Klong Luang Rice Experiment Stations for Fresh Water Allvial Soils (FWAS), for normal soils and Brackish Water Alluvial Soils (BWAS) or acid sulfate soil respectively, since 1968 with both wet and dry season cropping. Six levels of N as $(NH_4)_2SO_4$, receiving basal dressing of both P_2O_5 and K_2O at 37.5 kg/ha each respectively has been tested and compared with the check, 0-0-0 treatment. Each location has 3 main plots for promising varieties or hybrid lines and the varieties have been changed from time to time depending on either development of better rice varieties or past problems. The results are reported in Table 11-14 (RFRB, unpublished). It is clear from these tables that : (1) Each variety response to natural fertility, either without and with P and K and to various fertilizer N levels, differently depending on their genetic make up; (2) Dry season cropping is almost always better than the wet season cropping in the FWAS but vice versa for the BWAS; (3) Higher yields for the same treatment and variety in the FWAS than that of the acid sulfate soil is always observed; and (4) the BWAS has extremely low P and perhaps some K as can be seen from double or triple yields obtained from 0-37.5-37.5 over the 0-0-0 treatments for almost all varieties in the wet season and the gap is much wider for the dry season. These 12 varieties

Table 11 : Response to $(NH_4)_2SO_4$ of promising lines and improved varieties in wet season in a well irrigated Fresh Water Alluvial soil.

Statistics	Control	Levels of N (kg N/ha)					
		0	18.75	37.5	56.25	75.0	112.5
A. C 4-63 (3 crops during 1968-1970) (I)							
$\bar{X}$	1748	2915	3219	3669	3621	4015	4588
± s	378	667	245	134	22	309	83
CV (%)	21.6	22.9	7.6	3.6	0.6	7.7	1.8
B. Lt (2 crops during 1968-1969) (II)							
$\bar{X}$	1341	1984	2131	2053	2081	2078	1806
± s	4	234	407	164	97	22	504
CV (%)	0.3	11.8	19.1	8.0	4.7	1.1	27.9
C. Gp/2 x T (N_1) (2 crops during 1968-1969) (III)							
$\bar{X}$	1922	2706	3138	3553	3416	3741	3800
± s	358	362	159	358	102	75	398
CV (%)	18.6	13.4	5.1	10.1	3.0	2.0	10.5
D. T 442-36 (1 crop in 1971) (I)							
$\bar{X}$	1381	1938	2562	2688	3331	4038	4606
± s	-	-	-	-	-	-	-
CV (%)	-	-	-	-	-	-	-
E. RD 1 (6 crops during 1970-1975) (II)							
$\bar{X}$	1480	2171	2618	3103	3842	4192	4827
± s	168	198	363	316	297	261	501
CV (%)	11.4	9.1	13.9	10.2	7.7	6.2	10.4
F. RD 3 (6crops during 1970-1975) (III)							
$\bar{X}$	1564	2362	2751	3471	4028	4585	5138
± s	356	307	238	359	456	410	544
CV (%)	22.8	13.0	8.7	10.4	11.3	8.9	10.6

Table 11 : (Continue)

Statistics	Control	Levels of N (kg N/ha)					
		0	18.75	37.5	56.25	75.0	112.5
G. RD 5 (8 crops during 1972-1979) (I)							
$\bar{X}$	2046	2957	3305	3532	3824	4207	4549
± s	299	335	395	535	579	674	512
CV (%)	14.6	11.3	11.9	15.1	15.1	16.0	11.2
H. RD 7 (4 crops during 1976-1979) (II)							
$\bar{X}$	1673	2597	2883	3392	3569	3952	4436
± s	202	185	328	484	465	805	709
CV (%)	12.0	7.1	11.4	14.3	13.0	20.4	16.0
I. RD 9 (4 crops during 1976-1979) (III)							
$\bar{X}$	2206	2708	3131	3411	3625	3955	4269
± s	247	373	424	274	316	386	687
CV (%)	11.2	13.8	13.6	8.0	8.7	9.8	16.1
J. Rd 23 (1 crop in 1981) (I)							
$\bar{X}$	1606	2231	2825	3212	3444	3956	4212
K. RD 21 (1 crop in 1981) (II)							
$\bar{X}$	1619	2700	2944	3331	3525	3756	3988
L. RD 25 (1 crop in 1981) (III)							
$\bar{X}$	1312	2225	2375	3131	3312	3562	3984

Note : 1/ Each level of N receives 37.5 kg/ha of P_2O_5 and K_2O one day before transplanting and each level of N receives 50 % split application at transplanting and P.I. stage.

2/ Roman numer in parenthesis after each variety designates main plot number so that one could trace continuation of rice varieties used.

Table 12 : Response to $(NH_4)_2SO_4$ of promising lines and improved varieties in dry season in a well irrigated Fresh Water Alluvial soil.

Statistics	Control	Levels of N (kg/N/ha)					
		0	18.75	37.5	56.25	75.0	112.5
A. C 4-63 (5 crops during 1968-1971) (I)							
$\bar{X}$	2208	2706	3334	3671	3934	4374	4825
± s	555	482	508	550	358	395	382
CV (%)	25.1	17.8	15.2	15.0	9.1	9.0	7.9
B. Lt (3 crops during 1969-1970) (II)							
$\bar{X}$	1742	2106	2450	2627	2373	2665	2277
± s	778	956	1239	1252	1706	1342	1019
CV (%)	44.7	45.4	50.6	47.7	71.9	50.3	44.8
C. Gp/2 x T (N_1) (4 crops during 1968-1970) (III)							
$\bar{X}$	2403	2992	3238	3672	3494	3916	3817
± s	1336	1049	931	1087	925	772	442
CV (%)	55.6	35.1	28.7	29.6	26.5	19.7	11.6
D. T 442-36 (1 crop in 1972) (I)							
$\bar{X}$	2262	3106	3412	3919	4138	4625	5188
± s	-	-	-	-	-	-	-
CV (%)	-	-	-	-	-	-	-
E. RD 1 (6 crops during 1970-1976) (II)							
$\bar{X}$	2174	2877	3445	4109	4802	5142	6184
± s	404	527	692	855	917	1028	1042
CV (%)	18.6	18.3	20.1	20.8	19.1	20.0	16.8
F. RD 3 (6 crops during 1970-1976) (III)							
$\bar{X}$	2095	2924	3496	4472	4538	5183	5857
± s	629	563	505	777	823	788	645
CV (%)	30.0	19.3	14.5	17.4	18.1	15.2	11.0

Table 12 : (Continue)

Statistics	Control	Levels of N (kg/ N/ha)					
		0	18.75	37.5	56.25	75.0	112.5
G. RD 5 (9 crops during 1973-1981) (I)							
$\bar{X}$	1855	3099	3533	3737	3922	3990	4149
± s	496	533	615	729	872	912	1269
CV (%)	26.8	17.2	17.4	19.5	22.2	22.9	30.6
H. RD 7 (5 crops during 1976-1981) (II)							
$\bar{X}$	1838	2914	3334	3650	4036	4380	4991
± s	520	680	564	547	587	778	826
CV (%)	28.3	23.4	16.9	15.0	14.5	17.8	16.5
I. RD 9 (5 crops during 1976-1981) (III)							
$\bar{X}$	1859	2256	2574	3089	3350	3941	4628
± s	595	863	732	887	962	959	1176
CV (%)	32.0	38.2	28.5	28.7	28.7	24.3	25.4
J. RD 23 (1 crop in 1982) (I)							
$\bar{X}$	2312	3381	3738	4362	4919	5238	6369
K. RD 21 (1 crop in 1982) (II)							
$\bar{X}$	2419	4481	4481	4869	5600	5875	6069
L. RD 25 (1 crop in 1982) (III)							
$\bar{X}$	712	2275	3144	3988	3900	4231	4825

Note : See note of Table 11.

Table 13 : Response to $(NH_4)_2SO_4$ of promising lines and improved varieties in wet season in a well irrigated Brackish Water Alluvial soil.

Statistics	Control	Levels of N (kg N/ha)					
		0	18.75	37.5	56.25	75.0	112.5
A. C 4-63 (3 crops during 1968-1970) (I)							
$\bar{X}$	406	1617	2125	2379	2656	2785	3054
± s	161	274	528	804	925	1203	1413
CV (%)	39.6	17.0	24.9	33.8	34.8	43.2	46.3
B. Lt (2 crops during 1968 and 1969) (II)							
$\bar{X}$	581	1669	2069	2238	2556	2775	2916
± s	495	866	1211	1485	1618	1838	2099
CV (%)	85.2	51.9	58.5	66.4	63.3	63.3	72.0
C. Gp/2 x T(N_1) (2 crops during 1968 and 1969) (III)							
$\bar{X}$	719	1622	2041	2384	2656	2888	2925
± s	681	879	667	1030	1220	1220	1529
CV (%)	94.7	54.2	32.7	43.2	45.9	42.2	52.3
D. T 442-36 (1 crop in 1971) (I)							
$\bar{X}$	806	2094	2981	3162	3869	4288	4819
± s	-	-	-	-	-	-	-
CV (%)	-	-	-	-	-	-	-
E. RD1 (6 crops during 1970-1975) (II)							
$\bar{X}$	731	2121	2670	3027	3482	3773	4085
± s	272	346	391	482	416	507	726
CV (%)	37.2	16.3	14.6	15.9	11.9	13.4	17.8
F. RD3 (6 crops during 1970-1975) (III)							
$\bar{X}$	1001	2235	2841	3381	3712	4039	4166
± s	288	294	271	282	372	480	681
CV (%)	28.7	13.1	9.5	8.4	10.0	11.9	16.4

Table 13 : (Continue)

Statistics	Control	Levels of N (kg N/ha)					
		0	18.75	37.5	56.25	75.0	112.5
G. RD 5 (8 crops during 1972-1979)(I)							
$\bar{X}$	922	2145	2661	2837	3075	3145	3255
± s	323	400	445	565	645	610	811
CV (%)	35.0	18.6	16.7	19.9	21.0	19.4	14.9
H. RD 7 (4 crops during 1976-1979) (II)							
$\bar{X}$	786	1781	2180	2464	2714	2986	3481
± s	131	304	605	670	684	729	996
CV (%)	16.7	17.1	27.8	27.2	25.2	24.4	28.6
I. RD 9 (4 crops during 1976-1979) (II)							
$\bar{X}$	964	1917	2331	2791	2978	3044	3330
± s	87	360	279	247	358	466	500
CV (%)	9.0	18.8	12.0	8.8	12.0	15.3	15.0
J. RD 23 (2 crops during 1981 and 1982) (I)							
$\bar{X}$	1534	3028	3462	3762	4197	4247	4588
± s	287	57	230	150	102	243	495
CV (%)	18.7	1.9	6.6	4.0	2.4	5.7	10.8
K. RD 21 (2 crops during 1981 and 1982) (II)							
$\bar{X}$	1509	3375	3778	4131	4516	4697	4756
± s	526	44	199	106	13	4	62
CV (%)	34.8	1.3	5.3	2.6	2.9	0.09	1.3
L. RD 25 (2 crops during 1981 and 1982) (III)							
$\bar{X}$	997	2741	3141	3219	3294	3344	3791
± s	773	384	491	97	44	239	146
CV (%)	77.6	14.0	15.6	3.0	1.3	7.1	3.8

Note : See note of Table 11

Table 14 : Response to $(NH_4)_2SO_4$ of promising lines and improved varieties of rice in dry season in a well irrigated Brackish Water Alluvial soil.

Statistics	Control	Levels of N (kg N/ha)					
		0	18.75	37.5	56.25	75.0	112.5
A. C 4-63 (4 crops during 1968-1971) (I)							
$\bar{X}$	441 (2)	1744	2319	2391	2891	3086	3470
± s	66	548	444	321	367	530	489
CV (%)	15	31.4	19.2	13.4	12.7	17.2	14.1
B. Lt (3 crops during 1968-1970) (II)							
$\bar{X}$	488 (2)	1954	2312	2527	2731	2994	2562
± s	309	749	240	65	333	350	116
CV (%)	63.5	38.3	10.4	2.6	12.2	1.7	4.5
C. Gp/2 x T(N_1) (3 crops during 1968-1970) (III)							
$\bar{X}$	306 (2)	2200	2475	2856	3352	3558	3475
± s	186	734	607	605	784	789	878
CV (%)	60.6	33.4	24.5	21.2	23.4	22.2	25.3
D. T 442-36 (1 crop in 1972) (I)							
$\bar{X}$	0	1756	2400	2619	2531	2931	2144
± s	-	-	-	-	-	-	-
CV (%)	-	-	-	-	-	-	-
E. RD 1 (6 crops during 1971-1976) (II)							
$\bar{X}$	985 (3)	2300	2775	2936	3411	3335	3435
± s	702	560	468	472	600	730	894
CV (%)	71.3	24.3	16.9	16.1	17.6	21.9	26.0
F. RD 3 (6 crops during 1971-1976) (III)							
$\bar{X}$	781 (3)	2694	3088	3526	3709	3899	3890
± s	547	533	500	498	552	475	491
CV (%)	70.0	19.8	16.2	14.1	14.9	12.2	12.6

Table 14 : (Continue)

Statistics	Control	Levels of N (kg N/ha)					
		0	18.75	37.5	56.25	75.0	112.5
G. RD 5 (8 crops during 1973-1981) (I)							
$\bar{X}$	588 (2)	2397	2575	2562	2509	2512	2224
± s	619	527	387	464	433	562	591
CV (%)	105.3	22.0	15.0	18.1	17.3	22.4	26.6
H. RD 7 (4 crops during 1977-1981) (II)							
$\bar{X}$	1055	2197	2639	2870	2972	3288	3578
± s	493	865	903	1036	782	870	907
CV (%)	46.8	39.4	34.2	36.1	26.3	26.5	25.3
I. RD 9 (4 crops during 1977-1981) (III)							
$\bar{X}$	986	2305	2575	2942	3150	3311	3381
± s	341	904	1075	1203	1172	1381	1334
CV (%)	34.5	39.2	41.7	40.9	37.2	41.7	39.5
J. RD 23 (1 crop in 1982) (I)							
$\bar{X}$	788	2775	3438	3694	4031	4350	4775
K. RD 21 (1 crop in 1982) (II)							
$\bar{X}$	1294	3469	3625	3956	4462	4112	4125
L. RD 25 (1 crop in 1982) (III)							
$\bar{X}$	700	2512	2831	3138	3600	3744	3419

Note : See note of Table 11

selected are : one introduced (C_4-63); one selected native nonphoto period sensitive variety (Lt), two promising hybrids (Gp/2xT (N_1) and T 442-36; and eight RD's varieties. Their promising virtues are the basis of selection instead of their yield potential alone. The response to native and added N, thus are not really the same but all of them responsed well to added N up to the highest dose tested in the normal soil. More toxic substances in the soil in the dry season than that of wet season, because of either leaching out or dilution or both by rainfall, might be used to explain the poorer yields of dry season cropping than that of the normal cropping season in the acid sulfate soil. Toxic substances and extremely low P explain lower yields of rice in the BWAS than the FWAS. No evidence on adverse effects of the residual $SO_4^{=}$ upto 30 crops is clearly discernible.

Fertilization of both FWAS and BWAS based on soil test through Mitscherlich-Bray equation for both N and P has been attempted by Vajragupta et al (1973) and by the author (unpublished) but it is not practical at present because of the limited supply of the single grade fertilizer in the Thai market. The compound or mixed fertilizers : 16-20-0, 18-22-0, 20-20-0 or even, 13-13-13, 14-14-14 and 15-15-15 formulae available in the market have been accepted for the dry season cropping, because of their high availability in the market. Among these formulae the generally recommended 16-20-0 formula is the most widely used. Nammuang et al (1979), after 4 years of farmer's field experiments throughout country, are able to recommend N fertilization based on their developed quadratic equations and price ratio of the ammophos (AP, 16-20-0). The predicted equations are presented in Table 15. Though the predicted yield and amount of AP applied are expressed in kg/rai this can be easily converted to kg/ha by multiplying the figure on the rai basis by 6.25.

Improvement and fertilization of acid sulfate soils in Thailand has already been reviewed by the author (Prabuddham, 1982).

Table 15 : Quadratic equations for yield prediction from ammophos (16-20-0) application (Nammuang et al, 1979).

Varietal[1/] type	Season	Predicted equation[2/] ($\hat{Y}$ in kg/rai, AP in also kg/rai)	R^2
A. Normal soils			
a. Heavy texture soils of the Central Region			
NPS	DRY	$\hat{Y} = 379.4752 + 9.2299AP - 0.0438AP^2$	0.9811**
NPS	WET	$\hat{Y} = 587.3104 + 7.6386AP - 0.0324AP^2$	0.9942**
PS	WET	$\hat{Y} = 383.2857 + 5.7023AP - 0.0655AP^2$	0.8274*
b. Medium texture soils of the Northern Region			
NPS	DRY	$\hat{Y} = 470.5137 + 3.4999AP - 0.0128AP^2$	0.8834**
NPS	WET	$\hat{Y} = 308.9587 + 3.5862AP - 0.0105AP^2$	0.9465**
PS	WET	$\hat{Y} = 494.7362 + 2.7943AP - 0.0153AP^2$	0.9097**
c. Light texture soils of the Northeastern Region			
NPS	DRY	$\hat{Y} = 398.6713 + 4.3000AP - 0.0198AP^2$	0.9215**
NPS	WET	$\hat{Y} = 342.8041 + 4.4270AP - 0.0155AP^2$	0.9646**
PS	WET	$\hat{Y} = 387.8041 + 4.8891AP - 0.0280AP^2$	0.9422**
d. Light texture soils of the Southern Region			
NPS	DRY	$\hat{Y} = 385.1048 + 3.7921AP - 0.0147AP^2$	0.8845**
NPS	WET	$\hat{Y} = 305.8461 + 4.9436AP - 0.0224AP^2$	0.9087**
PS	WET	$\hat{Y} = 383.9230 + 3.0577AP - 0.0151AP^2$	0.9301
B. Acid sulfate soils			
a. Heavy texture soils of the Central Region			
NPS	DRY	$\hat{Y} = 173.1593 + 4.9319AP - 0.0131AP^2$	0.9919**
NPS	WET	$\hat{Y} = 259.7527 + 5.5327AP - 0.0221AP^2$	0.9668**
PS	WET	$\hat{Y} = 297.4909 + 3.2430AP - 0.0239AP^2$	0.9283**

Note : 1/ NPS = Nonphoto period sensitive varieties.
PS = Photoperiod sensitive varieties.
2/ 6.25 rai = 1 ha
* significant
** highly significant

D. Development of Rainfed Rice Cultivation Technologies

Rainfed rice cultivation, according to the Department of Agriculture (1983), is rice cultivation that relies only on rain without any supplemented irrigation. It can be transplanting, drilling or broadcasting types of cultivation depending on rainfall distribution, land form and soil properties. Success of rainfed rice farming depends on (1) availability and reliability of such rainfall statistics as daily, weekly, and monthly rainfall statistics; (2) land form (upland and lowland) and water holding capacity and fertility of the soils; (3) availability of suitable varieties that match very well with the rainfall pattern and (4) ability of farmers to adopt the technologies developed as well as capital for some investment.

a. Transplanted Rice Farming

This type of farming is the most suitable in lowlands and clayey soils which always receive good rains, flooding occurs but not deeper than 50 cm. This farming has the least risk and always the best yields, because yield components could be controlled through the growing season. The best yields could be obtained if :

(1) The flooding water could be kept < 50 cm. for the tall varieties and <30 cm for the improved RD's varieties;

(2) Growth duration after transplanting to maturing could be at least 80-90 days;

(3) If old seedling or poor fertility soils are to be used, several seedlings per hill or closer spacing (25 x 25 cm^2 spacing, is generally recommended);

(4) Maturity of the rice varieties selected and ending of rainy season are synchronized; and

(5) Fertilization, weeding and pest management recommended by rice cultivation experts could be followed.

b. Broadcasted Rice Farming

In rainfed areas, good crop yields can not be expected from broadcasted rice farming because of the weed problems. If rainfall distribution is poor, poor germination and death of some seedlings will reduce plant population greatly. Broadcasted farming, however, is always practiced in the deep flooding areas of the Central Region and other regions, whenever labors are scarce as well as in early drought year, when seedling preparation cannot be made. Good crop yields can also be obtained in some rainfed areas if :

(1) Growth duration of the varieties used can be controlled at 110-120 days or at least 90-100 days;

(2) Broadcasting over harrowing ridges 30-40 cm apart will make weeding easy, along the ridges machanically or chemically. Weed problems, thus, will be minimized;

(3) Seeding rate at 94-125 kg/ha is optimum for Thai conditions;

(4) If broadcasting must be done during heavy rainfall periods, drainage furrows within the paddy land have to be made; and

(5) In the deep flooding areas of the Central Plain where micro-landform can be differentiated, using early, medium and late floating rice varieties for the back slope of levees, flood plains and basins are operated respectively, provided that weeds can be controlled.

c. Drilled Rice Farming

This type of rice farming is recommended in the upland area or even lowland area of the Northeastern Region whenever seedling preparation and transplanting cannot be done but drainage furrows for each lowland paddy field have to be made. Good crop yields can be obtained if these recommendations are followed :

(1) Drill the soil with round headed wooden stick, about 1 in diameter, to a 4-5 cm depth, into rows of 25 x 25 cm^2 spacing. If the paddy field is dry, try 5-6 seeds/bore or 31 to 37 kg/ha of seed will be used, but germinated seeds are recommended for the wet fields instead;

(2) Treating dry seed with such insecticides as sevin, malathion or furadan will mimimize insect damage during germination;

(3) Weeding during the 15-30 days after germination can improve yield significantly; and

(4) Fertilization, if possible, with recommended doses at planting and P.I stage can double or triple yield increases over the check.

d. Drought Problems and Solutions

Quite a large area of paddy land that cannot be cultivated or harvested has always been reported in Thailand because of drought problem . This will, therefore, be discussed separately.

This drought problem is always the major problem of the Northeastern Region because of : (1) poor rainfall distribution (2) poor water holding capacity of soils, (3) sloping topography from West to East, and (4) poor forest and soil conservation. This drought conditions as well as very poor natural soil fertility bring about the lowest average yield of rice and the lowest per capita income of the country. The direct influence of the drought to rice cultivation and recommended solution developed will be separately discussed.

(a) Problems

1. Crop failure because of early rainy season drought or the paddy field is too dry to do land preparation;

2. Crop failure because of mid rainy season drought : Death of seedling and/or no water for transplanting and/or not enough tillering are the problems;

3. Crop failure because of late rainy season drought : Sterility is the major problem.

(b) Recommended Solutions

1. For land preparation

First plow soon after harvesting the last wet season crop while the soil is still soft enough. This plowing will allow the second plowing and harrowing for both seedling preparation and for broadcasting and/or drilling in the wet season crop to be possible.

2. For seedling preparation

Dry seeding preparation has already been practiced in many provinces of the Northeastern Region. A common seedling bed for the village is recommended. Lowland areas or areas near water sources big enough for the whole village need to be selected. First plowing will be done immediately after the first big rain of the season. The second plowing and harrowing will be done during the optimum date in regard to water availability. Unsoaked seed at the rate of 1250 kg/ha will be uniformly broadcasted on the dry land prepared and all weeds removed. The last harrowing will cover the seeds to minimize damages from birds, rats and other pests. Waiting for the coming rain is the last step.

3. For transplanting

3.1 Dry transplanting

Transplant dry seedlings into the land prepared (mentioned already) and moist enough for few days of seedling survival. The rain must be expected. Transplanting can be done by the aid of round ended bamboo drillers. Transplant 3-5 (30-45 day old) seedlings into the hole and fill in the hole tightly with the soil nearby.

3.2 Drilling or broadcasting

In case rain is not expected soon after the transplanting time, direct seeding into holes made by bamboo drillers or broadcasting the unsoaked seeds of early variety rice, such as RD 25 and Nam Skue is strongly recommended. Fertilization and weeding have proved to give satisfactory results for our Northeastern climatic conditions.

V. Proposed Rice Production Philosophy

Since most developing countries including Thailand are agricultural countries, a high proportion of their population engages in farming or related activities. It has been well accepted that most agro-based countries are developing countries. Lack of technologies and funds are the major causes of poverty of these countries.

It is very clear from Part I that rice is the most important crop of Thailand as can be easily seen from the number of paddy farmers areas used and its contribution to the national income and foreign currencies. Thailand has always been a top exporter in spite of her lowest average rice yield (Table 4). The lowest input for rice production discussed in Part II undoubtedly accounts for the lowest yield and this reflects how poor Thai paddy farmers are. Poverty of the farmers, the major group in Thailand, brings about, undoubtedly, a poor economy for the country. To solve this problem, efficient paddy land use planning and implementation should receive the highest attention from the Thai Government.

From available information discussed in Parts I-IV of this paper, the philosophy proposed is based on these hypothesises :

(1) Utilization of the most suitable paddy soils efficiently in the decreasing order of suitability along with reformation and consolidation of the land are the most socio-economic feasible justification;

(2) The better distribution of small farming by family.

(3) Utilization of the suitable rice varieties and proper cultural practices locally tested is the most appropriate technology, and

(4) Financial support for better rice production to the poorest but the biggest group of population is the most justified government investment expenses.

Since paddy soils in P-I group have no natural limiting factors at least during wet season, this soil group should be allocated for a industrial rice production zone. The lowest soil management input could be expected from the soil group utilization. Since development of a complete irrigation system needs a great deal of money, utilization of suitable rice varieties and fertilization in the P-I group soil and the present available irrigation system should be more economic feasible.

It is logic to believe that :

(1) All irrigated areas of each region presented in Table 3 are in P-I group and these soils are the most suitable for nonphoto period sensitive (NPS) varieties, in wet season cropping;

(2) The remaining areas of the P-I group soils presented in Table 6, after subtraction of the wet season irrigatable areas in (1), except that of the Central Plain, fit very well with rainfed photoperiod sensitive (PS) rice varieties in wet season cultivation;

(3) All areas used for dry season cropping, where NPS rice varieties have already been accepted, are completely in the P-I group;

(4) Such good NPS varieties as RD 1, 7 and 11 for the Central, Southeastern and Southern Region; RD 2, 7 and 11 for the Northern Region; and RD 1, 2 and 7 for the Northeastern Region and such PS rice varieties as LPT 123 for the Central and Southeastern Regions, NSP for the North and Northeastern Regions and NP 132 for

the Southern Region tested by Nammuang et al (1979) can be well accepted and;

(5) Partial subsidy or long term loans with very low interest for the ammophos fertilizer at the maximum yield dose should be one of our government's policies in the near future.

If these five beliefs could be planned and implemented, the P-I suitability group alone can supply 19.52 million tons of paddy yearly. Huge rice production could be up to 15.43 million tons of production in the wet season cropping from only 3.9363 million hectares and 4.09 million tons of dry season production from 0.68 million hectares, instead of 17 million tons from 12.4 million ha at the present. Complete calculation of this potential production is illustrated in Table 16. From this table, we can also see that almost 13 million tons of paddy could be produced from the P-I soils alone without fertilization, provided that varieties and cultural practices developed are accepted by farmers.

It should be pointed out here that 2.771 million tons of this total ammophos (16-20-0) fertilizer needed should stimulate a internal fertilizer industry from the natural gas base expected in the near future. If the partial subsidy or loan for the total 2.771 million ton demand is too big of a financial burden, 3 phases of a 5 year program should be evaluated. Phase I of the program should be focused at the improvement of rice production through fertilization of suitable varieties for the Central and Southeastern Regions because of their highest response to fertilization of the rice varieties used and their closeness to Bangkok, the biggest market. The phase II program should be aimed at the Northern Region because of its high irrigation potential and its medium responsiveness to the ammophos. The phase III program should be set for the Northeastern and Southern Regions. These two regions receive less attention, in spite of their highest social and security importances, because of risk for investment in the poor environments of the Northeast and less importance of

Table 16 : Potential rice production and amount of ammophos needed for the P-I soil improvement.

Season[1] and water supply	Expected area (10^6 ha)	Paddy yield[2] W/O AP (t/ha)	Paddy yield[2] wt AP max (t/ha)	Production W/O AP (10^6t)	Production wt AP max (10^6t)	AP max-used kg/ha	AP max-used total (10^6t)	ΔY(t) AP (t)
A. Central and Southeastern Regions								
W.Irr.	0.6755[3]	2.37	5.41	1.60	3.65	655.25	0.634	4.64
W.Rain.	0.9042	2.40	3.17	2.17	2.89	275.00	0.169	2.80
D.Irr.	0.55	3.67	6.49	2.02	3.58	737.50	0.406	3.82
Total	2.1297	2.72	4.75	5.79	10.12	567.75	1.209	3.58
B. Northern Region								
W.Irr.	0.3988	2.94	4.44	1.17	1.77	856.25	0.341	1.75
W.Rain.	0.5461	3.09	3.89	1.69	2.12	568.75	0.311	1.41
D.Irr	0.090	1.93	3.84	0.17	0.35	1068.75	0.096	1.79
Total	1.0349	2.93	4.10	3.03	4.24	722.78	0.748	1.62
C. Northeastern Region								
W.Irr.	0.0715	2.94	3.95	0.21	0.28	681.25	0.049	1.48
W.Rain.	0.9973	3.09	3.76	3.08	3.75	543.75	0.542	1.23
D.Irr.	0.03	2.14	4.12	0.06	0.12	893.75	0.027	2.22
Total	1.0988	3.05	3.78	3.35	4.15	562.43	0.618	1.30

Table 16 : (Continue)

Season[1/] and water supply	Expected area (10^6 ha)	Paddy yield[2/]		Production		AP max-used		ΔY(t) AP(t)
		W/O AP (t/ha)	wt AP max (t/ha)	W/O AP (10^6t)	wt AP max (10^6t)	kg/ha	total (10^6t)	
D. Southern Region								
W.Irr.	0.0997	2.49	3.94	0.25	0.39	806.25	0.080	1.80
W.Rain.	0.1732	2.42	3.37	0.42	0.58	631.25	0.109	1.50
D.Irr.	0.010	1.91	3.62	0.02	0.04	687.50	0.007	2.49
Total	0.2829	2.44	3.57	0.69	1.01	692.82	0.196	1.63
Country's	4.5463	2.83	4.29	12.86	19.52	609.51	2.771	2.40

Note : 1/ W.Irr. = Wet season irrigatable area.
W.Rain = Wet season rainfed area.
D.Irr. = Dry season irrigatable area.

2/ Paddy yield based on Nammuang et al (1979) reported
NPS for W.Irr. and D.Irr.
Ps for W.Rain.

3/ Irrigated area reported in Table 3 excluding area of P-III a and P-IVa reported by Prabuddham (1982).

rice than pararubber in the South. Once the Phase I has succeeded, a better national economy should be expected, thus expansion of irrigatable land for both wet and dry season of the two regions involved should be possible. Much more irrigatable land increases within this P-I soils, throughout the country, after completion of the 3 phases program should be possible.

In the following few decades, fertilization of the other soil suitability groups might still be too risky to accept by the paddy farmers except the soils of P-IIf group after flood control measures have been effective and special managements for P-IIIa and P-IVa have already been accepted. For the P-IIIa soils, urea and rock phosphate seems to be the most economic fertilization technology but for the P-IVa soils, liming with marl to reduce Al toxicity followed by ammophos can solve the acidity and fertility problems of the soil. With rainfed technologies development discussed in Part IV, even without fertilization, 50 % yield increase over the traditional procedure could be obtained. Rice farming in these soil groups except the P-IIf and P-IIIa and P-IVa should be aimed for home and local consumptions during the 3 phase fertilization program of the P-I soils. After phase III, a feasibility study on fertilization of these soils should be investigated.

If land reformation and consolidation planning in the P-I group soils can be formulated and implemented along with the fertilization program, great socio-economic improvements through land owning motivation should be expected. If the dry season irrigatable, the wet season irrigatable and the rainfed areas can be reformed at the rate of 2 ha, 2.5 ha and 3.0 ha per family respectively, over 60 % of the total paddy farmers calculated in Table 2 should have a better life. Distribution of the number of households proposed in each region and area is illustrated in Table 17. This table clearly demonstrates that 0.34 million families more could have better jobs in the Central and Southeastern Regions. If the planning can be implemented, 20 % of the poorest families of the poorest soil areas and climatic environments

Table 17 : Proposed number of households to be accommodated after reformation and consolidation of the P-I group soils.

Area and households 1/	Water availability within the P-I				Total 2/
	D.Irr.	W.Irr.	W.Rain	Total	
A. Central and Southeastern Regions					
Area ($x10^6$ ha)	0.55	0.6755	0.9042	2.1297	3.26
Household ($x10^6$)	0.275	0.2702	0.3014	0.8466	0.50
B. Northern Region					
Area ($x10^6$ ha)	0.09	0.3988	0.5461	1.0349	2.64
Household ($x10^6$)	0.045	0.1595	0.1820	0.3865	0.75
C. Northeastern Region					
Area ($x10^6$ ha)	0.03	0.0715	0.9973	1.0988	5.72
Household ($x10^6$)	0.015	0.0286	0.3324	0.3760	1.26
D. Southern Region					
Area ($x10^6$ ha)	0.01	0.0997	0.1732	0.2829	0.78
Household ($x10^6$)	0.005	0.0398	0.0577	0.1025	0.22
Whole country					
Area ($x10^6$)	0.68	1.2455	2.6208	4.5463	12.4
Household ($x10^6$)	0.34	0.4981	0.8736	1.7117	2.73

Note : 1/ Allocation of area/household is based on water availability by these rates :

a. D.Irr. 2 ha/family

b. W.Irr. 2.5 ha/family

c. W.Rain 3 ha/family

One family = one household = 7 persons

2/ Total area of each region reported in 1979 (Table 3)

Total households of each region calculated in 1978 (Table 2)

of the Northeastern Region could be resettled in this twin region, A better life for the poor farmers and a better economy for the country should be hoped.

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PRESENT LAND USE ON POTENTIAL AND ACTUAL ACID SULPHATE SOILS IN THE MEKONG DELTA

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1. Distribution of acid sulphate soils in teh Mekong Delta.

It has been estimated that about 2.6 million ha of potential and actual acid sulphate soils are present in various areas in southern Vietnam (Soils Survey Division, Ministry of agriculture, 1978, unpublished data). The well developed acid sulphate soils are found on large areas in the Plain of Reeds, the Plain of Hatien, and on scattered spots throughout the Vietnamese part of the Mekong Delta with a total area of about 870,000 ha. The potential acid sulphate soils in tidal marshes and underneath mangrove forests total to about 704,000 ha. Shallowly developed acid sulphate soils are found in empoldered backswamps subject to salt water intrusion with a total of about 1,015,000 ha. Another estimated 27,000 ha of potential acid sulphate soils can be found underneath 0.5-2.0 m of peat soils found mostly in Melaleuca, Avicenia, and Rhizophora forests in Minhhai province. Further survey by the University of Cantho and Agrocultural University of Wageningen cooperative research project (VH-10, 1982, unpublished data) have shown that in general the acid sulphate soils of the Delta are very dynamic. There are a great many varieties of soil types, from sulfaquent-related types found in tidal marshes along coastal lines and in backswamps situated between sand ridges to sulfaquept-related and sulfic tropaquept-related types found mostly in backswamps, broad depressions between ridges underlaid by old alluvium.

Through the years, the subsistent farmers, by trial and error, have found various ways to use the acidity or to overcome the

acidity of their soils using rainwater and saline or brackish water in the water management of their cropping systems. This paper describes some pertinent agroecological characteristics followed by corresponding methods for management of acid sulphate soils in south Vietnam.

2. Hydrology

The Mekong Delta includes a network of natural and man-made waterways. In estuary areas, tidal movements are felt strongly with magnitudes from 1.5 to 4.5 m. Far inland, tidal magnitude decreases considerably to not more than 1 m in the dry season when the water table is deeper than 1.2 m below the ground level. On the contrary, in the wet season (May to November) local rainfall added to the Mekong rivers' high flow discharge impounded in slowly drained lands result in various water regimes in the Delta. Depending on local physiography, several hydrologic conditions may be distinguished :

2.1 In the dry season

a. Most well-developed acid sulphate soils are not easily reached by river water, thus being extremely dry. The water table is too low (deeper than 1.5 m). Irrigation is impractical.

b. The newly developed acid sulphate soils are often flushed by river water which is brackish most of the time.

c. The potential acid sulphate soils are flushed daily (with saline water) by tidal movement along coastal plains.

2.2 In the rainy season

Rainfall varies from about 1,400 to 2,400 mm, distributed from May to November.

a. Most well developed acid sulphate soils are gradually flooded to a depth of 1 to 3 m, especially in the Plain of Reeds and the Plain of Hatien. The duration of flooding is about three months.

b. The young and potential acid sulphate soils are flooded to a maximum of about 80 cm.

3. Cropping systems on each type of land.

In the management of acid sulphate soils for crop production, no single measure can assure final success. Integrated systems of soil-water-crop management must always be considered in order to optimize the physical and social environment without destroying the natural ecology. The term "crop" used here envisions any appropriate generic stock of plants, livestock, fish, etc.

3.1 Potential acid sulphate soils.

3.1.1 Areas with a peaty layer in the topsoil : found in defoliated and newly opened Rizhophora and Avicenia forests along coastal marshes. Tidal movement flushes the topsoil daily. Polders of about 10 ha/unit were constructed. Each polder has network of drainage ditches. A flapgated culvert regulates the water level inside the polder to the depth where pyritic soil occurs.

The very first crop after land clearing was pumpkin (Cucurbita spp.). Starting with the first rains, farmers raised pumpkin seedlings in tiny soil packets, then planted in the peaty soil. Rainwater supplied fresh water for pumpkin growth while flushing the acids and salts from the topsoil. During the first two years, without any fertilization, the farmers obtained an average yield of 20 tons pumpkin/ha.

In the third year they constructed raised beds to plant a rotation of soybean-corn-soybean crops throughout the entire rainy season from May to December. Other farmers constructed ridges to plant sweet potato intercropped with short duration high yielding rice. The yield of 80-day soybeans was about 2t/ha while the rice in the furrows between ridges yielded about 1t/ha.

3.1.2 Areas with strong tidal movement and abundant freshly deposited alluvial and marine sediments : These areas are often found in coastal plains affected by brackish or saline water daily. The vegetation in these swamps consists of various species of Acanthaceae, Acrosticaceae and Ceriop scandolleura, Nipa frutican, etc. Marine sediment accretion may be up to 5 cm/year. The reduced subsoil (20 to 40 cm) contains about 0.3 to more than one percent pyrite. Experienced farmers exploited the areas by constructing 10-ha polders to raise shrimp during the dry season, then transplanted rice in the wet season. Coconuts were grown on the surrounding raised bunds made up of annual marine deposits. Each polder has a network of canals and ditches to serve as drainage system during the rainy period but in the dry season they serve as catchment pond for raising shrimp fries. A flapgate was constructed along the main water way. It lets brackish or saline water into the polder in order to keep the soil wet to prevent oxidation of sulfur containing substances, hence suppressing acidification of the soil. Fortunately the salt water also carries shrimp fries bred in the estuaries. Based on the lunar calendar, every full moon and new moon are periods for letting in shrimp fries. Adult shrimp are caught monthly until the start of the rainy season. The salinity on the surface of the soil is flushed away into the canals then out of the polder through the opened flapgate which remains closed at high tide period. Seedlings of medium term rice varieties such as IR 2823-399-5-6, IR 42, C4-63, C168... are now widely in use. The seedlings are raised on adjacent bunds underneath the coconut trees or on a nearly non-saline soil. The rice maturity coincides with the termination of the rainy season. Farmers harvest their rice, then re-excavate the ditches and canals to start the cycle again. Every other year they scrape off new sediments deposited on the land surface and gather them onto raised beds or bunds along the canals. When the raised beds attain an appropriate height, coconuts are planted on them. Shrimp yields of 300 to 500 kg/ha and paddy rice of 4 to 5 t/ha were common.

3.2 Actual acid sulphate soils.

3.2.1 Empoldered coastal ridges with thick marine deposits and deeply developed jarosite (more than 80 cm), often become dry during the dry season. Farmers take great care of the dikes to prevent salt water intrusions at all time. They start land preparation after a few rains which softens the soil, then directly broadcast rice seeds of medium term varieties such as mentioned under 3.1.2 above. advanced farmers use very short duration rice varieties such as IR9129 -169-2-3-5 (85 days) for the early rainy season crop in rotation with seedlings of medium-term varieties. Yields of 6 to 9 t/ha per year can be obtained with rain as the sole source of water. The land is then left fallow during the dry season.

3.2.2 Empoldered coastal backswamps with a thin (less than 15 cm) peaty topsoil, often become dry during the dry season, and jarosite occurs at 10 to 50 cm depth. Tidal movement is less pronounced in these areas. The farmers use a shallow drainage system to grow one crop using one of the tall, medium-term rice varieties. This system consists of shallow ditches (30 to 60 cm deep, 60 to 100 cm wide) excavated by hand, and spaced at 9 m intervals. The excavated unaltered thin slices of spade-shaped soil is spread evenly on the 9 m strips forming moderately raised beds. The ditches are connected to a deeper drainage canal running to a flapgate built on to the main dike. With the first heavy rains, normally in April, rainwater washes off the oxidized sulfidic soil material on the ridges and removes toxic substances such as aluminum and salts. These substances are collected in the shallow ditches and in the drainage canals. The outlet gates remain closed until the drained water is level with the surface of the raised beds. With the next rains, the accumulated water is allowed to run through the canals and out to the river at low tides. The cycle is repeated 2 or 3 times before the entire region is naturally flooded and drainage is no longer possible. Fourty-five to sixty-day-old seedlings (about 80 to 100 cm tall) are transplanted on to the raised

beds which are submerged under 10 to 40 cm of water. Traditional medium term rice varieties such as Than Nong Do, Trang Mot Buoi, Trang Hoa Binh, Trang Tep, etc. are commonly used. Yields of 2.5 to 3.8 t/ha were obtained compared to 0.2 to 0.5 t/ha on undrained soils.

3.2.3 Trans-Bassac floodplain with a high water table during the dry season and semi-deep water during wet season :

3.2.3.1 The soil may have a high organic matter content in the topsoil and clayey subsoil. Jarosite and pyrite may occur near the surface along the rivers Vaico East, during low flow period in the dry season, where land physiography is mostly depressed, water management by gravity with brackish water is possible. Farmers constructed polders of various sizes, each having a flapgated culvert to regulate water inside the polder. Within the polders, raised beds of 5 to 8 meter width separated by ditches of various depths (30-60 cm) and widths (50 to 100 cm), depending on the depth of jarosite, were constructed. The raised beds were planted with the following crops in sequence :

(a) Cassava-rice
(b) Jute or kenaf-rice or wet fallow
(c) Yam-wet fallow

Usually the entire polder is flooded from September to November. When water recedes, the farmers till the soil on the raised beds, then plant the first crop which grows during the dry season. River water is let into the polder up to the jarosite level in order to efficiently suppress the acidification of the topsoil. After the cassava is harvested in May, rice is transplanted on to the same spot.

The jute or kenaf germinates and grows up with the residual moisture in the soil to a height of about 50 cm when the soil becomes totally dry. It survices the dryness through the dry season and resumes growth again when the rains come. Jute is harvested in August, yielding about 1.5 t fiber per ha.

To plant yams, farmers construct high ridges before the first rains, and leave them uplanted troughout the rainy season. The ridges are gradually submerged in the flood. This is in fact a good method of leaching out toxic substances. As the flood subsides, the ridges are re-tilled and yam cuttings are planted. Harvesting is done in April, before the rainy season starts.

3.2.3.2 Wherever there is mostly peat in the first meter of topsoil in depressed areas, it is often perennially wet and the weed Ischaemum spp. predominates the vegetation. This weed can elongate during high flood. Farmers have long been using these areas as pastures for their cows and water buffaloes. In this marshy environment fresh water fish grow abundantly. If it dries out, the soil becomes extremely acidic, there will be no more fish, nor Ischaemum weed, and no water buffalo or cows can graze.

3.2.4 Coastal ridges and Trans-Bassac floodplain with moderate water table during the dry season : In these areas which are moderately flooded (less than 60 cm) during the rainy season, farmers grow pineapple or sugarcane quite successfully.

First they construct polders of different size depending on their land tenure. Then raised beds were constructed, 4 to 5 meters wide and about 60 cm higher than the original land surface. The width of the resulting excavated canal between two raised beds varies accordingly in order to give sufficient soil materials for the beds. Care should be taken during excavation : not to excavate pyritic materials and not to expose jarosite layers on top of the beds. The excavated soil was always set aside first, then the excavated jarosite subsoil was deposited on the position of the bed, and finally the excavated topsoil was spread evenly over the top of the bed. The beds were left to be leached through one whole wet season by rainwater before pineapple or sugarcane were planted. Irrigation can be carried out with water impounded in the canals, even if it is acidic. Yields of pineapple are usually from 6 to 8 t/ha, and sugarcane from 30 to 60 t/ha.

3.2.5 Trans-Bassac floodplain with a low water table in the dry season but with deep flooding during rainy season : This area is typical for a majority of the Plain of Reeds and the Plain of Hatien. Soil variability is so great that even within 50 m more than two different types of acid sulphate soils are found. Based on careful surveys through years of experience, farmers planted Melaleuca leucodendron on very acidic to extremely acidic zones, and floating rice on moderately acidic zones. This is in fact an agroforestry system where rice-Melaleuca-bees-fish can be raised together.

Melaleuca planting is simple. It is transplanted with 1 m tall seedlings if the supernatant water is cloudy : the best way is to drive a deep hole into the soil and insert carefully the root of a Melaleuca seedling without packing the soil afterward. In those places where supernatant acidic water is clear, the soil is usually plowed while still dry, then farmers wait until August or September when field water level is about knee-high. They go out in a sampan to broadcast Melaleuca seeds, which have been mixed with burned rice husks. The seeds sink to the bottom and start to germinate and grow in the submerged condition. As the water level increases gradually to 1-1.5 m, the young Melaleuca plants increase in height in the water. After the field water recedes the plants keep on growing in the dry soil. This is indeed an amazing plant. It grows equally well in any water regime. An average Melaleuca forest can yield about 100 to 120 cu m/ha after five years. One planted, regrowth of the forest is automatic thanks to the dropped seeds. However, measures should be taken to avoid forest fire during the dry season : shallow canals of 4 to 5 m width and about 1.5 m depth are dug, and the whole area is empoldered so that flood waters can be retained inside after the flood subsides. Fish from the flood are thus trapped inside too. Flowers of Melaleuca have long been recognized as good feed for honeybees. Therefore, honey production can be combined wtih Melaleuca production. The lowest spots inside these areas can be used for integrated lotus and fish production.

In zones having deeply developed jarosite, the floating rice-watermelon, or floating rice-sesame, or floating rice-mung bean sequence are suitable where fresh water is lacking during the early dry season. However, if fresh water can be pumped up cheaply, a crop of early maturing high yielding rice can be broadcast when floods are about to recede. This can be considered as an acid avoidance technique of planting rice.

4. Conclusion

Acid sulphate soil dynamics require careful planning for land use based on a accurate soil survey. At this state of the art, the use of acid sulphate soils should follow a step by step development of the land. Except the very strongly acidic areas where Melaleuca planting seems to be most profitable, other acidic areas may be rendered into better use when the following practices are achieved :

(1) Early plowing before the soil dries out. This operation will minimize the re-acidification of the plowed layer by capillary rise.

(2) Providing controlled drainage systems effective in the first two months of the rainy season. The controlled drainage systems should be empoldered complete with flapgates so that water level inside each polder can be regulated as required. The optimal size of the polder, of drain ditch and canal, of raised beds, the optimal kind and amount of chemical amendments and the most suitable and economic crops are yet to be determined for each type of acid sulphate soil. The task ahead is challenging.

THE AGRONOMIC & CULTURAL PRACTICES OF THE OIL PALM (Elaeis quineensis) IN MALAYSIA

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1. History of Introduction and Cultivation of Oil Palm in Malaysia.

Growing and planting of oil palms in South East Asia (Far East) started with the introduction of four seedlings from Reunion and Holland into Jawa in 1848. From these four seedlings planted at the Botanic garden in Bogor, the oil palm (Elaeis guineensis) spread through Jawa (Banja Mas) and Sumatra (Deli) to Malaysia in 1911-17. Commercial planting of oil palm commenced in the late 1930's (1938) with about 30,000 ha planted mainly in West Coast of Peninsular Malaysia. Expansion of oil palm planting in Malaysia started after the Second World War and achieved tremendous momentum from 1960. The extent of cultivation of oil palm in Malaysia is shown in Table 1.

2. Origin & Natural Habitat

The type of oil palm introduced and planted is the Elaeis guineensis which is native to Central West Africa; in Nigeria, Zaire, Cameroon, Equatorial Guinea, Guinea, Ghana, Ivory Coast and Angolia.

In Africa, the fresh water swamps and river floodplains have been suggested as the natural habitat for the oil palm which cannot tolerate permanent flooding or stagnant water but appears to be to tolerant of fluctuating water table and moving water in riverine alluvials. However, it has also been noted that oil palm, probably due to man's doing, also grows in forest fringes or in forest areas which have been cleared for cultivation.

The oil palm, mainly by the act of man, has now a wide distribution and can now be found in almost all the equatorial countrie

Table 1 Planted Area Under Oil Palm in Peninsular Malaysia. (In Hectares)

Year	Mature	Immature	Total Planted
1960	40,024	14,610	54,634
1961	43,302	13,841	57,143
1962	46,175	15,904	62,079
1963	49,073	21,957	71,030
1964	52,436	30,764	83,200
1965	58,544	38,403	96,947
1966	65,860	56,843	122,703
1967	74,992	78,618	153,610
1968	92,104	98,661	190,765
1969	115,386	115,790	231,176
1970	138,902	122,297	261,199
1971	169,482	124,667	294,149
1972	208,129	140,612	348,741
1973	250,338	161,732	412,070
1974	290,291	209,953	500,244
1975	340,971	227,799	568,770
1976	403,157	234,460	637,617
1977	490,676	221,326	712,002
1978 (e)	531,574	232,140	763,714
1979 (e)	599,634	220,311	819,945
1980 (e)	633,212	290,817	924,029

Note : (e) . Estimates

Source : 1. Dept. of Statistics
2. Mopqc
3. Porla

in the World. Within 7° of the equator and in some exceptional areas at higher altitudes, the typical African oil palm (Elaeis guineensis) has been cultivated fairly extensively.

In Malaysia, the oil palm has been planted as commercial groves (small-holder) and on plantations from the coastal plains to the hills and sometimes mountain, on all kinds of soils and terrain, but the coastal plain with riverine and marine alluvials are the preferred situation and location.

3. Botanical Characteristics & Types.

The oil palm is a large feather-palm having a single columnar trunk (stem) with short internodes. It is quite like a coconut palm but can be distinguished from the coconut palm by the much larger number of leaves with pointing leaflets and persistent leaf bases which are closely adherent to the trunk (stem) during the first 10 to 15 years of its life. The palm is normally monoecious with male or female but sometimes hermaphrodite inflorescences borne on short stalks (compared to the coconut inflorescence), in the axils of the leaves. Each leaf normally subtends an inflorescence in its axil and there are about 50 leaves on the palm.

The stem (trunk) is usually straight and upright except in soils which provide poor anchorage, as in deep peat or organic clay/muck. The trunk, depending on the varity, normally grows about 40 to 60 cm in a year.

Leaves are borne and arranged in two sets of spirals or parastiches (phyllotaxis) to the stem; eight running in one way and thirteen in the other. Such arrangement (or phyllotaxis) is described as (8 + 13). This is well shown in the pruned trunk. The spiral can be left or right handed. Leaves are persistent and normally adhere to the trunk until after 10-12 years when the bases become rotten and decayed. Number of leaves produced increases between 30 to 40 at 5-6 years, thereafter decline to about 25 per annum.

The roots of the oil palm are fibrous and adventitious. Roots are of four sizes; the primary (5-10 mm), secondary (1-4 mm), tertiary (0.5-1.5 mm) and quarternary (0.2-0.5 mm). The primary roots are mainly anchorage and grow either vertically or horizontally. Secondaries arise from primaries, and the tertiaries from the secondaries. The tertiaries and quarternaries are feeding roots and ramify the soil surface in the upper topsoil. Density of roots in the top 40 cm of soil usually decreases with distance from the palm and root may extend to over 10 m. The greatest quantify of roots is in the top 15-30 cm and within a radius of 3.0 m.

Roots of all classes respond to environmental condition or cultural practices and grow towards water and nutrient supplies. Hence density of roots (all classes) is greatest in fertiliser application zone, leave/frond heaps or under good leguminous covers (diagram of root distribution).

The inflorescence is a compound spike or spadix and the flowers, male of female, are borne on the spikelets or spadix. The inflorescence has a stout stalk or peduncle about 45 cm long and spikelets are also arranged spirally around the rachies. There are several thousands of female flowers and tens of thousand of male flowers in an inflorescence.

The fruit is a sessile drupe varying in shape from nearly spherical to ovoid or elongated. Fruits consist of outer exocarp (or skin) and mesocarp containing fibres, moisture, solid & fats, oil protein, gums, carotenoids etc and endocarp (shell) of lignified material enclosing the kernel. According to the pigments in the exocarp during ripening, the fruit types are named nigrescens (black to orange red), virecens (green to light orange), albecens (ivory to pale yellow). There are also intergrades - rutilo, rubro nigrescens, albo-nigrescens and albo-virescens. According to the thickness of the shell, the fruits have been classed into 3 varieties.

Dura - thick shelled, 2-8 mm. and no fibre ring.

Tenera - intermediate thick shelled, 0.5-4.0 mm, thick fibre ring.

Pisifera - shell-less, fibre ring may be present.

Commercially, planted varieties were, until recently (after 1960), Duras or mixed Duras and Teneras. After 1960, mainly Teneras, which is a hybrid between Dura and Pisifera, were planted.

Recently, interests on the other oil palm species have increased due to its slow growth in height. The American oil palm, Elaeis oleifera, which is native to Latin (Central) and South America; Mexico, Honduras, Guatemala, Panama, Guiana, Costa Rica, Surinam, Brazil and Columbia is more tolerant to diseases and has higher content of unsaturated fatty acid. These palms have been called E. melanococca, Corozo oleifera or Alfonsia oleifera. They differ from E. guineensis in having coiling and recumbent slow growing trunks, thick set and larger leaves and smaller fruits, but much larger bunches/inflorescence with persistent sheaths or spathes. Their natural habitat is also similar to that of the E. guineensis; in damp and swampy situations or riverbanks (slide showing E. oleifera). Of interest is the interspecific hybrid of this oleifera with guineensis which partakes the characters and morphologies of both parents. (slide showing hybrids).

4. Environment : Climate and Soils.

The oil palm is grown in regions differing widely in the climatic and soil conditions; from drought stricken areas with marked, extended dry season of 2 to 4 months and annual rainfall of less than 1300 mm in Africa, to areas with well distributed rainfall exceeding 5000 mm and no dry season or drought (South East Asia and South America), and on sands to heavy coastal alluvial clays and on soils formed of basalt or fresh (relatively)volcanic material (pumice and ash in Papua New Guinea). However, areas with the highest productions have the following climatic features.

(i) A rainfall of 2000 mm (80 ins) or more, evenly distributed through the year with no very marked dry season.

(ii) A mean maximum temperature of about 29°-33°C (85°-90°F) and a mean minimum temperature of about 22°-24°C (72°-75°F).

(iii) Constant sunshine amounting to at least 5.0 hours per day in all months of the year, rising to 7.0 hours in some months.

Of these climatic factors or parameters, the most important is the distribution and amount of rainfall/precipitaion and the annual water deficit, resulting from the interactions of these climatic factors and soil characteristics. The general relationship between water deficit and bunch yield in Africa (Ivory Coast) is shown in the following Figure 1.

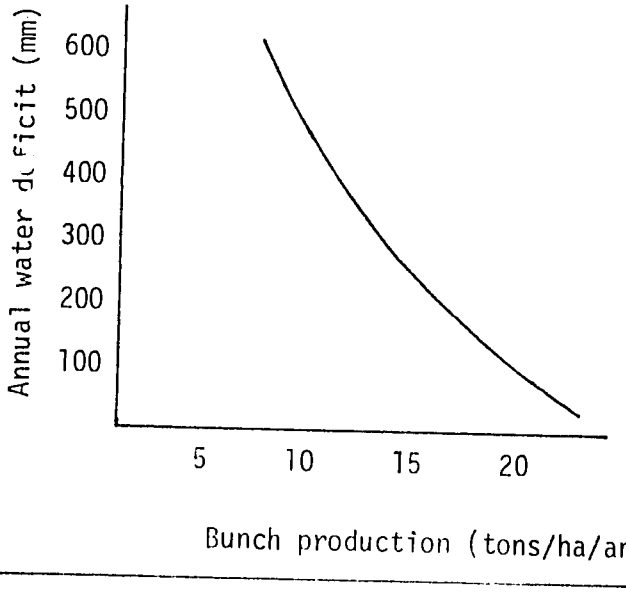

Fig 1. Relation between the annual water deficit and bunch production on Class 1 soils (I.R.H.O.).

More direct relationship of rainfall on yield and production of bunches has been investigated. Several models, incorporating the climatic parameters and the yield components, have been examined and proposed. More recently in Malaysia, partial correlation analysis has been used to determine the relationship between oil palm bunch yields and changes in rainfall and dry spells. It has been found using this

approach (Exploratory identification analysis), that bunch yields are associated with rainfall 16-18 months and 22-23 months previous, and dry spell at 29-30 months previous. Bunch yield is negatively correlated with rainfall 16-18 months previous but positively correlated with rainfall at 22-23 months previous and with dry spell 29-30 months previous. Although the correlation coefficients (about 0.50) of these relationships were calculated, the yields were not predicted and the study on the function has yet to be completed.

The oil palm has been cultivated and planted on a wide range of soils, ranging from loamy sand to heavy clays and fairly deep peat and on various slopes; from flat or even depressional land to hilly areas with slopes greater than 25°. In Malaysia, in order to reduce cost of establishment and to minimise the difficulties of harvesting, and erosion hazards, cultivation of oil palm is not recommended on slopes greater than 15°. It has also been observed that physical soil properties, like depth, texture and structure, are more important in deciding or determining the suitability of the soils for oil palm planting, as these affect the anchorage and penetration of the root (root growth/development) and the water and nutrient retention capacity of the soils.

In Malaysia, the recent marine and riverine clays, sub-recent alluvials and a wide range of sedentary soils derived from igneous and sedimentary rocks are found to be quite suitable for the cultivation of oil palm. On the other hand, soils with hardpan or plinthite (lateritic)near the surface, poor drainage and acid sulphate condition and organic soils and sands have been considered unsuitable and should be avoided. Experiments have been carried out by planting oil palm on these soils with these serious limitations, and growth and yields have not been satisfactory without any input to ameliorate and improve these limiting conditions.

The yields and growth of oil palm on three of these soils in Malaysia, have been compared and are shown in Fig. 2.

Over the last decade or so, attempts and efforts have been made to improve the cultivation or growing of oil palm in these less favourable soils; the organic soil (peat deeper than 1.0 m), acid sulphate soils and the lateritic soils. Methods and measures employed include the following :

On deep peat greater than 1.0 m - Pre drainage and intensify drainage followed by compaction and consolidation of the organic matter using compacting machines or heavy roller. After planting with oil palm, use and application of fertilisers including those containing trace elements, mainly copper and iron, are liberally applied. In some places, application of lime or limestone dust is also made to improve and enhance or accelerate decomposition and mineralisation of the organic matter. Foliar applications of trace element solution were also found to be quite effective for correction of such deficiencies on younger plams.

On acid sulphate/or potential acid sulphate (Para acid sulphate) soils, control of excessive drainage and maintenance of the water table above the oxidation zone, together with the application of alkaline fertilisers or liming have been found to be successful and effective amelioration methods for the oil palm growing on these soils.

On the lateritic soil and sands, mulching with empty bunches or other vegetative or plant materials have been tried. More recently, use of palm oil mill and rubber factory effluents have been tried and investigations on their uses on these soils are being continued with increasing interest. Results so far appear to be quite encouraging.

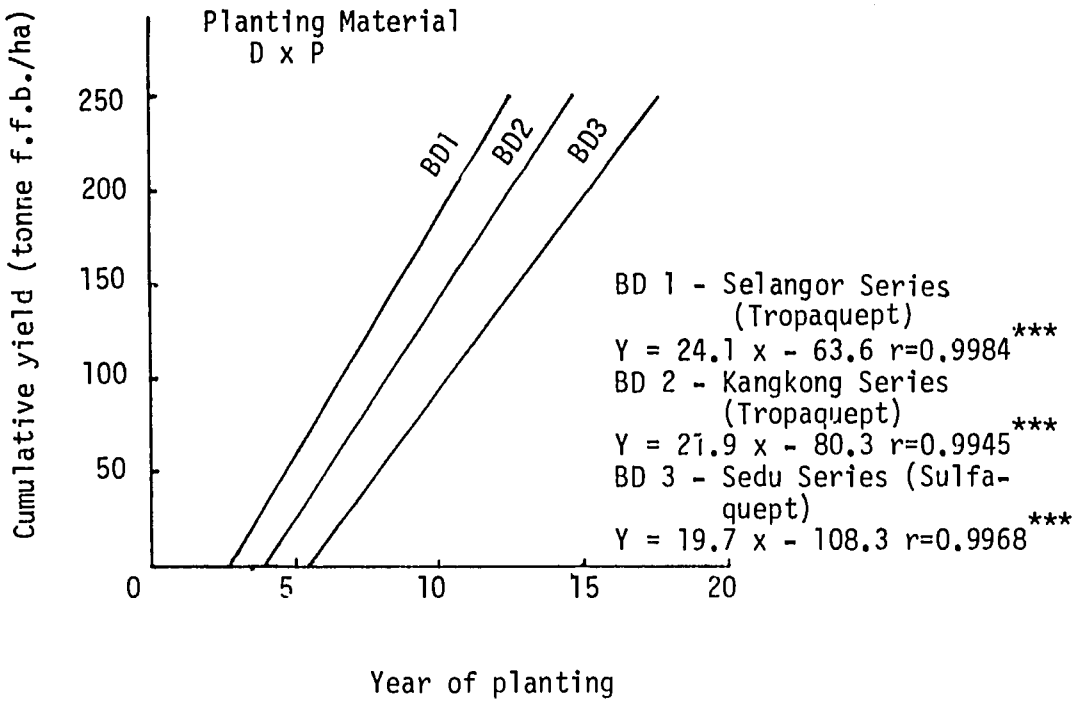

Figure 2. Cumulative yield curves of oil palm on the same estate but on three different soils.

5. Planting of Oil Palm and Husbandry Practices.

It is convenient to divided the cultivation and planting practices of oil palm into two aspects viz.

(i) Nursery establishment
(ii) Field planting

(i) Nursery Establishment

Nowadays, this involves the planting of germinated seeds into black, perforated polybags, usually of size 37.5 x 45.0 cm layflat. If the site is selected, usually on level or gently sloping terrain and near a water source (a river/stream) and space is available, the germinated oil palm seeds, normally at 5-7 days of germination, are planted directly into these polybags. If space is limited, or

the nursery site has not been prepared in advance, then a pre-nursery of small polybags of size 15.0 x 22.5 cm can be established, and the seedlings after 10-12 weeks in this pre-nursery are then transferred (transplanted) into the larger (37.5 x 45.0) polybags where they can remain for another 9 to 12 months. Temporary shade using attap (Nipa) leaves or nylon netting is usually provided over these polybags for about 10-12 weeks, after which the shade is removed. The seedlings are watered in large nurseries with overhead sprinkler irrigation installed prior to the planting of the germinated seeds, and after the nursery site has been prepared. About 10-25 mm of water are applied twice daily to the seedlings. In some nurseries, the water is applied from extended rubber or plastic hose fitted with a shower head. This is a more temporary measure.

About 10-12 weeks in the nursery, thinning or rogueing of the abnormal and runty seedlings is carried out. The abnormal and runty seedlings usually could be easily identified by their abnormal forms and peculiar growth habits. The seedlings are maintained in the nursery for about 10-12 months before they are removed for planting in the field. Prior to their removal for field planting, usually another round of thinning to remove abnormal and runty seedlings is carried out. In well established and maintained nurseries, such abnormal and runty seedlings should not be more than 15 %.

Besides watering, maintenance and care of the seedlings in the nursery include manuring and pest/disease control and upkeep of the ground cover. Usually the seedlings in polybags are triangular spaced at a distance of 75 cm. Weeds in the ground and in the polybags are regularly removed, usually manually in the earlier months, at monthly intervals. In a well grown and maintained nursery, disease incidences are usually very low and prophylactic sprayings are not necessary. However, insect pests are more common, especially the cockchafer beetles, and may require spraying for control. Some of the more common diseases in the nurseries are :

(a) Blast diseases - Phythium and Rhizotonia.
(b) Curunlaria leaf bligth.
(c) Anthracnow - Botryodiplodia.
(d) Corticium leaf rot.

These diseases would normally be controlled with fungicidal sprayings commonly Thiram, Thibenzole, Captan etc.

The more common insect pests are :

(a) Cockchafer beetles - Apogonia and Adoretus.
(b) Red spider mites - Tetranychus.
(c) Aphids
(d) Crickets and grasshoppers.

These insects are usually controlled with insecticidal sprayings, commonly dieldrex, dipterex, Thiodan, Roger, Bidrin etc.

In properly maintained nursery, nutrient deficiencies seldom occur. However, in nursery where sandy soils have been used to fill polybags, the more common deficiencies are those of nitrogen, potassium, magnesium and occasionally boron. Occasionally, toxicity symptoms, due to heavy and excessive fertiliser applications, also occur. The nutrient requirements and their levels for the seedlings in polybag nurseries are shown in Tables 2 & 3 and the common manuring programmes using fertiliser compounds, is shown in Table 4. In a well maintained polybag nursery, seedlings are normally well grown for planting out at 10-12 months.

Table 2. Mean nutrient concentration in oil palm seedlings at 8 and 14 months (Nutrients expressed as % of dry matter).

	N		P		K		Mg		Ca	
	8mths	14mths	8mths	14mths	8mths	14mths	8mths	14mths	8mths	14mths
Rengam	1.44	0.96	0.203	0.180	1.53	1.22	0.26	0.25	0.20	0.23
Munchong	1.61	1.15	0.191	0.203	1.54	1.31	0.24	0.26	0.18	0.23
Serdang	1.44	1.08	0.199	0.209	1.43	1.33	0.25	0.22	0.20	0.26
No Kieserite	1.54	1.07	0.201	0.184	1.53	1.22	0.14	0.11	0.23	0.29
5½ oz kieserite	1.46	1.05	0.194	0.211	1.47	1.33	0.37	0.37	0.15	0.19

Table 3. Average quantities of major nutrients in oil palm seedlings (gm).

Age	8 months	14 months	Increment
	Amount per seedling (gm)		
N	2.18	5.16	2.98
P	0.26	0.88	0.62
K	1.87	6.04	4.17
Mg	0.34	1.11	0.77
Ca	0.26	1.11	0.85

Table 4. Manuring schedule for polybag nursery with (A) inland and (B) coastal soil. Quantities of fertilisers in gm/seedling.

Growth stage	Nitro 26		Double Superphosphate		Muriate of potash		Kieserite	
Before 2 leaf stage			No fertiliser					
2 leaf to 4th month			184.28 gm Nitrophoska yellow or ammonium phosphate in 4.55 litre water at 113.4 cc per seedling at weekly intervals.					
	(A)	(B)	(A)	(B)	(A)	(B)	(A)	(B)
5 months	3.54	-	3.54	3.54	-	-	-	-
6 months	3.54	3.54	-	-	-	-	-	-
7 months	7.09	3.54	3.54	3.54	7.09	3.54	3.54	3.54
8 months	14.18	7.09	-	-	7.09	3.54	3.54	3.54
Total	28.35	14.18	7.09	7.09	14.18	7.09	7.09	7.09
9 months	14.18	7.09	7.09	7.09	3.54	7.09	7.09	3.54
10 months	-	-	-	-	-	-	-	-
11 months	14.18	14.18	7.09	3.54	14.18	7.09	7.09	3.54
12 months	-	-	-	-	-	-	-	-
13 months	-	-	-	-	-	-	-	-
14 months	14.18	14.18	-	-	14.18	7.09	-	-
Grand Total	70.88	49.61	21.26	14.18	49.61	28.35	21.61	14.18

6. Field Planting

Field planting includes the following :

(i) Land preparation.

(ii) Construction of terraces (in hilly terrain), drains (in flat alluvial and swampy situation) and roads and bridges.

(iii) Establishment of leguminous cover crops (L.C.C.).

(iv) Lining and planting.

(i) Land Preparation

Methods of land preparation involving clearing and cultivation of land commonly depend on the types and density of the vegetation/crops grown or existing, and the soils and terrain of the land. The vegetation to be cleared may be natural, like primary and secondary jungles or lowland forests or belukar or planted with perennial crops like rubber, oil palm, coconuts or shorter term crops like albaca. Planting ex-jungle, lowland forest or belukar is normally referred to as new planting while planting of ex-rubber, oil palm, coconut and other crops, as replanting.

In new planting, the natural vegetation or timber/shrubs are first slashed (under-brushing), then felled and stacked and burnt in the drier season, about 6-8 weeks after felling. Sometimes restacking and reburning may be carried out if the initial burn has not been satisfactory. After burning, roads and terraces and erosion control bunds or structures are constructed. Usually felling of the timber is done by powered chainsaw and stacking and heaping done by machines (bulldozer). The construction of roads, terraces and soil erosion control structures (where slopes exceed 10-12°) is undertaken by machines also. Usually these operations take about 5-6 months to complete, and weather conditions at the time of felling and burning

In replanting, the old stands of rubber, oil palm or coconut, are usually destumped and felled by up-rooting with machines/ bulldozers. The trunks or stems may then be sawn or cut into smaller lengths stacked in heaps or in rows, and burnt. The old stands of oil palm may be poisoned with sodium arsenite (previously), or paraquat, prior to destumping and burning. Up-rooting or destumping of oil palm and coconut appears to be advantageous because of the more complete or better destruction of the bole and roots, which are substrates for the colonisation of Ganoderma root disease organisms and breding of the rhinoceros beetles (Oryctes), which are serious pests on young oil palms in replantings. In more hilly terrain, where destumping may not be worthwhile or convenient, trees or palms are felled by chainsaw as close to the ground as possible. For the destumping of the old stand, mechanical aids in the form of winches are also employed to pull out the boles/stumps. Trunks and stumps of coconut and oil palm are usually cut into shorter lengths, split, stackes and burnt.

On heavy clay alluvial soils, mechanical operations in clearing and destumping may cause soil compaction and it may be necessary to cross plough and harrow the field in order to improve the tilth and at the same time break up the root system of the palm.

(ii) Drainage, Terracing and Roads

On alluvial soils and other soils of poor and impeded drainage which are subjected to periodic flooding, it is always necessary to improve drainage and aeration. In Peninsular Malaysia, satisfactory drainage can be obtained on marine clays by spacing main drain (5.0 x 1.0 x 3.0 m) at about 1320 m apart with sub or secondary drains (3.0 x 1.0 x 2.0 or 1.5 x 0.5 x 1.5 m) running at right angles to the main drains at 350-400 m intervals.

On shallow peat, less than 90 cm, a system of smaller drains, about 1.0 m. deep and spaced at intervals of two to four palm rows, has been found to be more advantageous than a system of deep drains dug at every eight palm row, to avoid rapid shrinkage

and accelerated and sometimes irreversible drying.

On undulating and hilly terrain with slopes greater than 12°, terracing is necessary. Terraces are usually 3-4 m wide and spaced at 10 m apart, supporting a density of 140 palms per hectare. On steeper slopes and on shallow soils, terracing may be hazardous and less desirable, as the parent rocks or materials (especially sandstone, quartzite or conglomerates) may be exposed. In these areas of lithic soils (lithosols), large platforms (2.25 x 3.00 m) for palm planting should preferably be made together with other soil erosion control structures like silt pits/bunds.

Nowadays, an efficient road system for transport of fruits and communication is absolutely necessary and should be well planned and designed. A general requirement is about 90 m of road per hectare of planted field. This requirement may be increased or decreased according to the terrain and physiographic features and the proximity of the mill/factory. Generally, the more hilly and more dissected the terrain, the greater will be the requirement for roads, in some cases, up to double the amount.

On peat, although the general intensity of the roads may be maintained, the costs of their construction are greater because of the larger requirement for ballast, stones or other surface and consolidating materials.

(iii) Establishment of Leguminous Cover Crops.

The planting and establishment of leguminous cover crops is a well recognised and adopted cultural practice in oil palm cultivation because of the substantial beneficial effects from these leguminous covers. Growth and crop yield have both been substantially increased with the planting of these legumes. This is shown in the results of experiments comparing the various ground covers in Table 5. Even on relatively fertilie coastal clay, *Puereria* and *Centrosema* covers gave more than 6 % higher yields than grasses over 4 3/4 years of harvesting. Much larger responses have been obtained with these

covers in plantings on inland soils.

Table 5. Effects of covers on fruit bunch production over 2½ - 7¼ years of young palms on marine clay (t/ha).

		As % of legume cover plot		
	With fertiliser	No fertiliser	With fertiliser	No fertilizer
Grass.....	110.8	110.9	92.4	92.5
Mikania	106.5	94.1	88.8	78.8
Nephrolepsis ...	116.7	103.3	97.3	86.1
Puereria-Centrosema	119.9	117.8	100	98.2

The mixture of liguminous covers which are commonly being planted are :

Puereria phaseoloides	2.0 kg/ha
Calopogonium caeruleum	1.0 kg/ha
Calopogonium muoncoides	1.5 kg/ha
Centrosema pubescens	0.5 kg/ha
	5.0 kg/ha

These legumes are usually sown in drills spaced at 1.5-1.8 m apart, between the palm rows, with additional drills sown at right angle to these drills. On contoured land, the seeds are sown between terraces. Seeds are usually pre-heated or scarified and mixed with rock phosphate (usually CIRP) and inoculated with Rhizobium, (10 gm to 10 kg seed) before sowing. The germinating L.C.C. are kept weed free by clean weeding either manually or with herbicidal sprayings (recently)

at fortnightly intervals initially for the first three months, after which they are weeded at monthly invervals until they are fully established.

To encourage their establishment and development, the L.C.C. are normally manured with a starter dose of compound fertiliser (nitrophoska 15:15:6:4), two-three weeks after germination, at the rate of 30 gm per 6 m drill, and at a rate of 60 kg/ha, of rock phosphate (broadcasted) 3 and 6 months after sowing. Further applications of rock phosphate at rates of 150-250 kg/ha are made at annual intervals for the subsequent two years.

Insect damages on germinating drills of the L.C.C. and during subsequent years after initial establishment may be quite serious, especially in new plantings (probably due to starvation of the insects after burning of the vegetation). Most common of these are the caterpillars (Lamprosema), beetles (Pagria, Epilachna) and grasshoppers. Snails and slugs can also cause severe defoliation damages. The caterpillars, beetles and grasshoppers may be controlled with the common insecticides, Bidrin, Servin (Carbaryl) and other chlorinated hydrocarbons, while snails and slugs can be controlled with metaldehyde baits at 25 kg/ha. Diseases of the L.C.C. are usually less common. Rhizoctonia solani seems to attack Puereria and Calopogonium more often during prolonged wet weather. Control measure involves spraying affected patches with 0.2 % ferbam or Thiram.

(iv) Field Planting

The seedlings are normally field planted at the age of 12-14 months when two-stage nursery is used, and 10-12 months when a single-stage nursery (planted directly into large polybags) is used. A final round of rogueing and removing of abnormal and runt seedlings is usually carried out prior to field planting. The seedlings may be lightly pruned to facilitate their lifting and loading onto vehicles and plantings in the field.

Holes as large as or slightly larger than the size of polybags are dug before planting the seedlings in them. About 200 gm of rock phosphate, usually CIRP, are first applied into the planting holes. The seedlings are then placed upright in the holes, the polybags are then split and the polythene removed and the holes are then filled with soil until the palm bulbs are level with the ground. The soil beneath is consolidated fairly firmly and the top (surface) should be more firmly packed. The polythene (of the polybag) may sometimes be placed around the palms, to serve as mulch and as a mark of planting.

In the fields, the seedlings are normally planted at a density of 148 per hectare. The fields are lined at a triangular spacing or system prior to planting, and each planting point is marked with a bamboo stick, which is usually top/tip painted (red or white) for easy aligning and checking.

In recent years, increasing attention has been given to the density and stand of palms after maturity. It has been observed that some planting materials, under more favourable environmental conditions or better standards of management and maintenance, showed marked differential growth at the density of 148 palms per hectare. Inter palm competition with these planting materials becomes evident at 8 or 9 years after planting, and trunk etiolation and reduction of crop become increasingly severe after the 12th to 13th year. It has become increasingly apparent that it will be necessary to study in much greater detail the interaction of density and environment and genetic materials, and the adaptation of various genetic materials to varying environmental conditions in space and time. For the time being, it would appear that the optimal density of oil palm under more favourable environmental condition and better maintenance in Malaysia may fall below 130 palms per hectare after the 14th to 15th year of planting.

Cultural/Agronomic Practices

Operations after planting of the seedlings in the field are

normally considered as husbandry, and main cultural practices in the oil palm plantation are :

(a) Weed Control
(b) Pest/Disease Control
(c) Ablation
(d) Assisted Pollination
(e) Pruning
(f) Harvesting
(g) Manuring

(a) Weed Control

This is to establish and maintain a ground cover condition or system which is most conducive and favourable to the establishment and growth of the oil palms. In Malaysia, this means the care and up-keep of the planted leguminous cover crops, removing all competitive weeds amongst the 'sward' in the initial years (about 4 years) and eradicating noxious, coarse and competitive weeds (grasses, wood and herbaceous plants and creepers) in the subsequent years. Some of the more common noxious and competitive weeds are the *Imperata cylindrica*, *Ischaemum* spp., *Panicum nodosum*, *Mikania scandes*, *Eupatorium odoratum*, *Melastoma* spp. and *Clademia* spp. These weeds are usually controlled by spraying with various appropriate types of herbicides that are well represented.

Some of the common herbicides used are dalapon, glyphosate, 2, 4 D-amine, MSMA, diuron, paraquat (gramoxone) and sodium chlorate. In cocktail mixture or in sequential programmes, these herbicides have been used to control weeds in the palm circles (usually 1.0-1.5 m radius) and harvester paths (1.5-2.0 m width), roads and drains (side) and in selective spraying programmes to remove the most noxious weeds, normally in the first 2 years after field planting and in fields in which leguminous cover crops have been established. The palm circles are kept clean and weed free by monthly to bimonthly

manual weeding. Subsequently, the palm circles are miantained with herbicidal spraying and the vegetation in the interrows or avenues are controlled by selective spraying or weeding to remove the more competitive weeds and woody plants.

In recent years, interests have been generated in the use of biological control of the competitive weed viz, Mikania scandens. The possibility of employing the natural insect predators (Acalitus, Liothrip, Teleonemia, Apion) to control these very competitive creepers is being examined and considered.

When the canopy of the crown closed, usually at the 5th or 6th year after planting, ground cover vegetation usually becomes sparse and comprises only the shade tolerant species, which are usually soft and less competitive. These are checked and controlled with two or three rounds of herbicidal sprayings per year.

Much concern has been shown in the use of hormonal types of herbicides and glyphosate in young plantings. The use of formulation containing 2, 4 D-amine and 2, 4, 5-T and glyphosate on palms younger than three years in the field is avoided or prohibited, since severe damage on the palms in the form of malformation and retarded emergence of the young leaves have been frequently experienced with these herbicides. However, palms older than three years and those which are well grown and robust, could tolerate and withstand the phytotoxic effects of these herbicides (within the normal and recommended rates of application of these herbicides).

Dense epiphytic vegetation on the trunks of the mature oil palms are also occasionally controlled with herbicidal spraying, usually one round in a year. Care should be exercised in these sprayings not to damage developing inflorescences with the herbicides.

(b) Pests and Disease Control

The more common pests of the field palms and their control are shown in the Table 6 below :

Table 6. Common Pests of Oil Palm & Their Control.

1. Insects		
(a) Night flying beetles (*Apogonia* and *Adoretus*)	Eat green leaves	Lead arsenate spraying 0.36-0.60 % or Dipterex (0.1 %)
+(b) Cockchafer grubs (*Psilopholis vestita*)	Feed on root system, ultimately killing palm	Rotavate and drench soil with 0.5 % a.i. of Aldrin, Heptachlor or Telodrin
+(c) Hispid leaf miners (*Coelaenomenodera*)	Destroy leaf tissue	BHC dust.
(d) Rhinoceros beetles (*Oryctes*)	Attack young and spear leaves leading to bud rot	Control by eradicating breeding sites and grubs
(e) Bagworms (*Metisa* and *Cremastopsyche* spp)	Eat leaf tissue	Spray with Dipterex at 1-1½ kg/ha is preferable to lead arsenate
(f) Nettle caterpillars (*Setora* and *Ploneta* spp)	Eat laminae leaving mildribs only	Lead arsenate at 4 kg/ha or Dipterex at 2 kg/ha
(g) Grasshoppers (*Vallanga*)	Cut out edges of pinnae	Lead arsenate at 4 kg/ha or spray with or dieldrin
(h) Bunch moth (*Tirathaba*)	Feed on mesocarp and kernel	Spray with Dipterex 0.5 kg/ha and Thiodan
2. Rodents		
(a) Porcupines	Eat out apical bud	Bait with zinc phosphide/coconut or flour
(b) Rats	As above	Bait with mixture containing rice bran and Warfarin or Tomorin. Also use protective wire collar

+ These are in South America and Africa.

3. Mammals (a) Elephants	Feed on the young cabbage and tender shoots; destroying the palm by pulling the spear or felling it	Shooting and hunting. Use of electric wire in fencing the boundary, construction of large trenches or ditches to surround the boundary
(b) Cattles & water buffalo	Graze on the leaves and tender spears	Herding and patrolling to chase and keep away these animals
(c) Squirrels	Feed on ripening fruits	Not serious and no control measures taken at present. Shooting, poisoning and trapping may be possible control measures
4. Birds (a) Parakeet	Feed on ripening fruits	Not serious and no control measures taken at present. Shooting, poisoning and trapping may be possible control measures

The more common diseases of the field palms and their control are shown in Table 7 below :

Table 7. Common Diseases of Oil Palm & Their Control.

1. Leaf Diseases and Disorder		
(a) Crown disease Usually on 2-3 yrs. old palms	Causual agent not known but genetical differences in susceptibility observed. Fungi associated are mainly Fusarium	Removal of diseased spears by cutting followed by spraying with 1.0 % Thiabendozol solution. Planting of more resistant materials
(b) Spear rot-Bud rot complex Usually on 2-5 yrs old palms	Causes not known but are probably associated with pathogenic microbes gaining entry by prior physical/ mechanical damage of the tissue/organs with vector insect and suffering physiological stress	Removal of diseased spear or drenching the cabbage with fungicide
2. Stem/Trunk Disease		
(a) Upper stem rot Usually on palms older than 10 years	Caused by pathogenic fungus Phellinus noxious (Fomes noxious)	If the disease could be detected early (by sonic means) trunk surgery to excise all diseased tissues and painting the exposed healthy tissues with preservations or wound dressings.
3. Root Disease		
(a) Basal stem rot (Ganoderma) Usually on palms older than 10-15 years but 5-6 yrs palms are also affected	Caused by pathogenic fungus Ganoderma spp.	Destruction of all infected tissues and of the root system of the old oil palm or coconuts. No effective method of control of the palms infected with this disease known.

(b)	Dry basal rot (Ceratocystis paradoxa) Usually on 5-7 years old palms	Caused by pathogenic fungus Ceratocystis paradoxa	No known treatment. Dead palms removed
(c)	Stem wet rot Usually on 3-10 years old plam	Associated with a disease infection of the root; possibly of bacteria or virus or mycoplasma-like organism and unfavourable wet soil water regime	No known treatment Drainage and eradication of grass covers have been suggested

(c) Ablation or Castration

The removal of young inflorescences and bunches as soon as these emerged or formed when the palms commence flowering has been termed ablation or disbudding or castration. Young palms usually commence to flower at about 10-12 months after field planting and ablation is usually carried out at monthly intervals from the 14th to 27th month. This practice has become quite common in the oil palm cultivation in Malaysia mainly because of the following advantages :

(i) improved vegetative growth and those of the root system by channelling assimilates and metabolites to these vegetative organs/parts.

(ii) encourages a more uniform stand and establishment of the planting.

(iii) more effective in the control of bunch rot diseases (Marasmius) and of attack by Tirathaba caterpillars.

(iv) higher yield at the commencement of harvesting with larger and better formed bunches with higher oil to mesocarp content.

(v) Better tolerance to attack of pests and diseases due to the improved growth and vigour.

Probably due to varying duration and time of commencement of ablation and also to the irregularity in the programme, responses to ablation in term of higher bunch production and improved growth and vigour were not consistent or as significant in some oil palm plantings as those achieved in some of the experiments conducted to investigate this practice. Timing of the programme to coincide with the better rainfall and climatic condition has also been shown to be critical in ensuring and sustaining higher initial bunch production. It has also been suggested that the practice of ablation is of more practical utility in region of low than high production and particularly so in extremely dry condition such as obtained in West Africa in which there was evidence of improved drought resistance due to improved vegetative development, including the root system. This practice should be considered for adoption in areas of poor soil conditions or poor growing conditions and drier climatic zones.

(d) Assisted Pollination

This refers to artificial pollination of the female inflorescences manually or mechanically. This has become necessary especially in new areas of oil palm cultivation in which the rainfall is excessive; exceeding 2,500 mm annually and in which there are no older oil palm plantings in the vicinity. Inadequate natural pollination due to the production of higher number of female inflorescences (higher sex ratio) of the improved planting materials at the earlier years and to the slow increase in population of the pollinator insects - until recently, mainly thrips in oil palm plantings - and to the heavy precipitation prevailing in the monsoon seasons have been the causes of poor fruit formation and production in Malaysia, especially in East Malaysia (Sabah and Sarawak). The necessity of assisted pollination has apparently been established by a series of experiments conducted in Malaysia in the 1950-1960, and until recently assisted

pollination with puffers, lance applicators and mechanical dusters has been a routine practice in all oil palm plantation in Malaysia. Pure pollens collected from the male inflorescences, either alone or mixed with talcum powder in a ratio varying from 1:4 to 1:10 by weight, have been used and applied at regular intervals of one every three days on palms from the third year to the eighth or ninth year from planting with the planting materials presently used.

The natural pollinator weevils Elaeidobius spp.were studies and introduced into Malaysia from Cameroon, Africa a few years ago. Following fairly detailed studies on the host specificity and their responses to the local environments, these weevils mainly Elaeidobius kamerunicus, were released and are now well spread over Malaysia. Over the last year or so after their release, the weevils have been observed to breed and survive well under the Malaysian climatic condition and have not been inhibited, restricted or checked in their pollination activities. These pollinator weevils are observed to be very efficient in their pollination activities, and bunch formation and thus crops or yield in most of the oil palm plantations, especially those in East Malaysia, have increased substantially; by as much as 40-60 % or 6.0-8.0 tonnes of fruit bunches per hectare, and bunch weight increases of over 2.50 kg each. Crude palm oil and palm kernel production in Malaysia has increased by about 24.0 % and 54.0 % last year (1982) to reach 3.5 million tonnes and over 900,000 tonnes repectively. It has been suggested that a substantial share of such increases has been attributed to these weevils. However, it remains to be seen whether these beneficial effects and contribution of these weevils over the longer term or in the near future could be sustained, since results of experiments on intensive pollination (assisted) have shown that appreciable abortion of the inflorescences and bunch failure followed the initial high increase in fruit bunch production; from the 40 months and there after.

The immediate concern and consideration are the nutrient drain and stress imposed by such large increases in the crop

or fruit bunch production. It seems likely that in oil palm plantation with marginal nutrient condition, such a stress could be expected and significant depletion and deterioration in the nutrient condition may be anticipated.

(e) Pruning

Pruning of leaves is also a common practice in oil palm cultivation and usually commences four or five months before fruit harvesting begins when young palms reach the age of about 32-36 months after planting. Pruning may commence earlier, at about 18 months, to facilitate circle weeding, ablation and pest/disease control. Leaf pruning is carried out to :

(i) facilitate circle weeding, ablation, assisted pollination and pest/disease control.

(ii) facilitate harvesting and viewing of bunch ripeness.

(iii) reduce the accumulation of rotting palm materials and lodging of fruits in the trunk which would encourage the growth and establishment of epiphytic plants which may cause difficulty in viewing and inspecting of the ripening bunches.

(iv) possibly improve aeration and evaporation in the field.

First systematic pruning is usually carried out when the lowest ripe bunch is about 60 cm above the ground. Subsequently, pruning is carried out at intervals of four to six months. All experiments on frond pruning and retention indicate that maximum yields are obtained by retaining as many green and functional leaves as possible, but the differences in yields in retaining more than 40 leaves in mature oil palm planting are usually small. However, severe pruning, leaving less than 32 leaves, has a rapid and serious depressive effect on bunch production and yields could be reduced by more than 25 %, and bunch weight (size) may be reduced after four months and

bunch production dropped after eight months. This has been accompanied by increase in abortion rate of the inflorescences.

It is common to prune to leave at least a whorl of leaves below a ripe bunch, with preference to leave 2 whorls of leaves below the bunch. This would leave about 48 leaves on the palms at any time. Timing of pruning may also be important in seasonal climate. It has been suggested that pruning at the beginning of wet season should be avoided.

In pruning, the leaves are cut as close to the trunk as possible with chisels or axes and in older palms with sickles (Malaysian knife) attached to the bamboo pole. However, care should be taken in pruning close to the trunk to avoid damage to the still younger leaves.

(f) Harvesting

With most of the precocious materials presently planted, harvesting could commence after 2½ years of planting and usually at 32-34 months in fields well established and maintained. In poorer plantings, harvesting may be delayed to 3½ - 4 years.

With *Elaeis guineensis var nigrescens*, as the fruit in the bunch ripens, the colour changes from deep purple or black to reddish orange and the oil content increases in the process. When the oil content reaches maximum, the fruits become loose and fall to the ground. Because of uneven ripening, it takes about 16-20 days for all fruits in a bunch to ripen. The fruit bunch has to be harvested neither in an under-ripe nor over-ripe condition. Until now there is no exact criterion for optimal ripeness and it is common practice to harvest when there are two loose fruits on the ground per estimated kilogramme of bunch weight, e.g. 25 loose fruits for a 12 kilogramme bunch.

Ripe bunches are cut with chisels or axes or knives on bamboo poles, depending on the height of palm. Generally harvesting

starts with chisel and is continued as long as practically possible; usually until 8 to 9 years and thereafter with curved knives on bamboo poles and care must be undertaken not to damage any functional green leave immediately around and above the ripe bunch to be harveste Leaf subtending the ripe bunch to be harvested is usually cut at the same time, and the cut leaves are normally stacked in the interrow/ avenue.

Havesting interval is normally 10 to 12 days in the early years and subsequently, 7-10 days provided that harvesters are available. Acute shortage of harvesters is presently being experience in Malaysia and under this situation, harvesting intervals have invariably been extended to 12-14 days or even longer.

Cut bunches and loose fruits are collected and carrie in bamboo baskets to a collection point or platform near the roadside. On more level terrain, wheelbarrows are becoming more popular. Use of drought animals, mules (in South America) or waterbuffalo (in Malaysia) has also been made in some plantations. Mechanised harvesting and collection of fruit bunches are being developed and are receiving increasing interest and attention.

From the collection point or platform, fruit bunches and loose fruits are transported to the factory/mill by a number of ways, depending on the initial planning on the infrastructure development. The more convenient and common system involves road transport by trucks, tractor/trailer and lorries fitted with hydraulic system for lifting and unloading (or tipping of the load) of the fruits. Fruit transport by road using trucks or lorries has become increasingly popular due to the reduction in labour requirement and to the convenience of weighing the harvested crops.

(g) Manuring

The oil palm requires large quantities of nutrients, both macro and micro elements, for growth and reproduction. Manuring and fertiliser applications are important and necessary cultural

practices to ensure and to maintain good growth and crop production in oil palm cultivation. Even on the relatively fertile environmental and soil conditions in Malaysia, applications of fertilisers and their requirement constitute over 40 % of the total annual field production costs.

Various estimates of the nutrient requirements and uptake of oil palms have been carried out in different oil palm growing countries. In Malaysia, the estimates of total nutrient uptake by 148 palm per hectare per annum are shown in the following Tables 8, 9 & 10.

More recently, the requiremtns of anionic nutrients, especially of chlorine and sulphur have received attention. Although the contents of these elements in the leaf have been analysed, estimates of these nutrients in the whole palm and in the fruit bunches have yet to be made.

The common technique in assessing the nutrient requirements and fertiliser needs of the oil palm in Malaysia is foliar analysis. This plant tissue anlaysis of leaf No. 17 in mature palms and of leaf No. 3 or 9 in young palms has received considerable research efforts and studies to establish the relationships of the nutrient contents in the leaf with growth and yield and their uptake in the palms. Sampling techniques and procedures to study the sampling error, intensity and seasonal variation of major nutrients have been studied and investigated and results of these studies, together with those from manurial experiments, have generally confirmed the preference of this technique for assessing the nutrient requirements of the oil palm. Positive and significant correlations of the nutrient levels with growth and yield of the oil palms, especially those of major nutrients viz, nitrogen, phosphorous and potassium, have been obtained and achieved.

The tentative critical levels of the nutrients presently being employed for nutrient assessments are as follows :

Table 8. Estimates of Total Nutrients Uptake by 148 Palms Per Hectare Per Annum.

Component	N		P		K		Mg		Ca	
	Kg	%	Kg	%	Kg	%	Kg	%	Kg	%
1. Nett cumulative vegetative matter	40.9	21.2	3.1	11.9	55.7	22.2	11.5	18.8	13.8	13.9
2. Pruned fronds	67.2	34.9	8.9	34.2	86.2	34.3	22.4	36.5	61.6	61.9
3. Fruit bunches (25 tonnes)	73.2	38.0	11.6	44.6	93.4	37.1	20.8	33.9	19.5	19.6
4. Male inflorescence	11.2	5.9	2.4	9.3	16.1	6.4	6.6	10.8	4.4	4.6
TOTAL	192.5	100	26.0	100	251.4	100	61.3	100	99.3	100

(26.0 kg P = 59.5 kg P_2O_5, 251.4 kg K = 302.8 kg K_2O)

Estimated Annual Uptake of Micronutrients by 148 Palms Per Hectare Per Annum (gm)

Component	B	Cu	Zn	Mn
1. Cumulative vegetative matter.....	50.32	48.84	226.44	467.68
2. Pruned leaves	125.80	88.80	177.60	2960.00
3. Fruit bunches	53.28	116.92	121.36	372.96
TOTAL	229.40	254.56	525.40	3800.64

Further, the nutrients removed or contained in 10.0 tons of fruit bunches has also been estimated and are as follows :-

Table 10. Estimates of Nutrients Removed in 10.0 tonnes of Fruit Bunches.

Per 10 tonnes of bunches	N	P	K	Mg	Ca	Mn	Fe	B	Cu	Zu	Mo
Kilogrammes	29.4	4.4	37.1	7.7	8.1						
Grammes						15.1	24.7	21.5	47.6	49.3	0.084

Table 10.1 Tentative Critical Levels of Nutrients Employed for Nutrient Assessments.

Nutrient	N	P	K	Mg	Ca	Cl	S	Mn	B	Cu
	% on dry matter							ppm		
Leaf No. 3	2.80-3.00	0.18-0.20	1.30-1.50	0.30-0.35	0.30-0.50	-	-	-	-	-
Leaf No. 17	2.70-2.80	0.16-0.18	1.00-1.20	0.20-0.25	0.45-0.55	0.30-0.50	0.20-0.24	200-250	10-12	2-4

It has also been observed and experienced that levels of major nutrients, especially of nitrogen and potassium seem to decline with age of the palms and are also related to soil water regime. Thus, it is not uncommon to observe lower nitrogen and potassium levels in plams older than 15-18 years and in palms growing on alluvial soils (on the marine/riverine alluvial). There are also indications that nutrient levels could also be related to the genetic materials.

The common types and rates of fertilisers applied to oil palm in Malaysia are shown in the following Table 11.

Table 11 : Rates & Types of Fertiliser Application for Oil Palm in Malaysia.

Rates of Sulphate of Ammonia (N) and Muriate of Potash (K) recommended for young plantings on four major soil groups in West Malaysia. (Kg palm)

Years in field	I. Sandy loams to sandy clays from granite, sandstone, older alluvium		II. Clays from basic igneous rocks		III. Silty clay from shales		IV. Marine clays	
	N	K	N	K	N	K	N	K
1	0.68	0.45-0.90	0.45	0.68	0.45-0.68	0.45	0-0.23	0
2	0.90-1.36	1.36-2.50	0.68-0.90	1.36-1.60	0.68-1.36	1.14	0-0.23	0.45-0.68
3	0.90-1.36	2.27-3.41	0.68-0.90	2.04	0.68-1.36	1.60-2.04	0-0.23	1.14-1.60
4	0.90-1.60	2.73-3.86	0.90-1.14	2.04-2.73	0.90-1.60	2.04-2.73	0-0.23	1.14-1.60
5	1.14-1.81	2.73-3.86	0.90-1.14	2.73	1.14-1.81	2.04-2.73	0-0.23	1.81-2.04
6	1.14-1.81	2.73-3.86	1.14-1.60	2.73	1.14-1.81	2.04-2.86	0.90-1.14	1.81-2.04
7	1.81-2.04	2.73-3.86	1.60	3.41-3.64	1.60-2.04	2.73-2.86	0.90-1.60	1.81-2.73
8	1.81-2.73	2.73-3.86	1.60	3.41-3.64	1.60-2.73	2.73-2.86	0.90-1.60	1.81-2.73

Source : Hew and Ng '50'

Rates of Christmas Island Rock Phosphate (P) and Kieserite (Mg) recommended for West Malaysia. (kg palm)

Years in field	I. Sandy loams-sandy clay loams from granites, sandstone and older alluvium		II. Clays from basic rocks		III. Silty clay loams-silty clays from shales		IV. Marine clays	
	P	Mg	P	Mg	P	Mg	P	Mg
1	0.45-0.90	0.23-0.45	0.23-0.45	0.23	0.45-0.90	0.23	0	0
2	0.68-1.14	0.45-1.14	0.23-0.45	0.45	0.68-1.14	0.45	0	0
3	0.68-1.60	0.90-1.14	0.45-0.68	0.45-0.68	0.68-1.60	0.68-0.90	0	0
4	0.90-1.60	0.90-1.60	0.90-1.14	0.68-0.90	0.90-1.60	0.90-1.14	0.23-0.45	0-0.23
5	1.14-1.60	1.14-1.60	0.90-1.14	0.68-0.90	0.90-1.60	0.90-1.36	0.23-0.45	0-0.23
6	1.14-2.04	1.14-1.81	0.90-1.14	0.90	1.14-2.04	1.14-0.45	0.23-0.45	0-0.23
7	1.60-2.04	1.36-1.81	1.14-1.36	0.90	1.14-2.04	1.14-1.60	0.45-0.90	0-0.45
8	1.60-2.04	1.36-1.81	1.14-1.36	0.90	1.36-2.04	1.14-1.60	0.45-0.90	0-0.45

Source : Hew and Ng '50'

The fertiliser programmes could be applied with mixtures of straights, or with blended or chemical compounds containing more or less the same quantities of nutrients. In practice, since most of the blended or chemical compounds do not contain the large requirement for potash and kieserite and trace elements, applications of such compounds have to be often supplemented with muriate of potash, kieserite and trace element fertiliser. Use of mixtures of these straight fertilisers is more convenient and is frequently cheaper.

Fertiliser programmes are commonly split into two or three rounds of applications, with applications timed to avoid the very dry and very wet seasons. In younger plantings of less than four years grown on more sandy or shallow soils, frequency of application is increased to four or six rounds in a year.

Placement of fertilisers is usually related to zone of high root activities and densities. For the immature palms of less than 2 years, placement near the palm base, in circle band between 1.0-2.5 m of the base is the most effective. For palms three years and older, this should be 2.0-4.0 m and for palms over eight or nine years, placement could be extended to the avenue or interrow, since the root system is then well distributed. However, it is common to apply fertilisers within a circle of radius of 3.0-5.0 m for the purpose of supervision. On flat and level land, mechanical application of fertiliser is being carried out, while in hilly land, the fertilisers are naturally applied along the terraces, usually at the back of the terraces.

Shortages, especially acute and demanding, of nutrients are fairly well reflected in defined symptoms of deficiencies. The most common of these are deficiencies of nitrogen, potassium, magnesium, boron and copper. The symptoms of these nutrient deficiencies are fairly well described and are easily recognisable. However, when such nutrient deficiencies become visually distinct and recognisable, the deficiencies are already in fairly advanced stage and the needs for fairly large amounts of fertilizers for correction and

amelioration of these deficiencies have well been demonstrated.

Soil anlaysis for assessing fertilizer requirements of oil palms has been less popular and less precise than the foliar anlaysis. This is mainly due to difficulty of correlating soil fertility with nutrient uptake and growth factors. The difficulty is due to the fact that i) roots extract nutrients from three sources; the soil solution, the exchangeable ions and the readily decomposable minerals of the soils which are interrelated in a complex manner; ii) a measure of any of these sources may not indicate the real availability of nutrients since soils differ in the rate at which they release exchangeable ions; iii) the rooting volume of the oil palm is large and thus, sampling is difficult; iv) the oil palm, being a perennial, can take up nutrients released by slowly weathering minerals and stored these in the large trunk and other organs, v) physical condition of the soil such as soil structure, soil moisture regime and depth of solum also influence, sometimes greatly, the availability of the nutrients and the ability of the roots to exploit and extract these nutrients. Nevertheless, significant correlations and relationships have been found and established between potassium mole fraction (Excha. K/CEC) and yield of fruit bunches in Nigeria. This relationship was further improved when the activity ratio in which activities of K, Mg and Ca and Al were taken into account was used. It was then found that potassium response was closely related in the following function :

$$AR = \frac{Ke}{Ca_e + Mg_e + 2.5\ Al_e}$$

where e = exchangeable

If the mole fraction was 0.015-0.020, K status was probably marginal and when it was less than 0.015, a likely response was expected. An activity ratio of 0.006 was considered critical.

Correlations have also been found on Acid Sands soils in Nigeria in which response to exchangeable K were obtained when this

falls below the range of 0.10-0.20 meg per 100 gm. Relationship between water soluble magnesium, in the topsoil and both deficiency symptoms and leaf Mg were also found in Congo in soils in which the exchangeable Mg was below 0.10 meg per 100 gm and a critical Mg : K ratio of about 2 and below.

In malaysia, although a considerable body of soil analytical data has been accumulated, there are no detailed and thorough studies on the relationship of soil nutrients and oil palm yields and the nutrient levels in the leaf. Some studies have been undertaken but no clear or significant relationship could be established, probably due to the generally better manurial practices in the plantation industry. However, the general pattern of the nutrient status of the soils in Malaysia could be described as follows :

(i) The generally higher nutrient status of the marine clays on the west coat of Peninsular Malaysia, particularly in P, K and Mg and occasionally N.

(ii) The very low K and Mg reserves in soils derived from granites, sandstones and quartzites, older and sub-recent alluvial sediments.

(iii) The very low K status of soils derived from basalts and andesites.

(iv) The variable but higher status of K of soils derived from shales.

(v) The very low N and P status of soils derived from pale coloured shales.

(vi) The extreme acidity of acid sulphate soils and low K and Mg status.

(vii) The generally low N and P status of most inland soils derived from acid igneous and sedimentary rocks, and the higher P status of soils derived from basic rocks.

Although measures of exchangeable cations have been widely used to indicate nutrient status, it has been found in Malaysia that differences between soil types in this respect are not very great although the total cations are sometimes considerable. Hence, the general pattern of fertility of the soils in Malaysia, as indicated above, has been observed. In regions where large areas are covered with soil of more or less the same origin, some correlations can be found. However, in areas where changes in soil type are abrupt with marked changes of underlying parent rocks, limited use can be made of analytical data. Nevertheless, in any feasibility study of oil palm development in new areas, regions or countries, soil suitability classification with field and laboratory data from soil survey is an essential and sometimes decisive component. The knowledge and the interpretation of these field and laboratory data in relation to oil palm growth and production requirement are the exercise and the objective of this exercise.

Agronomic Classification of Soils for Oil Palm Development.

The main characteristics used to classify soils for oil palm development are :

(i) texture

(ii) quantity of gravel or stones.

(iii) water permeability or lack of drainage.

(iv) chemical composition.

The broad and general suitability classification is shown below :

Table 12. Soil Classification for Oil Palm.

Class	Texture	Gravels and Stones	Drainage	Chemical Status
I	Sands to clays	None	Good	Organic-good Exch. cation-good
IIa	Sands to clayey	None or very little	Good to 90 cm	Organic-medium Exch. cation-medium
IIb	Sands to clays	Some gravel	Good to 60 cm	Exch. cation-medium
III	Sands to clays	Gravelly	Poor	Organic-medium Exch. cation-poor
IV	Leached sand or very heavy clay	Very gravelly	Deep peat or very bad	Poor

It will be seen that in this classification, it is mainly the physical properties of the soil which will determine its agronomic and suitability class. The more important of these physical properties are those which influence directly or indirectly the water regime, water availability and water retention of the soils, functioning with and responding to the climatic conditions, especially precipitation. It should be realised that the environmental factors for the highest production of oil palm are those concerning climate. This is not to discount the importance of soil conditions in the cultivation of oil palm but the climatic conditions provide the main frames, as it were, from which the picture of the oil palm could be painted and hung. Thus, there is increasing interest in and utilisation of the soil moisture regime as function of climatic condition and soil physical characteristics in the assessment of the suitability of the areas for oil palm cultivation. This is then or should be followed by trials and experiments designed to evaluate the agronomic requirement of the oil palm in these areas or regions where the soils occur.

The soils in Malaysia and their distribution and properties will be discussed by Dr. Paramanathan, and the soils in which the oil palm is cultivated in Malaysia have been shown by Dr. Ng Siew Kee. To recapitulate, the main groups of soils on which the oil palm is cultivated in Malaysia are :

Tropaquept and Dystropept
Paleudult
Haplorthox and Acrothox

The other soils are of lesser importance. However, the Typic Sulfaquept, Typic Tropaquent and the Fibrists may become more important with the expansion of the soil palm cultivation to these soils in the near future.

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A SHORT REPORT OF CORN IN THAILAND

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I. CORN PRODUCT IN THAILAND

Thailand is an agricultural country with a total cultivated area of 17.5 million hectares, of which 22 % of the area is counted as upland areas. In the past twenty years, upland areas in Thailand have expanded its area three times as demands for upland crops for the international market and for the national consumption have increased greatly.

Corn cultivation in Thailand is noteworthy because of the progress it has made. As partially shown in Table 1, total corn production[1,2] increased remarkably from 68,000 tons in 1955, 665,000 tons in 1962, 2,300,000 tons in 1971 to 3,000,000 tons in 1981, which is now one of the most important exporting upland crops, as well as cassava and sugar-cane (Table 2, 3). The cultivated areas were also expanded greatly from 56,000 ha. in 1955, 330,000 ha. in 1962, 1,000,000 ha. in 1971 to 1,400,000 ha. in 1981, or a 4.2-fold expansion in a matter of twenty years. The expansion has mainly been due to the convertion of forest into corn fields, leaving only a small amount of land for expansion. The average yield of corn per unit area has not increased, but fluctuated at a level of 1.2-2.2 ton/ha (Table 1), in spite of introducing more modern agrotechnology such as new varieties, improved cultural practices, weed, disease and insect control and even fertilizer application. A primary reason for this stagnation, considered to be based on water shortages during the growing period of the crop, which substantially constrains the improved agrotechnology. The water constraint was suggested from statistical data during the last 5 years on the relationship between the amount of average annual rainfall and the

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Table 1. Planted Area Production and Farm Values of Corn in Thailand.[2)]

Crop year	Planted area (1000 ha)	Production (1000 ton)	Yield (ton/ha)	Farm Price (US $/ton)
1971/72	1019	2300	2.25	31.4
1972/73	997	1315	1.32	38.6
1973/74	1148	2339	2.04	60.5
1974/75	1240	2500	2.02	92.4
1975/76	1312	2863	2.18	83.4
1976/77	1285	2675	2.08	74.9
1977/78	1205	1677	1.39	73.5
1978/79	1386	2791	2.01	72.2
1979/80	1525	2863	1.88	93.7
1980/81	1434	2998	2.09	109.0

Table 2. Planted area of major crops in Thailand.[1)]

(x 1000 ha)

Crop year	1976/77	77/78	78/79	79/80	80/81
Rice	8575	9031	9998	9435	9618
Rubber	1460	1484	1508	1532	1538
Corn	1285	1205	1376	1525	1434
Cassava	692	847	1165	846	1160
Sugarcane	499	567	510	437	468
Mungbean	223	435	422	424	447
Coconuts	391	410	412	415	416
Sorghum	143	170	176	189	247
Kenaf	164	257	320	227	171
Soybean	102	153	162	109	126
Groundnuts	122	103	106	97	105
Cotton	25	84	69	120	152
Kapok	60	57	50	54	56
Sesame	28	35	46	36	39
Tobacco	46	44	46	50	35
Castor beans	45	38	43	50	42
Gallic	29	41	40	39	40
Chilli	38	35	38	36	35
Onions	22	23	23	23	23

Table 3. Value of agricultural products (according to farmer received) and value of agricultural exports.[2)]

(Million of Baht)

Item	Value (Farmer received)	Value (Export)
Rice	46,460	19,818
Cassava	12,405	14,880
Sugarcane	9,053	3,357
Maize	7,285	7,300
Mungbean	1,527	612
Sorghum	531	661
Groundnut	1,030	61
Soybean	578	28
Sesame	339	162
Coconuts	2,287	10
Cotton	1,849	477
Kenaf	919	144
Kapok	328	255
Fruits	22,723	2,987
Vegetable	11,227	2,322
Ornamental plants	-	430
Tobacco	2,058	1,372
Rubber	7,434	12,971
Forestry products	7,580	597
Buffaloes	4,878	
Cattle	6,219	
Swines	21,025	1,696
Poultry	6,182	
Eggs	10,951	
Milk	133	
Fresh water fishery	3,549	4,400
Marine fishery	10,507	

average yield in six major corn producing provinces :

Crop Year	1976/77	1977/78	1978/79	1979/80	1980/81
Average annual rainfall (mm) in major 6 provinces	1201	874	1232	815	1221
Average yield (t/ha)	2.2	1.4	2.2	1.9	2.2

Corn in Thailand is produced primarily in Northern Central uplands, inclusive of Petchabun (653,000 tons), Lob Buri (306,000 tons) Nakhon Sawan (294,000 tons), Loei (282,000 tons), Nakorn Ratchasima (262,000 tons), Saraburi (167,000 tons) provinces, accounted for 61 % of total output of Thailand in the 1980/81 crop year[2]. The amount of annual rainfall in the corn growing areas fluctuates between 650 mm to 1,450 mm with the average about 1,200 mm. Corn usually undergoes a severe drought about once in every three years.

II. SOILS OF MAJOR CORN AREAS

The soils of corn producing areas are mainly classified as clayey, montmorillonitic, Calciustolls and Haplustolls, clayey, montmorillonitic Paleustolls and loamy to clayey, kaolinitic Haplustults, where ustic moisture regimes predominate. The Mollisols and the Vertisols have relatively less problems with water shortage and soil fertility as compared with the Ultisols. The Farmer's Yield Contest carried out under supervision of JICA in Lop Buri and Saraburi Provinces in 1981, showed that the grain yield of corn in 30 farms ranged between 2.0 to 6.6 tons/ha. There was a large variation in yields in spite of the most careful farm management by individual farmers. The yield of corn was strongly dependant upon the soil type in the corn field. The higher yields (4.3-6.6 ton/ha) were obtained

from the fields of clayey, montmorillonitic, Mollisols or Vertisols. The lower yields (2.0-4.3) tons/ha) were from clayey, kaolinitic, Ultisols.

The maintenance of soil fertility must be considered as the first prerequisite as well as improvement of soil moisture retention, particularly in clayey, kaolinitic, Haplustults, as corn is a crop with a high absorption demand of nutrients. As mentioned by SATO,T[1], yields of 2.0 tons/ha of corn removes nutrients from a hectare of soil equivalent to 100 kg of nitrogen, 40 kg of P_2O_5 and 80 kg K_2O. Unless fertilizer is applied, the current yields cannot be maintained.

III. A LOW INPUT TECHNOLOGY FOR CORN PRODUCTION IN THAILAND.

Under the agroclimatic conditions prevailing in corn growing areas in Thailand, there is a tendency for crop yield potentials of soils to decrease. This leading to deterioration of agricultural land. In the light of the demand for the maximum production with the minimum utilization of energy, organic residues (produced in situ) should be properly used in a form of soil conditioners together with a optimum dosage of fertilizer.

The effective use of organic residues in corn fields under rainfed conditions have been studied since 1976 for the stabilization of the soil productivity in Oxic Paleustults (Pakchong Clays) at Phraputthabat Field Crop Experiment Station. A long-term experiment on corn yield under different soil organic managements demonstrated that plant residue mulching to corn plants had a remarkable effect on the stabilization of corn yields as shown in Fig. 1. Under no addition of organic materials, the yield of corn fluctuated a great deal. It dropped to very low levels during drought years independent of fertilization. In the year with normal or high rainfall, the yields were significantly increased by fertilization. The compost incorporation (20 tons/ha) had basically no effects on the yield for the first four years, but gradually gave higher yields from the fifth year compared with the control. This was probably due to improvement soil

physical and/or chemical properties. Mulching with rice straw (4 tons/ha) resulted in a stable corn yield irrespective to the amount of rainfall, suggesting the significant effects improve soil moisture regimes for the growth of corn.

In practice, it is very difficult to introduce this technology directly to the farmer's field because of the high transportation costs of these materials. A weed (Pennisetum pedicellatum T), Nanaely Ya-Kachon-Chob, which is available in sufficient amounts in the corn field at a time of the planting, can be used to replace the rice straw as a mulching material[3,4,5]. Mulching practices have favorable effects on corn yields which can be divided in two kinds; A yearly effect and a long-term effect. The former includes erosion and run-off control, moderation of soil temperature, soil moisture conservation and in some cases, weed control, resulting in prevention against drought. The long-term effects are expected to be an improvement of soil physical structure and soil fertility status resulting from cumulative incorporation of the mulching material into a soil.

The soil mulching practice has, however, some technical problems to be solved in farm practices. It requires a laborious process for covering the soil by mulching material, even when the materials like weeds are easily available in the field at a time of planting. It could have a possibility to be a cause of pests and diseases. It may introduce some weed seeds when weed mulch is used Farmers may have some trouble when carrying out top dressing, hilling-up, soil dressing and weeding. Due to enhancement of downward movement of infiltrating water into soil, leaching loss of nitrate nitrogen may increase, particularly in a growing season with high rainfall, which was observed in 1977 at Phraputthabat (Fig. 1). Incorporated mulching material with high C/N ratio may temporary cause a nitrogen deficiency through the nitrogen competition between crop roots and soil micro-organisms. However, these technical problems can be overcome by introducing an appropriate farm technology such as minimum tillage, proper fertilization and agrochemical management, introduction

of suitable cover crops and so on. Table 4 shows a simple economical evaluation of the long-term experiment as illustrated in Fig. 1. Suggesting the mulching practice with fertilizer application has an ability to give a higher and more stable income to the farmers at any type of cropping year. Introduction of legumes with suitable plant type as cover crops which have rather low C/N ratio in their crop residues and do not compete with the corns growth cycle, have been proved to be successful for mulching practices. Such cover crops include Mimosa sp. (Mimosa invisa), Phaseolus calcalatus and Dolichos lablab. These low input technologies for introducing in-situ-mulch practice may convince farmers that stabilization of corn production in rainfed areas of Thailand is possible.

Table 4. "Net income (baht/ha)" from corn fields under different soil management practices.

Soil management and fertilization		Year							
		1976	1977	1978	1979	1980	1981	1982	average
		Rainfall (mm)							
		1198	1037	1643	1002	1218	1478	1238	1259
Control	-NPK	6820	880	5720	1540	5500	2200	2640	3614
	+NPK	5540	-2990	8010	-2550	5040	7680	5700	4630
Rice straw mulch	-NPK	7040	3960	3300	3080	5040	3300	5280	4557
	+NPK	6470	6030	5590	4930	6800	8560	9000	6769
Compost	-NPK	5660	380	5660	16[illegible]	5660	3020	4560	3797
	+NPK	4870	-4150	6190	750	4900	7500	6300	3766

Derived from Fig. 1 based on

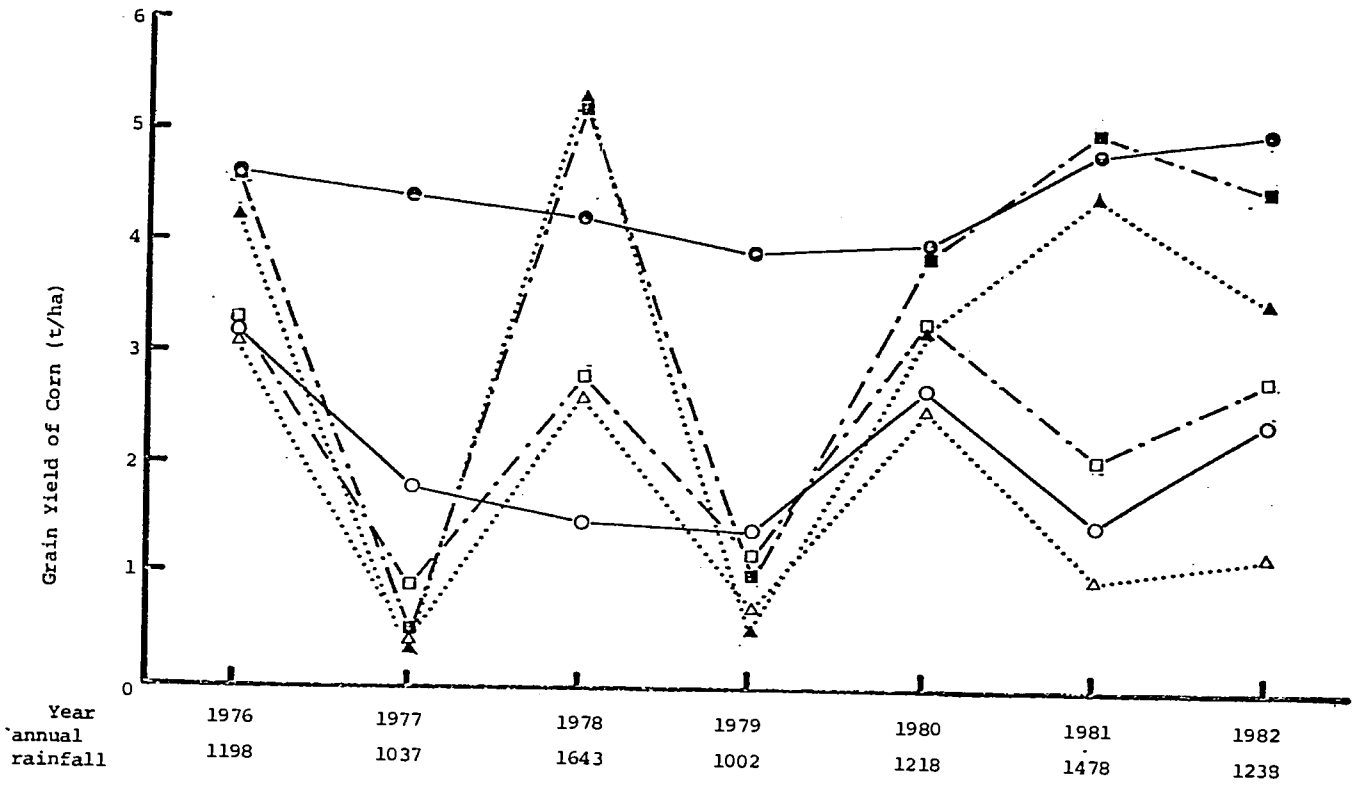
"Net income" = (Crude income) - (Cost of fertilizer and compost).

Fertilizer applied 1976-1979, 100-100-50 kg/ha = 4100 baht/ha

1980-1981, 63- 63- 0 kg/ha = 2000 baht/ha

Farm price of corn 2.20 baht/kg. Fertilizer price N, P_2O_5, K_2O = 19, 13, 9 baht/kg.

Compost price; 0.80 baht/kg.



Control
+ Fertilizer
Compost
Compost + Fertilizer
Rice straw mulch
Rice straw mulch + Fertilizer

Fertilization ($N-P_2O_5-K_2O$ Kg/ha) : 100-100-100 in 1976-1979, 63-63-0 in 1980-1982

compost : 20t/ha Rice straw : 4·ton/ha

Fig.1 Long-term effect of rice straw mulch and compost incorporation on the grain yield of corn at Phraputthabat Field Crop Experiment Station (intiated by Igarashi, T. et.al6) in 1976 and succeeded by Petchawee. S. et.al of Soil Science Division, Department of Agriculture, THAILAND).

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SOIL- PLANT RELATIONSHIP : SUGARCANE

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INTRODUCTION

Production of a modern pure white sugar in Thailand dated back to the year 1938 when the Royal Thai Government set up the first sugar mill at Lampang. Sugarcane extension work was started then too. In 1941, another sugar mill was opened in Uttaradit and the production of sugarcane started to spread out. The native sugarcane varieties such as Oi Daeng, Oi Kha Kai were grown to supply the mill at the commencement, and later, the introduction of the Indian Co's varieties was initiated. Collection of foreign varieties for the breeding program of sugarcane was then founded by the pioneer agronomists of Lampang and Uttaradit Sugar Mills, which was then under the Department of Industry, Ministry of Industry. Two useful sugarcane varieties were released from the Lampang Sugar Mill, they are L.P. 5 and L.P. 9. Due to later changes in the Governments policy, the sugarcane breeders from Lampang Sugar Mill were transferred to the Sugar Institute (SI) which was established in 1968, the breeding program has been deterred since then. A new breeding program and cultivation research have been resumed by Bang Phra Sugar Pilot Mill, under the SI at Chon Buri a few years later, and produced three promising varieties, B.P. 6, B.P. 11 and B.P. 45. After the reorganization of the sugar industry in Thailand, the sugar technology and sugar economics were incorporated into the SI. Department of Agriculture. By its nature the SI is responsible for sugarcane breeding and cultivation practice research and transfer of technology to the extension workers and sugarcane farmers.

There were 45 sugar mills and sugar refineries in Thailand in 1977. The average sugar recovery is about 80 kg white sugar from

a ton of cane which is very low compare to Taiwan and Australia. In 1973/1974, the price of sugar in the world market skyrocketted and subsequently, expansion of growing areas of sugarcane was affected. Virgin land was invaded and the native environment was destroyed to transform it into sugarcane plantations. The main growing area was inflated and the distance from the sugar mills was extended. The cost of transportation was then increased, as well as the cost of operation and management thus the surveillance of the plantation was less and a low quality cane was obtained. Low quality cane brought about the exhaustion of labour and a diminished profit for the farmers. For example, a 3.0 million rai growing area of sugarcane at present, and the average yield of 6.03 ton/rai in 1980 - 81 was obtained (table 1).

Table 1. Thailand's sugarcane cropping area, yield/rai,* sugar/rai during 1972 - 1982.

Year	Planted area, rai	Total cane tonnage	Average Yield, ton/rai	Total sugar, ton	Average recovery kg per tonnage
1972-73	1,133,439	9,512,794	8.39	648,438	68.16
1973-74	1,616,304	12,694,491	7.85	922,827	72.70
1974-75	1,935,253	13,413,442	6.93	1,060,328	79.50
1975-76	2,347,450	19,099,066	8.14	1,603,592	83.96
1976-77	3,118,689	26,094,453	8.37	2,212,303	84.78
1977-78	3,541,096	18,941,209	5.35	1,584,453	83.77
1978-79	3,132,834	20,244,328	6.46	1,795,184	88.68
1979-80	2,730,235	12,612,472	4.62	1,045,507	82.90
1980-81	3,093,895	18,651,652	6.03	1,602,647	85.92
1981-82	3,640,293	26,059,827	7.16	-	-

*rai = 0.4 acre, 1 acre = 2.5 rai.

Source : Sugar Institute.

ADAPTATION TO THAILAND ENVIRONMENT

Production of field crops in the Western region of the Central Plain of Thailand apart from paddy, are sugarcane, cotton, sorghum and mungbean as a relay crop. In the past, sorghum was widely grown in the area before sugarcane became an important export crop of Thailand. Cotton was also a former cash crop of that area before the out break of boll weevil occurred.

The Western region comprises the mountainous parts in the west. It stretches from south of Prachuab Khiri Khan on the peninsula and as far north as Tak. To the west and north, the region is bounded by the hill and mountain ranges of the Western and Northern mountains and valleys. In the east it borders on Takhli - Chai Badan - Pak Chong uplands and to the southeast, the region merges into the lower lying Southern Central Plain. During South - west monsoon, rainfall is low to very low in the western part of the plain. Average annual rainfall is 1,050 mm near Kanchanaburi and 1,250 mm near Suphan Buri. Air humidity is above 80 % in September and October. Mean annual air humidity ranges from 69 % in Kanchanaburi to 79 % in Prachuab Khiri Khan. Mean minimum temperature in the coolest month (January) varies from 20.3°C in Hua Hin in the Southern Central Plain to 18.3°C near Suphan Buri and to 15.1°C near Tak. Mean maximum temperature is 27.0°C for Hua Hin, but above 27.7°C to 28.2°C for the rest of the region, summarizing diurnal and seasonal fluctuations are low in the south and become more pronounced towards the northern part of the region. In this region, sugarcane is the most important upland crop and occupied more than 70 percent of arable land of this region. The main soil type of this area is Non-Calcic Brown soils.

The Eastern region is comprised of the hilly areas in the east. It is bordered by the hill and mountain ranges between the Northeastern and the Eastern region by Phanom Dong Rak ranges. The rainfall distribution is more intensive and lasts longer than in the

west. The monsoon rainfall is more densely distributed in Chanburi and Trad where rubber trees and orchards are grown. Sugarcane occupies about 15 percent of the area. The typical soil types of this area are Regosols, Gray Podzolic and Low Humic Gley soils.

Table 2. Thailand's sugar production 1972 - 1982.

Year	Pure white sugar, ton	Refined sugar, ton	Raw sugar ton	Total
1972-73	371,616	18,293	258,529	648,438
1973-74	420,532	14,899	487,396	922,827
1974-75	494,024	17,313	548,991	1,060,328
1975-76	439,559	40,515	1,123,519	1,603,593
1976-77	540,651	77,226	1,594,427	2,212,204
1977-78	469,998	78,561	1,035,894	1,584,453
1978-79	395,520	119,300	1,280,365	1,795,184
1979-80	432,223	85,997	526,255	1,045,507
1980-81	458,979	143,374	1,000,293	1,602,646

Source : Sugar Institute.

Table 3. Thailand's sugar export 1972 - 1981.

Year	Sugar Export (ton)	Value million Baht*
1972	426,808	1,252
1973	258,294	1,086.2
1974	420,241	3,533.5
1975	584,988	5,234
1976	1,081,627	6,414.8
1977	1,637,587	7,395.2
1978	1,002,641	3,844
1979	1,177,243	4,684.5
1980	446,349	2,914.8
1981	1,115,823	8,944.9

* 1 Baht = 0.05 U.S. $ (approximately)

Source : Sugar Institute

PRODUCTION

At present, sugar cane is one of the most important export commodities of Thailand. Its export value exceeded 7,395 million Baht in 1977, and the total requirements for local consumption is approximately 550,000 tons white sugar and this amount is subjected to increases annually. (Table 3).

The production of sugarcane in Thailand can be divided regionally as follow, North region in Lampang, Uttaradit and Sukhothai 11 percent, Northeast region in Udorn, Ubon Ratchathani and Mukdahan 9 percent; Eastern region is Chon Buri, Rayong 10 percent, and in Central and South Western region 70 percent. The average yield of sugarcane production is around 8 ton per rai, and the growing area was about 3.6 million rai in 1981/82.

Department of Agriculture (DOA) started its first sugarcane research program in 1952 at Agricultural Experiment Station 3, Nakhon Ratchasima (Now Banmai Samrong Experiment Station) to investigate the chewing type of sugarcane and in 1954 by setting up a fertilizer experiment plot at Mae Jo Field Crop Experiment Station and continued the experiment through the subsequent ratoon crops. In 1959, fourteen demonstration plots were carried out in Lampang, Ubon Ratchathani and Udorn and extension work of sugarcane research activities were released to the farmers ever since then.

The Institute of Field Crops, DOA created the variety program in 1974, a yearly average of approximately 50,000 seeds were produced for the breeding program during the past three years. Prior to this breeding program, the collection of approximately 200 varieties of sugarcane has been established at U-Thong, Chai Nat and Huai Pong Field Crop Exp.Sta. Meanwhile, the varietal testing experiment plots were carried out randomly in the main growing area in Kanchanaburi, Suphan Buri, Chon Buri and Chai Nat, both in irrigated and non - irrigated areas. And the recommended varieties are; F 140 from Taiwan and Q 83, Pindar and Ragnar from Australia. These varieties are well

adapted to local environments, but are susceptible to many major diseases and insect pests and subsequently lower yields and lower sugar quality were obtained.

The sugarcane research conducted by the Institute of Field Crops has been on a problem oriented basis, with added emphasis on the breeding program. During the 1975-1977 period, three varietal yield trial plots were set up randomly in the main sugarcane growing area, to evaluate 12 collected and introduced sugarcane varieties from various countries. Varieties basically more productive, resistant to smut disease and erect stalks are selected as a promising variety which will be collected for multiplication and then will be distributed to the farmers. Emphasis on non - lodging varieties is a special consideration on selection of variety since most farmers in Thailand are still using machine as tool to harvest sugarcane. However, some strong and hard rind varieties such as F 140 is refused, even though it does not lodge and contains a high sugar content.

Spacing trial plots and methods of planting sugarcane on poorly drained soil were also investigated. To solve the farmers' problem in how to prepare the prevailing heavy structure soil formerly employed as a paddy production area in the Central Plain. From the results, the experiment revealed that stump planting sets at 45 degree was obviously advantageous to other methods of planting, germination is brought up to 100 percent within the second week after planting. The spacing in and between rows of sugarcane is recommended as 130 x 50 cm, this is an optimum rate for many varieties now growing in this country. Although, closer space provided a number of good weight of millable stalks but did not allow good space between row for a 2 wheel tractor to work dexterously.

Before releasirg procedures and recommendations to the farmers, the practical testing and evaluation of the procedures and techniques are tested under farm conditions. Some promising sugarcane varieties were tested in farmers fields at 10 locations in Central

Thailand. F 140, Q 83, Ragnar and the farmers' own original variety were grown and yield and C.C.S. were collected. From the results of the experiments, the yields of the plant cane were very high, ranged about 13-14 ton/rai. Most cane entries yielded lower in first ratoon cane according to drought condition in year 1977. The farmers' entries are Pinder, some are Q 83 and F 140, that made no difference between the recommended varieties and the farmers' own.

Fortunately, Thailand has not had any problem concerning surplus by-products such as bagasse and molasses. Most of bagasse has been used as fuel for the power generator supply for the mills and some surplus amount has been used as a raw material for a paper craft mill located at the center of the sugarcane belt in Kanchanaburi.

Another kind of by-product, which is produced total 1.3 million ton per year, molasses, has been partly fermented as a liquor. Up to 300 million litres per annum and exported for foreign currency.

MILLING

In Thailand, cane is normally harvested without burning. The milling season, according to the Sugar Act 1968, starts as early as the first of November. Most sugar mills pay for cane on a flat rate basis, only 4 government owned and one private sugar mill are paying for cane based on its quality. Methods to be used for calculating the prices to be paid for farmer's cane have been set by a Sugarcane Board which is chaired by the Minister of Industry. The formula used for evaluating cane has been known as the C.C.S. (Commercial Cane Sugar) adopted by Australian sugar industry since 1915. But this is employed by the 4 government mills and the one private sugar mill only. The Sugarcane Board annouces the basic price for cane annually before the milling season. The price of cane is influenced mainly by the world's sugar price and stock (Table 4).

Table 4. Price of sugarcane tonnage (flat rate) agreed by cane grower association and sugar mill owners, and officially announced by the Sugarcane Board committee since 1972 (included delivery cost).

Year	*Price per ton. ฿
1972/73	183
1973/74	212
1974/75	300
1975/76	300
1976/77	300
1977/78	320
1978/79	450
1979/80	600
1980/81	650
1981/82	540

*Source : Sugar Institute

*For computing the price of cane sold to juice evaluation system. The mill shall pay this rate per ton for cane of standard quality, containing 10 percent CCS, with a premium of 20 Baht for each degree above 10 and a penalty of 10 Baht for each degree below. The premiums are subject to change annually.

There are 45 sugar mills in this country, four of them belong to the government, 28 of them belong to the Thai Sugar Manufacturing Association group, 9 of them belong to the Thai Sugar Trading Association group, the rest are free lance companies (Table 5).

Table 5. Name, location and capacity of sugar mills in Thailand.

Name of Sugar mill	Location	Capacity t/d
Member of the Thai Sugar Trading Association		
1. Mitr Phol	Ratchaburi	9,500
2. Mitr Siam	Kamphaeng Phet	9,000
3. Kamphaeng Phet	Kamphaeng Phet	2,200
4. Ban Pong	Ratchaburi	8,000
5. New Kwang Sun Lee	Chon Buri	1,500
6. New Krung Thai	Kanchanaburi	7,000
7. Tha Maka	do	8,500
8. Thon Buri (1)	Ratchaburi	7,500
9. Thon Buri (3)	do	3,500
Member of the Thai Sugar Manufacturing Association		
10. Ang Wien	Chon Buri	4,500
11. Khon Kaen	Khon Kaen	8,000
12. Prachuap Industry	Kanchanaburi	9,600
13. Nam Tal Thai	Kanchanaburi	8,000
14. Mitr Kàset	do	8,000
15. Saha Thai Rung Rueng	Burirum	500
16. Ta Wan Auk	Rayong	6,953
17. Pran Buri	Prachuap	2,410
18. Ruam Phol Industry	Nakhon Sawan	2,500

	Name of Sugar mill	Location	Capacity t/d
19.	Ratchaburi	Ratchaburi	8,000
20.	Kumphawapi	Udon Thani	5,000
21.	Nong Yai	Chon Buri	8,000
22.	Phetchaburi	Phetchaburi	1,500
23.	Nakhon Pathom	Nakhon Pathom	1,500
24.	Wana Chai	Lampang	825
25.	Chai Mongkhol	Suphan Buri	3,500
26.	Thai Rung Rueng	Kanchanaburi	16,500
27.	Thai EK Laks	Uttaradit	6,000
28.	Kanchanaburi	Kanchanaburi	8,000
29.	Krung Thai	do	2,500
30.	Ruam Karn Lab	do	4,000
31.	Thai Pherm Phun	do	8,000
32.	Thai Industry	do	12,000
33.	Saha Karn Nam Tal	Chon Buri	3,300
34.	Si Racha	Chon Buri	2,500
35.	Thai Ruam Charoen	Rayong	1,500
36.	Maha Khuna	Sing Buri	8,000
37.	Prachuab	Prachuab	13,294
	Government enterprise		
38.	Lampang	Lampang	1,200
39.	Uttaradit	Uttaradit	1,200
40.	Suphan Buri	Suphan Buri	3,000
41.	Chon Buri	Chon Buri	3,000
	Free private enterprise		
42.	Saha Rueng	Mukdahan	445
43.	Rerm Udon	Udon Thani	1,500
44.	Chiang Mai	Chiang Mai	200
45.	Rayong	Rayong	1,500
	Total		245,557

PRICING OF SUGARCANE

In 1982, The Royal Thai Government (RTG) decided to settle the disputes in regard to cane payment by adopting this following measures :

1. Sugarcane planters may elect to receive either sugar or cash payment for his share.

2. The grower shall receive not less than 70 percent the value of sugar produced from the cane supplied by him, but all molasses belongs to the mill.

3. Set up a Thai Sugar Company which equally shares the investment i.e. the cane growers association, the millers and the RTG The office shall manage the practice to the production of the exported part of raw sugar when the commencement of crushing season begins, then proceed to handle the rest of the sugar production for of the year. The company shall also take care of the internal marketing of sugar.

4. Set up fund for a Central Sugar Marketing Office, under the Ministry of Commerce. From 1979, a fixed price was set up on sugar consumed domesticly, that white sugar was fixed to 10 baht per kilogram and the refine sugar was 11 baht. In 1982, the trend of world market prices of sugar is down to 81 pounds sterling per ton (London daily price-LDP) or about 3.70 baht per kilogram. But the domestic price of sugar is still frozen to 12 baht for white sugar and 13 baht for refine sugar per kilogram. A sum of balance will go directly to the fund.

5. Before the 1982 milling season, the RTG calls for bid to sell sugar in advance by 600,000 ton yearly for 5 consecutive years. The tender has to offer a loan to the Thai Sugar Company to use as a cash advance to the sugarcane growers.

6. To increase the efficiency of sugar production, the Sugarcane Board announced that all sugar factories must pay for sugarcane on C.C.S. basis in the crop year 1984 onwards. This measure

proved unsatisfactory to the growers but since the growers have been informed and trained upon sugarcane evaluation in the laboratory by the Department of Agriculture and other organizations, the situation proved to be better.

Transportation of cane in Thailand is the task of cane growers. Ten-wheel trucks are usually used to move cane to the mill. In the past, Lampang Sugar mill, the first modern sugar mill in the country, used to transport cane by railway which is independent of the mill. Stale cane was quite common in that situation, and the growers could not avoid tracking cane loaded ox-carts to the railway station nearby. So transportation by train has been out of fashion since then. Trucking cane by ten-wheeler reduces cost of transportation, well-tied cane stalks are arranged neatly, one truck load weighs about 20 ton or more. Cane is delivered to the mill by the grower at his expense. The grower pays the cost of loading and delivery according to the distance from his farm to the mill. Normally, within 100 kilometers, one truck load costs about 2,400 Baht (about 120 baht/ton cane). Mechanical cane harvesters are not popular since manual harvesting labour is plentiful and more over, chopped cane needs more loaders and that means a higher cost of transportation.

Most sugar mills in Thailand do not have their own field division, only that of the government enterprises are an exception. So, a "quota man" is necessary to take his role in managing cane to the mill in agreed proportionate quantities throughout the season. The quota man offers his tender to supply certain amounts of cane through the milling season and he is responsible to supply the cane for 50-60 percent at the least. He is supposed to give in advance to his subordinate farmers eg. fertilizer (correct grade), tractors and some other inputs to the planter. When the time to harvest arrives the farmer who sends his cane to the mill under his quota, shall be paid by the miller; deducting the cost of fertilizer etc., and also a bonus of 10 Baht per ton for the quota man.

Looking forward into the future of sugarcane and sugar production of Thailand, many problems should be solved. Areas planted sugarcane should be limited and cane produced should be allotted to the mill fairly, to reduce the cost of transportation.

To raise up the recovery of sugar from the present average of 8.5 percent is also urgently needed. Adoption of selling cane on a juice quality basis is essential. Growers must know their own cane as well as its sugar content, time to harvest, and collaborate well with the mill. The farmer shall promise to cut his cane only when he gets his order. The mill also must be just and fair in rotating his bill of order, especially, in the good year that supply of cane may be in excess, trafficking of the bill of order should be prohibited and considered illegal.

A career of the quota man should be registered and looked after by the government as well as the contracts signed by him and the sugar mill. Contracts between sugar farmers and the quota man should also be registered by the Amphoe Office, for the quota man should not be allowed to get too much benefit from the sugarcane growers.

APPLICATIONS OF SOIL SURVEY AND CLASSIFICATION FOR TREE CROP DEVELOPMENT AND IMPROVEMENT THE MALAYSIAN EXPERIENCE

Ng Siew Kee
Agromac Snd Bhd

1. Introduction

Since 1965, the Malaysian agriculture economy has undergone major changes through the expansion and diversification of export commodity tree crops. While maintaining her position as the world's largest producer of natural rubber into the eighties, Malaysia has emerged in the seventies as the world's largest producer of palm oil and palm kernel, and is rapidly developing into one of the top producers of cocoa by 1990. These structural changes are shown by the hectarages planted to rubber, oil palm and cocoa in Table 1.

Table 1 : Planted Area in Hectares (,000)

Year	Rubber	Oil Palm	Cocoa
1965	1,600	100	5
1981	2,100	1,100	100
Increase	+ 500	+ 1,000	+ 95

It is pertinent to state these tree crop expansion and diversification efforts were not haphazard or random but on the contrary based on systematic soil resource inventory and capability evaluation, backed by agronomic research data and commercial plantation experience on productivity performance. Pivotal to all this is a strong and comprehensive national soil survey programme incorporating soil mapping, classification and measurements of key pedological properties. The applications of soil survey and classification to the development of the Malaysian plantation industry are elaborated in the ensuing.

2. Conceptual Framework of Applications.

The major objectives of soil survey and classification in crop production embrace not only allocation of soil resources for large scale development but also optimisation of agricultural practices such as fertiliser inputs and water management, as well as delineation of 'problem' areas for research. Experience in Malaysia has indicated that the scope of applying soil survey and classification data is considerably enhanced if they are complemented by agronomic data from multi-disciplinary crop research programmes as well as commercial yield performance on discrete soil entities. However, the availability of such crop production information depends on institutions such as national research institutes or private experimental stations and large plantations that maintain detailed yield performance and farm input records. In this respect, Malaysia is fortunate to have these two complementary ingredients as they facilitated the transfer of technology to new areas. These Malaysian attributes are depicted in Figure 1. It is perhaps this unique combination of the three factors that has made Malaysia particularly successful thus far in tree crop enterprise involving rubber, oil palm and to a lesser degree cocoa.

Figure 1 : Concept of Integrated Applications of Soil Survey and Classification.

A. Main Applications	B. Allied Data Base	C. Institutions
i) Determine suitability of crop systems and optimise use of soil resources		
ii) Optimise agronomic practices, i.e. - fertiliser inputs - varietal/clone selection	a) Long term commercial yield performance on different soils with input records	

A. Main Applications	B. Allied Data Base	C. Institutions
- spacing, cover cropping - land preparation	b) Findings from long term agronomic trials	Large commercial plantations and Research Institutes/ Private Experimental Stations
iii) Define and delineate 'problem' or marginal soils for special research		

3. Optimising Soil Resource Utilisation.

In the expansion and diversification of oil palm, rubber and cocoa or cocoa/coconut cultivation, due cognisance has been taken of soil capability as determined by soil surveys and classification, as well as yield performance and agronomic input data. Thus, in the extension of rubber into new zones, soil resources comprise predominantly Great Groups of Paleudult, Tropudult, Acrothox and Haplorthox on relatively hilly the rain, while a major shrinkage of rubber cultivation on Tropaquepts occurred, which has been estimated at about 2000,000 hectares.

The large expansion of oil palm planting occurred by a major conversion of rubber land on Tropaquepts, Sulfaquepts and Tropaquults on relatively flat to undulating terrain and more massive extension onto jungle lands incorporation Paleudults, Tropudults, Haplorthox and Acrothox. To a much lesser but significant extent, Tropofibrists and Quartzipsamment were also brought under oil palm cultivation.

In the case of cocoa, which is known to prefer soils with higher base saturation, diversification has taken place largely on Tropaquepts, Tropudults and Haplorthox.

The fourth tree crop, coconut, in contrast has witnessed some contraction by conversion to oil palm on Tropaquepts and Sulfaquepts, while the remaining of the Aquepts with coconut have been intercropped with cocoa.

The status of soil resource utilisation for the major tree crops in Malaysia is still evolving. With continuing techno-economic developments, further improvements in optimisation of land use for tree crop culture can be envisaged. The potential trend for future is shown in Table 2.

Table 2. Projected Status of Soil Resource Utilisation for Tree Crops in Malaysia.

Tree Crop	Great Soil Groups Decreasing Order in Extent			
a) Rubber	Acrothox	Paleudult Tropudult	Dystropept	
b) Oil Palm	Tropaquept Sulfaquept Sulfaquent	Tropudult Paleudult Haplorthox Quartzipsamment	Tropofibrist Dystropept	Acrothox
c) Cocoa	Haplorthox Tropaquept	Paleudult Tropudult	Sulfaquept	
d) Coconut	Tropaquept (INTERCROPPED with COCOA)	Tropaquod Tropohumod		

4. Yield Performance

The present and projected trend in utilisation of soil resources for tree crops is also based on yield performance data derived from commercial plantings as well as field experiments.

Several workers have studied the relationship between crop performance and soil survey units and the findings for rubber (Chan & Pushparajah, 1972; Eswaran et al, 1983), oil palm (Ng, this paper), cocoa (Thong, pers. comm.) and coconut (Ng, this paper) are presented in Table 3.

It can be noted there is complete rational in diversifying from rubber on Aquepts to oil palm or to cocoa/coconut on the relatively better Tropaquepts. With improved technology from research, it can be envisaged that the Tropofibrists would be upgraded into a higher yield performance rating. Cocoa cultivation is likely to be concentrated on the better Aquepts, Orthox and Udults only. In the case of coconut as a monocrop, its scope of expansion is restricted to the Spodosols in coastal situations. As an intercrop with cocoa, however, its potential still prevails in the better groups within the Aquepts.

Table 3. Yield Performance on Different Soil Groups.

Soil Group	Rubber* kg/ha/yr.	Oil Palm** tonne/ha/yr.	Cocoa*** kg/ha/yr.	Copra** kg/ha/yr.
Tropaquept	1300-1500	25-30	1000-1200	1500-1800
Sulfaquept	1200	20-25	700-800	1000-1200
Dystropept	1400-1700	18-22	600-700	-
Sulfaquent	700	15-20	400-500	600-800
Paleudult	1500-1700	20-22	800-900	-
Tropudult	1400-1600	20-22	900-1000	-
Acrothox	1400-1800	20-22	900-1100	-
Haplorthox	1700	22-25	1100-1200	-
Quartzipsamment	800	18-20	500-600	-
Tropaquod	600	-	-	400-500
Tropohumod	700	-	-	500-600
Tropofibrist	600	12-15	<400	-

* Eswaran et al. (1983); Chan & Pushparajah (1972).

** Ng, this paper.

*** Thong, pers. comm.

5. Soil Fertility Considerations.

As mentioned in the outset, a growing application of an integrated soil survey and classification system is the determination of specific fertiliser inputs for each individual crop for each practically defined soil moiety. This information can only be achieved by sound multi-disciplinary research and Malaysia is fortunate in having the available institutions such as Rubber Research Institute of Malaysia (RRIM), Palm Oil Research Institute of Malaysia (PORIM), as well as complementary research units in the commercial plantation sector. Through such efforts, the priorities of nutrient inputs for various soil groups are defined, as presented in Table 4.

It can be seen that priorities of nutrient inputs vary with soil characters as well as crops. Thus, in the case of oil palm, lower nutrient demands are apparent in most of the Aquepts, while higher nutrient demands including copper and boron are needed for Psamments and Fibrists. For cocoa, calcium or limestone is a necessity but this is not true for rubber.

The present state of knowledge is by no means complete and further agronomic research is necessary in order to refine the differences further.

Table 4. Principal & Subsidiary Nutrient Inputs for Various Tree Crops.

Soil Group	Rubber	Oil Palm	Cocoa	Coconut
Tropaquept	N, k	N, k	N, CA, k	N, k
Sulfaquept	P, n, k	P, CA, n,k	CA, P, N	P, ca
Dystropept	P, N	P, N, k, mg	CA, P, N	-
Sulfaquent	P	P, CA, n, k	CA, P, n, k	P, CA, n
Paleudult	N, K, P	N, K, P, mg	CA, N, K, P	N, K, P
Tropudult	N, K, p	N, K, P, mg	CA, N, K, P	N, K, P
Acrothox	N, K, P	N, P, K, mg	CA, P, N, k	-
Haplorthox	N, K, p	N, P, k, mg	CA, P, N, k	-
Quartzipsamment	K, P, N, mg	N, P, K, MG,B	-	-
Tropaquod	-	-	-	K, n
Tropohumod	-	-	-	K, n, p
Tropofibrist	-	CU, K, CA, B	-	K, CA

Note : Capital letter denotes Principal Input
Small letter denotes Subsidiary Input.

6. Problem Soils

Thus far, the soil survey and classification effort has defined 3 major 'Problem Soils' where low productivity levels occur for the various tree crops cultivated. These are :-

a) Sulfaquents & Sulfaquept
(Acid Sulphate Soil)

b) Tropofibrists (Peat)

c) Tropaquods & Tropohumods
(Podsols)

Since human settlements are located on these soils, research has to be intensified so that appropriate crop adaptation and higher productivity can be achieved. Already, significant advances have been made in oil palm productivity on Acid Sulphate Soils (Hew & Khoo, 1970; Bloomfield, 1976) and peats (Cheong & Ng, 1977 & 1980; Ng, 1983) and it is possible further advances are in the offing through sustained research, which will render these hitherto marginal soils economically productive. However, the spodosols on coastal situations still present formidable obstacles to satisfactory production of coconut and cashew nuts. Much more concerted research needs to be carried out to enhance the fertility and more diversified use of these Spodosols.

Since these problem soils occupy over 3 million hectares in extent, their early reclamation would facilitate the expansion of tree crop culture as soil resources are becoming increasingly limiting.

7. Conclusions

The Malaysian experience in systematic tree crop expansion and diversification since the early sixties has demonstrated the practical value of soil survey and classification. Coupled with agrotechnological input data and commercial yield performance on plantations, this has afforded high productivity and rapid technology transfer. In addition, 'problem' soils of economic importance are defined and delineated and appropriate research programmes undertaken to improve them.

However, maximum efficiency of soil resource utilisation is by no means attained yet, and further refinements in soil survey and taxonomy that are closely integrated with agrotechnological research should enhance further the strength and resilience of the tree crop sector in Malaysian agriculture, especially in the agrotechnology transfer from Peninsular Malaysia to Sabah and Sarawak in East Malaysia.

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SOIL AND WATER CONSERVATION IN THAILAND

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Soil erosion never was a problem in Thailand as recent as 30-35 years ago. The upland areas were largely then untouched and well covered with forests. Although there has been some degrees of forest destruction by shifting cultivation on the hills and timber cutting, erosion problem then was insignificant and natural in nature. Timber cutting in the past was quite selective and did not completely destroy ground cover. Farming then only occupied the flat land of the Central Plain and the valley areas of other regions for rice. Rubber growing in the South at that time was limitted and was on the flat or slightly sloping land only.

The increase in population from less than twenty million people at that time to about forty-five million people at present together with the recent diversification of crops for industries and export have created much demand for more land. Forests and hilly areas were opened up for upland crops such as sugarcane, maize, kenaf etc. at rapid rates in all regions. In 1982, the Northeast has only 15.3 % of its land remained under forest, and the country has 19 %.

Being an agricultural country in the tropical monsoon region together with its undulating topography, Thailand has been facing with erosion problems and production losses in the past few decades. However, the extents of the damages depend on management and the typoes of land use. It is now estimated that 17.2 million hectares or 33 % of the country is moderately to severely eroded. Fertility status survey

of the soils of Thailand found that 51.71 % of the land is low in fertility, 16.88 % is moderately fertile and only 0.04 % is highly fertile. Erosion has affected environments and has also caused siltation in streams and reservoirs. Suspended sediments from all watersheds is now estimated to be 27 million tons annually. Budgets for dredging rivers, streams and channels have increases considerably in the past years.

Man is probably the major factor that has influenced erosion more than others through continuous misuse and mistreatment of the land in this country. The average annual rainfall of 1,550 mm. is also an important factor. Rain-storms are often of high intensities and can cause very severe erosion expecially when they arrive in May-June, the early growing season. Many soil types are highly erodible when bare, especially the sandy soils of the Northeast. The already detached soil particles can be easily transported whenever there is sufficient runoff.

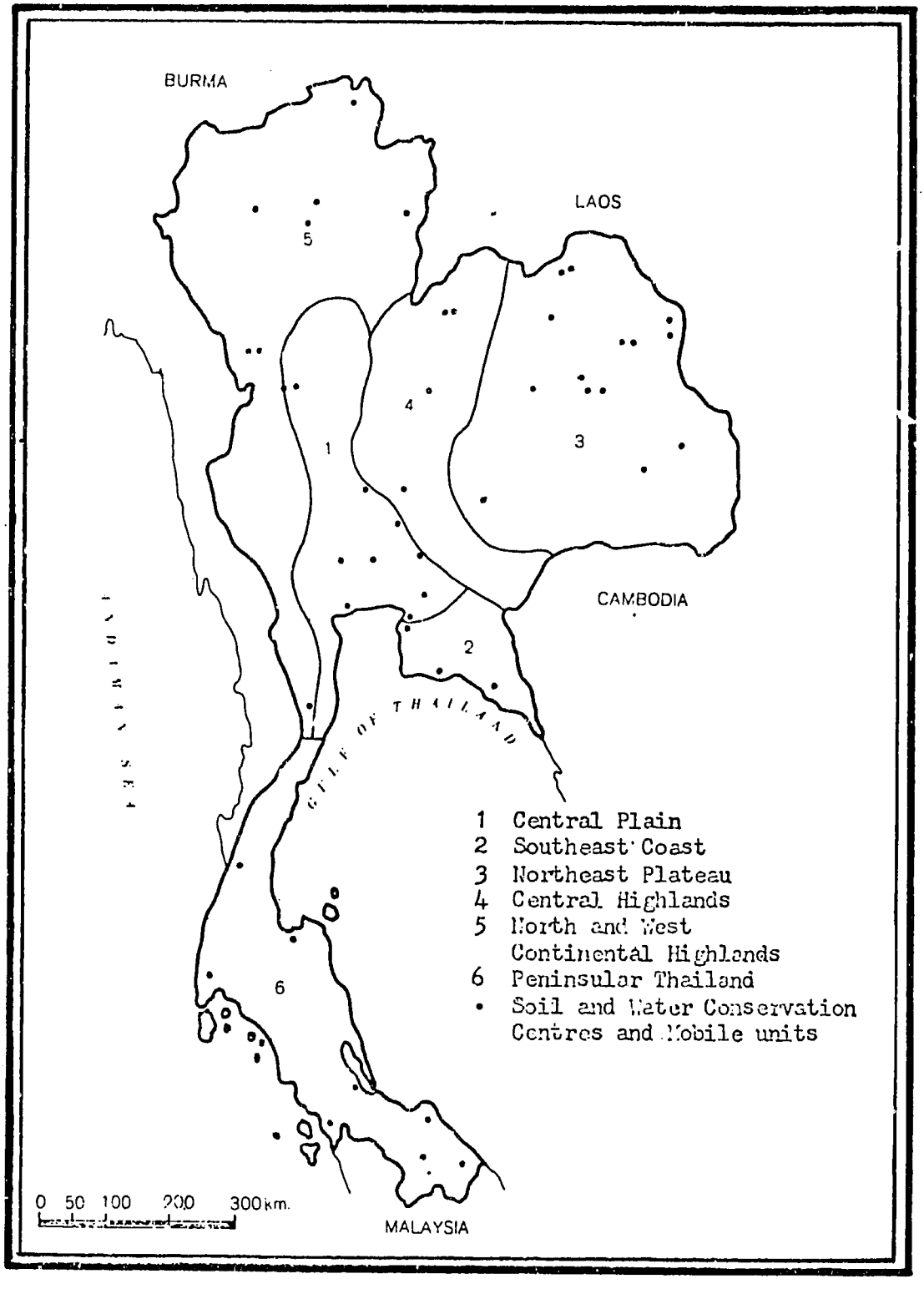
In order to conserve land resource, the Land Development Department was created in 1963 and is now an agency under the Ministry of Agriculture and Cooperative. It is given the responsibilies of planning efficient use of land, protecting cultivated land from erosion and depletion, and bringing depleted and problem land into production. Therefore, its main function at present consists of the following :

1. Establishment of land policies and land use planning.
2. Conservation of land and water resources.
3. Land reclamation.

The Soil and Water Conservation and Management Division of the Land Development Department of responsible for soil and water conservation and reclamation of land. The Division is made up of research, extension, and operation. Operation work is carried out by twenty-three Soil and Water Conservation Centres and thirteen Soil Conservation Mobile Units which are scattered through-out the country. Research workers and subject matter specialists and conservation extension staff are stationed at the main office.

Soil erosion problem in Thailand (1981)

erosion status	estimated soil loss (t/ha/yr)	area (million hectare)	%	land use type
very low	0.06 - 6.25	18.99	36	forest and paddy field
low	6.31 - 31.25	14.44	28.1	forest, orchard, rubber and paddy
moderate	31.31 - 125	4.15	8.07	ruber, orchard, upland crop and forest
severe	125.06 - 625	6.82	13.27	rubber, orchard upland crop forest and chifting cultivation
very severe	625.06 - 6,041.56	6.27	12.19	upland crop, forest, chifting cultivation
others	-	0.73	0.23	fish and shrimp ponds, mangrove swamp and beach


BURMA
LAOS
CAMBODIA
MALAYSIA
GULF OF THAILAND
ANDAMAN SEA
1
2
3
4
5
6
1 Central Plain
2 Southeast Coast
3 Northeast Plateau
4 Central Highlands
5 North and West Continental Highlands
6 Peninsular Thailand
• Soil and Water Conservation Centres and Mobile units
0 50 100 200 300 km.

285a

PART 4

GENERAL DISCUSSIONS

AN ASEAN NETWORK OF BENCHMARK SITES FOR AGROTECHNOLOGY TRANSFER

CHAIRMAN

Prof. A. Van Wamebeke

PANELISTS

Dr. S. Panichapong

Dr. F. H. Beinroth

Dr. M. Sharifuddin

Dr. S. Rojanasoonthon

Dr. E. Pushparajah

RAPPORTEUR

Dr. H. Eswaran

AN ASEAN NETWORK OF BENCHMARK SITES FOR AGROTECHNOLOGY TRANSFER

Chairman

After introducing the Panel, the chairman indicated the scope of the discussion. The title of the subject includes three words which could be elaborated -- network, benchmark sites and Agrotechnology. Network is like a set of strings of equal strengths, with connecting knots of equal importance to catch as many fish as possible. There are many ways to structure such a network. Generally it is a group of individuals or institutions who have agreed to carry out activities each in its respective fields or areas but aiming at common objectives with a commitment to sharing experiences and results. A network approach is particularly applicable to soil or agricultural research because soil research is so site specific. A multilocational network achieves more than isolated and unrelated experiments. The second is benchmark sites which implies that we must conduct our experiments on selected, representative and well characterized locations. We may want to discuss what the components of the site will be. We frequently refer to soils, climate, vegetation, farming systems, socioeconomic factors etc. and the Panel may want to look into what we as Soil Scientists should include and what we can handle.

The third word is agrotechnology. The Panel may want to consider what kind of technology seeds testing and developing for transfer. We may want to define the areas of work.

I have prepared a set of points for discussion. These are the objectives, the collaborators, the nature of the work and finally the logistics of the network.

Panichapong

I have been personally very interested in the Benchmark Soils Project (BSP) and now I am very happy to hear of the new International Benchmark Sites Network for Agrotechnology Transfer (IBSNAT). We in the ASEAN region have been trying to cooperate in several activities and the ASEAN Soils Conference is an example. The countries have a common agricultural base and have similar standards of living. Research inputs vary from country to country and crop to crop and it is obvious that no one country can place equal emphasis on all crops. An ASEAN IBSNAT is not only relevant but also necessary as we are convinced that it is mutually beneficial.

Dr. Beinroth in his earlier talk on IBSNAT indicated that a project of this type should meet several conditions which I like to repeat :

Is the projects,

a. technologically possible
b. economically feasible
c. socially desirable
d. administratively manageable
e. politically acceptable
f. environmentally sound

Some of these are of some concern to me as I am not sure that we can meet all these requirements. For example, if a project is politically accepted, the economic feasibility may be of little significance. I would like to say that these are desirable guidelines but we cannot use them to dictate over activities.

I like now to say a few words on the Thai experience on agrotechnology transfer which is purely a national effort. We, in the Soil Survey Division, have already a collaborative program with the Ministry of Agriculture in conducting experiments on defined soil families. This is a three year project which expects to be extended

longer. Having initiated this we would like to cooperate on a regional scale -- through the ASEAN network -- and at an international scale, through IBSNAT. In Thailand there are 11 economic crops -- rice, corn, cassava, sugarcane, soybean, mungbean, rubber, kenaf, coconut, cotton and oilpalm. We are interested in improving the production of all the crops and so we are interested in any regional or international activities. However, if we have to make a choice for the ASEAN network or IBSNAT, the principle we could follow could be based on the problematic crops or soils.

SHARIFUDDIN

Mr. Chairman, I must first say that we in Malaysia are a bit disappointed that we were not considered in BSP but we are happy now that we are included in IBSNAT, I cannot, of course, speak on behalf of all the institutions in Malaysia but as a rule we have been responsive to all collaborative efforts and this has been particularly in the case of University Pertanian.

Malaysian agriculture is based heavily on non-food commodities such as rubber and oilpalm. This does not imply that we do not do research on the annuals. However, over research inputs on food crops needs considerable impetus and so we welcome the proposed network.

I will not elaborate on the objectives of the network as in a way this is obvious. However, the logistics of setting up a network is not easy as many institutions are involved. This has prevented us in getting together in the past. But through the umbrella provided by IBSNAT, I am sure we can achieve many things. For the immediate, we must set up a secretariat in the ASEAN region.

ROJANASOONTHON

Agriculture in Thailand, as you all know, has not reached the sophistication of the western world. Our farmers work hard,

perhaps harder than many others but yet his productivity is low. Our national output is high because we have large areas and not because of the productivity of the individual farms. Like other developing countries, we cannot afford the luxury of research. At the same time we must continue to increase the productivity as land is a finite resource but population is increasing. These are our motivating forces for establishing the ASEAN network and collaborating with IBSNAT.

PUSHPARAJAH

In the ASEAN countries, all cultivable land are already under some form cultivation and pressure of land is forcing people to move into marginal land and particularly the environmentally delicate areas. The detrimental effects of this is already being felt.

I like now to clarify a misconception held by many donor countries regarding technical assistance and agrotechnology transfer with respect to perennial crops like rubber and oilpalm. Rubber is grown by all countries of the ASEAN countries and including India, Bangladesh, Sri Lanka, Papua New Guinea, Vietnam, Burma. In all these countries, rubber is a small farmer's crop. In Malaysia 70 % is small holding and in Thailand practically all are in small holdings. So politically it is important in all these countries. In a country like Malaysia, the farmer sells his rubber and buys his food and in the Malaysian context, this is the best use of the soil. For these reasons, rubber should be an IBSNAT crop and an important crop of the ASEAN network.

(Dr. Pushparajah then proceeded to explain the current linkages available between natural rubber producers and kinds of technology transfer activities already underway. These transfers are with germ plasm and not agronomy which is lacking).

BEINROTH

I would like to mention briefly some of the methodologies being considered by IBSNAT. The basic concept is the matching of existing agricultural knowledge and technologies to land qualities at a new location. The methodology would be basically using computer simulation using minimum data sets. There are several models already available in the US. The most comprehensive model, developed by a group of the Agricultural Research Service of USDA, is called the Erosion Productivity Impact Calculator (EPIC). It is designed to simulat the long term change in yield resulting from change in soil properties resulting from wind and water erosion. There are also several crop models and other kinds of models. A new effort that is currently underway by the same group at Temple, Texas, is called ALMANAC -- Agricultural Land Management Alternative with numerical assessment criteria. This is mere comprehensive and will include all the previous models.

The idea is to use these simulation models to perform the matching exercise. We think that this will be an intergral part of IBSNAT activities.

We already have indications of several regional and national networks and I have referred to these before.

CHAIRMAN

How can the ASEAN network be linked to IBSNAT particularly with respect to modelling ?

BEINROTH

In the first phase of the project the contributions will be mainly from the collaborators to IBSNAT. We have to develop the data base for the crops that are selected. This data will be used to refine the models after which the models will be validated in the field by the collaborators.

The other question is if the collaborators involved in the development of the models ? To the extent feasible, they will be (Dr. Beinroth then explained the forth coming meeting at ICRISAT, India -- March 21-26 -- and the future strategies of IBSNAT).

CHAIRMAN

Some of the previous speakers have indicated that for certain crops like rubber and oilpam, a data base already exists. What are IBSNAT's plans for such situations ?

BEINROTH

IBSNAT needs the data base for good modelling. Probably the data base for rubber is sufficient while in other crops there may be knowledge gaps which need experimentation to fill up.
(Meeting adjourned for coffee at 10.15 and reconvened at 10.45).

CHAIRMAN

To summarize the discussions so far, it appears that it is desirable and possible to have an ASEAN network. One of the objectives is to obtain more accurate prediction of crop performance through matching of crop requirements to land qualities. One of the speakers stipulated that research efforts should be initially concentrated on the least productive soils or problem soils. The linkage of the ASEAN network with IBSNAT was also considered necessary.

We should perhaps now consider on how to implement the network, what will be the workplan, the logistics and details and finally we can perhaps discuss some recommendations for consideration during the final session this afternoon.

BEINROTH

I would like to clarify the question of the nature of the network. IBSNAT is a prototype of an international network which can

be duplicated, with necessary modifications, at the regional or national levels.

When the national network becomes a part of a larger, regional or international network, automatically you will have access to a larger pool of information that has been generated elsewhere. This information will become readily available through the communication established by IBSNAT.

ESWARAN

I like to elaborate on some of the points already raised by the Panel members. The first question is, can the ASEAN countries form a network. The ingredients to an operational network are several and include the following. First is experimental stations, there is no lack of such stations, many of them have done excellent work. Second is information on soils. The region is lucky in this sense as it has a long tradition of soil survey. Third, there is a need for a common language and have again, all the countries use Soil Taxonomy. In this respect, there is already a tradition of collaboration as for example through the ASEAN Soils Conference. One project that has been repeatedly discussed is to make a soil map of the ASEAN countries using Soil Taxonomy. The ASEAN network can have this as one of their collaborating activities and SMSS will be glad to assist. The fourth point is weather information and most countries have a good network. However, more frequent and accurate data need to be collected and IBSNAT is considering providing the equipment for this purpose. Fifthly, is the question of personnel which is also not a constraint. Sixthly, the region presents a range of soils and crops, making the network complete.

So there is a need, there is a desire and there is a possibility. What is to be done now is to develop the mechanism and I hope this Forum will lead to it.

MONCHAROEN

I would like to ask Dr. Beinroth what levels of management or technology is used in the models. This is important when we wish to use the models here.

BEINROTH

The models have the flexibility to simulate any kinds of economical inputs.

PARAMANATHAN

I would like to reiterate one of the points of Dr. Eswaran. We are talking about agrotechnology transfer and we cannot do a transfer even if we have all crop information, if we do not have a common soil map. Further, in order to select the sites in the ASEAN region for the network, we must know the soils and the extent of the soils. So I concern that developing a soil map of the ASEAN region could because one of the tasks of the Network of collaborators.

PANICHAPONG

We are hoping that through IBSNAT, there will be a marked decrease in our research costs and this will be very satisfactory to over administrators. I wanted to mention this as it is an important practical point to participate in IBSNAT or develop an ASEAN network.

I agree with Eswaran and Paramanathan on the need for a soil map of the ASEAN countries. This is also an immediate necessity of the ASEAN network and I hope SMSS can assist us. Next, we may develop an ASEAN network but in order for this to become effective, there should be a lot of training which I hope IBSNAT will do. The models mentioned by Dr. Beinroth are good but if we do not understand them, they are little use to us.

SHARIFUDDIN

With respect to implementation, probably the first step is to develop a secretariat to coordinate all activities. The dedication of all individuals concerned is critical to the success of the project. The secretariat will then develop a project proposal and I hope we can have the assistance of IBSNAT and SMSS. This proposal can then be circulated to individuals and institutions for collaboration and support and particularly for funding.

I like to mention one other important point. All institutions have ongoing project If we join IBSNAT, we may have to do some experiments required by IBSNAT. This will require detailed justification and possibly alternative source of funding.

BEINROTH

The question that has been raised is what will be the inputs of IBSNAT to the ASEAN network. The staff of IBSNAT can assist in several respects. Firstly the selection of the Benchmark Site and possibly of providing the equipment to monitor the weather. When a site is decided, we will assist in the characterization of the site.

The secretariat that was mentioned will be the main link with IBSNAT. IBSNAT will be willing to assist the secretariat in developing the project proposal.

ROJANASOONTHON

(Dr. Rojanasoonthon discussed the mechanisms to request the assistance of the Committee of Science and Technology (COST) of ASEAN in developing the proposed network. He indicated that he will volunteer to do this).

CHAIRMAN

We have discussed the needs, the mechanism and probably we can now go into the workplan. The soil map of the ASEAN countries has already been mentioned.

BEINROTH

It is extremely important to have a reliable resource base so that you have an indication of the geographic applicability of the well conducted experimental station. As this map transcends national boundaries it must have a common legend.

CHAIRMAN

We can now suppose we have a secretariat, we have agreed to have a soil map with a common legend, we have a series of experimental stations and have selected the sites but we don't have any among yet. Any ideas ? With respect to methodology, it is basically one of matching and perhaps IBSNAT can provide it. Any comments ?

PUSHPARAJAH

We have to develop a strong project proposal and approach funding agencies. We definitely need assistance from IBSNAT and SMSS.

BEINROTH

I would like to offer the assistance of IBSNAT, if it is so desired, to work with you in developing a proposal for a regional network that would enable you to obtain some funding.

ESWARAN

Perhaps the Chairman could indicate if the proposed International Board for Soil Resource Management (IBSRM) could play a role in this.

CHAIRMAN

(The Chairman then explained the objectives of IBSRM).

CHAIRMAN

We are now towards the end of the discussion. We now have to get the wheels turning but the most important thing must take the initiative. We can now discuss some of the recommendations we may want to table later.

PUSHPARAJAH

One of the things to decide is the crops. If rubber is a crop then we at the Rubber Research Institute will play a significant role. So if the project proposal is made we must be explicit on the crops to be investigated.

RAJANASOONTHON

Our immediate task is to develop the project proposal and with the support of IBSNAT and SMSS, I think we can achieve many things.

On final word is that we should use the 3 S's to guide us -- Soil, Sharing and Safe.

BEINROTH

I would like to say on behalf of IBSNAT that we have been extremely pleased with the reaction and discussion and I would like to reiterate that it will be a privilege and pleasure to work with you all.

CHAIRMAN

In closing, I would like to say that I am extremely grateful to Hari for giving me an easy profile to discuss and an excellent panel to lead the discussions. I thank you all for your active participation.

SOIL TAXONOMY PROBLEMS-ASIAN COUNTRIES

S. Paramananthan, Lek Moncharoen, Vo Tong Xuan

Diagnostic horizons

S. Paramananthan (Malaysia). Oxic horizons. Soils with very week, very fine structure (may have thin patchy coats on ped faces) present problems. The Malaysians would like to call these horizons oxic. The clayey soil is well to excessively drained. They would redefine the oxic horizon to include these soils ignoring the clay increase.

If the soil has 30 cm of oxic than an albic over an argillic, the soil is called an oxisol but they would prefer oxic subgroup of Alfisols.

Cambic. The organic carbon requirement in poorly drained soils states that organic carbon decreases regularly with depth and reaches a content of 0.2 % or less at 1.25 m. These soils have mottling and many other features common to cambic horizons but fail the 0.2 % OC at 1.25 m requirement. They would delete this organic carbon criterion and define the horizon according to other features common to the cambic.

Paudy soils with vertic features. The problem is how deeply the soil cracks and if cracks are wider than 2 cm at a 50 cm depth. The soils are artificially flooded and to determine cracking characteristics would require expensive field observations. They also have trouble determining if the slickensides intersect.

Aquic moisture regime. They may have below the surface of a nonaquic, flooded well drained soil a gray layer that puts the soil in an aquic subgroup. The gray layer has formed due to the cultural practice of flooding for rice. They do not believe that this soil should be in an aquic subgroup.

Soils high in organic matter content hardly ever have chromas below 2, which keeps the soil out of the Aquept suborder. However,

these soils are associated with acid sulfate soils which are aquic. They suggest that perhaps some attention should be given to the organic matter content and that the chromas should be adjusted accordingly.

Udic vs. ustic moisture regimes. Their main problem is the wide range within the udic moisture regime. The whole country of Malaysia is udic but there is a large difference between the north and the south in effective precipitation. They would like a split in the udic.

Lateritic gravel. Should be placed higher in the system instead of at the family level. The discussion was rather lengthy on this subject and concerned whether the gravels were genetic.

Sulfic subgroups and sulfuric horizons. If the sulfic layer is below 1 m, it has little affect on the management of soils. However, if horizons occur above 50 cm or between 50 cm and 1 m and they suggest that perhaps a subgroup separation should be made.

Histosols. They do not like the requirement of Walkeley-Black organic carbon in the definition of organic soils. They would like loss on ignition as the criterion.

Ultisols on weathered shale (saprolite) at 80 cm. The clay does not decrease in the saprolite; therefore, the soils are classified in the pale great group which they deem as a misnomer. Calling the saprolitic material a paralithic contact does not help since depth to a lithic or paralithic contact is left out of the pale definition in Ultisols.

Mr. Lek Moncharoen (Thailand). Argillic horizon. Identification in the field is very difficult because of identifying clay skins. He would prefer just an increase of clay for field determination ?

Cambic horizon. Poorly drained soil organic carbon decrease with depth is a problem as it is in Malaysia. He states that these soils are associated with Sulfaquepts and they would prefer that they not be Entisols.

Aquic moisture regime. Soils that have high chroma but have a water table at or near the surface for 3 to 6 months. They have a number of soils that have reddish colored quartz and have a very high water table during a large part of the year. These soils do not fall in the aquic suborders because of too high a chroma. In fact, when keying these soils out under the Alfisol key, they fall "through the crack", and do not classify. There is an error in the keys on page 109 for Udalf and Ustalf. A statement is needed for the situation where chromas are too high for aquic. This statement of chromas too high for aquic is in the definition for Udalfs and Ustalfs but was left out of the key on page 109.

Acid sulfate soils. He states that the pH of 3.5 or less is used as criterion, but most of the acid sulfate soils in Thailand have a pH greater than 3.5 because of high calcium in the river (flood) water. Therefore, he would prefer to raise the pH requirement to < 4.0.

Base saturation--Alfisol vs. Ultisol break. In soils with low CEC (3 to 5 meq CEC in the Northeast) have an annual fluctuation in base saturation because of sodium in the water. Thus classification changes with the season.

Mapping. They have soils that occur together but are in aeric and typic subgroups because of a 1 chroma difference in color. They must separate but impractical for separation in the field. We discussed this and suggested perhaps a complex map unit would be in order.

Dr. Vo Tong Xuan (Viet Nam). They use the FAO classification system and after 1975 have been trying to use the USSR system. They still use Moorman's soil map which uses the FAO system. They are testing soil taxonomy at his university with respect to acid sulfate soils. Therefore, most of his comments deal with acid sulfate soils.

Sulfaquepts and Sulfaquents. Depth at which the sulfidic or sulfuric horizons occur is very important. They are proposing

sulfaqueptic and sulfaquentic subgroups for soils where the horizons occur above 50 cm. Paramanathan mentioned in conjunction with Dr. Vo Tong Xuan's comments that if sulfidic material is at or above 50 cm the soil is a Sulfaquent, and if a thin cambic is above the sulfidic material, the soil is still a Sulfaquent. He would prefer that where cambic horizons are above the sulfidic horizon that the soils be called Inceptisols.

Mr. Moncharoen (Thailand) commented that the language in "Soil Taxonomy" is ambiguous and difficult for the Thais to understand. I mentioned that it creates problems for us also.

Discussion and Suggestions

This session was conducted by Hari Eswaran.

Cambic horizons--problem has to do with high organic carbon and aquic moisture regime, but other properties point to a distinct cambic. In this respect the participants would rather place these soils as Inceptisols. Dr. Van Wambeke asked the question if they had thin bedding but still had structure, would they still prefer them as Inceptisols. Paramanathan stated that in marine clays you cannot see the varies so they call them Inceptisols. But in other soils where they have distinct layering, they would prefer to call them Entisols.

Sulfuric horizon. Definition--pH must be less than 3.5; however, the Thais would prefer that the pH be raised to <4.0. Paramanathan (Malaysia)stated that if they see jarosite, they don't bother to check pH. The discussion also indicated that the intent of low pH was probably devised for the specific instance in Thailand and the calcium rich waters and that these soils perhaps should not be classified with a sulfuric horizon. Paramanathan (Malaysia) stated that if they see jarosite plus seashells they would not call the soils Sulfaquepts. They also discussed the problem of high organic matter causing jarosite mottles to be redder than the 2.5Y hue called for in "Soil Taxonomy". They indicated that perhaps the hue should be raised

after a critical level of organic matter and suggested that 6 percent organic matter may be the critical point.

Oxic vs. argillic. Clay skins are difficult to identify in the field. ICOMOX has proposed the kandic horizon. Kandic horizons must have a dominance of kaolinite plus have CEC of less than 16 meq/ 100 g clay. In addition, the soil must have a specific clay increase --the upper 18 cm after mixing must have less than 40 percent clay. No mention is made of clay skins, thus soils that have a clay increase but low CEC would go into the kandic great group. There are two kinds of kandic horizons based on thickness of the argillic. The thin kandics are called kanhapudults and the thick ones are called kandudults. If clay is more than 40 percent and clay increases, the soils would go directly into Oxisols. Kandic horizons are special argillic horizons.

Aquic moisture regime (flooded). The discussion centered around Moorman's proposed anthraquic horizon. Dr. Samarn Panichapong (Thailand) stated that he understands the naturally poorly drained situation for aquic, but that Moorman's anthraquic would also include well drained soils in Thailand. He stated that in a matter of a few years there is evidence of saturation and of gray mottles but that the ground water level is often below the gray layer. Should this be aquic or should it be anthraquic? Mr. Lek Moncharoen, also of Thailand, stated that the native vegetation reflects an Ustic regime but after flooding the soil is aquic. Paramanathan of Malaysia said this is particularly noticeable in the loamy soils. Dr. Van Wambeke asked how to write the definition to separate out different aquic moisture regimes. Lek Moncharoen suggested that may be an usticaquic similar to a proposal in the United States. The discussion also included the aquic soils with high chroma and high organic matter. There is an indication that high organic matter contents may affect chromas.

Udic vs. Ustic transition areas. Malaysia is all udic but they have a dryer area in the northern part of Malaysia that has a

dramatic effect on crop yields. Dr. Van Wambeke stated that we have five moisture regimes, therefore, because of necessity, they are broadly defined. The discussion indicated that perhaps separations within the Udic should be made at the series level. Dr. Pushparajah (Malaysia) suggested that for the transfer of technology it would be advantageous to separate dry Udic from wet Udic. This separation would come at a higher category level. These higher categories will most likely be used in the transfer of technology. Mr. Lek Moncharoen of Thailand stated that he has extensive moisture regime data and would like to test his model if SMSS will fund it.

The laterite, petrol plintite, or ironstone gravels--all three terms refer to the same material. Taxonomy defines a petroferric contact but it must be a cemented laterite layer. The Malaysians feel lateritic gravels should fall out at a higher categorical level than at the family as a skeletal soil. In 1975, Dr. Guy Smith proposed a specific Lethoplinthitic horizon which would be lateritic material that is very visecular. However, these gravels would not fall under this term. Malaysians argued that lateritic gravel should fall out at a higher level since gibbsite falls out at the great group level. They said that lateritic gravels below the surface cause problems with management such as windthrow. (I have serious doubt that these gravels are pedogenic but simply are remnants of a previous soil material that has been moved around. I would leave them in the skeletal family since windthrow is a problem in skeletal material too). Dr. Pushparajah mentioned there will be some proposed changes offered from Malaysia concerning the lateritic gravel problem. The proposal defines a petroplintic material which would come out at the great group level.

Acid sulfate soils. Paramanathan of Malaysia presented a paper at the acid sulfate conference. He stated that they would like the depth separations of sulfidic and sulfuric horizons at the series level. He mentioned again the cambic overlying the sulfidic material and stated that it is very important with regard to management to

recognize this cambic horizon at the subgroup level. There is no provision in the Inceptisols to take care of this situation.

Ultisols. The pale great group is defined only on decrease in clay content. The problem comes in with stratified materials and saprolite that underlies an argillic horizon. The lithic and paralithic contact statement was left out of the key for pale great groups in Ultisols.

COMMENDATION

The participants commend the Soil Management Support Service of the US Department of Agriculture for initiating, assisting in the organization of, and tedinically and financially supporting the Fourth International Forum held in Thailand. We further commend the participation and contributions of staff of the Benchmark Soils Project the International Benchmark Sites Network for Agrotechnology Transfer of the Universities of Hawaii and Puerto Rico and the Ford & Agrc. as guw. By implication, this commendation extends to the US Agency for International Development which is funding the SMSS, BSP and IBSNAT program.

Dr. Paramanathan
Dr. S. Rojanasoonthon

The participants of the Fourth International Forum on Soil Taxonomy and Agrotechnology Transfer express their sincere appreciation to the Land Development Department, and particularly its Soil Survey Division, for organizing, hosting and co-sponsoring the Forum in Thailand, and to the Ministry of Agriculture and Cooperatives for financially supporting this international encleavor. The Organizing Committee is highly commended for the excellent organization of the conference sessions and field trip. The overwhelming hospitality extended to the participants is gratefully acknowledged.

Dr. H. Ikawa
Mr. Wong Nan Chong

RECOMMENDATION

The Forum participants recommend that the idea of establishing an ASEAN Network for Agrotechnology Transfer be actively pursued for the purpose of sharing and communicating agricultural knowledge and experience and research findings in the region.

In order to initiate that process it is proposed that the Land Development Department establishes a Steering Committee whose first task would be to develop a proposal detailing the rationale, goals, objectives, and activities in a concise and logical manner. The offer by IBSNAT and SMSS to assist in the preparation of this document should be considered. The purpose of the proposal would be to create awareness of, and to obtain administrative and financial support for the project from the appropriate authorities and institutions.

Dr. E. Pushparajah
Dr. F. Beinroth

The participants of the Forum recommend that in view of the need for Agrotechnology Transfer within and without the Asean Region, SMSS should support both technically and financially the production of a soil map based on Soil Taxonomy initially of the Asean Region.

This map should be at a scale of 1 : 500,000

It is proposed that the soil science Department, University of Pertanian Malaysia, Establishes a working group to coordinate, the activities leading to the proposed soil map.

Recommended by : Dr. S. Paramanathan

Seconded by : Dr. S. Panichapong

It is recommended that the key to the Soil Taxonomy be translated in the Thai, Malaysian, and Indonesian languages with the support of the SMSS.

Recommended by : Dr. Samarn Panichapong
Seconded by : Mr. Eric M. Gliessman

FORUM EVALUATION

Vietnamese Evaluation

1. General observations -- They had not used taxonomy, so this forum was their first exposure to it. They were convinced that it is a convenient medium for agrotechnology transfer.

2. They suggested that the subjects of the forum should be arranged in a logical sequence, such as the sequence that the items occur in "Soil Taxonomy". They commented that some of the slides and material were at times weak. They specifically mentioned that the lectures on laboratory procedures were too brief. They would not have had two separate field trips.

3. The organization was very good. Both the SMSS and LDD are to be congratulated for the planning and execution of the forum. Their only minor complaint was that the luncheons were too heavy, making it difficult to stay awake in the afternoon sessions. The comment was well taken except that most people enjoyed the heavy luncheons.

4. Conclusions -- This was more than just a forum since it was a chance for international colleagues to get together and discuss mutual, technological problems.

On behalf of the Vietnam participants, Dr. Vo Tong Xuan would like to express his appreciation to SMSS, particularly to Dr. H. Eswaran for supporting their needs in understanding "Soil Taxonomy"; to the LDD, particularly to Dr. Samarn Panichapong for giving them the opportunity to participate with colleagues from Thailand and Malaysia; to Mr. Pisoot, Mr. Lek, and Mrs. Chalinee, and other Thai supporting personnel for their kind treatment throughout the forum; to all Thailand and Malaysian colleagues for being very nice to them, and for exchanging valuable experiences.

The chairman for this session was Hari Eswaran, and he asked for comments from the floor and there was complete silence.

When asked, one of the Thai participants commented that she gained more knowledge about calculations of data that she was not aware of before. She works in the thin section lab and has little field experience thus the field trips were valuable to her in that she was able to see what an argillic horizon looked like in the field as compared through a microscope.

Dr. Paramanathan from Malaysia commented that the organization was almost perfect, and he had no complaints. With respect to the forum proper, he suggested that we should have followed a set sequence in studying taxonomy. It then sets up a sequence of thoughts to follow when classifying a pedon. With respect to the various crops, he suggested that in future fora, there should be a guideline to authors so that they would orient their papers similarily; i.e., transfer of soils knowledge through taxonomy.

Mr. Wong Nam Chong from Malaysia commented that he had an extensive background in soil taxonomy so it was fairly easy for him to follow but that others had trouble following if they had little experience with soil taxonomy. He mentioned that his discussion of contacts was very beneficial to him. Lectures on soil analysis were very helpful, he had never had the comprehensive presentation before. He was not as happy with the land evaluation lectures. These were too fast and too superficial in coverage. He thought that the FAO method was relatively useful for large scale evaluation but that at the farm level it would be very difficult to convince administrators to follow the FAO procedures (Mr. Wong and the other Malaysians would haved liked detailed lectures on land evaluation). He would have discussed soil characteristics that are important for crop production on the field trips. As far as agro-technology transfer, he would like to see a similar program for rice but would use the "shot gun" approach instead of concentrating on one family.

Dr.Anchalee Suddhiprakarn, from Kasetsart University, Bangkok Thailand, has a background in soil mineralogy. She had been exposed to soil taxonomy to some extent, but this session was very beneficial to her in that she now thinks she would be able to teach soil taxonomy. She thought that the agro-technology transfer on crops was very good from the other countries but not her own. She also enjoyed the field trip.

Dr. Samarn Panichapong commented that Thailand had more experienced agronomists but unfortunately they were at other meetings.

Dr. Jitti Pinthong from Chiang Mai University had 3 comments:

1. The pedon was three dimentional but actually we only described a profile, which is a criticism of chapter 4 of the Soil Survey Manual.

2. Practicalities of "Soil Taxonomy" are highly dependent on the pedon description, and field identification is very important. He would like to try to correlate lab data to field morphology.

3. Classification and typifying pedon. He mentioned that we choose this pedon subjectively thus the area of extent must be considered. As far as agrotechnology transfer, is it mostly horizontal among nations ? What do we do it for, all mankind, nations, or poor people ? He thinks it should be for the farmers and betterment of living. These are realities that cannot be overlooked in agro-technology transfer. He also mentioned that the organization was very good, and he was very glad to be part of the forum.

Mr. Abdul Aziz Bir Maarof from Malaysia commented that this was his first exposure to "Soil Taxonomy". He had problems the first few days with keeping up with some of the lectures on "Soil Taxonomy" but, in general, it was very beneficial to him. He congratulated the organizing committee for a very good forum.

Hari talked a little bit about the how and why the forum was organized. He mentioned the philosophy of organized around was that the participants needed a refresher type course, thus, the speed at which some of the topics were covered. He also wanted to stress interpretations especially with respect to crops, but perhaps the forum failed somewhat in that respect. He asked the participants what they liked best, the coverage of "Soil Taxonomy" or soil interpretations ? The reactions were that they would probably have preferred a full fledged soil interpretations course.

Dr. Samarn Panichapong discussed how the forum was organized. They assumed most scientists from the ASEAN countries had some knowledge of "Soil Taxonomy", therefore, they wanted to connect taxonomy to crops which seemed to be lacking in this region. He also mentioned that during the preparation of the course, they did not foresee the difficulty in getting people to come and lecture. The problems were mostly financial and some of the lecturers were not able to come, therefore, they had to make quick revisions at the last moment. He mentioned that perhaps we should concentrate on both subjects (Taxonomy & interpretations) in future courses but feels that "Soil Taxonomy" is still being revised yearly, thus, it is necessary to hold courses on that subject. He mentioned that some are not receiving the circulars on proposals from the various taxonomy committees. He also mentioned that he thought soil interpretations were very important and should be included in future fora. He would probably modify the field trips after seeing how the present trip went. The group was too big and only a few people could get into the pits. He would split the groups into small groups and rotate them around the pits in a specific area.

Mr. Purnell from the FAO was most impressed by the general usefulness of the forum and was gratified that the soil survey will be used in agro-technology transfer. He would not give specific FAO support but, in general, FAO is supportive of IBSNAT in using soil survey information. FAO, as far as possible, would like to help in

anyway possible. FAO uses the classification scheme used by the country that they are assisting, thus, training in "Soil Taxonomy" was very useful to him.

Mrs. Chalinee Niamskul was thankful that there were no arguments among the participants during the forum.

Hari made one last comment, that he was disappointed that more of the people did not get into the pits and examine the soils.

VOTE OF THANKS

A. Van Wambeke

The last job Hari gave me on this forum is not an easy one, this time.

The expression of gratitude should have the same order of magnitude as the welcome and hospitality we all enjoyed here in Thailand, as I have come to learn in the Land of the Free.

The few words I will speak will have little weight, but I can assure you that they express a profound respect for all that this forum has achieved.

Let us as back and proceed in a chronological order. I wish to thank all those who are working or making soil science more accurate, precise and therefore more effective. I remember back 30 years ago when I started, that what made soil science attractive to young scientists, was that it came up with precise criteric that one could criticize and correct if found unsatisfactory. Dr. Smith was a man who should listen and act in this manner.

This is still the spirit and I wish to include in these vote of thanks to the sponsors of this forum, which is focusing on explaining the mechanisms of soil science to a new generation of soil investigator.

I wish to thank the organizing committee for developing a program that was not only comprehensive but covered almost all aspects of soil research, including views from crop scientists.

I thank the instructors for their excellent approach in presenting their contributions. They did not come here with ready made solutions to the problems, but presented alternative ways and approaches to these problems.

I thank the participants for their continuing interest in soils and their sharp criticism, which indicates they really know what they are talking about. The countries and institutions which

helped the participants to attend this forum should also be acknowledged.

Department at Land Development
Soil Conservation Service
University of Puertorico
University of Hawaii
University of Pertanian Malaysia
Kasetsart University
Soil Management Support Survices behalf

Last but not least allow me to express on behalf of this forum our thanks to all individuals who were involved in the organization of this forum :

Mr. Anunt Komes Director of Department of Land Development.
Dr. Samarn Panichapong Director of Soil Survey Division.
Mr. Lek Moncharoen
Mr. Pisoot Vijarnsorn
Mrs. Chalinee Niamskul

and all the staff, in the field and out. The drivers secretaries and people in the soil micromorphology lab.

Let us finally thank Dr. Hari Eswaran for all his hard work during the forum.

In clossing I am very grateful to the agencies, national and international who have contributed to the success at this workshop.

Thank you very much.

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PART 5

TOUR GUIDE

SUMMARY OF FIELD TRIP PEDONS

SOIL SERIES	LANDFORM	ELEVATION	MOISTURE REGIME	DIAGNOSTIC HORIZON(S)	FAMILY and SUBGROUP	LAND USE	REMARKS
BANG LEN	FLOODPLAIN		AQUIC	MOLLIC, CAMBIC	Fine, montmorillonitic, isohyperthermic TYPIC PELLUDERT	Paddy rice	If pedon fails cracking criteria of Vertisols it is a Vertic Haplaquoll
THA MUANG	FLOODPLAIN		USTIC	OCHRIC	Coarse-loamy, mixed (calcareous), isohyperthermic TYPIC USTIFLUVENT	Fruit trees	
NAMPHONG	UPLAND RIDGE		USTIC	OCHRIC	Siliceous, isohyperthermic TYPIC USTIPSAMMENT	Diperocarp forest	
KAMPAENG SAEN	RIVER VALLEY TERRACE		USTIC	OCHRIC, CAMBIC	Fine-loamy, mixed, isohyperthermic FLUVENTIC USTROPEPT	Banana	
LAT YA	ALLUVIAL FAN		USTIC	OCHRIC, ARGILLIC	Fine-loamy, siliceous, isohyperthermic, USTOXIC PALEHUMULT	Diperocarp forest	
MAUK LEK	MOUNTAIN SIDE-SLOPE		USTIC	OCHRIC, ARGILLIC	Loamy-skeletal, siliceous, isohyperthermic, ULTIC PALEUSTALF	Mixed deciduous forest	
RANGSIT	FORMER TIDAL MARSH		AQUIC	UMBRIC, SULFURIC	Fine, mixed, acid, isohyperthermic SULFIC TROPAQUEPT	Paddy rice	If sulfuric were above 50 cm the pedon would be a Typic Sulfaquept
SARABURI	RIVER VALLEY TERRACE		AQUIC	OCHRIC, ARGILLIC	Fine, mixed, isohyperthermic AERIC TROPAQUALF	Paddy rice	
TAKHLI	INTERMOUNTAIN BASIN		USTIC	MOLLIC	Loamy-skeletal, carbonatic, isohyperthermic UDORTHENTIC HAPLUSTOLL	Maize, coconut	Pedon lacks secondary carbonates of calcic horizon
LOB BURI	LAKE PLAIN		USTIC	MOLLIC	Fine, montmorillonitic, isohyperthermic TYPIC PELLUDERT	Paddy rice	Udic moisture regime when under paddy rice
SATUK VARIANT	RIVER VALLEY TERRACE KORAT PLATEAU	200 m	USTIC	OCHRIC, NATRIC	Coarse-loamy, siliceous, isohyperthermic TYPIC NATRUSTALF	Cassava	
KULA RONGHAI	RIVER VALLEY TERRACE KORAT PLATEAU	195 m	AQUIC?	OCHRIC, NATRIC	Coarse-loamy, siliceous, isohyperthermic TYPIC NATRAQUALF	Paddy rice	If no natric (structure) or argillic the pedon an Aeric Halaquept
PHLAMI VARIANT	FLOODPLAIN KORAT PLATEAU	167 m	AQUIC	OCHRIC, ARGILLIC	Fine, mixed, isohyperthermic AERIC TROPAQUALF	Paddy rice	Lacks structure for natric if natric it is a Typic Natraqualf
FONG NAM RON	UPLAND SIDE-SLOPE	200 m	USTIC	MOLLIC, CAMBIC	Fine-loamy, mixed, shallow, isohyperthermic UDIC HAPLUSTOLL	Cassava	With erosion probably will be a Lithic Ustropept
THA KUA THUANG	TIDAL MARSH	1 m	AQUIC	OCHRIC, SULFIDIC	Fine-loamy, siliceous, nonacid isohyperthermic TYPIC SULFAQUENT	Mangrove	
THA MAI	FOOTSLOPE	30 m	UDIC	OCHRIC, OXIC, CAMBIC?	Clayey, kaolinitic, isohyperthermic TROPEPTIC HAPLORTHOX	Rubber, durian	
KLAENG	RIVER VALLEY LOW TERRACE	15 m	AQUIC	OCHRIC, ARGILLIC PLINTHITE	Clayey, mixed, isohyperthermic PLINTHIC TROPAQUULT	Paddy rice	Typic Plinthaquult if > 50% plinthite
NARTHIWAT VARIANT	RIVER ESTUARY	1 m	AQUIC	OCHRIC, SULFIDIC	Euic, isohyperthermic TYPIC SULFIHEMIST	Mangrove	If mineral it is a Sulfic Fluvaquent
BAN THON	BEACH RIDGE	4 m	USTIC	OCHRIC, ALBIC, SPODIC	Sandy, siliceous, isohyperthermic, ortstein TYPIC TROPOHUMOD	Coconut	Borders udic moisture regime. Arenic Ustic subgroup may be proposed.

GENERAL INFORMATION

Thailand – its Land and People

The Kingdom of Thailand covers 513,115 square kilometers, shares its border with Loas to the north and east, with Burma to the north and west, Cambodia to the southeast, and to the south with Malaysia. The country's longest north-south span is about 1,620 kilometers (1,000 miles) and its widest east-west extent is 750 kilometers (500 miles). Geographycally, Thailand is open to the seas having a 2,614 kilometers (1,634 miles) of the coastal line running through 23 out of 73 provinces.

The People

Many theories exist regarding the origin of the Thai people but there is no conclusion. Recent archaeological discoveries at Ban Chieng in Thailand's northeast point to the existence of a people with well developed agrarian economy, keeping cattle, using bronze utensils and artifacts, dating back to 3,600 BC. This has led to the speculation that Thailand may be the site of the world's oldest civilization.

Again, a very popular theory contends that the Thai people originally inhabited southern China and were slowly pushed out by the Chinese and Tartars over a thousand years ago. The Thai people fled in tribes, working their way southwards over the mountains

until they settled in the fertile Chao Phaya basin and established a Thai kingdom in the 13th century.

Another theory contends that Thais have existed on this land all along and the new comers from southern China were absorbed into the community living in the Chao Phaya basin. While Thai boundaries have stretched at various times in the past, to various points inside Laos, Kampuchea, Burma and Malaysia, the heart of the Thai nation has always been the Chao Phaya basin. Covering most of northern and central Thailand, this immensely fertile land has been the home of the Thai people and the seat of administration over 700 years.

The nation's first recorded history dated from 1238 when King Intratit established Sukhothai as the first Thai capital Sukhothai's power soon expanded westward reaching the Bay of Bengal, south covering the Malay peninsular, and northeast reaching Vientienne. Sukhothai reached its zenith in the reign of King Ramkamhaeng the Great who is acknowledged father of the Thai nation. Buddhism became the state religion and numerous temples and stupas were built many of which exist today "Phra Buddha Sihing", one of Thailand's most revered image was brought over from Sri Lanka in this period. The image is now kept in the national museum except on special occasions when the image is brought out for worship. Many of Thailand's colourful festivals like Songkran and Loy Krathong also originated in the Sukhothai days. The Thai alphabet was

created by King Ramkamhaeng out of existing Khmer and Pali script, the alphabet is still in use today with very little modifications.

The next period with Ayutthaya as the second capital lasted from the 14th to the 18th century. In this period the Thai nation achieved a level of grandeur and prosperity unequalled in Southeast Asia. Trade flourished with Asian and Western nations and Ayutthaya became a very cosmopolitan city.

Ayutthaya was completely destroyed by invading Burmese in 1767, and in December 1768 King Taksin the Great rallied the Thai people under the third capital Thonburi, near the mouth of the Chao Phaya river. Thonburi proved to be a temporary capital as his successor King Rama I the Great moved the capital again across the river to the East bank. Thus on 6th April, 1782, Bangkok became the fourth capital of the Thai Kingdom, heralding the Rattanakosin period when Thailand opened up to Western influences while at the same time evading direct dominion by countries of the West. King Rama I was the first monarch under the Chakri dynasty of which the present monarch King Bhumibol is the ninth king. Thailand has just completed a grand celebration of two centuries of Rattanakosin period, last year in 1982.

Government

Since 1932, Thailand has been a Constitutional Monarchy

with the King as Head of State. In a succession of administrations, the country had moved steadily towards democracy. A permanent constitution was adopted in 1978 which provided Thailand with its present two-house governmental system, the House of Representatives with 301 elected members and the Senate having 225 nominated members.

Monarchy

The King is Head of State and Protector of all religions. His Majesty King Bhumibol Adulyadej and Her Majesty Queen Sirikit are both highly respected and revered by the people. Their Majesties, accompanied by the Royal Children, frequently visit their rural subjects in the most remote areas of their Kingdom. His Majesty had personally initiated numerous rural projects such as building reservoirs, irrigation canals and agricultural projects, replacing opium growing with cash-crops, brackish water fish farming, development to rice strains and the production of pasteurized milk. All are of immense value to raising the living standards of the Thai people. The Thai Royal Family, through their exemplary conduct, had contributed much to strengthen the national unity.

Capital

The capital city of Bangkok (officially known as Krung Thep Phra Maha Nakhon Amorn Rattanakosin) with a population of over 5 million, is the seat of government and the business and industrial

centre of the country.

Population

The population of Thailand in 1977 was recorded to be 44.27 million against 43.21 million in 1976, indicating an increase of 2.45 percent over one year. The present population density is about 85.5 persons per one square kilometer. Bangkok, the capital of Thailand, presents the most dense population in the country. It totals 4.74 million in 1977 and 4.54 million in 1976, showing a growth rate of 4.33 percent over that year. Bangkok's population density was then 3,030.13 persons per square kilometer.

Language

The national language both written and spoken is Thai, and is used by the majority of the population. English is a compulsory language in high schools and universities.

Religion

Buddhism is the national religion practised by 95% of the population. Its emphasis on tolerance has maintained the absence of religious friction within the country. There are about 1.8 million Muslims chiefly living in the southern provinces. The rest are Christians, Hindus, Sikhs and others.

The Economy

Thailand, known as the "Rice Bowl of Asia" is a major exporter of food, has agriculture as the backbone of her economy, and a fast developing industrial sector. Agriculture and essential commodities account for 60% of exports, being the world's largest exporter of tapioca, the second largest exporter of rice and a leading exporter of rubber, kenaf, sugar, tin and marine products. Manufactured goods accounted for 35% of the total exports in 1980.

Thailand has one of the strongest economies of the developing countries of the world. The country's GDP has been growing at an average of 7% annually in the past two decades, while inflation had remained under 10% throughout the 1970's decade. In 1980 Thailand's GDP reached 673,732 million baht with agriculture accounting for 26% and manufacturing 18% of the GDP.

The manufacturing sector has grown steadily, at a rate of 10% since 1960, with food processing representing one-fourth of all manufacturing activities. Textiles, garments, chemicals and petroleum products, mining on land and offshore, cement, electronic equipment, integrated circuits, food-wear, iron, steel and wood products, paper and plastics are among Thailand's major industries.

Financial Institutions

The country's central bank is the Bank of Thailand, whose

Table 1 Gross national product and national income at current market prices by industrial origin

millions of baht

Industrial origin	1976	1977	1978	1979	1980
Agriculture:	104,657	110,929	129,094	147,076	176,303
Crops	77,509	79,069	96,180	107,980	128,527
Livestock	12,354	14,409	13,503	16,954	23,455
Fisheries	9,792	12,456	13,086	13,017	13,710
Forestry	5,002	4,995	6,325	9,125	10,611
Mining and quarrying	5,174	8,139	10,610	12,614	14,444
Manufacturing	63,025	74,676	89,089	109,740	125,830
Construction	15,784	20,251	24,844	29,240	39,011
Electricity & water supply	3,745	4,384	5,168	6,075	5,802
Transportation & communication	21,828	24,706	29,606	37,844	47,746
Wholesale and retail trade	59,391	74,931	90,053	102,853	12[illegible],998
Banking, insurance and real estate	16,075	19,537	24,624	31,396	39,021
Ownership of dwellings	4,840	5,272	5,826	6,297	7,312
Public administration and defence	13,571	14,810	17,943	21,623	28,831
Services	29,545	35,395	43,095	51,482	64,434
GROSS DOMESTIC PRODUCT (GDP)	337,635	393,030	469,952	556,240	673,732
Plus: Net factor income payment from the rest of the world	-1,261	-2,014	-5,402	-9,791	-14,406
GROSS NATIONAL PRODUCT (GNP)	336,374	391,016	464,550	546,449	659,326
Less: Indirect taxes less subsidy	33,438	43,717	51,733	60.903	71,083
Provision for the consumption of fixed capital	24,041	28,609	34,428	41,877	50,888
NATIONAL INCOME (NNP)	278,895	318,690	378,389	443,659	537,355
PER CAPITA GNP (Baht)	7,830	8,879	10,300	11,843	13,977

Source of data: Gross Regional and Provincial Product.

functions, powers and responsibilities are broadly similar to those of other national banks. The Bank of Thailand has the sole right to issue bank notes, and manages currency reserves. According to the Currency Act, paper currency must be backed by assets of which 60% are in the form of gold, foreign currencies and other assets whose maturity is not more than one year.

There are 16 Thai commercial banks with extensive network of over 1,300 branches. A number of leading ones have overseas branches. Twenty-four foreign banks have branches or representative offices in Thailand. More than 100 finance and securities companies are also in operation under the strict control of the Bank of Thailand.

Currency

The currency is the Baht, which is divided into 100 Satangs. It is officially tied to a basket of currencies and heavily weighted to the US Dollar. The value is about 23 Baht to a US Dollar.

Communication

Thailand has a well developed system of communications. The Communications Authority of Thailand provides a wide range of services including cable, telex facility , VHF radio and paging system, and a speedy postal service. Except for postal services which are available to all villages, the other facilities are available only in Bangkok and major cities.

Telephone

Telephone service, provided by the Telephone Organizatic of Thailand is up to international standards, with subscriber tru dialing available nationwide. Overseas telephone service is available to 162 countries.

Shipping

Port of Bangkok, located at the mounth of the Chao Phaya river, has modern facilities to handle both conventional and container vessels. Sattahip port in the upper Gulf of Thailand is being upgraded to a proper seaport for bulk loading and container vessels of up to 120,000 tons. Coastal ports dot the southern coastline,and many, like the ports of Songkhla and Phuket, are being upgraded to handle ocean going vessels.

Aviation

Three international airports are in operation in Thailand--Bangkok airport, Chiang Mai airport in the north and Haad Yai airport in the south. The biggest, Bangkok airport processes over two million passengers in a year, and is served by 35 airlines. Smaller airports exist in the main cities and towns of all the provinces.

The country's national airline, Thai Airways International is acknowledged one of Asia's finest airlines, and provides direct flights to Europe, United States, Australia and every destinations in Asia.

Domestic air service to all parts of the country are provided by Thai Airways.

Railways

Thailand has around 4,000 kilometres of railway tracks reaching all parts of the country. The State Railway of Thailand provides smooth rail service, with first class and air-conditioned sleeper coaches on long distance journeys to the north, northeast and south.

Roadways

Roadways have become the most popular mode of transportation in Thailand, leading to an intensive development of the

national highways and feeder roads. 44,000 kilometres of roads already exist, reaching all corners of the country.

Waterways

Traditionally the transportation route for bulky agricultural produce, rivers and canals have recently regained popularity because it consumes less fuel than other modes of transportation. A vast network of inland waterways connect the entire central part of the country.

EXCURSION PROGRAMME

Field Trip I

Friday, 11 February 1983

0730	Leave Ambassador Hotel, Bangkok
0930-1030	See Pedon 1: Bang Len series
1115-1215	See Pedon 2: Tha Muang series
1215-1315	Lunch at Agricultural Extension Center
1345-1445	See Pedon 3: Nam Phong series
1530-1630	See Pedon 4: Kam Paeng Saen series
1700	Night at River Kwai Hotel, Kanchanaburi

Saturday, 12 February 1983

0830	Leave River Kwai Hotel
0900-1000	See Pedon 5: Lat Ya series
1100-1200	See Pedon 6: Muak Lek series
1200-1430	Lunch at Erawan Water Falls
1730	Night at Ambassador Hotel, Bangkok

Field Trip II

Tuesday, 15 February 1983

0700	Leave Ambassador Hotel
0815-0915	See Pedon 7: Rangsit series
0945-1045	See Pedon 8: Saraburi series
1145-1230	Lunch at Marl Station, Lopburi
1245-1345	See Pedon 9: Takhli series
1415-1515	See Pedon 10: Lopburi series
1800	Night at Khao Yai National Park

Wednesday, 16 February 1983

0830	Leave Khao Yai National Park
1000-1100	See Pedon 11: Satuk variant
1115-1215	See Pedon 12: Kula Ronghai series
1230-1330	Lunch at
1415-1515	See Pedon 13: Phimai variant
1500	Night at Korat Hotel, Nakhon Ratchasima

Thursday, 17 February 1983

0800	Leave Korat Hotel
1200-1300	Lunch at Sakaew district
1500-1600	See Pedon 14: Pong Namron series
1700	Night at Eastern Hotel, Chanthaburi

Friday, 18 February 1983

0830	Leave Eastern Hotel
0845-0945	See Pedon 15: Thakua Thung series
1015-1115	See Pedon 16: Tha Mai series
1215-1315	Lunch at Chanthaburi Soil Conservation Center
1415-1515	See Pedon 17: Klaeng series
1600	Night at Wang Kaew Resort

Saturday, 19 February 1983

0900	Leave Wang Kaew
0910-1010	See Pedon 18: Narathiwas variant
1040-1140	See Pedon 19: Ban Thon series
1200-1300	Lunch at Ban Phrae Resort
1630	Night at Ambassador Hotel

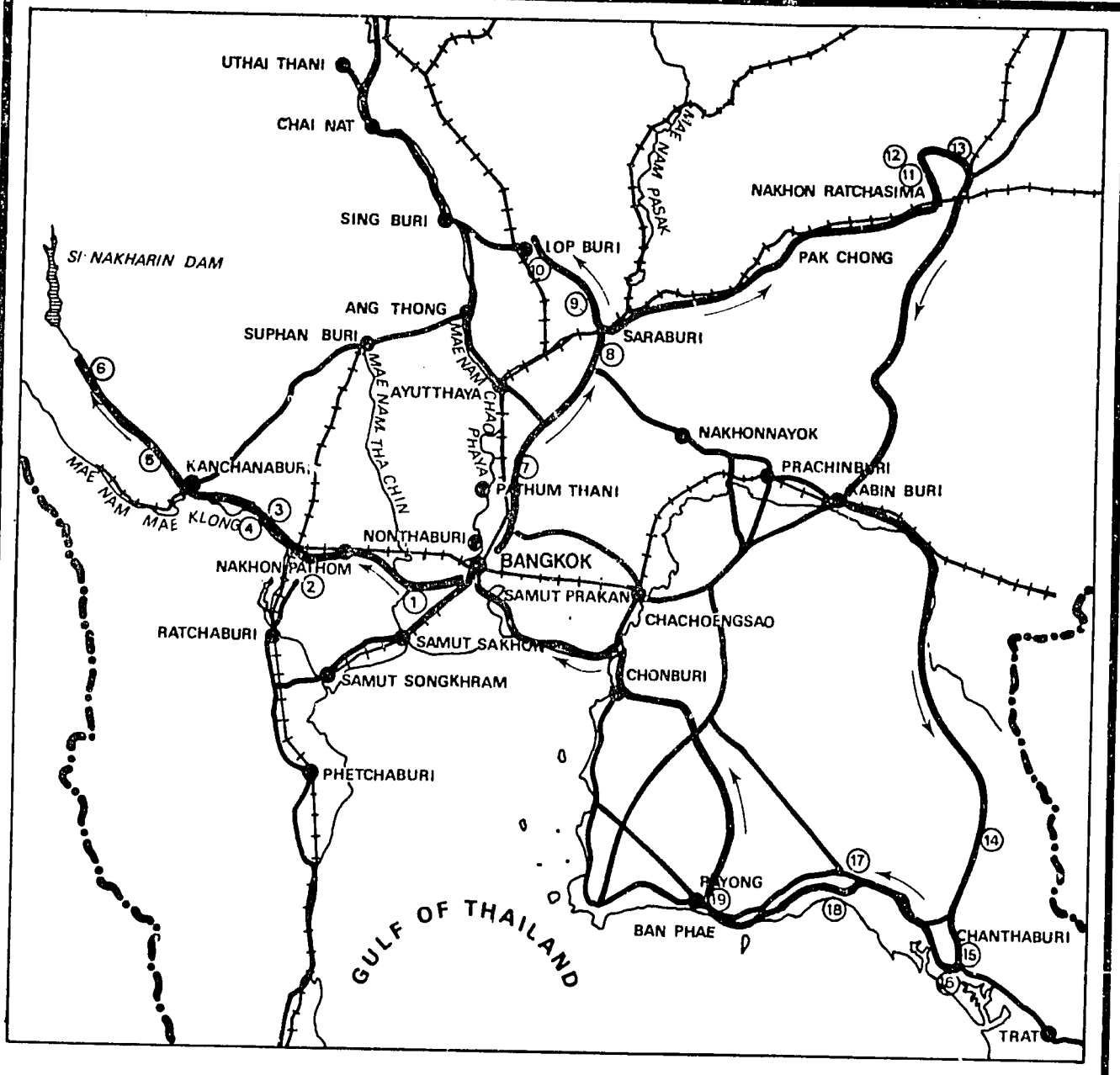


Fig.9 TOUR ROUTE MAP

First trip (red route)	Second trip (blue route)	
1 Bang Len series	7 Rangsit series	14 Pong Nam Ron series
2 Tha Muang series	8 Saraburi series	15 Tha Kua Thung series
3 Nam Phong series	9 Takli series	16 Tha Mai series
4 Kam Phang Saen series	10 Lop Buri series	17 Klaeng series
5 Lat Ya series	11 Satuk variant	18 Narathiwat series
6 Muak Lak series	12 Kula Ronghai series	19 Ban Thon series
	13 Phimai variant	

SOILS OF THE EXCURSION AREA

The area where the tour route takes place has already been covered by a detailed reconnaissance survey. Textural phases of great groups according to current USDA Soil Taxonomy are shown in the General Soil Map of the excursion area (Figure 8). Four textural phases are being used to subdivide each great group, these are sandy, loamy, clayey and skeletal. Sandy phase refers to soils having sandy texture to a depth of more than 100 cm. Loamy phase is used to describe soil which, in general, is finer than loamy sand but the amount of clay is less than 35 percent in most parts of the subsoils. On the contrary, the clayey phase implies that the soils contain clay more than 35 percent in most subsurface layers. If the soils contain coarse fragments larger than 2.mm in diameter such as rock, stones, gravels or ironstones in most subsoil horizons, skeletal phase will be used. 9 orders are recognized as follows:

Ultisols

The ultisols in this area have ochric epipedon and an argillic horizon of low base saturation. They are the most common soils in the region. Apart from beach sand and coastal swamps, they occur on all land forms and on a wide range of parent materials. The poorly drained Ultisols that are differentiated into great groups are Plinthaquults, Paleaquults and Tropaquults. The Plintustults, Haplustults, Paleustults and Paleudults are included

in well-drained Ultisols.

Inceptisols

The Inceptisols consist mainly of soils that are weakly developed or have altered horizons. The most common horizon sequence of these soils is an orchric horizon overlying a cambic horizon. They, occupy for the most part of inland coastal plains, alluvial plains, fans and alluvial terrace in the north-east. The unit is differentiated into six great groups such as the Tropaquepts, Ustropepts, Sulfaquepts, Dystropepts, Eutropepts and Halaquepts. The Tropaquepts, Sulfaquepts, and Halaquepts commonly occur on low-lying terrain with seasonal high water tables whereas the Eutropepts and Dystropepts are on the gently sloping totography.

Mollisols

The Mollisols are found in the Central Highlands and are generally formed on very calcareous materials, such as marl, weathered fragments of limestone and weathered products of basalt. These soils are medium to fine textured and show high base saturation. Three great groups, Calciustolls, Haplustolls and Haplaquolls are recognized. Nearly all of the Calciustolls are underlain by marl at shallow depth.

Entisols

Soil in this order show little or no profile development. The unit occupies beach areas, sand dunes, active tidal flats of

recent marine deposits, flood plains, alluvial terraces and colluvial slopes. The texture varies from sandy to clayey. The natural drainage class ranges from very poorly to somewhat excessively drained. The Entisols occurring on the coastal plains are differentiated into Hydraquents, Sulfaquents, Tropaquents and Quartzipsamments, whereas Ustifluvents and Ustorthents on Troporthents are found or river levees and colluvial slopes respectively. Soils developed from sandy alluvium derived from sandstone in the northeast often identify as Quartzipsamments.

Alfisols

These soils are characterized by a thin surface horizon (ochric epidedon) and a high-base saturated subsoil having an appreciable amount of translocated clay, also known as an argillic horizon. They are commonly developed in parent materials relatively enriched in bases. Alfisols in this area include 5 great groups, namely Tropaqualfs, Natraqualfs, Paleustalfs, Haplustalfs and Tropudalfs. The Tropaqualfs and Natraqualfs are poorly drained Alfisols occur mostly on low-lying topography whereas the remainder are on gently to moderately sloping terrain. The Natraqualfs are one of the problem soil in the north-east.

Vertisols

This unit is a limited extent only in the southern part of central highlands and found on rich, clayey material associated with limestone, marl and limestone derived alluvium. Less

important in extent are Vertisols on materials derived from basic igneous rocks (basalt and some andesite). Vertisols found in this area can be differentiated into Pelluderts, Pellusterts, Chromudert and Chromusterts.

Spodosols

Soils in this order contain a spodic horizon in which amorphous mixtures of organic matter and iron have accumulated. In most cases, the spodic horizon is overlain by a light gray eluvial horizon, also called a albic horizon. These soils are restricted to parts of the sandy beaches along the south-eastern shoreline. The Tropohumods are the only great group found in the area.

Oxisols

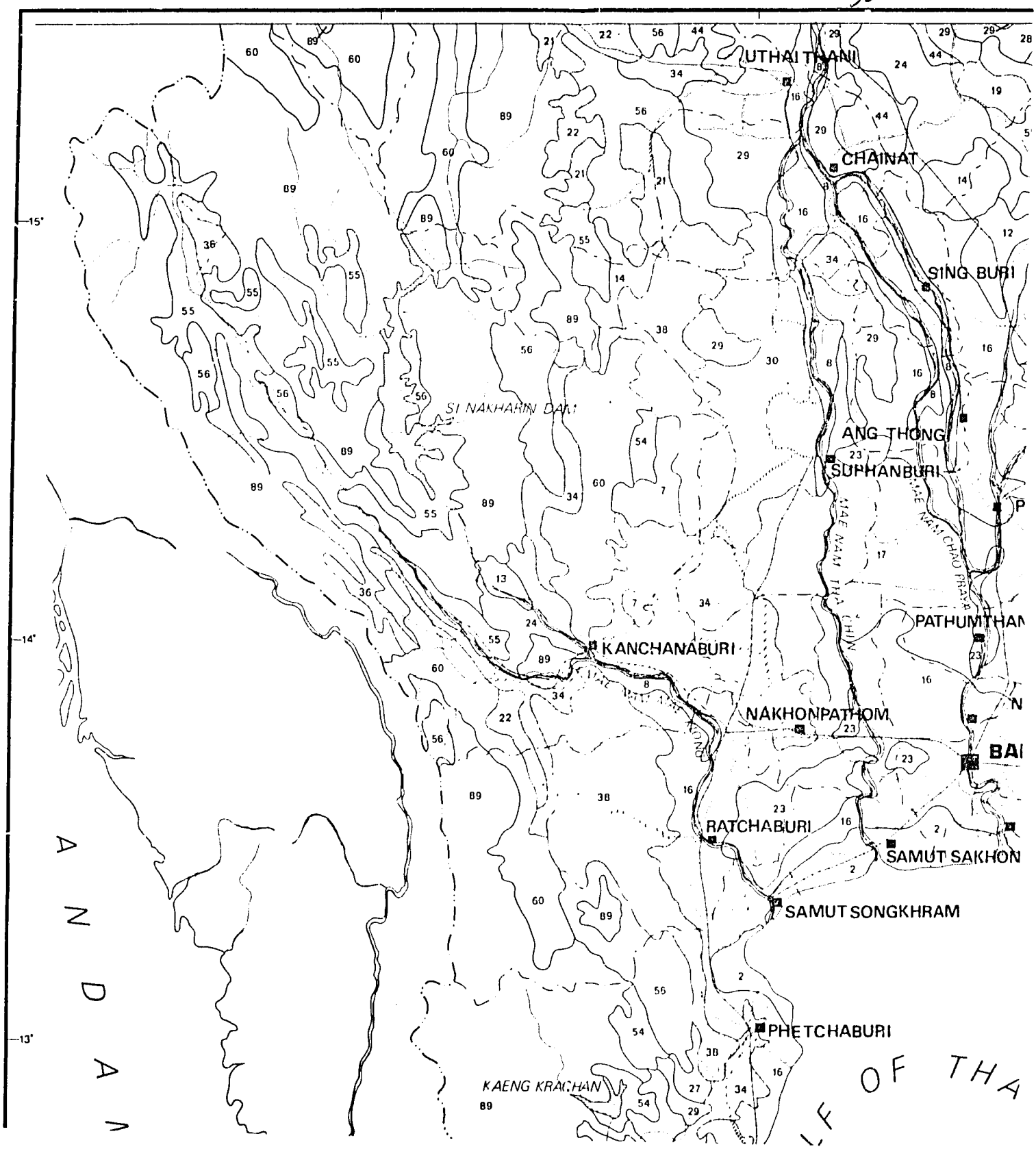
Although these soils have a limited distribution. They have a unique subsurface horizon in which the weathering stage, has been greatly accelerated. Thus, these soils generally are very deep, porous and well drained. In the region they are exclusively found on basalt formations. Only the great group Haplorthox is recognized within order.

Histosols

These organic soils occur in only one area, the south-eastern shoreline of Rayong Province. They occupy swampy depression of river mouths and are thus situated only slightly above sea level. Only one great group, Tropofibrists, is recognized.

Slope complex

This unit is not a soil order, but it is a complex of soils developed from residuum and slope colluvium derived from various kinds of rock on hills and mountains. Thus, most of these areas have slopes greater than 35%. The components of the slope complex are not identified for reasons of inaccessibility and limited agricultural potential.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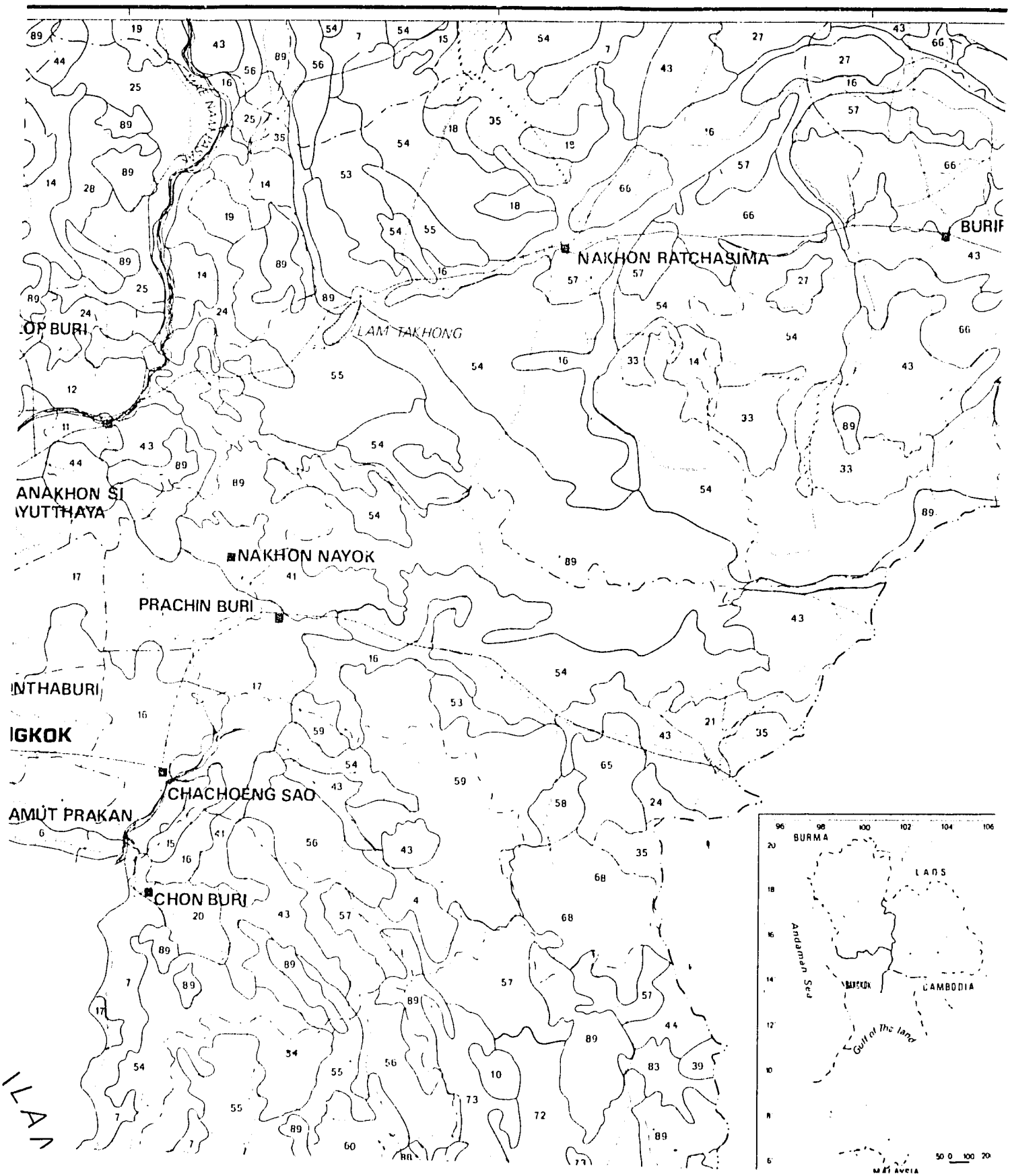
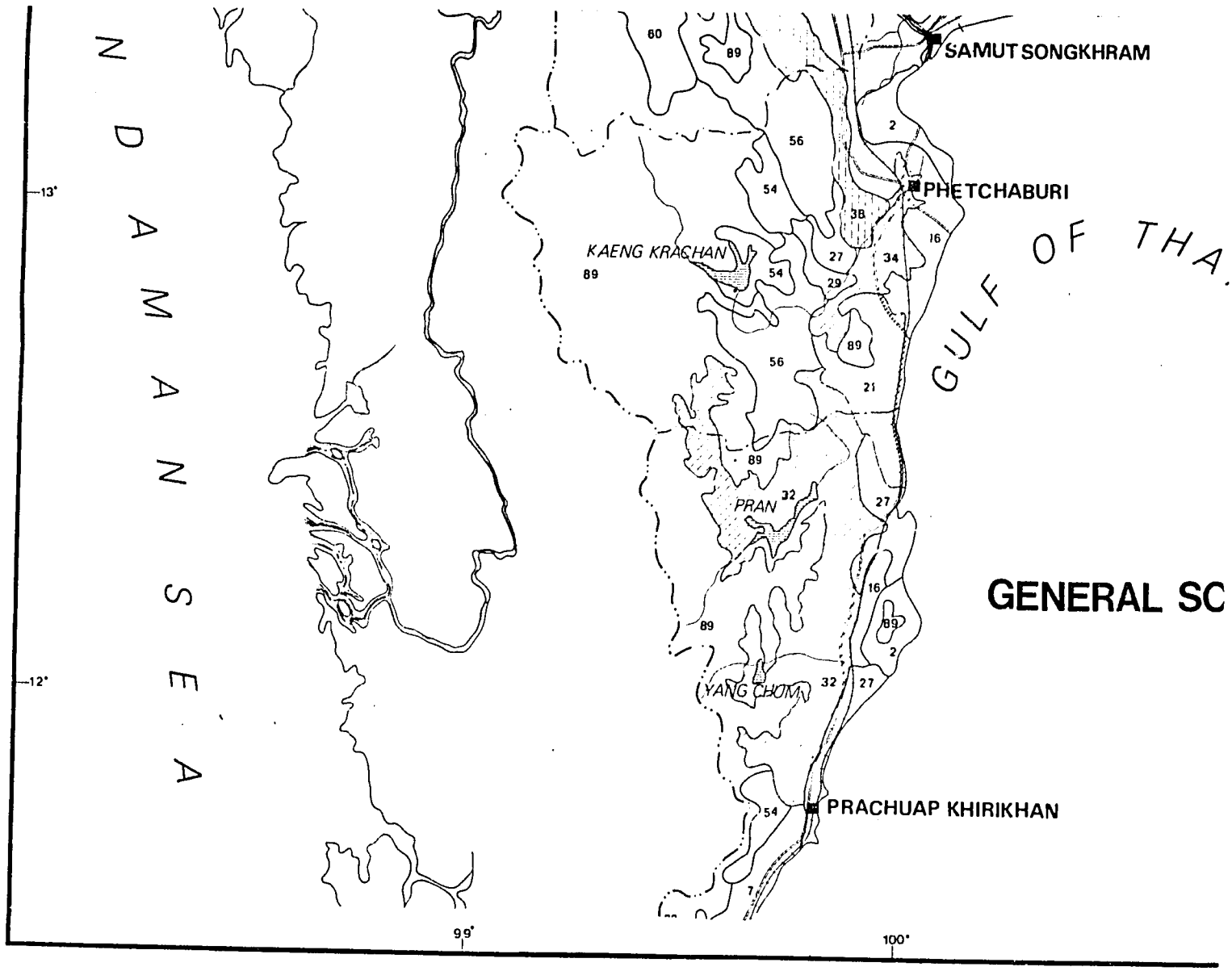
CHAINAT
SING BURI
ANG THONG
SUPHANBURI
SI NAKHARIN DAM
KANCHANABURI
NAKHONPATHOM
RATCHABURI
SAMUT SAKHON
SAMUT SONGKHRAM
PHETCHABURI
KAENG KRACHAN
PATHUMTHAN
MAE NAM THA CHIN
MAE NAM CHAO PRAYA
15°
14°
13°


NAKHON RATCHASIMA
LAM TAKHONG
OP BURI
ANAKHON SI
AYUTTHAYA
NAKHON NAYOK
PRACHIN BURI
NTHABURI
IGKOK
CHACHOENG SAO
AMUT PRAKAN
CHON BURI
BURMA
LAOS
Andaman Sea
BANGKOK
CAMBODIA
Gulf of Thailand


N D A M A N S E A
GULF OF THA
SAMUT SONGKHRAM
PHETCHABURI
KAENG KRACHAN
PRAN
YANG CHOM
PRACHUAP KHIRIKHAN
GENERAL SC
13°
12°
99°
100°
60
89
56
2
54
38
16
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34
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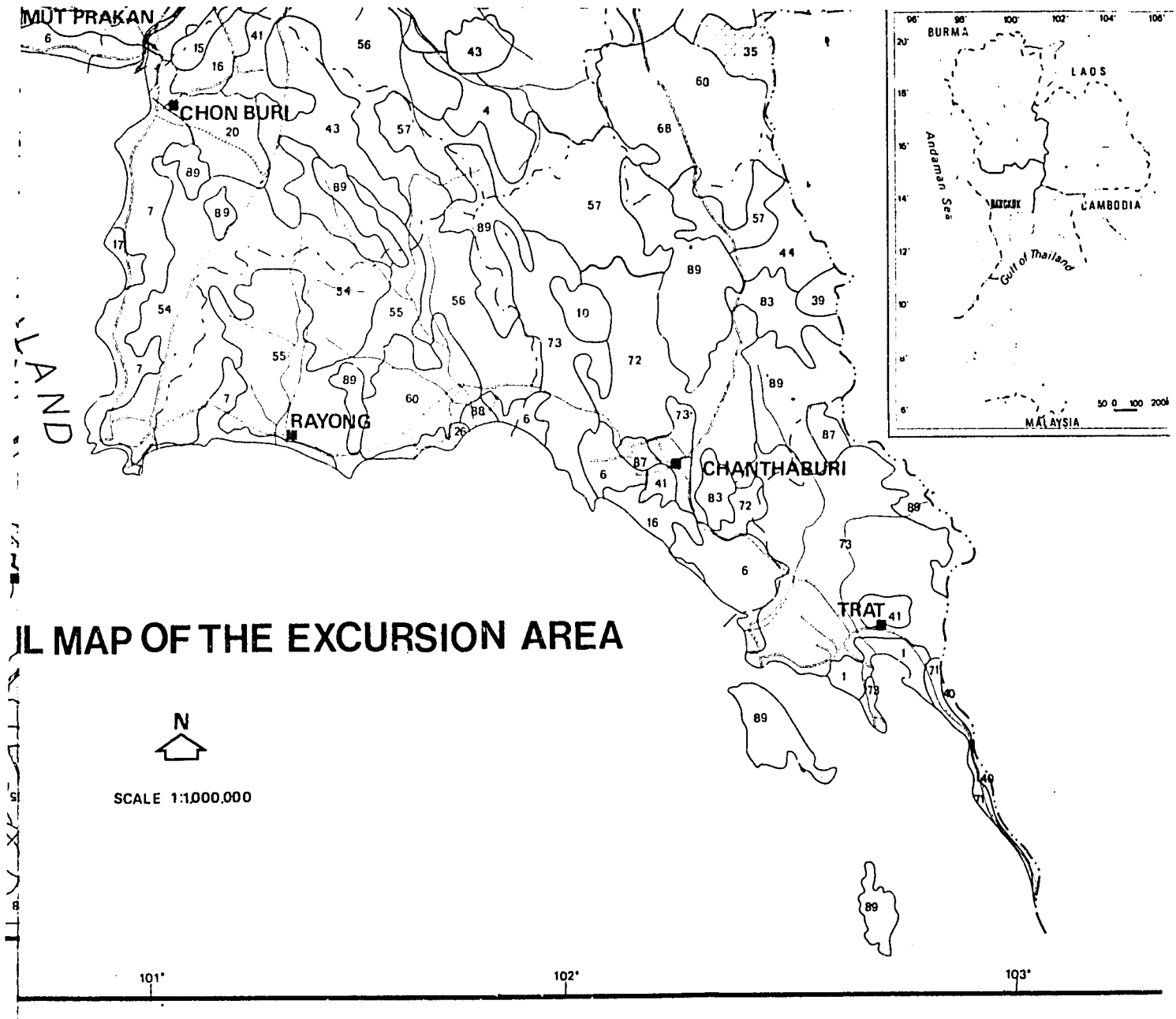
32
7

336b



IL MAP OF THE EXCURSION AREA

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SOIL LEGEND

ORDERS	SUBORDERS	MAPPING NUMBER	SOIL NAMES
ENTISOLS	AQUENTS	1	LOAMY, CLAYEY SULFAQUENTS
		2	CLAYEY HYDRAQUENTS
		3	LOAMY FLUVAQUENTS
		4	CLAYEY FLUVAQUENTS
		5	SANDY TROPAQUENTS
		6	CLAYEY HYDRAQUENTS/LOAMY, CLAYEY SULFAQUENTS
	PSAMMENTS	7	SANDY QUARTZIPSAMMENTS
	FLUVENTS	8	LOAMY USTIFLUVENTS
	FLUVENTS/AQUEPTS	9	LOAMY USTIFLUVENTS/CLAYEY TROPAQUEPTS
	ORTHENTS	10	SKELETAL TROPORTHENTS
VERTISOLS	UDERTS	11	CLAYEY CHROMUDERTS
		12	CLAYEY PELLUDERTS
	USTERTS	13	CLAYEY CHROMUSTERTS
		14	CLAYEY PELLUSTERTS
INCEPTISOLS	AQUEPTS	15	LOAMY CLAYEY TROPAQUEPTS
		16	CLAYEY TROPAQUEPTS
		17	CLAYEY ACID TROPAQUEPTS
		18	LOAMY HALAQUEPTS
	TROPEPTS	19	CLAYEY USTROPEPTS
		20	SANDY EUTROPEPTS
		21	LOAMY DYSTROPEPTS
		22	SKELETAL DYSTROPEPTS
MOLLISOLS	AQUOLLS	23	CLAYEY HAPLAQUOLLS
	USTOLLS	24	CLAYEY CALCIUSTOLLS
		25	CLAYEY HAPLUSTOLLS
SPODOSOLS	HUMODS	26	SANDY TROPOHUMODS
ALFISOLS	AQUALFS	27	LOAMY NATRAQUALFS
		28	LOAMY TROPAQUALFS
		29	CLAYEY TROPAQUALFS
	AQUALFS/AQUEPTS	30	CLAYEY TROPAQUALFS/CLAYEY TROPAQUEPTS
	AQUALFS/USTALFS	31	CLAYEY TROPAQUALFS /CLAYEY HAPLUSTALFS
	USTALFS	32	LOAMY PALEUSTALFS
		33	SKELETAL PALEUSTALFS
		34	LOAMY HAPLUSTALFS
		35	CLAYEY HAPLUSTALFS
		36	SKELETAL HAPLUSTALFS
	USTALFS/AQUALFS	37	LOAMY HAPLUSTALFS/CLAYEY TROPAQUALFS
	USTALFS/USTULTS	38	LOAMY HAPLUSTALFS/LOAMY PALEUSTULTS
	UDALFS	39	CLAYEY TROPUDALFS
ULTISOLS	AQUULTS	40	LOAMY PLINTHAQUULTS
		41	CLAYEY PLINTHAQUULTS
		42	SKELETAL PLINTHAQUULTS
		43	LOAMY PALEAQUULTS
		44	CLAYEY PALEAQUULTS
		45	SKELETAL PALEAQUULTS
		46	CLAYEY TROPAQUULTS
		47	LOAMY/PALEAQUULTS/LOAMY PLINTHAQUULTS
		48	CLAYEY PALEAQUULTS/CLAYEY PLINTHAQUULTS
		49	CLAYEY PALEAQUULTS/CLAYEY TROPAQUULTS
	AQUULTS/AQUALFS	50	CLAYEY PALEAQUULTS/LOAMY NATRAQUALFS
		51	CLAYEY PALEAQUULTS/CLAYEY TROPAQUALFS
	USTULTS	52	LOAMY PLINTHUSTULTS
		53	SKELETAL PLINTHUSTULTS
		54	LOAMY PALEUSTULTS
		55	CLAYEY PALEUSTULTS
		56	SKELETAL PALEUSTULTS
		57	LOAMY HAPLUSTULTS
		58	CLAYEY HAPLUSTULTS
		59	SKELETAL HAPLUSTULTS
		60	LOAMY PALEUSTULTS/SKELETAL PALEUSTULTS
		61	LOAMY PALEUSTULTS/SKELETAL HAPLUSTULTS
		62	CLAYEY PALEUSTULTS/LOAMY PALEUSTULTS
		63	SKELETAL PALEUSTULTS/SKELETAL HAPLUSTULTS
	USTULTS/AQUULTS	64	SKELETAL PLINTHUSTULTS SKELETAL PLINTHAQUULTS
		65	SKELETAL PLINTHUSTULTS/LOAMY PALEAQUULTS
		66	LOAMY PALEUSTULTS/LOAMY PALEAQUULTS
	USTULTS/USTALFS	67	SKELETAL PALEUSTULTS SKELETAL HAPLUSTALFS
		68	CLAYEY HAPLUSTULTS/CLAYEY HAPLUSTALFS
	HUMULTS	69	CLAYEY PALEHUMULTS
	UDULTS	70	LOAMY PLINTHUDULTS
		71	LOAMY PALEUDULTS
		72	CLAYEY PALEUDULTS
		73	SKELETAL PALEUDULTS
		74	LOAMY TROPUDULTS
		75	SKELETAL TROPUDULTS
		76	LOAMY PALEUDULTS/LOAMY DYSTROPEPTS
		77	LOAMY PALEUDULTS/SKELETAL PALEUDULTS
		78	LOAMY PALEUDULTS/LOAMY TROPUDULTS
		79	LOAMY PALEUDULTS/SKELETAL TROPUDULTS
		80	CLAYEY PALEUDULTS/LOAMY TROPUDULTS
		81	SKELETAL PALEUDULTS / SKELETAL PLINTHUDULTS
		82	SKELETAL PALEUDULTS SKELETAL TROPUDULTS
		83	LOAMY TROPUDULTS/ SKELETAL TROPORTHENTS
		84	LOAMY TROPUDULTS/SKELETAL TROPUDULTS
	UDULTS/AQUULTS	85	LOAMY PALEUDULTS/CLAYEY PALEAQUULTS
	UDULTS/ORTHENTS	86	SKELETAL TROPUDULTS/SKELETAL TROPORTHENTS
OXISOLS	ORTHOX	87	CLAYEY HAPLORTHOX
HISTOSOLS	FIBRISTS	88	TROPOFIBRISTS
		89	SLOPE COMPLEX

DESCRIPTIONS OF SELECTED PEDONS

Series: Ban Thon
Pedon No: S82FN-875-001 Date: 3/83
Taxonomy: Sandy, siliceous, isohyperthermic, ortstein Typic Tropohumods.
Location: 232 km (stone) E of Bangkok. 100 m right of Rayong Ban Pae road. Rayong Province, Muang Dist. Ban Nong Hin Ar
Physiography: Beach barrier
Geomorphic Position: On the crest
Slope and Aspect: 1 pct convex Elevation: 4 m M.S.L
Air Temp. 27 C Summer: Winter:
Precipitation: 240 cm Ustic moisture regime.
Water Table: 140 cm Apparent
Drainage: Moderately well drained Permeability: Rapid
Stoniness:
Land Use: Cropland-cleared for coconuts.
Erosion or Deposition: Slightly eroded
Parent Material: Beach sand
Described by: L. Moncharoen, W. Silicheuchu, M. Hausbach

The Bh horizons are discontinuous across the 3 m pit face.

Ap 0 - 17 cm Dark gray (10YR 4/1) sand; weak fine granular structure; soft, friable, non-sticky; non-plastic; common fine roots; pH=5.0, strongly acid; clear smooth boundary.
82P1859

E1 17 - 37 cm Light brownish gray (10YR 6/2) sand; structureless; loose, loose, non-sticky; non-plastic; a few fine roots; pH=6.5, slightly acid; clear smooth boundary.
82P1860

E2 37 - 80 cm Sand, white (10YR 8/1, moist); structureless; loose, loose, non-sticky; non-plastic; very few fine roots; pH=8.0, moderately alkaline; clear broken boundary.
82P1861

Bh1 80 - 90 cm Sand, very dark grayish brown (10YR 3/2, moist); structureless; firm, moderately smeary, very moist or wet; weakly cemented; pH=4.7, extremely acid; clear broken boundary.
82P1862

Bhs 90 - 130 cm Sand, dusky red (2.5YR 3/2, moist); weak medium blocky structure; friable, moderately smeary, very moist or wet; pH=5.0, strongly acid; clear broken boundary.
82P1863

Bh2 130 - 147 cm Sand, very dark grayish brown (10YR 3/2, moist); structureless; weakly cemented; pH=5.0, strongly acid; clear broken boundary.
82P1864

BAN THON

CLASSIFICATION: SANDY, SILICEOUS, ISOHYPERTHERMIC, ORTSTEIN TYPIC TROPOHUMOD

S 82FN-875 -001 SAMPLE NOS. 82P1859 - 1864 DATE REVISED APRIL 1983

THAILAND

GENERAL METHODS 1B1A, 2A1, 2B

U. S. DEPARTMENT OF AGRICULTURE
SOIL CONSERVATION SERVICE
NATIONAL SOIL SURVEY LABORATORY
LINCOLN, NEBRASKA

SAMPLE NO.	HZN NO.	DEPTH (CM)	HORIZON	-1- TOTAL CLAY LT .002	-2- TOTAL SILT .002-.05	-3- TOTAL SAND .05-2	-4- CLAY FINE LT .0002	-5- CLAY CO3 LT .002	-6- SILT FINE .002-.02	-7- SILT COARSE .02-.05	-8- SAND VF .05-.10	-9- SAND F .10-.25	-10- SAND M .25-.50	-11- SAND C .5-1	-12- SAND VC 1-2	-13- COARSE FRACTIONS (MM) WEIGHT 2-5	-14- WEIGHT 5-20	-15- WEIGHT 20-75	-16- .1-75	-17- (>2MM) WT PCT OF WHOLE SOIL
				<- - - PCT OF <2MM (3A1) - - ->												<- PCT OF <75MM (3B1) ->				
821859	1S	0- 17	AP	1.6	2.0	96.4			6.8	1.2	5.5	58.0	26.9	5.5	0.5	—	—	—	91	—
821860	2S	17- 37	E1	2.2	0.2	97.6			0.1	0.1	4.7	59.8	27.5	4.7	0.4	—	—	—	92	—
821861	3S	37- 80	E2	0.8	0.9	98.3			0.8	0.1	4.7	61.0	27.5	4.7	0.4	—	—	—	94	—
821862	4S	80- 90	BH1	6.2	5.3	88.5			3.7	1.6	4.8	54.7	23.9	4.5	0.6	TR	—	—	84	—
821863	5S	90-130	BHS	0.8	1.2	98.0			1.1	0.1	5.0	63.3	25.5	3.8	0.4	TR	—	—	93	—
821864	6S	130-147	BH3	2.9	0.7	96.4			—	0.7	3.8	55.6	29.8	6.1	1.1	TR	TR	—	93	TR

SAMPLE NO.	HZN NO.	ORGN C 6A1C	TOTAL N 6B3A	EXTR P	TOTAL S 6R3A	DITH-CIT EXTRACTABLE FE 6C2B	AL 6G7A	MN 6D2A	(RATIO/CLAY) CEC 8D1	15 BAR 8D1	(ATTERBERG LIMITS) LL 4F1	PI 4F	(BULK DENSITY) FIELD MOIST 4A3A	1/3 BAR 4A1D	OVEN DRY 4A1H	COLE WHOLE SOIL 4D1	(WATER CONTENT) FIELD MOIST 4B4	1/10 BAR 4B1C	1/3 BAR 4B1C	15 BAR 4B2A	WRD WHOLE SOIL 4C1
		<- - - PCT OF <2MM - - ->									PCT <0.4MM		<- - G/CC - ->			CM/CM	<- - PCT OF <2MM - ->				CM/CM
821859	1	1.08	0.030			—	TR	—	1.81	1.31				1.63	1.63	—			5.0	2.1	0.05
821860	2	0.20	0.004			—	—	—	0.14	0.41										0.9	
821861	3	0.12	—			—	—	—	0.25	1.00										0.8	
821862	4	4.32	0.101			TR	1.0	—	4.02	1.45				1.37	1.42	0.012			17.3	9.0	0.11
821863	5	0.43	0.009			—	TR	—	1.63	1.50										1.2	
821864	6	1.59	0.034			—	0.3	—	2.97	1.07				1.58	1.59	0.002			10.9	3.1	0.12

SAMPLE NO.	HZN NO.	NH4OAC EXTRACTABLE BASES CA 5B5A 6N2E	MG 5B5A 6O2D	NA 5B5A 6P2B	K 5B5A 6Q2B	SUM BASES	ACIDITY 6H5A	EXTR AL 6G9A	CEC SUM CATS 5A3A	CEC NH4-OAC 5A8B	CEC BASES + AL 5A3B	AL SAT 5G1	BASE SAT SUM 5C3	BASE SAT NH4 OAC 5C1	CO3 AS CACO3 <2MM 6E1G	RES. OHMS /CM 8E1	SURFACE AREA EGME 7D2 M2/G	EGME 7D2 M2/G	PH CACL2 .01M 8C1F 1:2	PH H2O 8C1F 1:1
		<- - - MEQ / 100 G - - ->										<- - PCT - ->								
821859	1	0.4	0.1	TR	—	0.5	5.8	0.5	6.3	2.9	1.0	50	8	17			7	25	3.5	4.2
821860	2	--	TR	--	—	TR	0.7	0.1	0.7	0.3	0.1	100		7			6	21	3.9	4.7
821861	3	--	--	TR	—	TR	1.1	—	1.1	0.2				10			5	18	4.4	5.0
821862	4	0.2	—	TR	—	0.2	48.0	6.0	48.2	24.9	6.2	97	TR	1			19	66	4.0	4.4
821863	5	TR	—	TR	—	TR	3.6	0.7	3.6	1.3	0.7	100		2		79000	6	21	4.0	4.5
821864	6	TR	—	TR	—	TR	19.2	2.2	19.2	8.6	2.2	100		TR			10	35	4.1	4.4

SAMPLE NO.	HZN NO.	SPODIC HORIZON CRITERIA: NA PYROPHOSPHATE EXTRACTABLE C 6A4A	FE 6C5A	AL 6G5A	FE+AL DIVIDED BY DI-CI FE+AL	FE+AL DIVIDED BY PCT CLAY	AL+C DIVIDED BY PCT CLAY	INDEX OF ACCUM	(MINERALOGY) TOTAL RES 7B1A	DOM WEATH 7B1A
		<- PCT OF <2MM ->							<- - PCT - ->	
821859	1	0.4	--	--			0.2			
821860	2	0.1	—	—						
821861	3	TR	—	—			—			
821862	4	4.0	—	0.6	0.6		0.7	451	99	PK 1
821863	5	0.3	—	—	—		0.4			
821864	6	1.5	—	0.1	0.3		0.6		99	PK 1

SPODIC HORIZON: INDEX OF ACCUMULATION 451

FAMILY CONTROL SECTION: DEPTH 25-100 PCT CLAY 2 PCT .1-75MM 92

ANALYSES: S= ALL ON SIEVED <2MM BASIS

MINERALOGY: KIND OF MINERAL PK POTAS-FELD

RELATIVE AMOUNT 6 INDETERMINATE 5 DOMINANT 4 ABUNDANT 3 MODERATE 2 SMALL 1 TRACE

Series: Klaeng
Pedon No: S82FN-875-002 Date: 3/83
Taxonomy: Clayey, mixed, isohyperthermic Plinthic Tropaquults.
Location: 2 km E of Sukhumvid road. From Klang 1.5 km to Ban Pae. Rayong Province Klaung District.
Physiography: Low terrace in river valley
Geomorphic Position:
Slope and Aspect: 1 pct planar Elevation: 15 m M.S.L
Air Temp. 27 C Summer: Winter:
Precipitation: 240 cm Aquic moisture regime.
Water Table: 160 cm Apparent
Drainage: Poorly drained Permeability: Slow
Stoniness:
Land Use: Cropland-paddy rice
Erosion or Deposition: None
Parent Material: Alluvium
Described by: L. Moncharoen, W. Silicheuchu, M. Mausbach

Ap 0 - 18 cm Light brownish gray (10YR 6/2) silt loam, white (10YR 8/1,dry); many medium distinct strong brown (7.5YR 5/6) mottles; structureless; very hard, friable, slightly sticky; slightly plastic; common fine roots; pH=4.5, extremely acid; abrupt smooth boundary.
82P1865

BAg 18 - 37 cm Light brownish gray (10YR 6/2) silty clay loam, light gray (10YR 7/2, dry); many medium distinct yellowish brown (10YR 5/8) mottles; weak medium subangular blocky structure; very hard, friable, slightly sticky; slightly plastic; a few fine roots; pH=4.5, extremely acid; clear smooth boundary.
82P1866

Btg1 37 - 51 cm Light brownish gray (10YR 6/2) silty clay loam; many coarse prominent strong brown (7.5YR 5/6) and a few fine prominent light red (2.5YR 4/8) mottles; moderate medium prismatic parting to moderate medium subangular blocky structure; very hard, firm, slightly sticky; slightly plastic; some thin patchy clay skins on faces of peds and many skeletans on faces of peds; very few fine roots; a few plinthite; pH=4.5, extremely acid; clear smooth boundary.
82P1867

Btg2 51 - 66 cm Light brownish gray (10YR 6/2) clay; many coarse prominent red (10R 4/8) and a few fine distinct yellowish brown (10YR 5/8) mottles; moderate medium prismatic parting to moderate medium subangular blocky structure; extremely hard, very firm, slightly sticky; slightly plastic; some thin patchy clay skins on faces of peds and many skeletans on faces of peds; very few fine roots; common plinthite; pH=4.5, extremely acid; clear smooth boundary.
82P1868 Plinthite is less than 50%.

Btb1 66 - 96 cm Gray (10YR 5/1) clay; many coarse prominent red (10R 4/8) and common medium distinct strong brown (7.5YR 5/8) mottles; strong medium prismatic parting to strong medium subangular blocky structure; very firm, sticky; plastic; many continuous clay skins on faces of peds and many continuous clay skins in channels and pores; very few fine roots; common plinthite; pH=4.5, extremely acid; gradual smooth boundary.
82P1869 80 - 90 cm many charcoal fragments.

Btb2 96 - 120 cm Pinkish gray (7.5YR 6/2) clay; many coarse prominent red (10R 4/6) and common fine distinct brownish yellow (10YR 6/8) mottles; weak medium prismatic parting to weak medium subangular blocky structure; very firm, sticky; plastic; many continuous clay skins on faces of peds and many continuous clay skins in channels and pores; pH=4.5, extremely acid; clear smooth boundary.
82P1870

BCgb 120 - 161 cm Light brownish gray (10YR 6/2) clay; common medium distinct brownish yellow (10YR 6/8) and common fine distinct red (2.5YR 4/8) mottles; weak medium subangular blocky structure; firm, slightly sticky; plastic; pH=4.5, extremely acid.
82P1871

KLAENG

CLASSIFICATION: CLAYEY, MIXED, ISOHYPERTHERMIC PLINTHIC TROPAQUULT

S 82PH-875 -002 SAMPLE NOS. 82P1865 - 1871 DATE REVISED APRIL 1983

U. S. DEPARTMENT OF AGRICULTURE
SOIL CONSERVATION SERVICE
NATIONAL SOIL SURVEY LABORATORY
LINCOLN, NEBRASKA

THAILAND

GENERAL METHODS 1B1A, 2A1, 2B

SAMPLE NO.	HZN NO.	DEPTH (CM)	HORIZON	TOTAL CLAY LT .002	TOTAL SILT .002 -.05	TOTAL SAND .05 -2	CLAY FINE LT .002	CLAY CO3 LT .002	SILT FINE .002 -.02	SILT COARSE .02 -.05	SAND VF .05 -.10	SAND F .10 -.25	SAND M .25 -.50	SAND C .5 -1	SAND VC 1 -2	COARSE FRACTIONS (MM) 2 -5	5 -20	20 -75	>75MM (3B1) .1- 75	(>2MM) WT PCT OF WHOLE SOIL
				<- PCT OF <2MM (3A1) ->												<- PCT OF <75MM (3B1) ->				
821865	1S	0- 15	AP	24.1	72.0	3.9	7.4		60.2	11.8	1.5	1.2	0.7	0.4	0.1	—	—	—	2	—
821866	2S	18- 37	BAG	26.9	70.2	2.9	12.6		48.1	22.1	1.6	0.4	0.3	0.4	0.2	—	—	—	1	—
821867	3S	37- 51	BTG1	35.2	61.7	3.1	18.4		49.9	11.8	0.8	0.8	0.6	0.7	0.2	—	—	—	2	—
821868	4S	51- 66	BTG2	42.0	51.9	6.1	21.4		44.9	7.0	1.6	2.0	1.3	0.8	0.4	—	—	—	4	—
821869	5S	66- 96	BTB1	55.8	31.6	12.6	28.1		28.5	3.1	3.3	4.8	2.5	1.6	0.4	—	—	—	9	—
821870	6S	96-120	BTB2	39.7	19.7	40.6	18.8		16.4	3.3	6.6	14.4	8.8	7.0	3.8	TR	—	—	34	—
821871	7S	120-161	BCGB	32.0	31.4	36.6	15.0		22.7	8.7	9.4	13.8	7.0	5.5	1.3	—	—	—	27	—

SAMPLE NO.	HZN NO.	ORGN C 6A1C	TOTAL N 6B3A	NITR F	TOTAL S 6H3A	EXTRACTABLE PH 6C2B	EXTRACTABLE AL 6G7A	EXTRACTABLE BH 6D2A	RATIO/CLAY CEC 8D1	RATIO/CLAY 15 BAR 8D1	ATTERBERG LIMITS LL 4F1	ATTERBERG LIMITS PI 4F	BULK DENSITY FIELD MOIST 4A3A	BULK DENSITY 1/3 BAR 4A1D	BULK DENSITY OVEN DRY 4A1H	COLE WHOLE SOIL 8D1	WATER CONTENT FIELD MOIST 4B4	WATER CONTENT 1/10 BAR 4B1C	WATER CONTENT 1/3 BAR 4B1C	WATER CONTENT 15 BAR 4B2A	HRD WHOLE SOIL 4C1
		<- PCT OF <2MM ->									PCT <0.4MM		<- G/CC ->			CM/CM	<- PCT OF <2MM ->				CM/CM
821865	1	0.90	0.089			--	0.3	—	0.22	0.42	35	9		1.39	1.43	0.010			27.8	10.1	0.25
821866	2	0.33	0.038			1.2	0.1	—	0.26	0.44				1.37	1.45	0.019			26.6	11.7	0.20
821867	3	0.36	0.044			1.8	0.2	—	0.28	0.42				1.36	1.46	0.024			28.0	14.9	0.18
821868	4	0.46	0.055			3.2	0.3	—	0.27	0.49	47	23		1.33	1.50	0.041			28.9	20.4	0.11
821869	5	0.51				3.4	0.3	—	0.25	0.41				1.30	1.51	0.051			30.6	23.0	0.10
821870	6	0.31				3.9	0.2	—	0.22	0.40				1.37	1.57	0.046			26.5	15.9	0.15
821871	7	0.18				0.3	0.1	—	0.19	0.39	35	19		1.64	1.76	0.024			17.1	12.6	0.09

SAMPLE NO.	HZN NO.	NH4OAC EXTRACTABLE BASES CA 5B5A 6H2E	MG 5B5A 6G2D	NA 5B5A 6P2B	K 5B5A 6Q2B	SUM BASES	ACID- ITY 6H5A 100 G	EXTR AL 6G9A	SUM CATS 5A3A	CEC NH4- OAC 5A8B	BASES + AL 5A3B	AL SAT 5G1	BASE SUM 5C3	SAT- NH4 OAC 5C1	CO3 AS CACO3 <2MM 6H1G	BRS. OHNS /CM 8H1	SURFACE AREA EGME 7D2 MG/G	SURFACE AREA EGME 7D2 M2/G	PH CACL2 .01M 8C1F 1:2	PH H2O 8C1F 1:1
		<- MEQ / 100 G ->										<- PCT ->								
821865	1	1.1	0.6	0.1	0.1	1.9	5.5	1.2	7.4	5.3	3.1	39	26	36			19	66	3.9	4.5
821866	2	1.2	0.8	0.1	TR	2.1	7.5	2.7	9.6	7.1	4.8	56	22	30			23	80	4.3	4.6
821867	3	1.9	0.8	0.1	0.1	2.1	9.7	4.4	11.8	9.8	6.5	68	18	21			27	94	4.3	4.6
821868	4	1.1	0.9	0.1	0.1	2.2	12.1	5.4	14.3	11.5	7.6	71	15	19			33	115	4.2	4.6
821869	5	1.0	1.1	0.2	0.1	2.4	15.0	6.3	17.4	13.7	8.7	72	14	18			38	133	4.3	4.6
821870	6	0.6	0.9	0.2	0.1	1.8	9.7	4.0	11.5	8.9	5.8	69	16	20		10000	27	94	4.2	4.4
821871	7	0.4	0.7	0.1	0.1	1.3	6.6	3.4	7.9	6.2	4.7	72	16	21			20	70	4.2	4.3

SAMPLE NO.	HZN NO.	TOTAL ANALYSIS 7C3 CLAY K2O 6Q3A	Fe 6C7A	MINERALOGY CLAY X-RAY <2U 7A2I	7A2X	7A2I	7A2X	DTA <2U 7A3	DTA 7A3	TOTAL ORG MATR 7B1A	DOM 7B1A
		<- PCT ->		<- RELATIVE AMOUNTS ->				<- PCT ->			
821865	1	1.7	3.3	KK 3	HI 2			KK14			
821866	2	1.5	3.6	KK 3	HI 2	VR 1	HT 1	KK31			
821867	3	1.5	3.8	KK 4	HI 2	VR 1	HT 1	KK38			
821868	4	1.6	4.7	KK 4	HI 2	VR 1	HT 1	KK42			
821869	5	1.6	4.1	KK 4	HI 2	HT 1		KK36			
821870	6	1.6	4.1	KK 4	HI 2	HT 1		KK56			
821871	7	1.4	2.2	KK 4	HI 2	HT 1		KK59			

FAMILY CONTROL SECTION: DEPTH 37- 87 PCT CLAY 46 PCT .1-75MM 6

ANALYSES: S= ALL ON SIEVED <2MM BASIS

MINERALOGY: KIND OF MINERAL KK KAOLINITE HI MICA VR VERMICULITE HT MONTMORILL

RELATIVE AMOUNT 6 INDETERMINATE 5 DOMINANT 4 ABUNDANT 3 MODERATE 2 SMALL 1 TRACE

Series: Tha Kua Thaung
Pedon No: S82FN-875-003 Date: 3/83
Taxonomy: Fine-loamy, siliceous, nonacid, isohyperthermic Typic Sulfaquent
Location: 7 KM from Chantaburi Province to Thackaluep. Chantaburi Province, Muang District, Hua Him Area.
Physiography: Salt water tidal marsh in coastal plains
Geomorphic Position:
Slope and Aspect: 0 pct planar Elevation: 1 m M.S.L
Air Temp. 27 C Summer: Winter:
Precipitation: Aquic moisture regime.
Water Table: 10 cm Apparent
Drainage: Very poorly drained Permeability:
Stoniness:
Land Use: Swamp or marshland, drained (Mangrove)
Erosion or Deposition: Slightly eroded
Parent Material: Marine sediments
Described by: L. Moncharoen, W. Silicheuchu, M. Mausbach

A1 0 - 10 cm Very dark grayish brown (10YR 3/2) clay loam - muck; structureless; slightly sticky; slightly plastic; pH=7.0, neutral; clear boundary.
82P1872 About 15% of organic matter is rizophora spp.

A2 10 - 35 cm Very dark grayish brown (10YR 3/2) clay loam; structureless; firm, slightly sticky; slightly plastic; pH=7.0, neutral; gradual boundary.
82P1873

C1 35 - 72 cm Loam; very dark grayish brown (10YR 3/2, rubbed); structureless; slightly sticky; slightly plastic; pH=7.0, neutral; gradual boundary.
82P1874

C2 72 - 120 cm Loam; very dark grayish brown (10YR 3/2, rubbed); structureless; slightly sticky; slightly plastic; pH=7.0, neutral.
82P1875 Sampled by auger.

THA KUA THUANG

CLASSIFICATION: FINE-LOAMY, SILICEOUS, NONACID, ISOHYPERTHERMIC TYPIC SULFAQUENT

S 82PN-875 -003 SAMPLE NOS. 82P1872 - 1875 DATE REVISED APRIL 1983

U. S. DEPARTMENT OF AGRICULTURE
SOIL CONSERVATION SERVICE
NATIONAL SOIL SURVEY LABORATORY
LINCOLN, NEBRASKA

THAILAND

GENERAL METHODS 1B1A, 2A1, 2B

-1- -2- -3- -4- -5- -6- -7- -8- -9- -10- -11- -12- -13- -14- -15- -16- -17- -18- -19- -20-

SAMPLE NO.	HZN NO.	DEPTH (CM)	HORIZON	(- - -TOTAL - - -) CLAY LT .002	SILT .002 -.05	SAND .05 -2	(- -CLAY- -) FINE LT .0002	CO3 LT .002	(- -SILT- -) FINE .002 -.02	COARSE .02 -.05	VF .05 -.10	(- - - - - -SAND- - - - - -) F .10 -.25	M .25 -.50	C .5 -1	VC 1 -2	(-COARSE FRACTIONS(MM)-) 2 -5	5 -20	20 -75	(>2MM) .1- 75	WT PCT OF WHOLE SOIL
				<- - - - - - - - - - - - PCT OF <2MM (3A1) - - - - - - - - - - - - ->												<- PCT OF <75MM (3B1) ->				
821872	15	0- 10	A1	35.9	23.3	40.8			12.5	10.8	12.3	13.3	7.2	5.3	2.7	1	—	—	23	1
821873	25	10- 35	A2	25.2	30.8	44.0			19.3	11.5	13.1	14.2	8.6	6.2	1.9	1	—	—	32	1
821874	35	35- 72	C1	28.2	35.6	36.2			22.0	13.6	14.5	10.9	4.9	4.3	1.6	1	—	—	22	1
821875	45	72-120	C2	33.7	37.4	28.9			24.3	13.1	12.2	9.6	3.5	2.9	0.7	1	TR	—	18	1

SAMPLE NO.	HZN NO.	ORGN C 6A1C	TOTAL N 6B3A	EXTR P	TOTAL S 6H3A	(- - DITH-CIT - -) FE 6C2B	AL 6G7A	MN 6D2A	(RATIO/CLAY) CEC 8D1	15 BAR 8D1	(ATTERBERG) - LIMITS - LL 4F1	PI 4F	(- BULK DENSITY -) FIELD MOIST 4A3A	1/3 BAR 4A1D	OVEN DRY 4A1H	COLE WHOLE SOIL 4D1	(- - -WATER CONTENT - -) FIELD MOIST 4B4	1/10 BAR 4B1C	1/3 BAR 4B1C	15 BAR 4B2A	HRD WHOLE SOIL 4C1
		<- - - - - - -2CT OF <2MM - - - - - - ->									PCT <0.4MM		<- - G/CC - - ->			CM/CM	<- - -PCT OF <2MM - ->				CM/CM
821872	1	9.23	0.383		0.2				1.04	0.75				0.59	1.10	0.230			100.8	27.1	0.43
821873	2	9.42	0.204		0.8				1.00	0.83				0.84	1.23	0.135			68.0	20.8	0.40
821874	3	12.8	0.201		5.0				1.25	0.93				0.51	0.91	0.212			122.5	26.1	0.49
821875	4	12.3	0.172		4.4				0.94	0.64										21.7	

SAMPLE NO.	HZN NO.	(- NH4OAC EXTRACTABLE BASES -) CA 5B5A 6N2E	MG 5B5A 6Q2D	NA 5B5A 6P2B	K 5B5A 6Q2B	SUM BASES	ACID- ITY 6H5A	EXTR AL 6Q9A	(- -CEC- -) SUM CATS 5A3A	NH4- OAC 5A8B	EXCH NA 5D2 PCT	SAR 5E	BASE SATURATION SUM 5C3	NH4OAC 5C1	CARBONATE AS CACO3 <2MM 6H1G	<20MM 8H1	SURFACE AREA EGME 7D2 M2/G	EGME 7D2 M2/G	(- - - -PH - - -) SAT PASTE 8C1B	CACL2 .01M 8C1F 1:2	H2O 8C1F 1:1
		<- - - - - - - - - - -MEQ / 100 G - - - - - - - - - - ->									<- -PCT- ->				<- -PCT ->						
821872	1	9.8	24.3	63.6	2.5	100.2	22.0	0.1	122.2	37.2	32	53	82	100			65	227	5.0	5.1	5.1
821873	2	6.3	15.4	31.0	1.3	54.0	21.8	0.2	75.8	25.1	68	38	71	100			54	189	4.5	4.7	4.7
821874	3	6.4	20.3	58.2	0.1	85.0	66.9	27.4	151.9	35.2	35	47	56	100			71	248	1.7	2.2	2.1
821875	4	6.3	19.5	50.2	0.2	76.2	56.9	25.9	133.1	31.8	15	50	57	100					1.8	2.3	2.2

SAMPLE NO.	HZN NO.	(- - - - - - - -WATER EXTRACTED FROM SATURATED PASTE- - - - - - - - -) CA 6B1B	MG 6O1B	NA 6P1B	K 6Q1B	CO3 6I1B	HCO3 6J1B	CL 6K1C	SO4 6L1C	NO3 6M1C	B 8A	TOTAL SALTS EST. 8D5	ELEC. COND. 8A3A	(STATE OF DECOMPOSITION) MINL CONT 8F	(FIBER VOL) UNRB 8G	RUB 8G	SOLUBILITY BH	PH CACL .01M 8C1E	(MINERALOGY) TOTAL RES 7B1A	DOM WEATH 7B1A
		<- - - - - - - - - - -MEQ / LITER - - - - - - - - - - ->									<- -PCT ->		MMHOS /CM	<-----PCT----->			MUN COLOR		<- -PCT- ->	
821872	1	24.1	112.9	435.2	10.7	—	0.9	5.9	—	—	118.6	4.2	39.80	79	36	8	10YR 7/3	5.7		
821873	2	28.8	119.0	328.4	7.1	—	0.2	290.8	—	—	42.1	1.2	32.70	82	22	8	10YR 5/3	3.3		
821874	3	24.8	173.4	469.3	0.2			206.8	300.5	—	97.7	4.1	46.30	76	58	28	2.5YR8/1	2.1	95	FK 4
821875	4	24.3	189.2	514.8	0.5			3.1	4.0	—	88.3	3.8	47.30	76	48	28	7.5YR6.5/2	1.5		

ANALYSES: S= ALL ON SIEVED <2MM BASIS

MINERALOGY: KIND OF MINERAL FK POTAS-FELD

RELATIVE AMOUNT 6 INDETERMINATE 5 DOMINANT 4 ABUNDANT 3 MODERATE 2 SMALL 1 TRACE

Series: Pong Nam Ron
Pedon No: S82PN-875-004 Date: 3/83
Taxonomy: Fine-loamy, mixed, isohyperthermic shallow Udic Haplustolls.
Location: 12 km from A. Pong Nam Ron to Refugee camp. Chantaburi Province, Pong Nam Ron Dist., Pong Nam Ron area.
Physiography: Upland ridge in level to undulating uplands
Geomorphic Position: On upper third hillside
Slope and Aspect: 7 pct SE convex Elevation: 200 m M.S.L
Air Temp. 27 C Summer: Winter:
Precipitation: 270 cm Ustic moisture regime.
Water Table: Not observed
Drainage: Well drained Permeability:
Stoniness:
Land Use: Cultivated-cassava
Erosion or Deposition: Eroded
Parent Material: Residual material from sandstone
Described by: L. Moncharoen, W. Silicheuchu, M. Mausbach

10% boulders on surface and in Ap1 horizon.

Ap1 0 - 4 cm Brown (7.5YR 5/2) loam; very dark grayish brown (10YR 3/2, moist); moderate fine to medium granular structure; very hard, firm, slightly sticky; slightly plastic; many very fine to fine roots; pH=7.0, neutral; clear smooth boundary.
82P1876

Ap2 4 - 14 cm Brown (7.5YR 5/2) clay loam, dark brown (7.5YR 3/2, moist); weak medium subangular blocky parting to moderate fine to medium granular structure; extremely hard, firm, slightly sticky; slightly plastic; common; pH=6.5, slightly acid; clear smooth boundary.
82P1877 After mixing 18 cm, color is brown (10YR 5/3), dark brown (10YR 3/3, moist).

Bw1 14 - 26 cm Light yellowish brown (10YR 6/4) clay loam, dark yellowish brown (10YR 4/4, moist); moderate medium subangular blocky structure; extremely hard, firm, slightly sticky; slightly plastic; a few; pH=6.0, slightly acid; clear smooth boundary.
82P1878

Bw2 26 - 43 cm Pale brown (10YR 6/3) clay loam, brown to dark brown (10YR 4/3, moist); moderate medium subangular blocky structure; extremely hard, firm, slightly sticky; slightly plastic; coarse fragments, 10 pct larger than 19 mm mixed lithology; pH=5.5, strongly acid; abrupt irregular boundary.
82P1879

Cr 43 - 68 cm Brownish yellow (10YR 6/6) and white (10YR 8/2) weathered rock or saprolite ; structureless; a few medium roots in cracks.
82P1880 Continuous coats of soil material along fracture planes.

PONG HAN BON

CLASSIFICATION: FINE-LOAMY, MIXED, ISOHYPERTHERMIC, SHALLOW UDIC HAPLUSTOLL

S 87PN-875 -004 SAMPLE NOS. 82P1876 - 1880 DATE REVISED APRIL 1983

THAILAND

GENERAL METHODS 1B1A, 2A1, 2B

U. S. DEPARTMENT OF AGRICULTURE
SOIL CONSERVATION SERVICE
NATIONAL SOIL SURVEY LABORATORY
LINCOLN, NEBRASKA

-1- -2- -3- -4- -5- -6- -7- -8- -9- -10- -11- -12- -13- -14- -15- -16- -17- -18- -19- -20-

SAMPLE NO.	HZN NO.	DEPTH (CM)	HORIZON	TOTAL CLAY LT .002	TOTAL SILT .002 -.05	TOTAL SAND .05 -2	TOTAL FINE LT .0002	CLAY CO3 LT .002	SILT FINE .002 -.02	SILT COARSE .02 -.05	SAND VF .05 -.10	SAND F .10 -.25	SAND M .25 -.50	SAND C .5 -1	SAND VC 1 -2	COARSE FRACTIONS (MM) 2 -5	5 -20	20 -75	.1- 75	(>2MM) WT PCT OF WHOLE SOIL
				<- - - - - - - - - - - - - PCT OF <2MM												<- PCT OF <75MM (3B1) ->				
821876	1S	0- 9	AP1	24.0	33.3	42.7	8.1		19.3	14.0	13.3	16.0	7.3	3.3	2.8	2	TR	1	32	3
821877	2S	9- 14	AP2	26.8	32.0	41.2	12.2		20.5	11.5	11.5	13.6	6.1	3.3	6.7	9	TR	—	33	9
821878	3S	14- 26	BW1	27.4	31.0	41.6	11.2		19.1	11.9	10.9	12.8	6.7	4.5	6.7	15	2	1	43	18
821879	4S	26- 43	BW2	26.6	30.9	42.5	10.4		20.8	10.1	10.7	13.0	7.5	5.2	6.1	13	2	2V	43	17
821880	5S	43- 68	CR	7.8	19.6	72.5	0.8		9.5	10.1	11.6	21.2	20.8	13.9	4.9	1	TR	—	61	1

SAMPLE NO.	HZN NO.	ORGN C 6A1C	TOTAL N 6B3A	NITR P	TOTAL S 6R3A	DITH-CIT EXTRACTABLE FE 6C2B	AL 6G7A	MN 6D2A	RATIO/CLAY CEC 8D1	15 BAR 8D1	ATTERBERG LIMITS LL 4F1	PI 4F	BULK DENSITY FIELD MOIST 4A3A	1/3 BAR 4A1D	OVEN DRY 4A1H	COLE WHOLE SOIL 4G1	WATER CONTENT FIELD MOIST 4B4	1/10 BAR 4B1C	1/3 BAR 4B1C	15 BAR 4B2A	HRD WHOLE SOIL 4C1
		<- - - - - - -PCT OF <2MM - - - - - - - ->									PCT <0.4MM		<- - G/CC - - ->			CM/CM	<- - -PCT OF <2MM - ->				CM/CM
821876	1	3.06	0.208			1.5	0.2	0.1	0.80	0.47	37	10		1.19	1.29	0.027			22.7	11.2	0.13
821877	2	1.51	0.129			2.2	0.2	0.1	0.60	0.42				1.34	1.41	0.017			21.0	11.2	0.13
821878	3	0.90	0.088			2.1	0.2	0.1	0.57	0.40	34	12		1.33	1.40	0.016			21.2	11.0	0.12
821879	4	0.65				2.3	0.2	0.1	0.62	0.43				1.26	1.36	0.023			24.1	11.4	0.15
821880	5	0.20				1.9	0.2	0.1	2.53	0.90				1.93	2.02	0.015			12.7	7.0	0.11

SAMPLE NO.	HZN NO.	NH4OAC EXTRACTABLE BASES CA 5B5A 6N2E	MG 5B5A 6Q2D	NA 5B5A 6P2B	K 5B5A 6Q2B	SUM BASES	ACID-ITY 6H5A	EXTR AL 6G9A	CEC SUM CATS 5A3A	NH4-OAC 5A8B	BASES + AL 5A3B	AL SAT 5G1	BASE SUM 5C3	SAT-NH4 OAC 5C1	CO3 AS CACO3 <2MM 6E1G	RES. OHMS /CM 8K1	SURFACE AREA EGME 7D2 MG/G	EGME 7D2 M2/G	PH CACL2 .01M 8C1F 1:2	H2O 8C1F 1:1
		<- - - - - - - - - - - - -MEQ / 100 G - - - - - - - - - - - ->										<- - - - -PCT - - - ->								
821876	1	12.3	4.1	0.1	0.3	16.8	8.2		25.0	19.1			67	88			30	105	5.8	5.9
821877	2	9.0	3.3	TR	0.2	12.5	7.5		20.0	16.2			62	77			31	108	5.3	5.6
821878	3	6.9	3.1	TR	0.1	10.1	7.7	0.7	17.8	15.6	10.8	6	57	65			32	112	4.9	5.2
821879	4	7.0	3.6	0.1	0.1	10.8	8.8	0.9	19.6	16.6	11.7	8	55	65		11000	36	126	4.7	5.0
821880	5	12.0	5.0	0.2	0.1	17.3	4.7	0.3	22.0	19.7	17.6	2	79	88			32	112	5.0	5.3

SAMPLE NO.	HZN NO.	TOTAL ANALYSIS 7C3 CLAY K2O 6Q3A	Fe 6C7A	MINERALOGY CLAY X-RAY 7A2I	7A2I	7A2I	7A2I	DTA 7A3	7A3	TOTAL CLAY 7B7A	DOM RES 7B7A	WEATH
		<- - - - - - - PCT - - - - - - ->		<- RELATIVE AMOUNTS ->				<- - - - -PCT - - - ->				
821876	1	2.1	5.4	KK 2	VR 2	HI 2		KK 5				
821877	2	2.0	5.8	KK 3	VR 2	HI 2		KK18				
821878	3	1.9	6.1	KK 3	VR 2	HI 2	HT 1	KK23				
821879	4	1.9	6.2	KK 3	VR 2	HI 2		KK21		42	PK15	
821880	5											

FAMILY CONTROL SECTION: DEPTH 25- 43 PCT CLAY 27 PCT .1-75MM 43

ANALYSES: S= ALL ON SIEVED <2MM BASIS V= 75-20MM FROM VOLUME ESTIMATES

MINERALOGY: KIND OF MINERAL KK KAOLINITE VR VERMICULITE HI MICA HT MONTMORILL PK POTAS-FELD

RELATIVE AMOUNT 6 INDETERMINATE 5 DOMINANT 4 ABUNDANT 3 MODERATE 2 SMALL 1 TRACE

Series: Narathiwat VAR.
Pedon No: S82FN-875-005 Date: 3/83
Taxonomy: Sandy siliceous, nonacid, isohyperthermic Sulfic Fluvaquents.*
Location: 4 km from Mae Phim Beach to Ban Phe. Rayong Province, Klaeng District, Tha Fad area, Ban Klam Village.
Physiography: River estuary
Geomorphic Position:
Slope and Aspect: 0 pct planar Elevation: 1 m M.S.L
Air Temp. 27 C Summer: Winter:
Precipitation: Aquic moisture regime.
Water Table: 10 cm Apparent
Drainage: Very poorly drained Permeability:
Stoniness:
Land Use: Swamp or marshland, undrained (Mangrove)
Erosion or Deposition:
Parent Material: Organic sediments
Described by: L. Moncharoen, W. Silicheuchu, M. Mausbach

*The accompanying data support this taxonomic placement. However the site visited on the field trip was organic with mineral content of less than 50%. If organic, the pedon is a euic, isohyperthermic Typic Sulfihemist. It appears that the area is a complex of the two taxa.

A1 0 - 8 cm Very dark grayish brown (10YR 3/2) loamy sand; weak medium subangular blocky structure; very friable, non-sticky; non-plastic; many very fine to fine roots; pH=8.0, moderately alkaline; clear smooth boundary. 82P1881

A2 8 - 18 cm Sand; brown to dark brown (10YR 4/3, rubbed); non-sticky; non-plastic; pH=7.0, neutral; clear smooth boundary. 82P1882

Oi1 18 - 53 cm Very dark brown (10YR 2/2) fresh material; grayish brown (10YR 5/2, rubbed); pH=8.0, moderately alkaline; gradual smooth boundary. 82P1883

Oi2 53 - 110 cm Very dark grayish brown (10YR 3/2) fresh material; very dark brown (10YR 2/2, rubbed); pH=8.0, moderately alkaline. 82P1884 Sampled by auger.

NARATHIWAT V.

CLASSIFICATION: SANDY, SILICEOUS, NONACID, ISOHYPERTHERMIC SULFIC FLUVAQUENT

REVISED

S 82PN-875 -005 SAMPLE NOS. 82P1881 - 1884 DATE APRIL 1983

U. S. DEPARTMENT OF AGRICULTURE
SOIL CONSERVATION SERVICE
NATIONAL SOIL SURVEY LABORATORY
LINCOLN, NEBRASKA

THAILAND

GENERAL METHODS 1B1A, 2A1, 2B

SAMPLE NO.	HZN NO.	DEPTH (CM)	HORIZON	TOTAL CLAY LT .002	TOTAL SILT .002-.05	TOTAL SAND .05-2	CLAY FINE LT .0002	CLAY CO3 LT .002	SILT FINE .002-.02	SILT COARSE .02-.05	SAND VF .05-.10	SAND F .10-.25	SAND M .25-.50	SAND C .5-1	SAND VC 1-2	COARSE FRACTIONS (MM) 2-5	5-20	20-75	>75MM WT PCT OF WHOLE SOIL
				<- - - - - - - - - - - - - PCT OF <2MM (3A1) - - - - - - - - - - - - - ->												<- PCT OF <75MM (3B1) ->			
821881	1S	0- 8	A1	1.7	6.5	91.8			2.4	4.1	25.8	62.0	3.4	0.3	0.2	TR	TR	—	82	TR
821882	2S	8- 18	A2	0.4	6.6	93.0			3.4	3.2	23.3	63.3	4.7	1.3	0.4	TR	1	—	70	1
821883	3S	18- 53	O11	2.2	5.7	92.1			2.2	3.5	19.8	58.5	9.9	3.6	0.3	—	—	—	72	—
821884	4S	53-110	O12	8.8	17.0	74.2			5.6	11.4	23.6	45.9	3.4	0.9	0.4	—	—	—	51	—

SAMPLE NO.	HZN NO.	ORGN C 6A1C	TOTAL N 6B3A	NITR P	TOTAL S 6H3A	DITH-CIT EXTRACTABLE FE 6C2B	AL 6G7A	MN 6D2A	CEC 8D1	RATIO/CLAY 15 BAR 8D1	ATTERBERG LIMITS LL 4F1	PI 4F	BULK DENSITY FIELD MOIST 4A3A	1/3 BAR 4A1D	OVEN DRY 4A1H	WHOLE SOIL 4D1	COLE FIELD MOIST 4B4	WATER CONTENT 1/10 BAR 4B1C	1/3 BAR 4B1C	15 BAR 4B2A	WRD WHOLE SOIL 4C1
		<- - - - - - - PCT OF <2MM - - - - - - - ->									PCT <0.4MM		<- - G/CC - - ->			CM/CM	<- - -PCT OF <2MM - ->				CM/CM
821881	1	2.55	0.111		TR				2.56	4.06				1.13	1.15	0.006			29.4	6.9	0.25
821882	2	2.92	0.098		TR				25.25	27.25				0.98	1.09	0.036			34.1	10.9	0.23
821883	3	8.15	0.158		0.5				8.41	7.68				0.50	0.84	0.189			98.6	16.9	0.41
821884	4	10.9	0.193		0.8				1.99	2.01										17.7	

SAMPLE NO.	HZN NO.	NH4OAC EXTRACTABLE BASES CA 5B5A	MG 5B5A	NA 5B5A	K 5B5A	SUM BASES	ACID-EXTR ITT 6H5A	AL 6G9A	CEC SUM CATS 5A3A	NH4-OAC 5A8B	EXCH 5D2 PCT	SAR 5E	BASE SATURATION SUM 5C3	NH4OAC 5C1	CARBONATE AS CACO3 <2MM 6E1G	<.05MM 8H1	SURFACE AREA EGME 7D2 M2/G	EGME 7D2 M2/G	PH SAT PASTE 8C1B	CACL2 .01B 8C1F 1:2	H2O 8C1F 1:1
		<- - - - - - - - - -MEQ / 100 G - - - - - - - - - - ->									PCT		<- -PCT- >		<- -PCT ->						
821881	1	3.7	11.3	33.5	0.8	49.3	2.7	—	52.0	10.0	100	55	95	100					5.6	5.7	5.6
821882	2	3.4	10.5	33.5	0.8	48.2	3.2	--	51.4	10.1	100	63	94	100					5.3	5.5	5.5
821883	3	6.2	16.5	51.7	1.2	75.6	23.4	1.2	99.0	18.5	100	58	76	100					3.1	3.5	3.4
821884	4	6.6	21.2	70.1	1.6	99.5	23.3	1.1	122.8	17.5	100	65	81	100					3.5	4.1	4.0

SAMPLE NO.	HZN NO.	WATER EXTRACTED FROM SATURATED PASTE CA 6H1B	MG 6O1B	NA 6P1B	K 6Q1B	CO3 6I1B	HCO3 6J1B	CL 6K1C	SO4 6L1C	NO3 6M1C	H2O 8A	TOTAL SALTS EST. 8D5	ELEC. COND. 8A3A MMHOS /CM	STATE OF DECOMPOSITION MINL CONT 8F	(FIBER VOL) UNRB 8G	RUB 8G	PYROPHOSPHT SOLUBILITY 8H HUE	COLOR	PH CACL .01M 8C1E	MINERALOGY TOTAL RES 7B1A	DOM WEATH 7B1A
		<- - - - - - - - - - -MEQ / LITER - - - - - - - - - ->									<- -PCT ->		/CM	<-----PCT----->						<- - -PCT- - ->	
821881	1	16.8	92.8	406.6	8.9	—	1.1	373.6	—	—	55.4	1.7	35.40								
821882	2	21.7	118.7	528.4	11.0	—	1.3	876.6	—	—	81.1	3.1	43.00								
821883	3	39.8	188.6	614.8	11.2			891.1	146.6	—	45.9	2.0	48.20	81	72	60	7.5YR	7/2	2.5		
821884	4	44.9	221.5	753.1	14.8	—	—	1254.7	150.2	--	63.9	3.3	56.30	82	60	48	7.5YR	7/2	2.8	95	FK 4

ANALYSES: S= ALL OF SIEVED <2MM BASIS

MINERALOGY: KIND OF MINERAL FK FOTAS-FELD

RELATIVE AMOUNT % INDETERMINATE 5 DOMINANT 4 ABUNDANT 3 MODERATE 2 SMALL 1 TRACE

Series: Phimai VAR.
Pedon No: S82FN-875-006 Date: 3/83
Taxonomy: Fine, mixed, isohyperthermic Aeric Tropaqualfs.
Location: 4 km S of A. Non Thai. Nakhomzatchasima Province, Non Thai District, Lam Chaeng Kai area.
Physiography: Floodplain in river valley, Korat plateau
Geomorphic Position:
Slope and Aspect: 1 pct planar Elevation: 167 m M.S.L
Air Temp. 27 C Summer: Winter:
Precipitation: 130 cm Aquic moisture regime.
Water Table: 123 cm Apparent
Drainage: Very poorly drained Permeability: Slow
Stoniness:
Land Use: Cropland-paddy rice.
Erosion or Deposition: None
Parent Material: Alluvium
Described by: C. Silicheuchu, P. Vichaidit, B. Boonsompoppan

Ap 0 - 15 cm Grayish brown (10YR 5/2) clay loam, brown (10YR 5/3, dry); many fine distinct yellowish brown (10YR 5/6) mottles; weak medium subangular blocky parting to moderate medium granular structure; extremely hard, friable, slightly sticky; slightly plastic; a few fine roots; pH=6.5, slightly acid; abrupt smooth boundary.
82P1885

BAg 15 - 23 cm Grayish brown (10YR 5/2) clay, light brownish gray (10YR 6/2, dry); many fine distinct yellowish brown (10YR 5/6) mottles; strong medium to coarse angular blocky structure; extremely hard, firm, slightly sticky; slightly plastic; some slickensides; a few fine roots; pH=8.0, moderately alkaline; gradual smooth boundary.
82P1886 Thin sand coats on vertical faces of peds.

Btg1 23 - 69 cm Grayish brown (10YR 5/2) clay; many fine distinct yellowish brown (10YR 5/4) mottles; strong medium to coarse angular blocky structure; extremely hard, firm, slightly sticky; slightly plastic; a few clay skins; some slickensides; pH=8.0, moderately alkaline; clear smooth boundary.
82P1887 Slickensides are close enough to intersect; thin sand coats on vertical faces of peds.

Btg2 69 - 93 cm Light brownish gray (10YR 6/2) clay; many fine distinct yellowish brown (10YR 5/6) mottles; weak very coarse prismatic structure; firm, sticky; plastic; a few clay skins; some slickensides; common fine calcium carbonate concretions; pH=8.0, moderately alkaline; gradual smooth boundary.
82P1888 Slickensides are close enough to intersect; thin sand coats on vertical faces of peds.

2BCg 93 - 123 cm Light brownish gray (10YR 6/2) clay; many fine distinct yellowish brown (10YR 5/8) mottles; weak very coarse prismatic structure; firm, sticky; plastic; some slickensides; a few fine calcium carbonate concretions; pH=8.0, moderately alkaline; clear smooth boundary.
82P1889

2Cg 123 - 170 cm Light brownish gray (10YR 6/2) clay; many medium distinct yellowish brown (10YR 5/8) mottles; weak very coarse prismatic structure; firm, sticky; plastic; a few fine calcium carbonate concretions; pH=8.0, moderately alkaline.
82P1890

PRIMAY V.

CLASSIFICATION: FINE, MIXED, ISOHYPERTHERMIC ARRIC TROPAQUALF

S 82PH-875 -006 SAMPLE NOS. 82P1885 - 1890 DATE APRIL 1983 REVISED

THAILAND

GENERAL METHODS 1B1A, 2A1, 2B

U. S. DEPARTMENT OF AGRICULTURE
SOIL CONSERVATION SERVICE
NATIONAL SOIL SURVEY LABORATORY
LINCOLN, NEBRASKA

SAMPLE NO.	HZN NO.	DEPTH (CM)	HORIZON	TOTAL CLAY LT .002	TOTAL SILT .002 -.05	TOTAL SAND .05 -2	CLAY FINE LT .0002	CLAY CO3 LT .002	SILT FINE .002 -.02	SILT COARSE .02 -.05	SAND VF .05 -.10	SAND F .10 -.25	SAND M .25 -.5	SAND C .5 -1	SAND VC 1 -2	COARSE FRACTIONS (MM) 2 -5	5 -20	20 -75	.1- 75	WT PCT OF WHOLE SOIL
				<- - - - - - - - - - - PCT OF <2MM					(3A1) - - - - - - - - - - - - ->						<- PCT OF <75MM (3B1) ->				
821885	1S	0- 15	AP	26.5	37.4	35.9	21.1		12.4	24.9	23.9	10.9	0.5	0.2	0.4	1	TR	—	13	1
821886	2S	15- 23	BAG	34.5	34.9	30.5	21.6		12.8	22.0	20.5	9.0	0.5	0.1	0.4	1	—	—	11	1
821887	3S	23- 69	BTG1	37.0	35.7	27.1	27.8		13.7	22.0	18.8	7.4	0.3	0.2	0.5	1	1	—	10	2
821888	4S	69- 93	BTG2	34.9	40.1	24.8	22.0		17.0	23.1	18.0	5.2	0.5	0.5	0.6	4	6	—	16	10
821889	5S	93-123	2BCG	40.0	37.6	22.2	21.7		17.9	19.7	15.2	5.9	0.3	0.3	0.5	1	3	2	13	6
821890	6S	123-[illegible]	2CG	25.9	30.2	43.8	16.4		10.3	19.9	29.6	13.7	0.4	0.1	—	1	4	1	19	6

SAMPLE NO.	HZN NO.	ORGN C 6A1C	TOTAL N 6B3A	EXTR P	TOTAL S 6R3A	DITH-CIT FE 6C2B	DITH-CIT AL 6G7A	DITH-CIT MN 6D2A	RATIO/CLAY CEC 8D1	RATIO/CLAY 15 BAR 8D1	ATTERBERG LIMITS LL 4F1	ATTERBERG LIMITS PI 4P	BULK DENSITY FIELD MOIST 4A3A	BULK DENSITY 1/3 BAR 4A1D	BULK DENSITY OVEN DRY 4A1H	COLE WHOLE SOIL 4D1	WATER CONTENT FIELD MOIST 4B4	WATER CONTENT 1/10 BAR 4B1C	WATER CONTENT 1/3 BAR 4B1C	WATER CONTENT 15 BAR 4B2A	WRD WHOLE SOIL 4C1
		<- - - - - - PCT OF <2MM - - - - - - ->									PCT <0.4MM		<- G/CC - - ->			CM/CM	<- - -PCT OF <2MM - ->				CM/CM
821885	1	0.80	0.059			0.7	0.1	TR	0.56	0.37	31	16		1.42	1.54	0.027			19.5	9.7	0.14
821886	2	0.36	0.030			0.6	0.1	—	0.56	0.39				1.56	1.81	0.051			21.1	13.3	0.12
821887	3	0.22	0.016			0.5	0.1	TR	0.60	0.42	48	32		1.51	1.88	0.075			23.6	15.6	0.12
821888	4	0.17	0.010			0.3	0.1	—	0.63	0.43				1.52	1.88	0.069			24.8	15.0	0.14
821889	5	0.16				0.5	0.1	TR	0.63	0.42	51	36		1.44	1.87	0.076			26.6	16.6	0.14
821890	6	0.13				0.5	0.1	TR	0.61	0.44				1.60	1.85	0.048			20.5	11.3	0.14

SAMPLE NO.	HZN NO.	NH4OAC EXTRACTABLE BASES CA 5B5A 6N2K	MG 5B5A 6O2D	NA 5B5A 6P2B	K 5B5A 6Q2B	SUM BASES 6H5A	ACIDITY 6H5A	CEC SUM CATS 5A3A	CEC NH4-OAC 5A8B	BACH NA 5D2	SAR 5E	BASE SATURATION SUM 5C3	BASE SATURATION NH4OAC 5C1	CO3 AS CACO3 <2MM 6E1G	BES. OHMS /CM 8E1	SURFACE AREA EGME 7D2 HG/G	SURFACE AREA EGME 7D2 M2/G	PH SAT PASTE 8C1B	PH CACL2 .01M 8C1F 1:2	PH H2O 8C1F 1:1
		<- - - - - - - - - - - MEQ / 100 G - - - - - - - - - ->								PCT		<- PCT- >		PCT						
821885	1	10.8	2.0	1.6	0.2	14.6	4.4	19.0	14.9	7	6	77	98			42	147	6.3	5.7	5.8
821886	2	14.7	1.8	3.9	0.2	20.6	1.7	22.3	19.3	15	14	92	100	—		52	182	7.2	7.0	7.2
821887	3	16.9	1.8	7.6	0.2	26.5			22.1	25	24		100	TR		54	189	7.7	7.6	7.7
821888	4	21.4	1.7	9.4	0.2	32.7			21.9	29	31		100	TR		55	192	7.9	7.9	7.9
821889	5	19.1	1.9	14.0	0.3	35.3			25.1	36	38		100	TR	410	57	199	7.8	7.8	7.7
821890	6	10.1	1.1	10.2	0.2	21.6			15.7	36	44		100	TR		37	129	7.7	7.8	7.8

SAMPLE NO.	HZN NO.	WATER EXTRACTED FROM SATURATED PASTE CA 6N1B	MG 6O1B	NA 6P1B	K 6Q1B	CO3 6I1B	HCO3 6J1B	CL 6K1C	SO4 6L1C	NO3 6M1C	B 8A	TOTAL SALTS EST. 8D5	ELEC. COND. 8A3A MMHOS /CM	MINERALOGY CLAY X-RAY <2U 7A2I	CLAY X-RAY <2U 7A2I	CLAY X-RAY <2U 7A2I	CLAY X-RAY <2U 7A2I	CLAY DTA <2U 7A3	CLAY DTA <2U 7A3	TOT ANL 7C3 CLAY K2O 6Q3A	TOT ANL 7C3 CLAY Fe 6C7A
		<- - - - - - - - - - - - MEQ / LITER - - - - - - - - - ->									<- PCT ->			<- RELATIVE AMOUNTS ->						<- - - - PCT - - - ->	
821885	1	7.8	1.7	13.3	0.1	—	0.9	14.0	7.2	—	44.8	0.1	2.27	KK 3	HT 3	HI 1		KK36		0.9	4.2
821886	2	2.6	0.4	16.9	TR	—	1.5	15.5	3.5	—	57.4	0.1	1.96	KK 3	HT 3	HI 1	QZ 1	KK36		0.8	4.0
821887	3	2.3	0.3	27.7	TR	—	2.0	23.4	6.4	—	76.9	0.2	2.99	KK 3	HT 3	HI 1	QZ 1	KK36		0.9	4.3
821888	4	2.7	0.4	38.5	TR	—	1.6	34.9	6.3	—	76.6	0.2	4.04	HT 3	KK 3	HI 1	QZ 1	KK27		1.1	4.1
821889	5	3.9	0.6	57.7	TR	—	1.5	52.4	12.1	—	85.2	0.4	5.82	HT 4	KK 3	HI 2	QZ 1	KK24		1.4	4.5
821890	6	4.9	0.7	73.1	0.1	—	1.4	66.7	12.5	—	62.7	0.3	7.03	HT 4	KK 2	HI 2	QZ 1	KK14		1.3	4.8

FAMILY CONTROL SECTION: DEPTH 25-100 PCT CLAY 37 PCT .1-75MM 12

ANALYSES: S= ALL OD SIEVED <2MM BASIS

MINERALOGY: KIND OF MINERAL KK KAOLINITE HT MONTMORILL HI MICA QZ QUARTZ

RELATIVE AMOUNT 6 INDETERMINATE 5 DOMINANT 4 ABUNDANT 3 MODERATE 2 SMALL 1 TRACE

Series: Kula Ronghai
Pedon No: S82PN-875-008 Date: 3/83
Taxonomy: Coarse-loamy, siliceous, isohyperthermic Typic Natraqualfs.
Location: 17 km stone from Mitraparp road to A. Nom Thai. Nakhomzatchasima Province, Non Thai Dist., Nong Suang area Kula Ronghai
Physiography: Terrace in river valley, Korat plateau
Geomorphic Position:
Slope and Aspect: 1 pct planar Elevation: 195 m M.S.L
Air Temp. 27 C Summer: Winter:
Precipitation: 115 cm Aquic moisture regime.
Water Table: 113 cm Apparent
Drainage: Somewhat poorly drained Permeability: Moderately slow
Stoniness:
Land Use: Cropland-paddy rice
Erosion or Deposition: None
Parent material: Alluvium
Described by: W. Silicheuche, C. Changprai, B. Boonsompoppan

Apg 0 - 21 cm Brown (7.5YR 5/2) and strong brown (7.5YR 5/8) loamy fine sand, pinkish gray (7.5YR 6/2, dry); common fine distinct yellowish brown (10YR 5/6) mottles; weak fine to medium subangular blocky structure; slightly hard, very friable, non-sticky; non-plastic; common very fine to fine roots; pH=6.5, slightly acid; clear smooth boundary.
82P1898

Bt 21 - 35 cm Brown (7.5YR 5/4) loamy fine sand; a few fine distinct yellowish brown (10YR 5/6) mottles; weak coarse prismatic parting to weak coarse subangular blocky structure; extremely hard, very firm, non-sticky; non-plastic; some clay skins bridging between sand grains; common fine roots; pH=8.0, moderately alkaline; gradual smooth boundary.
82P1899

E' 35 - 70 cm Light brown (7.5YR 6/4) sandy loam; a few fine faint strong brown (7.5YR 5/8) mottles; weak coarse prismatic parting to weak coarse subangular blocky structure; friable, slightly sticky; slightly plastic; a few fine roots; a few fine iron concretions; pH=8.0, moderately alkaline; gradual smooth boundary.
82P1900

B'tg1 70 - 88 cm Light brown (7.5YR 6/4) sandy clay loam; many fine faint reddish yellow (7.5YR 6/8) mottles; weak very coarse prismatic structure; friable, slightly sticky; slightly plastic; some thin clay skins in channels and pores; a few fine roots; a few fine iron concretions; pH=8.0, moderately alkaline; gradual smooth boundary.
82P1901

B'tg2 88 - 113 cm Light brown (7.5YR 6/4) sandy clay loam; common fine faint reddish yellow (7.5YR 6/8) mottles; weak very coarse prismatic structure; friable, slightly sticky; slightly plastic; some thin clay skins in channels and pores; a few fine roots; a few iron concretions and a few very coarse calcium carbonate concretions; pH=8.0, moderately alkaline; gradual smooth boundary.
82P1902

B'tg3 113 - 180 cm Pinkish gray (7.5YR 7/2) and light brown (7.5YR 6/4) clay loam; a few fine faint yellowish brown (10YR 5/6) mottles; weak coarse prismatic parting to weak coarse subangular blocky structure; friable, slightly sticky; slightly plastic; a few very coarse calcium carbonate concretions and a few fine iron concretions; pH=8.0, moderately alkaline.
82P1903

Series: Satuk VAR. Date: 3/83
Pedon No: S82FN-875-007
Taxonomy: Coarse-loamy, siliceous, isohyperthermic Typic Natrustalfs.
Location: 15 km stone C Mitraparp road to A. Nom Thai. Na Pro., Kham Thale So Dist., Don Ma Klua area
Physiography: Terrace in river valley, Korat plateau
Geomorphic Position:
Slope and Aspect: 1 pct planar Elevation: 200 m M.S.L
Air Temp. Summer: Winter:
Precipitation: Ustic moisture regime.
Water Table: 0 cm
Drainage: Permeability: Moderately rapid
Stoniness: exceedingly stony
Land Use: Dipterocarp cleared for cassava
Erosion or Deposition: None
Parent Material: Old alluvium
Described by: W. Silicheuchu, C. Changprai, B. Boonsompoppan

Ap1 0 - 13 cm Light brown (7.5YR 6/4) sandy loam, brown (7.5YR 5/4, moist); weak medium subangular blocky structure; slightly hard, very friable, non-sticky; non-plastic; common fine roots; pH=6.5, slightly acid; clear wavy boundary.
82P1891

Ap2 13 - 30 cm Light brown (7.5YR 6/4) and pinkish gray (7.5YR 6/2) sandy loam, brown (7.5YR 5/2, moist); weak coarse subangular blocky structure; hard, friable, non-sticky; non-plastic; a few fine roots; pH=5.5, strongly acid; abrupt smooth boundary.
82P1892

BA1 30 - 62 cm Reddish yellow (7.5YR 6/6) fine sandy loam, strong brown (7.5YR 5/6, moist); weak coarse subangular blocky structure; very friable, non-sticky; non-plastic; a few very fine to fine roots; pH=5.0, strongly acid; gradual smooth boundary.
82P1893

BA2 62 - 84 cm Fine sandy loam, strong brown (7.5YR 5/8, moist); a few fine faint strong brown (7.5YR 5/6) mottles; weak medium to coarse subangular blocky structure; very friable, non-sticky; non-plastic; a few fine roots; pH=5.5, strongly acid; abrupt smooth boundary.
82P1894

Bt1 84 - 100 cm Sandy loam, brown (7.5YR 5/4, moist); many fine faint brownish yellow (10YR 6/8) and common fine distinct strong brown (7.5YR 5/6) mottles; moderate coarse columnar parting to moderate coarse subangular blocky structure; extremely hard, friable, non-sticky; non-plastic; some clay bridging between sand grains; a few fine roots on vertical faces of peds; a few fine iron concretions; pH=7.0, neutral; gradual smooth boundary.
82P1895

Bt2 100 - 140 cm Sandy loam, light brown (7.5YR 6/4, moist); weak medium subangular blocky structure; extremely hard, firm, slightly sticky; slightly plastic; a few iron-manganese coats on faces of peds; very few fine roots on vertical faces of peds; a few fine iron concretions; pH=8.0, moderately alkaline; gradual smooth boundary.
82P1896

Bt3 140 - 180 cm Sandy loam, light brown (7.5YR 6/4, moist); common fine distinct reddish yellow (7.5YR 6/8) and a few fine distinct strong brown (7.5YR 5/6) mottles; weak medium subangular blocky structure; extremely hard, firm, slightly sticky; slightly plastic; some thin clay skins in channels and pores; pH=8.0, moderately alkaline.
82P1897

SATUK V

CLASSIFICATION: COARSE-LOAMY, SILICEOUS, ISOHYPERTHERMIC TYPIC MATRUSTALF

S 82PH-875 -007 SAMPLE NOS. 82P1891 - 1897 DATE REVISED APRIL 1983

THAILAND

GENERAL METHODS 1B1A, 2A1, 2B

U. S. DEPARTMENT OF AGRICULTURE
SOIL CONSERVATION SERVICE
NATIONAL SOIL SURVEY LABORATORY
LINCOLN, NEBRASKA

-1— -2— -3— -4— -5— -6— -7— -8— -9— -10- -11- -12- -13- -14- -15- -16- -17- -18- -19- -20-

SAMPLE NO.	HZN NO.	DEPTH (CM)	HORIZON	(- - -TOTAL - - -) CLAY LT .002	SILT .002 -.05	SAND .05 -2	FINE LT .0002	(- -CLAY- -) CO3 LT .002	FINE .002 -.02	(- -SILT- -) COARSE .02 -.05	VF .05 -.10	(- - - - - -SAND- - - - - -) F .10 -.25	M .25 -.50	C .5 -1	VC 1 -2	(-COARSE FRACTIONS (MM) -) 2 -5	5 -20	20 -75	.1- 75	(>2MM) WT PCT OF WHOLE SOIL
				<- - - - - - - - - - - PCT OF <2MM						(3A1) - - - - - - - - - - - - -						<- PCT OF <75MM (3B1) ->		
821891	1X	0- 13	AP1	3.2	18.9	77.7	1.2		4.9	14.1	22.6	39.5	12.8	2.6	0.1	—	—	—	55	—
821892	2X	13- 30	AP2	4.4	18.6	77.0	0.4		6.9	11.7	21.3	38.7	13.9	2.8	0.3	—	—	—	56	—
821893	3X	30- 62	BA1	7.7	19.0	73.3	2.0		6.9	12.1	20.0	36.2	13.5	3.3	0.3	—	—	—	53	—
821894	4X	62- 84	BA2	5.2	22.1	72.7	1.6		9.3	12.8	21.9	35.9	11.8	2.6	0.5	—	—	—	51	—
821895	5X	84-100	BT1	12.5	17.0	70.5	6.9		5.3	11.7	20.6	33.8	12.5	3.1	0.5	—	—	—	50	—
821896	6X	100-140	BT2	12.6	10.5	68.9	6.9		6.1	12.4	21.0	32.7	11.9	3.0	0.3	TR	—	—	48	TR
821897	7X	140-180	BT3	14.5	16.2	69.3	8.9		5.7	10.5	19.9	32.3	12.5	3.6	1.0	—	—	—	49	—

SAMPLE NO.	HZN NO.	ORGN C 6A1C	TOTAL N 6B3A	NITR TOTAL P	S 6B3A	(- - DITH-CIT - -) EXTRACTABLE FE 6C2B	AL 6G7A	MN 6D2A	(RATIO/CLAY) CEC 8D1	15 BAR 8D1	(ATTERBERG) - LIMITS - LL 4F1	PI 4F	(- BULK DENSITY -) FIELD MOIST 4A3A	1/3 BAR 4A1D	OVEN DRY 4A1H	COLE WHOLE SOIL 4D1	(- - -WATER CONTENT - -) FIELD MOIST 4B4	1/10 BAR 4B1C	1/3 BAR 4B1C	15 BAR 4B2A	WRD WHOLE SOIL 4C1
		<- - - - - - PCT OF <2MM - - - - - - ->									PCT	<0.4MM	<- - G/CC - - ->			CM/CM	<- - -PCT OF <2MM - ->				CM/CM
821891	1	0.42	0.028			0.2	TR	TR	0.81	0.56			1.66	1.67	0.002		4.1	1.8	0.04
821892	2	0.32	0.027			0.2	TR	TR	0.59	0.45			1.68	1.68	—		5.5	2.0	0.06
821893	3	0.17	0.021			0.3	0.1	—	0.43	0.39			1.58	1.63	0.010		5.9	3.0	0.05
821894	4	0.13	0.015			0.3	0.1	—	0.46	0.46			1.55	1.57	0.004		6.7	2.4	0.07
821895	5	0.17				0.3	TR	TR	0.46	0.42			1.76	1.87	0.020		11.0	5.3	0.10
821896	6	0.15				0.2	TR	TR	0.51	0.44			1.63	1.74	0.022		12.8	5.5	0.12
821897	7	0.13				0.3	TR	TR	0.50	0.44	21	5	1.57	1.73	0.033		15.5	6.4	0.14

SAMPLE NO.	HZN NO.	(- NH4OAC EXTRACTABLE BASES -) CA 5B5A 6N2H	MG 5B5A 6Q2D	NA 5B5A 6P2B	K 5B5A 6Q2B	SUM BASES	ACID- ITY 6H5A	HYTR AL 6G9A	(- - - -CEC - - -) SUM CATS 5A3A	NH4-OAC 5A8H	BASES + AL 5A3B	AL SAT 5G1	-BASE SUM 5C3	SAT- NH4 OAC 5C1	CO3 AS CACO3 <2MM 6A1G	RES. OBNS /CM 8H1	SURFACE AREA EGME MG/G 7D2	EGME M2/G 7D2	(- - - -PH - - -) CACL2 .01M 8C1F 1:2	H2O 8C1F 1:1
		<- - - - - - - - - - - - - -NHQ / 100 G - - - - - - - - - -									- ->	<- - - - -PCT - - - ->								
821891	1	1.2	0.7	TR	—	1.9	1.2		3.1	2.6			61	73			8	28	5.2	5.6
821892	2	1.0	0.7	TR	TR	1.7	1.5	0.1	3.2	2.6	1.8	6	53	65			8	28	4.7	5.1
821893	3	0.3	1.1	—	TR	1.4	2.7	1.2	4.1	3.3	2.6	46	34	42			15	52	4.4	4.7
821894	4	0.2	0.9	0.3	—	1.4	1.5	0.5	2.9	2.4	1.9	26	48	58			10	35	4.9	5.4
821895	5	1.1	2.8	2.1	TR	6.0	0.7		6.7	5.8			90	100		3200	18	63	6.3	6.7
821896	6	5.0	3.6	2.7	TR	11.3				6.4				100	TR		20	70	8.5	9.0
821897	7	1.8	3.5	3.2	TR	8.5				7.3				100	TR		22	77	8.3	8.7

SAMPLE NO.	HZN NO.	(- - - TOTAL ANALYSIS 7C3 - - -) CLAY K2O 6Q3A	Fe 6C7A	(- - - - - - - - -MINERALOGY - - - - - - - -) (- - - - - - - CLAY - - - - - - -) (- -VFS -) (- - - - X-RAY - - - -) (- -DTA - -) TOTAL DOM (- - - - - <2U - - - -) (- -<2U - -) RES WEATH 7A2X	7A2X	7A2X	7A2X	7A3	7A3	7B1A	7B1A
		<- - - - - - - PCT - - - - - - - ->			<- RELATIVE AMOUNTS ->										<- - - - -PCT - - - ->					
821891	1	0.2	2.9		HT 3	KK 2	QZ 2													
821892	2	0.2	4.1		HT 4	KK 3	QZ 1				KK				99	PK 1				
821893	3	0.2	4.0		HT 5	KK 3	QZ 2	CL 1			KK 8				99	PK 1				
821894	4	0.2	3.9		HT 5	KK 3	QZ 1				KK 18				99	PK				
821895	5																			
821896	6																			
821897	7																			

FAMILY CONTROL SECTION: DEPTH 84-138 PCT CLAY 13 PCT .1-75MM 49

ANALYSES: S= ALL ON SIEVED <2MM BASIS

MINERALOGY: KIND OF MINERAL HT MONTMORILL KK KAOLINITE QZ QUARTZ PK POTAS-FELD CL CHLORITE

RELATIVE AMOUNT 6 INDETERMINATE 5 DOMINANT 4 ABUNDANT 3 MODERATE 2 SMALL 1 TRACE

KULA BONGHAI

CLASSIFICATION: COARSE-LOAMY, SILICEOUS, ISOHYPERTHERMIC TYPIC HAPLAQUALF

S 82PH-875 -008 SAMPLE NOS. 82P1898 - 1903 DATE REVISED APRIL 1983

THAILAND

GENERAL METHODS 1B1A, 2A1, 2B

U. S. DEPARTMENT OF AGRICULTURE
SOIL CONSERVATION SERVICE
NATIONAL SOIL SURVEY LABORATORY
LINCOLN, NEBRASKA

-1- -2- -3- -4- -5- -6- -7- -8- -9- -10- -11- -12- -13- -14- -15- -16- -17- -18- -19- -20-

SAMPLE NO.	HZN NO.	DEPTH (CM)	HORIZON	(TOTAL) CLAY LT .002	SILT .002 -.05	SAND .05 -2	(CLAY) FINE LT .0002	CO3 LT .002	(SILT) FINE .002 -.02	COARSE .02 -.05	VF .05 -.10	(SAND) F .10 -.25	M .25 -.50	C .5 -1	VC 1 -2	(COARSE FRACTIONS (MM)) 2 -5	WEIGHT 5 -20	20 -75	.1- 75	(>2MM) WT PCT OF WHOLE SOIL
				<- - - - - - - - - - - - - PCT OF <2MM						(3A1)		- - - - - - - - - - - - - ->				<- PCT OF <75MM (3B1) ->				
821898	1S	0- 21	APC	6.5	15.0	78.5	2.4		4.0	11.0	21.6	38.3	14.6	3.4	0.6	—	—	—	57	—
821899	2S	21- 35	BT	10.1	15.3	74.6	4.4		3.6	11.7	21.2	35.4	13.6	3.1	0.3	—	—	—	53	—
821900	3S	35- 70	B'	13.8	18.6	67.6	9.7		6.5	12.1	20.3	32.7	11.9	2.5	0.2	TR	—	—	47	TR
821901	4S	70- 88	B'TG1	13.8	20.4	65.8	5.3		5.7	14.8	20.2	31.4	11.1	2.6	0.5	—	—	—	46	—
821902	5S	88-113	B'TG2	14.5	21.2	64.3	5.7		7.7	13.5	20.4	29.9	10.7	2.6	0.7	—	—	—	44	—
821903	6S	113-180	B'TG3	18.3	21.8	59.9	4.9		7.3	14.5	20.2	27.9	8.9	2.3	0.6	1	4	—	43	5

SAMPLE NO.	HZN NO.	ORGN C 6A1C	TOTAL N 6B3A	NITR P	TOTAL S 6R3A	(DITH-CIT EXTRACTABLE) FE 6C2B	AL 6G7A	MN 6D2A	CEC 8D1	(RATIO/CLAY) BAR 15 8D1	(ATTERBERG) LL 4F1	LIMITS PI 4P	(PORE DENSITY) FIELD MOIST 4A3A	1/3 BAR 4A1D	OVEN DRY 4A1H	COLE WHOLE SOIL 4D1	(WATER CONTENT) FIELD MOIST 4B4	1/10 BAR 4B1C	1/3 BAR 4B1C	15 BAR 4B2A	WHOLE SOIL 4C1
		<- - - - - - -PCT OF <2MM - - - - - - ->									PCT <0.4MM		<- - G/CC - - ->			CM/CM	<- - -PCT OF <2MM - ->				CM/CM
821898	1	0.53	0.035			0.1	TR	—	0.49	0.37				1.70	1.73	0.006			8.8	2.4	0.11
821899	2	0.12	0.014			0.2	TR	—	0.57	0.46	23	5		1.66	1.76	0.020			15.5	4.6	0.18
821900	3	0.08	0.003			0.1	TR	TR	0.63	0.58	43	28		1.62	1.71	0.018			18.0	8.0	0.16
821901	4	0.08	0.003			0.2	TR	—	0.62	0.51				1.68	1.81	0.025			18.2	7.0	0.19
821902	5	0.08				0.2	TR	TR	0.66	0.61	52	37		1.58	1.86	0.056			21.9	8.9	0.21
821903	6	0.08				0.1	TR	TR	0.68	0.64	74	61								11.7	

SAMPLE NO.	HZN NO.	(NH4OAC EXTRACTABLE BASES) CA 5B5A	MG 5B5A	NA 5B5A	K 5B5A	SUM BASES	ACID- ITY 6H5A	(CEC) SUM CATS 5A3A	NH4-OAC 5A8B	NACN NA 5D2	SAR 5E	BASE SATURATION SUM 5C3	NH4OAC 5C1	CO3 AB CACO3 <2MM 6H1G	BES. OHMS /CM 8H1	SURFACE AREA KGME MG/G 7D2	KGME M2/G 7D2	(PH) SAT PASTE 8C1D	CACL2 .01M 8C1F	H2O 8C1F
		<- - - - - - - - - - -MEQ / 100 G - - - - - - - - - ->								PCT		<- -PCT- >		PCT					1:2	1:1
821898	1	1.4	0.8	1.0	TR	3.2	0.6	3.8	3.2			84	100			9	32		5.9	6.6
821899	2	1.4	1.5	5.0	—	7.9	0.1		5.8	65	49		100	TR		13	46	0.5	8.1	8.5
821900	3	1.8	2.1	11.0	TR	14.9	—		8.7	77	91		100	TR		18	63	9.0	8.9	8.7
821901	4	0.8	1.9	10.2	TR	12.9	—		8.6	76	79		100	TR		18	63,	9.0	8.7	8.8
821902	5	1.4	2.2	10.1	TR	13.7	—		9.5	77	65		100	TR	400	23	80	9.0	9.0	9.0
821903	6	8.3	3.4	11.9	TR	23.6	—		12.4	77	52		100	TR		30	105	9.2	9.3	9.3

SAMPLE NO.	HZN NO.	(WATER EXTRACTED FROM SATURATED PASTE) CA	MG	NA	K	CO3	HCO3	CL	SO4	NO3	B	TOTAL SALTS EST. 8D5	ELEC. COND. 8A3A MMHOS	(MINERALOGY) (CLAY) (X-RAY) 7A2I	7A2I	7A2I	7A2I	(DTA) (<2U) 7A3	(<2U) 7A3	TOTAL DOM 7B1A	DOM WEATH 7B1A
		<- - - - - - - - - - -MEQ / LITER - - - - - - - - - ->										<- -PCT ->	/CM	<- RELATIVE AMOUNTS ->				<- - - - -PCT - - - ->			
821898	1												0.17	HY 4	KK 3	QZ 1					
821899	2	0.5	0.3	30.8	TR	—	4.6	19.7	7.3	—	4D.8	0.1	3.01							99	FK 1
821900	3	0.3	0.3	49.9	TR	—	3.2	36.9	10.4	—	87.5	0.3	4.72	HY 5	KK 2	CL 1	HI 1	KK 2		99	FK 1
821901	4	0.3	0.2	39.7	TR	—	3.9	28.4	8.7	—	90.9	0.3	3.90								
821902	5	0.2	0.1	25.3	—	—	3.7	18.4	7.3	—	109.4	0.2	2.58	HY 5	KK 2	CL 1	HI 1	KK 2			
821903	6	0.1	0.1	16.4	—	—	5.0	10.3	1.5	—	142.3	0.2	1.70	HY 5	QZ 2	KK 2	CL 1				

FAMILY CONTROL SECTION: DEPTH 21- 71 PCT CLAY 12 PCT .1-75MM 49

MMHOS/CM OF 1:2 WATER EXTRACT (8I) FOR LAYERS 1,

ANALYSES: S= ALL OF SIEVED <2MM BASIS

MINERALOGY: KIND OF MINERAL HY HOMTMORILL KK KAOLINITE QZ QUARTZ FK POTAS-FELD CL CHLORITE

HI MICA

RELATIVE AMOUNT 6 INDETERMINATE 5 DOMINANT 4 ABUNDANT 3 MODERATE 2 SMALL 1 TRACE

TOTAL ANALYSIS 7C3

SAMPLE NO.	HZN NO.	CLAY K2O 6Q3A	CLAY Fe 6C7A
		<- - - -PCT- - - ->	
821898	1	0.1	1.8
821899	2		
821900	3	0.1	3.6
821901	4		
821902	5	0.1	3.6
821903	6	0.1	3.6

Series: Lob Buri
Pedon No: S82PN-875-009 Date: 3/83
Taxonomy: Fine, montmorillonitic, isohyperthermic Typic Pelluderts.
Location: 5.5 km from Lopburi Province to A. Phrapudhabat. Lopburi Pro., Muang Dist., Sam Yak Nikham area, Gok Go vil
Physiography: Lake plain
Geomorphic Position:
Slope and Aspect: 0 pct planar Elevation:
Air Temp. 27 C Summer: Winter:
Precipitation: 140 cm Ustic moisture regime.
Water Table: Not observed
Drainage: Well drained Permeability: Slow
Stoniness:
Land Use: Cropland-paddy rice.
Erosion or Deposition: None
Parent Material: Lacustrine
Described by: W. Silicheuchu, C. Changprai, M. Singhavara

Poorly drained when flooded. Cracks at 50 cm are > 1 cm wide.

Ap 0 - 12 cm Very dark gray (10YR 3/1) heavy clay, black (10YR 2/1, moist); strong medium subangular blocky parting to strong fine to medium granular structure; extremely hard, extremely firm, very sticky; very plastic; many very fine to fine roots; strongly effervescent; pH=8.0, moderately alkaline; clear smooth boundary.
82P1904

A 12 - 34 cm Very dark gray (10YR 3/1) heavy clay, black (10YR 2/1, moist); moderate coarse angular blocky structure; extremely hard, extremely firm, very sticky; very plastic; many very fine roots; strongly effervescent; pH=8.0, moderately alkaline; gradual smooth boundary.
82P1905 Few pieces of shell fragments.

AC 34 - 51 cm Dark gray (10YR 4/1) heavy clay, very dark grayish brown (10YR 3/2, moist); strong medium to coarse subangular blocky parting to strong fine subangular blocky structure; extremely firm, very sticky; very plastic; some slickensides; a few fine roots; a few fine iron concretions; strongly effervescent; pH=8.0, moderately alkaline; gradual smooth boundary.
82P1906 Few pieces of shell fragments.

C1 51 - 100 cm Very dark gray (10YR 3/1) and dark gray (10YR 4/1) heavy clay, very dark gray (10YR 3/1, moist); many fine faint dark brown (10YR 3/3) mottles; strong medium subangular blocky parting to strong fine angular blocky structure; extremely firm, very sticky; very plastic; many prominent slickensides; a few fine roots; a few fine calcium carbonate concretions; strongly effervescent; pH=8.0, moderately alkaline; gradual smooth boundary.
82P1907 Slickensides intersect

C2 100 - 170 cm heavy clay, Dark gray (10YR 4/1, moist); many fine distinct dark yellowish brown (10YR 4/4) mottles; strong medium subangular blocky parting to strong fine subangular blocky structure; extremely firm, very sticky; very plastic; many prominent slickensides; a few fine roots; a few fine calcium carbonate concretions; strongly effervescent; pH=8.0, moderately alkaline.
82P1908 Slickensides intersect

LOB BURI

CLASSIFICATION: FINE, MONTMORILLONITIC, ISOHYPERTHERMIC TYPIC PELLUDERT

S 82PN-875 -009 SAMPLE NOS. 82P1904 - 1908 DATE REVISED APRIL 1983

U. S. DEPARTMENT OF AGRICULTURE
SOIL CONSERVATION SERVICE
NATIONAL SOIL SURVEY LABORATORY
LINCOLN, NEBRASKA

THAILAND

GENERAL METHODS 1B1A, 2A1, 2B

-1- -2- -3- -4- -5- -6- -7- -8- -9- -10- -11- -12- -13- -14- -15- -16- -17- -18- -19- -20-

SAMPLE NO.	HZN NO.	DEPTH (CM)	HORIZON	(- - -TOTAL - - -) CLAY LT .002	SILT .002 -.05	SAND .05 -2	FINE .0002	(- -CLAY- -) CO3 LT .002	(- -SILT- -) FINE .002 -.02	COARSE .02 -.05	VF .05 -.10	F .10 -.25	(- - - - - -SAND- - - - - -) M .25 -.50	C .5 -1	VC 1 -2	(-COARSE FRACTIONS(MM)-) (>2MM) 2 -5	5 -20	20 -75	.1- 75	PCT OF WHOLE SOIL
				<- - - - - - - - - - - - PCT OF <2MM									(3A1) - - - - - - - - - - - - ->			<- PCT OF <75MM (3B1) ->				
821904	1S	0- 12	AP	61.0	33.2	5.8	22.6		28.0	5.2	1.6	2.2	1.3	0.7	—	—	—	—	4	—K
821905	2S	12- 34	A	60.4	31.7	7.9	17.8		27.1	4.6	1.9	2.7	1.7	1.0	0.6	—	—	—	6	—K
821906	3S	34- 51	AC	60.9	25.4	13.7	15.4		20.7	4.7	3.6	5.4	2.7	1.5	0.5	—	—	—	10	—K
821907	4S	51-100	C1	58.6	24.7	16.7	10.6		19.8	4.9	3.9	5.8	3.1	1.8	2.1	2	—	—	15	2K
821908	5S	100-170	C2	57.9	23.1	19.0	11.4	TR	18.4	4.7	4.3	6.2	3.5	2.6	2.4	3	1	—	18	4K

SAMPLE NO.	HZN NO.	ORGN C 6A1C	TOTAL N 6B3A	NITR P	TOTAL S 6E3A	(- - DITH-CIT - -) EXTRACTABLE FE 6C2B	AL 6G7A	MN 6D2A	CEC 8D1	(RATIO/CLAY) 15 BAR 8D1	(ATTERBERG) LL 4F1	- LIMITS - PI 4F	(- BULK DENSITY -) FIELD MOIST 4A3A	1/3 BAR 4A1D	OVEN DRY 4A1H	COLE WHOLE SOIL 4D1	(- - -WATER CONTENT - -) FIELD MOIST 4B4	1/10 BAR 4B1C	1/3 BAR 4B1C	15 BAR 4B2A	WRD WHOLE SOIL 4C1
		<- - - - - - -PCT OF <2MM - - - - - - ->									PCT <0.4MM		<- - G/CC - - ->			CM/CM	<- - -PCT OF <2MM - ->				CM/CM
821904	1	2.65	0.211			1.0	0.2	0.1	0.88	0.42	75	49		1.08	1.72	0.160			41.8	25.4	0.18
821905	2	1.53	0.124			1.1	0.2	0.1	0.89	0.41				1.26	1.89	0.145			34.6	24.8	0.12
821906	3	0.71	0.054			1.1	0.2	0.2	0.92	0.40	70	43		1.28	1.89	0.139			34.3	24.6	0.12
821907	4	0.53	0.036			1.0	0.1	0.2	0.89	0.41				1.27	1.95	0.151			34.7	23.8	0.14
821908	5	0.44	0.021			0.9	0.1	0.1	0.88	0.40	71	46		1.30	1.96	0.142			33.7	23.4	0.13

SAMPLE NO.	HZN NO.	(- NH4OAC EXTRACTABLE BASES -) CA 5B5A 6N2H	MG 5B5A 6Q2D	NA 5B5A 6P2B	K 5B5A 6Q2B	SUM BASES	ACID- ITY 6H5A	EXTR AL 6G9A	(- - - -CEC - - -) SUM CATS 5A3A	NH4- OAC 5A8B	BASES + AL 5A3B	AL SAT 5G1	-BASE SAT- SUM 5C3	NH4 OAC 5C1	CO3 AS CACO3 <2MM 6H1G	RES. OHRS /CM 8H1	SURFACE AREA EGME 7D2 MG/G	EGME 7D2 M2/G	(- - - -PH - - -) CACL2 .01M 8C1F	H2O 8C1F
		<- - - - - - - - - - - - - - -MEQ / 100 G - - - - - - - - - - - - ->										<- - - - -PCT - - - ->							1:2	1:1
821904	1K		6.0	0.7	0.9					53.5				100	3		95	332	8.0	8.4
821905	2K		5.2	1.1	0.5					53.7				100	2		92	322	7.7	7.9
821906	3K		4.2	1.2	0.3					55.8				100	TR		99	346	7.4	7.3
821907	4K		3.6	1.1	0.2					52.1				100	1	580	101	353	7.6	7.6
821908	5K		3.6	1.3	0.2					50.8				100	4		101	353	7.6	7.7

SAMPLE NO.	HZN NO.	(------- TOTAL ANALYSIS 7C3 -------) CLAY K2O 6Q3A	Fe 6C7A	(- - - - - - - - -MINERALOGY - - - - - - - - -) (- - - - - - - CLAY - - - - - - -) (- - - - X-RAY - - - -) 7A2I	7A2I	7A2I	7A2I	(- -DTA - -) (- - -<2U - - -) 7A3	7A3	TOTAL DOM (- -<2U - -) RES WEATH 7B3A	7B1A
		<- - - - - - - -PCT - - - - - - ->		<- RELATIVE AMOUNTS ->				<- - - - -PCT - - - ->			
821904	1	0.4	5.7	HT 5	KK 3			KK31			
821905	2	0.3	5.5	HT 5	KK 3			KK26			
821906	3	0.1	5.6	HT 5	KK 3			KK27			
821907	4	0.1	5.7	HT 5	KK 3			KK25			
821908	5	0.1	5.6	HT 5	KK 3			KK27			

FAMILY CONTROL SECTION: DEPTH 25-100 PCT CLAY 59 PCT .1-75MM 13

ANALYSES: S= ALL OF SIEVED <2MM BASIS K= CACO3 ON 20-2 AND <2MM FRACTION

MINERALOGY: KIND OF MINERAL HT MONTMORILL KK KAOLINITE

RELATIVE AMOUNT 6 INDETERMINATE 5 DOMINANT 4 ABUNDANT 3 MODERATE 2 SMALL 1 TRACE

Series: Takhli
Pedon No: S82FN-875-010 Date: 3/83
Taxonomy: Loamy-skeletal, carbonatic, isohyperthermic Udorthentic Haplustolls.
Location: 100 m from Marl station center of DLD. Saraburi Province, Phrapudhabat District, Phu Klang village.
Physiography: Basin in intermountain area
Geomorphic Position:
Slope and Aspect: 1 pct planar Elevation:
Air Temp. Summer: Winter:
Precipitation: Ustic moisture regime.
Water Table: Not observed
Drainage: Well drained Permeability: Slow
Stoniness: None
Land Use: Cropland-coconuts and corn
Erosion or Deposition: Slightly eroded
Parent Material: Residuum from marl
Described by: W. Silicheuchu, C. Changprai, M. Singhavara

Ap 0 - 25 cm Dark gray (10YR 4/1) clay loam, very dark gray (10YR 3/1, moist); strong fine to medium granular structure; hard, friable, sticky; plastic; common fine roots; 10% marl fragments; a few fine calcium carbonate concretions; pH=8.0, moderately alkaline; gradual smooth boundary.
82P1909 Coarse fragments are marl.

AC 25 - 39 cm Dark gray (10YR 4/1) gravelly clay loam, very dark grayish brown (10YR 3/2, moist); moderate medium subangular blocky parting to moderate fine granular structure; friable, sticky; plastic; a few fine roots and a few coarse roots; 3% marl fragments; a few fine calcium carbonate concretions; pH=8.5, moderately alkaline; gradual smooth boundary.
82P1910 Coarse fragments are marl.

C1 39 - 56 cm Grayish brown (10YR 5/2) very gravelly clay loam, very dark grayish brown (10YR 3/2, moist); structureless; sticky; plastic; a few coarse roots; coarse fragments, 60 pct larger than 2 mm sedimentary rock; pH=8.5, moderately alkaline; gradual smooth boundary.
82P1911 Coarse fragments are Marl. 40% are hard.

C2 56 - 87 cm very gravelly clay loam, Dark yellowish brown (10YR 4/4, moist); structureless; sticky; plastic; a few coarse roots; coarse fragments, 80 pct larger than 2 mm sedimentary rock; pH=8.5, moderately alkaline; diffuse smooth boundary.
82P1912 Coarse fragments are Marl. 40% are hard.

C3 87 - 130 cm very gravelly clay loam, Dark yellowish brown (10YR 4/4, moist); structureless; coarse fragments, 90 pct larger than 2 mm sedimentary rock; pH=8.5, moderately alkaline.
82P1913 Coarse fragments are Marl. 40% are hard.

TAKELX

CLASSIFICATION: LOAMY-SKELETAL, CARBONATIC, ISOHYPERTHERMIC UDORTHENTIC HAPLUSTOLL

S 82PH-875 -010 SAMPLE NOS. 82P1909 - 1913 DATE APRIL 1983 REVISED

U. S. DEPARTMENT OF AGRICULTURE
SOIL CONSERVATION SERVICE
NATIONAL SOIL SURVEY LABORATORY
LINCOLN, NEBRASKA

THAILAND

GENERAL METHODS 1B1A, 2A1, 2B

SAMPLE NO.	HZN NO.	DEPTH (CM)	HORIZON	TOTAL CLAY LT .002	TOTAL SILT .002 -.05	TOTAL SAND .05 -2	CLAY FINE LT .0002	CLAY CO3 .002	SILT FINE .002 -.02	SILT COARSE .02 -.05	SILT VF .05 -.10	SAND F .10 -.25	SAND M .25 -.50	SAND C .5 -1	SAND VC 1 -2	COARSE FRACTIONS (MM) WEIGHT 2 -5	5 -20	20 -75	>2MM .1-75	BY PCT OF WHOLE SOIL
				<- - - - - - - - - - - - - PCT OF <2MM							(3A1)	- - - - - - - - - - - - -				<- PCT OF <75MM (3B1) ->				
821909	1S	0- 25	AP	32.1	53.6	14.3		1	40.2	13.4	2.0	2.2	1.9	2.8	5.4	11	10	—	31	21K
821910	2S	25- 39	AC	30.1	51.6	18.3		1	41.2	10.4	1.7	1.9	2.1	4.0	8.6	19	21	—	50	40K
821911	3S	39- 56	C1	24.2	53.5	22.3		3	43.4	10.1	2.2	3.0	3.2	5.1	8.8	25	34	TR	67	59K
821912	4S	56- 87	C2	18.9	57.6	23.5		5	46.4	11.2	2.3	3.6	4.2	5.8	7.6	17	28	—	57	45K
821913	5S	87-130	C3	14.7	62.6	22.7		3	50.4	12.2	2.6	4.4	5.3	5.6	4.8	16	24	2	54	42K

SAMPLE NO.	HZN NO.	ORGN C	TOTAL N	NITR TOTAL F	TOTAL S	EXTRACTABLE FE	EXTRACTABLE AL	EXTRACTABLE MN	DITH-CIT CEC	15 BAR	RATIO/CLAY 15 BAR	ATTERBERG LIMITS LL	ATTERBERG LIMITS PI	BULK DENSITY FIELD MOIST	BULK DENSITY 1/3 BAR	BULK DENSITY OVEN DRY	COLE WHOLE SOIL	WATER CONTENT FIELD MOIST	WATER CONTENT 1/10 BAR	WATER CONTENT 1/3 BAR	WATER CONTENT 15 BAR	WRD WHOLE SOIL
		6A1C	6B3A		6B3A	6C2B	6G7A	6D2A	8D1	8D1		4F1	4F	4A3A	4A1D	4A1H	4D1	4B4	4B1C	4B1C	4B2A	4C1
		<- - - - - - -		-PCT OF <2MM		- - - - - - - ->						PCT <0.4MM		<- - G/CC	- - ->		CM/CM	<- - -PCT OF <2MM		- ->		CM/CM
821909	1	2.04	0.175			0.2	TR	0.3	1.29	0.60		60	32		1.22	1.52	0.067			29.5	19.3	0.11
821910	2	1.14	0.096			0.2	TR	0.3	1.12	0.61					1.34	1.61	0.046			22.7	18.4	0.04
821911	3	0.58	0.051			0.1	TR	0.2	0.91	0.52		48	26		1.61	1.71	0.010			13.4	12.5	0.01
821912	4	0.34	0.029			0.1	TR	0.1	0.73	0.46					1.51	1.58	0.010			15.3	8.7	0.07
821913	5	0.28	0.026			0.1	—	0.1	0.70	0.44		31	8		1.30	1.33	0.006			23.0	6.5	0.16

SAMPLE NO.	HZN NO.	EXTRACTABLE BASES CA 5B5A 6H2B	MG 5B5A 6G2D	NA 5B5A 6P2B	K 5B5A 6Q2B	SUM BASES	ACID-EXTR ITY 6H5A	AL 6G9A	CEC SUM CATS 5A3A	CEC NH4-OAC 5A8B	CEC BASES + AL 5A3B	AL SAT 5G1	BASE SAT SUM 5C3	BASE SAT NH4 OAC 5C1	CARBONATE AS CACO3 <2MM 6E1C	CARBONATE AS CACO3 <20MM 8E1	SURFACE AREA EGME 7D2 M2/G	SURFACE AREA EGME 7D2 M2/G	PH CACL2 .01M 8C1F 1:2	PH H2O 8C1F 1:1
		<- - - - - - - - - - - - -				-MEQ / 100 G			- - - - - - - - - - - -		->	<- - - - -		-PCT	- - - - - - - ->					
821909	1K		3.8	TR	0.5					41.5				100	45	56	80	280	7.7	8.0
821910	2K		3.7	—	0.2					33.8				100	54	65	75	262	7.6	8.2
821911	3K		2.5	TR	0.1					22.1				100	70	88	56	196	7.7	8.2
821912	4K		1.2	TR	0.1					13.8				100	81	89	38	133	7.8	8.1
821913	5K		1.0	0.1	TR					10.3				100	86	90	28	98	7.8	8.2

SAMPLE NO.	HZN NO.	TOTAL ANALYSIS CLAY K2O 6Q3A	TOTAL ANALYSIS CLAY Fe 6C7A	MINERALOGY CLAY X-RAY 7A2I	MINERALOGY CLAY X-RAY 7B2I	MINERALOGY CLAY X-RAY <2U 7A2I	MINERALOGY CLAY X-RAY <2U 7B2I	MINERALOGY CLAY DTA <2U 7A3	MINERALOGY CLAY DTA <2U 7A3	TOTAL POR RES HEATH 7B1A	TOTAL POR RES HEATH 7B1A
		<- - - - - - -	PCT - - - - - - ->	<- RELATIVE AMOUNTS ->				<- - - -	-PCT	- - ->	
821909	1	0.2	5.1	HT 5	CA 1						
821910	2	0.1	5.0	HT 5	CA 2						
821911	3	0.1	4.4	HT 5	CA 2						
821912	4	0.1	4.9	HT 5	CA 2						
821913	5	0.1	3.3	HT 5	CA 3						

FAMILY CONTROL SECTION: DEPTH 25-100 PCT CLAY 18 PCT .1-75MM 57

ANALYSES: S= ALL ON SIEVED <2MM BASIS K= CACO3 ON 20-2 AND <2MM FRACTION

MINERALOGY: KIND OF MINERAL BY MONTHORILL CA CALCITE

RELATIVE AMOUNT 6 INDETERMINATE 5 DOMINANT 4 ABUNDANT 3 MODERATE 2 SMALL 1 TRACE

Series: Hin Kong
Pedon No: S82FN-875-011 Date: 3/83
Taxonomy: Fine-silty, siliceous, isohyperthermic Typic Paleaquults.
Location: 8 km from Saraburi to A. Nong Kae. Saraburi Province, Muang district.
Physiography: Terrace in river valley semi-recent
Geomorphic Position:
Slope and Aspect: 1 pct planar Elevation:
Air Temp. 27 C Summer: Winter:
Precipitation: 220 cm Aquic moisture regime.
Water Table: Not observed
Drainage: Poorly drained Permeability: Slow
Stoniness:
Land Use: Cropland-paddy rice
Erosion: None
Parent Material: Alluvium
Described by: W. Silicheuchu, C. Changprai, M. Singhavara

Ap 0 - 11 cm Pinkish gray (5YR 6/2) silt loam, pinkish gray (5YR 6/2, dry); common fine distinct yellowish brown (10YR 5/6) mottles; moderate medium to coarse subangular blocky structure; hard, friable, slightly sticky; slightly plastic; many very fine to fine roots; many very fine to fine interstital pores; pH=5.5, strongly acid; clear smooth boundary.
82P1914

BA 11 - 29 cm Pinkish gray (5YR 6/2) silt loam, pinkish gray (5YR 7/2, dry); many fine distinct brown to dark brown (7.5YR 4/4) and common fine distinct strong brown (7.5YR 5/6) mottles; weak coarse subangular blocky structure; hard, friable, slightly sticky; slightly plastic; some thick continuous clay skins in channels and pores; a few fine roots; common very fine to fine interstital and common very fine to fine vesicular pores; pH=5.0, strongly acid; gradual smooth boundary.
82P1915

Bt1 29 - 58 cm Pinkish gray (7.5YR 7/2) silt loam, pinkish gray (5YR 7/2, dry); common fine distinct strong brown (7.5YR 5/6) mottles; weak coarse subangular blocky structure; hard, friable, slightly sticky; slightly plastic; some thick continuous clay skins in channels and pores; a few very fine to fine interstital pores; pH=5.5, strongly acid; gradual smooth boundary.
82P1916

Bt2 58 - 120 cm Pinkish gray (7.5YR 6/2) silty clay loam, pinkish gray (5YR 7/2, dry); many fine distinct dark brown (10YR 3/3) mottles; structureless; hard, friable, sticky; plastic; many thick continuous clay skins in channels and pores and a few thick patchy clay skins on faces of peds; pH=5.0, strongly acid; gradual smooth boundary.
82P1917

Bt3 120 - 180 cm Silty clay loam; gray (5YR 5/1, rubbed); common fine distinct strong brown (7.5YR 5/6) mottles; sturctureless; a few iron concretions; pH=5.0, strongly acid.
82P1918 Sampled by auger.

HIN KONG

CLASSIFICATION: FINE-SILTY, SILICEOUS, ISOHYPERTHERMIC TYPIC PALEAQUULT

S 82PH-875 -011 SAMPLE NOS. 82P1914 - 1918 DATE REVISED APRIL 1983

U. S. DEPARTMENT OF AGRICULTURE
SOIL CONSERVATION SERVICE
NATIONAL SOIL SURVEY LABORATORY
LINCOLN, NEBRASKA

THAILAND

GENERAL METHODS 1B1A, 2A1, 2B

-1- -2- -3- -4- -5- -6- -7- -8- -9- -10- -11- -12- -13- -14- -15- -16- -17- -18- -19- -20-

SAMPLE NO.	HZN NO.	DEPTH (CM)	HORIZON	TOTAL CLAY LT .002	TOTAL SILT .002 -.05	TOTAL SAND .05 -2	TOTAL FINE LT .0002	CLAY CO3 LT .002	SILT FINE .002 -.02	SILT COARSE .02 -.05	SAND VF .05 -.10	SAND F .10 -.25	SAND M .25 -.50	SAND C .5 -1	SAND VC 1 -2	COARSE FRACTIONS (MM) HEIGHT 2 -5	5 -20	20 -75	>2MM .1- 75	PCT OF WHOLE SOIL
				<- - - - - - - - - - - - - PCT OF <2MM							(3A1) - - - - - - - - - - - - -					<- PCT OF <75MM (3B1) ->				
821914	15	0- 11	AP	9.0	84.6	6.4	4.1		64.7	19.9	4.1	1.2	0.6	0.5	—	—	—	—	2	—
821915	25	11- 29	BA1	17.1	77.8	5.1	10.6		61.4	16.4	2.9	1.1	0.6	0.5	—	—	—	—	2	—
821916	35	29- 58	BT1	11.7	84.6	3.7	4.9		65.5	19.1	2.1	0.5	0.4	0.4	0.3	—	—	—	2	—
821917	45	58-120	BT2	22.3	75.6	2.1	12.6		64.6	11.0	1.0	0.4	0.4	0.3	—	—	—	—	1	—
821918	55	120-180	BT3	21.5	75.4	3.1	10.5		62.0	13.4	1.1	0.5	0.5	0.6	0.4	TR	TR	—	2	—

SAMPLE NO.	HZN NO.	ORGN C 6A1C	TOTAL N 6B3A	EXTR P	TOTAL S 6E3A	EXTRACTABLE FE 6C2B	AL 6G7A	MN 6D2A	CEC 8D1	15 BAR 8D1	LIMITS LL 4F1	PI 4F	BULK DENSITY FIELD MOIST 4A3A	1/3 BAR 4A1D	OVEN DRY 4A1H	COLE WHOLE SOIL 4D1	FIELD MOIST 4B4	1/10 BAR 4B3C	1/3 BAR 4B1C	15 BAR 4B2A	WHOLE SOIL 4C1
		<- - - - - - - PCT OF <2MM - - - - - - - ->									PCT <0.4MM		<- - G/CC - - ->			CM/CM	<- - - PCT OF <2MM - ->				CM/CM
821914	1	0.82				0.1	TR	—	0.36	0.49	31	5		1.28	1.30	0.005			27.3	4.4	0.29
821915	2	0.30				0.2	TR	TR	0.26	0.45				1.50	1.55	0.011			20.1	7.7	0.19
821916	3	0.16				0.2	TR	—	0.23	0.40	28	6		1.60	1.63	0.006			18.4	4.7	0.22
821917	4	0.16				0.1	TR	TR	0.22	0.38				1.61	1.65	0.008			17.6	6.5	0.15
821918	5	0.14				0.2	TR	—	0.23	0.40	25	6								8.5	

SAMPLE NO.	HZN NO.	NH4OAC EXTRACTABLE BASES CA 5B5A 6N2E	MG 5B5C 6Q2D	NA 5B5A 6P2B	K 5B5A 6Q2B	SUM BASES	ACID- ITY 6H5A	EXTR AL 6G9A	CEC SUM CATS 5A3A	NH4- OAC 5A8B	BASES + AL 5A2B	AL SAT 5G1	BASE SUM 5C3	SAT- NH4 OAC 5C1	CO3 AS CACO3 <2MM 6M1G	RES. OHMS /CM 8B1	SURFACE AREA EGME 7D2 MG/G	EGME 7D2 M2/G	PH CACL2 .01M 8C1F	H2O 8C1F
		<- - - - - - - - - - - - - - MEQ / 100 G - - - - - - - - - - - - - ->										<- - - - PCT - - - ->							1:2	1:1
821914	1	1.4	.2	TR	0.1	1.7	2.3	0.3	4.0	3.2	2.0	15	42	53			9	32	4.6	5.1
821915	2	2.1	.3	0.1	TR	2.5	3.2	0.4	5.7	4.4	2.9	14	44	57			10	35	4.6	5.2
821916	3	0.9	TR	0.2	TR	1.1	1.8	0.7	2.9	2.7	1.8	39	38	41			10	35	4.2	5.1
821917	4	0.7	—	0.6	0.1	1.4	4.2	2.2	5.6	5.0	3.6	61	25	28		15000	13	46	3.9	5.1
821918	5	0.5	TR	0.6	0.1	1.2	4.4	2.4	5.6	5.0	3.6	67	21	24			13	46	3.8	4.8

SAMPLE NO.	HZN NO.	TOTAL ANALYSIS 7C3 CLAY K2O 6Q3A	Fe 6C7A	MINERALOGY CLAY X-RAY <2U 7A2X	7A2I	7A2X	7A2I	DTA 7A3	DSC 7A3	TOTAL DOM RES 7B1A	WEATH 7B1A
		<- - - - - - - PCT - - - - - - ->		<- RELATIVE AMOUNTS ->				<- - - - PCT - - - ->			
821914	1	1.8	0.5	KK 3	HI 2	MT 1	QZ 1			98	FK 2
821915	2										
821916	3	2.6	2.3	KK 3	HI 3	MT 1	QZ 1	KK15		98	FK 2
821917	4									97	FK 2
821918	5	2.8	2.2	KK 3	HI 3	MT 1	QZ 1	KK21			

FAMILY CONTROL SECTION: DEPTH 58 - 108 PCT CLAY 22 PCT .1-75MM 1

ANALYSES: S= ALL ON SIEVED <2MM BASIS

MINERALOGY: KIND OF MINERAL KK KAOLINITE HI MICA MT MONTMORILL QZ QUARTZ FK POTAS-FELD

RELATIVE AMOUNT 6 INDETERMINATE 5 DOMINANT 4 ABUNDANT 3 MODERATE 2 SMALL 1 TRACE

Series: Saraburi
Pedon No: S82PN-875-012 Date: 3/83
Taxonomy: Fine, mixed, isohyperthermic Aeric Tropaqualfs.
Location: 1 km from A. Nong Kae to Saraburi. Saraburi Province, Mong Kae District, Kak Yai area.
Physiography: Terrace in river valley, semi-recent
Geomorphic Position:
Slope and Aspect: 0 pct planar Elevation:
Air Temp. 27 C Summer: Winter:
Precipitation: 120 cm Aquic moisture regime.
Water Table: Not observed
Drainage: Poorly drained Permeability: Slow Stoniness:
Land Use: Cropland-paddy rice
Erosion or Deposition: None
Parent Material: Alluvium
Described by: W. Silicheuchu, C. Changprai

Apg 0 - 13 cm Brown (10YR 5/3) silt loam, light brownish gray (10YR 6/2, dry); many medium distinct strong brown (7.5YR 5/6) mottles; weak medium to coarse subangular blocky structure; hard, firm, slightly sticky; slightly plastic; many fine roots and common medium roots; common fine interstital and common fine vesicular pores; pH=4.5, extremely acid; clear smooth boundary.
82P1919

BAg 13 - 32 cm Grayish brown (10YR 5/2) clay loam, pinkish gray (7.5YR 6/2, dry); common medium prominent yellowish red (5YR 4/6) mottles; moderate coarse angular blocky structure; extremely hard, firm, slightly sticky; slightly plastic; some thin clay skins in channels and pores; a few fine roots; pH=5.0, strongly acid; gradual smooth boundary.
82P1920

Btg1 32 - 57 cm Light brownish gray (10YR 6/2) heavy clay loam; common medium prominent strong brown (7.5YR 5/8) and common fine prominent yellowish red (5YR 4/6) mottles; moderate coarse angular blocky parting to moderate fine to medium subangular blocky structure; very hard, firm, slightly sticky; plastic; some thin patchy clay skins on faces of peds and some thin patchy clay skins in channels and pores; a few very fine roots; pH=5.0, strongly acid; gradual smooth boundary.
82P1921

Btg2 57 - 94 cm Pinkish gray (7.5YR 6/2) clay; many medium distinct strong brown (7.5YR 5/8) and common fine prominent yellowish red (5YR 5/6) mottles; strong coarse angular blocky parting to strong medium subangular blocky structure; hard, firm, sticky; plastic; common thick patchy clay skins in channels and pores; a few very fine roots; pH=5.5, strongly acid; gradual smooth boundary.
82P1922

Btg3 94 - 115 cm Light brownish gray (10YR 6/2) clay; many medium distinct strong brown (7.5YR 5/6) and common fine prominent red (2.5YR 4/7) mottles; strong coarse angular blocky structure; hard, firm, sticky; plastic; some thin patchy clay skins in channels and pores; some slickensides; a few fine iron-manganese concretions; pH=6.0, slightly acid; gradual smooth boundary.
82P1923 Sickensides are close enough to intersect.

Btg4 115 - 170 cm Light gray to gray (10YR 6/1) clay; many coarse prominent red (2.5YR 4/6) and many medium distinct yellowish brown (10YR 5/6) mottles; strong very coarse angular blocky structure; firm, sticky; plastic; some thin patchy clay skins in channels and pores and some slickensides; common iron concretions; pH=6.5, slightly acid.
82P1924

SARABURI

CLASSIFICATION: FINE, MIXED, ISOHYPERTHERMIC ARIC TROPAQUALF

S 82PH-875 -012 SAMPLE NOS. 82P1919 - 1924 REVISED DATE APRIL 1983

THAILAND

GENERAL METHODS 1B1A, 2A1, 2B

U. S. DEPARTMENT OF AGRICULTURE
SOIL CONSERVATION SERVICE
NATIONAL SOIL SURVEY LABORATORY
LINCOLN, NEBRASKA

-1- -2- -3- -4- -5- -6- -7- -8- -9- -10- -11- -12- -13- -14- -15- -16- -17- -18- -19- -20-

SAMPLE NO.	HZN NO.	DEPTH (CM)	HORIZON	TOTAL CLAY LT .002	TOTAL SILT .002 -.05	TOTAL SAND .05 -2	TOTAL FINE .0002	CLAY CO3 LT .002	SILT FINE .002 -.02	SILT COARSE .02 -.05	SAND VF .05 -.10	SAND F 7.10 -.25	SAND M .25 -.50	SAND C .5 -1	SAND VC 1 -2	COARSE FRACTIONS (MM) WEIGHT 2 -5	5 -20	20 -75	>2MM .1-75	WT PCT OF WHOLE SOIL
				<- PCT OF <2MM												<- PCT OF <75MM (3B1) ->				
821919	15	0- 13	APG	22.5	66.6	10.9	14.6		43.3	23.3	7.6	2.6	0.2	0.2	0.3	TR	—	—	3	—
821920	25	13- 32	BAG	21.9	64.9	13.2	12.8		42.5	22.4	7.3	3.1	0.8	1.6	0.4	TR	—	—	6	—
821921	35	32- 57	BTG1	26.4	57.3	16.3	14.9		38.7	18.6	9.7	4.2	0.5	0.6	1.3	2	TR	—	8	2
821922	45	57- 94	BTG2	47.7	54.7	7.6	30.2		30.6	14.1	4.6	2.1	0.3	0.3	0.3	TR	—	—	3	TR
821923	55	94-115	BTG3	46.5	45.9	7.6	29.4		32.3	13.6	4.1	1.9	0.5	0.4	0.7	TR	—	—	3	—
821924	65	115-170	BTG4	50.0	44.9	5.1	27.7		34.4	10.5	3.1	1.3	0.3	0.3	0.1	TR	—	—	2	—

SAMPLE NO.	HZN NO.	ORGN C 6A1C	TOTAL N 6B3A	NITR P	TOTAL S 6B3A	DITH-CIT EXTRACTABLE FE 6C2B	AL 6G7A	MN 6D2A	RATIO/CLAY CEC 8D1	BAR 8D1	ATTERBERG LIMITS LL 4F1	PI 4F	BULK DENSITY FIELD MOIST 4A3A	1/3 BAR 4A1D	OVEN DRY 4A1H	COLE WHOLE SOIL 4D1	WATER CONTENT FIELD MOIST 4B4	1/10 BAR 4B1C	1/3 BAR 4B1C	15 BAR 4B2A	HRD WHOLE SOIL 4C1
		<- PCT OF <2MM									PCT <0.4MM		<- G/CC			CM/CM	<- PCT OF <2MM				CM/CM
821919	1	0.98	0.079			1.2	0.1	TR	0.53	0.43	33	12		1.33	1.42	0.022			28.1	9.7	0.24
821920	2	0.64	0.048			1.3	0.1	TR	0.52					1.47	1.54	0.016			25.0		
821921	3	0.55	0.045			2.1	0.2	0.1	0.47	0.42	32	13		1.52	1.60	0.017			22.5	11.2	0.17
821922	4	0.33	0.044			2.1	0.2	0.1	0.43	0.38				1.42	1.80	0.082			26.8	18.3	0.12
821923	5	0.28				2.2	0.1	0.1	0.46	0.38	53	34		1.56	1.84	0.057			23.3	17.7	0.09
821924	6	0.15				2.3	0.1	TR	0.48	0.37				1.57	1.88	0.062			23.7	18.3	0.08

SAMPLE NO.	HZN NO.	NH4OAC EXTRACTABLE BASES CA 5B5A 6N2B	MG 5B5A 6Q2D	NA 5B5A 6P2B	K 5B5A 6Q2B	SUM BASES	ACID- ITY 6H5A	NITR AL 6G9A	CEC SUM CATS 5A3A	NH4- OAC 5A8B	BASES + AL 5A3B	AL SAT 5G1	BASE SUM 5C3	SAT- NH4 OAC 5C1	CO3 AS CACO3 <2MM 6E1G	BES. OBES /CM 8E1	SURFACE AREA EGME 7D2 MG/G	EGME 7D2 M2/G	PH CACL2 .01M 8C1F 1:2	PH H2O 8C1F 1:1
		<- MEQ / 100 G										<- PCT ->								
821919	1	4.4	2.2	0.2	0.1	6.9	7.8	1.3	14.7	11.9	8.2	16	47	58			24	84	4.3	4.7
821920	2	3.2	2.1	0.3	0.1	5.7	8.3	1.9	14.0	11.3	7.6	25	41	50			24	84	4.4	4.8
821921	3	2.7	2.6	0.5	0.1	5.9	8.6	2.4	14.5	12.3	8.3	29	41	48			27	94	4.3	4.9
821922	4	6.0	8.1	1.9	0.2	16.2	8.9	1.1	25.1	20.3	17.3	6	65	80			46	161	4.9	5.1
821923	5	5.8	9.8	2.6	0.2	18.4	6.9	0.5	25.3	21.4	18.9	3	73	86		1700	48	168	4.8	5.0
821924	6	6.6	12.2	3.6	0.2	22.6	5.9	0.2	28.5	24.2	22.8	1	79	93			50	175	5.1	5.1

SAMPLE NO.	HZN NO.	TOTAL ANALYSIS 7C3 CLAY K2O 6Q3A	Fe 6C7A	MINERALOGY CLAY X-RAY 7A2I	7A2I	7A2I	DTA CZU 7A2I	7A3	TOTAL 7A3	DOM NES 7B1A	WEATH 7B1A
		<- PCT		<- RELATIVE AMOUNTS ->					<- PCT		
821919	1	1.0	5.7	KK 8	MT 3	LM 1	GI 1	KK15			
821920	2	1.1	4.5	KK 3	MT 3	MI 1	QZ 1	KK20			
821921	3	1.1	5.6	KK 3	MT 2	MI 1	QZ 1	KK17			
821922	4	1.1	5.3	KK 4	MT 3	MI 1	QZ 1	KK37			
821923	5	1.2	5.1	KK 3	MT 3	MI 1	QZ 1	KK32			
821924	6	1.2	5.9	KK 3	MT 3	MI 1	QZ 1	KK32			

FAMILY CONTROL SECTION: DEPTH 32- 82 PCT CLAY PCT .1-75MM 6

ANALYSES: S= ALL ON SIEVED <2MM BASIS

MINERALOGY: KIND OF MINERAL KK KAOLINITE MT MONTMORILL LM LEPIDOCROCIT MI MICA QZ QUARTZ
GE GOETHITE

RELATIVE AMOUNT 6 INDETERMINATE 5 DOMINANT 4 ABUNDANT 3 MODERATE 2 SMALL 1 TRACE

Series: Rangsit
Pedon No: S82PN-875-013 Date: 3/83
Taxonomy: Fine, mixed, acid, isohyperthermic Sulfic Tropaquepts.
Location: Ayutthaya Province, Wang Nai District.
Physiography: Old tidal flat
Geomorphic Position:
Slope and Aspect: 0 pct planar Elevation:
Air Temp. 27 C Summer: Winter:
Precipitation: 140 cm Aquic moisture regime.
Water Table: 127 cm Apparent
Drainage: Poorly drained Permeability: Slow
Stoniness:
Land Use: Cropland-paddy rice
Erosion or Deposition: None
Parent Material: Brackish water deposit
Described by: W. Silicheuchu, C. Changprai

Apg 0 - 11 cm Very dark gray (10YR 3/1) clay, dark gray (10YR 4/1, dry); many fine distinct strong brown (7.5YR 5/8) mottles; strong very coarse subangular blocky structure; extremely hard, very firm, sticky; plastic; many very fine to fine roots; pH=4.5, extremely acid; clear smooth boundary.
82P1925 Stress faces at boundary.

Ag 11 - 27 cm Very dark grayish brown (10YR 3/2) clay, dark gray (10YR 4/1, dry); common fine distinct strong brown (7.5YR 5/8) mottles; strong very coarse subangular blocky structure; extremely hard, very firm, sticky; plastic; common fine roots; pH=4.0, extremely acid; clear wavy boundary.
82P1926

ABg 27 - 45 cm Red (10R 4/8) and strong brown (7.5YR 5/8) clay; common medium prominent dark gray (10YR 4/1) and common fine distinct pinkish gray (7.5YR 6/2) mottles; moderate coarse subangular blocky parting to strong medium subangular blocky structure; extremely hard, firm, sticky; plastic; a few fine roots; pH=4.0, extremely acid; gradual smooth boundary.
82P1927

Bg1 45 - 65 cm Pinkish gray (7.5YR 6/2) clay; many coarse prominent red (10R 4/8) and common fine distinct strong brown (7.5YR 5/8) mottles; moderate medium to coarse subangular blocky parting to weak fine subangular blocky structure; hard, friable, sticky; plastic; a few fine roots; pH=4.0, extremely acid; gradual smooth boundary.
82P1928 Few Jarosite mottles (2.5Y 7/6) at 55 cm.

Bg2 65 - 110 cm Pinkish gray (7.5YR 6/2) clay; common coarse prominent light red (10R 6/8) and common medium distinct strong brown (7.5YR 5/8) mottles; moderate fine to medium subangular blocky structure; friable, sticky; plastic; pH=4.0, extremely acid; gradual smooth boundary.
82P1929 Common Jarosite mottles (2.5Y 7/6)

Bg3 110 - 127 cm Brown (7.5YR 5/2) clay; many medium distinct brownish yellow (10YR 6/8) and common medium distinct yellow (10YR 7/6) mottles; moderate fine to medium subangular blocky structure; sticky; plastic; pH=4.0, extremely acid; gradual smooth boundary.
82P1930 Common Jarosite mottles (2.5Y 7/6)

BCg 127 - 150 cm Brown (7.5YR 5/2) and light brownish gray (10YR 6/2) clay; structureless; sticky; plastic; pH=4.0, extremely acid.
82P1931 Common Jarosite mottles (2.5Y 7/6)

BANGSIT

CLASSIFICATION: FINE, MIXED, ACID, ISOHYPERTHERMIC SULFIC TROPAQUEPT

S 82PH-875 -012 SAMPLE NOS. 82P1925 - 1931 REVISED FORM APRIL 1983

THAILAND

GENERAL METHODS 1B1A, 2A1, 2B

U. S. DEPARTMENT OF AGRICULTURE
SOIL CONSERVATION SERVICE
NATIONAL SOIL SURVEY LABORATORY
LINCOLN, NEBRASKA

-1- -2- -3- -4- -5- -6- -7- -8- -9- -10- -11- -12- -13- -14- -15- -16- -17- -18- -19- -20-

SAMPLE NO.	HZN NO.	DEPTH (CM)	HORIZON	TOTAL CLAY LT .002	TOTAL SILT .002 -.05	TOTAL SAND .05 -2	CLAY FINE LT .0002	CLAY CO3 LT .002	SILT FINE .002 -.02	SILT COARSE .02 -.05	SAND VF .05 -.10	SAND F .10 -.25	SAND M .25 -.50	SAND C .5 -1	SAND VC 1 -2	COARSE FRACTIONS (MM) HEIGHT 2 -5	5 -20	20 -75	>2MM .1-75	WT PCT OF WHOLE SOIL
				<- PCT OF <2MM							(3A1)				->	<- PCT OF <75MM (3B1) ->				
821925	1S	0- 11	APG	66.7	31.8	1.5	37.4		27.1	4.7	1.0	0.4	0.1	—	—	—	—	—	TR	—
821926	2S	11- 27	AG	65.2	32.3	2.5	36.2		27.3	5.0	1.5	0.8	0.2	—	—	—	—	—	1	—
821927	3S	27- 45	AB2	57.4	38.6	4.0	32.6		33.8	4.8	1.5	1.5	0.7	0.3	—	—	—	—	2	—
821928	4S	45- 65	BG1	56.1	32.0	11.9	34.0		27.6	4.4	2.3	1.1	2.5	2.6	1.4	—	—	—	10	—
821929	5S	65-110	BG2	61.6	34.1	4.3	37.8		29.1	4.9	1.0	1.0	0.8	0.8	0.7	—	—	—	3	—
821930	6S	110-127	BG3	56.8	37.1	6.1	33.8		30.8	6.3	1.7	1.6	1.3	1.1	0.4	—	—	—	4	—
821931	7S	127-150	BCG	53.6	44.1	2.3	36.0		32.9	12.2	1.6	0.6	0.1	—	—	—	—	—	1	—

SAMPLE NO.	HZN NO.	ORGN C 6A1C	TOTAL N 6D1A	EXTR P	TOTAL S 6H3A	DITH-CIT EXTRACTABLE FE 6C2B	AL 6G7A	MN 6D2A	CEC 8D1	RATIO/CLAY .5 BAR 8D1	ATTERBERG LIMITS LL 4F1	PI 4F	BULK DENSITY FIELD MOIST 4A3A	1/3 BAR 4A1D	OVEN DRY 4A1H	COLE WHOLE SOIL 4D1	WATER CONTENT FIELD MOIST 4B4	1/10 BAR 4B1C	1/3 BAR 4B1C	15 BAR 4B2A	WRD WHOLE SOIL 4C1
		<- PCT OF <2MM									PCT	<0.4MM	<- G/CC			CM/CM	<- PCT OF <2MM				CM/CM
821925	1	3.49	0.208		0.4	1.6	0.2	—	0.43	0.39	56	25		1.30	1.64	0.081			33.2	26.1	0.09
821926	2	2.00	0.171		0.5	1.0	0.4	TR	0.47	0.38				1.25	1.55	0.074			33.4	24.5	0.11
821927	3	0.91	0.095		0.2	1.5	0.3	—	0.43	0.39	56	28		1.34	1.66	0.074			30.9	22.2	0.12
821928	4	0.43	0.051		0.1	8.5	0.4	—	0.39	0.40				1.32	1.69	0.086			32.7	22.4	0.14
821929	5	0.45	0.044		0.3	3.4	0.3	—	0.38	0.40	61	35		1.16	1.71	0.138			41.7	24.4	0.20
821930	6	0.97	0.051		0.5	4.5	0.2	—	0.40	0.44				0.95	1.57	0.182			59.8	25.0	0.33
821931	7	2.79	0.066		0.3	0.1	0.2	—	0.47	0.41	55	28		0.96	1.65	0.198			60.0	22.2	0.36

SAMPLE NO.	HZN NO.	NH4OAC EXTRACTABLE BASES CA 5B5A 6N2B	MG 5B5A 6Q2D	NA 5B5A 6P2B	K 5B5A 6Q2D	SUM BASES	ACIDITY 6H5A	EXTRAL 6G9A	SUM CATS 5A3A	VSA-OAC 5A6B	EXCH NA 5D2	SAR 5E	BASE SATURATION SUM NH4OAC 5C3	5C1	CO3 AS CACO3 <2MM 6E1G	NHS. OHMS /CM 8N1	CASO4 AS GYPSUM <2MM 6P1A	<20MM 6P4	PH SAT PASTE 8C1B	CACL2 .01M 8C1F 1:2	H2O 8C1F 1:1
		<- MEQ / 100 G									->		<- PCT- >		PCT		<- PCT ->				
821925	1	9.4	6.3	1.0	0.5	17.2	24.5	4.2	41.7	28.8	2	2	41	60			—		4.4	4.2	4.3
821926	2	4.7	4.1	0.9	0.4	10.1	33.4	11.4	43.5	30.6	2	2	23	33			—		3.9	3.9	4.2
821927	3	3.4	3.3	0.7	0.3	7.7	27.8	13.7	35.5	24.8	3	2	22	31			—		3.7	3.6	3.7
821928	4	3.0	3.5	0.6	0.4	7.5	27.5	12.9	35.0	22.0	1	2	21	34			—		3.4	3.4	3.4
821929	5	2.8	3.4	0.8	0.4	7.4	26.6	13.9	34.0	23.6	1	2	22	31		900	—		3.3	3.3	3.3
821930	6	2.6	3.6	1.0	0.3	7.5	26.9	11.9	34.4	22.7	2	3	22	33			—		3.3	3.3	3.2
821931	7	3.0	3.5	1.1	0.3	7.9	28.5	13.7	36.4	25.4	2	3	22	31			—		3.5	3.4	3.3

SAMPLE NO.	HZN NO.	WATER EXTRACTED FROM SATURATED PASTE CA 6B1B	MG 6D1B	NA 6P1B	K 6Q1B	CO3	HCO3	CL 6K1C	SO4 6L1C	NO3 6M1C	H2O 8A	TOTAL SALTS EST. 8D5	ELEC. COND. 8A3A MMHOS /CM	MINERALOGY CLAY X-RAY <2U 7A2I	7A2I	7A2I	(-, -DTA -) (- -<2U - -) 7A3	7A3	TOT ANL CLAY K2O 6Q3A	Fe 6C7A
		<- MEQ / LITER									->	<- PCT ->		<- RELATIVE AMOUNTS ->			<- PCT			->
821925	1	12.5	10.2	5.8	0.2	—	TR	1.7	31.9	—	71.2	0.1	2.53	KK 3	HT 2	HI 1		KK44	1.2	3.2
821926	2	9.8	9.9	5.5	0.1	—	—	1.3	27.7	—	69.0	0.1	2.20							
821927	3	7.9	8.5	5.1	0.1	—	—	1.2	24.8	1.2	—	TR	1.93	KK 3	HT 2	HI 2		KK43	1.6	3.0
821928	4	8.1	9.4	5.5	0.5	—	—	1.3	28.9	1.2	68.7	0.1	2.20	HT 4	KK 4	HI 3	GE 1	KK41	1.8	6.2
821929	5	7.6	9.3	6.2	0.5	—	—	1.4	30.4	—	75.7	0.1	2.30	KK 3	HT 3	HI 2		KK39	1.7	4.4
821930	6	9.0	14.0	8.7	0.4	—	—	2.7	41.4	—	74.0	0.2	3.12	KK 3	HT 3	HI 2		KK39	1.4	4.5
821931	7	11.9	17.0	9.7	0.4	—	—	2.8	51.8	—	66.1	0.2	3.55	KK 3	HT 3	HI 2		KK46	1.2	2.1

FAMILY CONTROL SECTION: DEPTH 25-100 PCT CLAY 59 PCT .1-75MM 5

ANALYSES: S= ALL ON SIEVED <2MM BASIS

MINERALOGY: KIND OF MINERAL KK KAOLINITE HT MONTMORILL HI MICA GE GOETHITE

RELATIVE AMOUNT 6 INDETERMINATE 5 DOMINANT 4 ABUNDANT 3 MODERATE 2 SMALL 1 TRACE

Series: Tha Muang
Pedon No: S82PN-875-014 Date: 3/83
Taxonomy: Coarse-loamy, mixed (calcareous), isohyperthermic Typic Ustifluvents.
Location: West Pond of Agricultural Extension. Ratchaburi Province, Ban Phong District.
Physiography: Floodplain in river valley
Geomorphic Position: On the crest
Slope and Aspect: 2 pct convex Elevation:
Air Temp. 27 C Summer: Winter:
Precipitation: 125 cm Ustic moisture regime.
Water Table: Not observed
Drainage: Well drained Permeability: Rapid Stoniness:
Land Use: Cropland
Erosion or Deposition: Slightly eroded
Parent Material: Alluvium
Described by: W. Silicheuchu, C. Changprai, C. Manotham, C. Niamskul

A 0 - 28 cm Yellow (10YR 7/6) fine sandy loam, dark yellowish brown (10YR 4/4, moist); weak very coarse subangular blocky parting to weak fine to medium subangular blocky structure; hard, friable, non-sticky; non-plastic; common fine roots; strongly effervescent; pH=8.0, moderately alkaline; clear smooth boundary.
82P1932 Common flakes of mica.

AC 28 - 53 cm Brownish yellow (10YR 6/6) loamy sand, dark yellowish brown (10YR 4/4, moist); weak very coarse subangular blocky parting to weak fine to medium subangular blocky structure; soft, friable, non-sticky; non-plastic; a few very fine to fine roots and a few coarse roots; strongly effervescent; pH=8.0, moderately alkaline; gradual smooth boundary.
82P1933 Common flakes of mica.

C1 53 - 73 cm Very pale brown (10YR 7/4) loamy sand, yellowish brown (10YR 5/4, moist); weak very coarse subangular blocky parting to weak fine to medium subangular blocky structure; soft, friable, non-sticky; non-plastic; common fine roots and a few; strongly effervescent; pH=8.0, moderately alkaline; clear wavy boundary.
82P1934 Common flakes of mica.

C2 73 - 84 cm Yellowish brown (10YR 5/4) sand, dark yellowish brown (10YR 4/4, moist); loose, non-sticky; non-plastic; common fine roots and a few medium roots; strongly effervescent; pH=8.0, moderately alkaline; clear smooth boundary.
82P1935 Common flakes of mica.

C3 84 - 155 cm Brownish yellow (10YR 6/6) loamy sand, yellowish brown (10YR 5/6, moist); weak fine to medium subangular blocky structure; very friable, non-sticky; non-plastic; a few fine roots and a few; strongly effervescent; pH=8.0, moderately alkaline; gradual smooth boundary.
82P1936 Common flakes of mica.

C4 155 - 200 cm loamy sand, brownish yellow (10YR 6/6, moist); weak medium to coarse subangular parting to structureless; very friable, non-sticky; non-plastic; a few fine roots and a few; strongly effervescent; pH=8.0, moderately alkaline.
82P1937 Common flakes of mica.

THA HUANG

CLASSIFICATION: COARSE-LOAMY, MIXED (CALCAREOUS), ISOHYPERTHERMIC TYPIC USTIFLUVENT

S 82PH-875 -014 SAMPLE NOS. 82P1932 - 1937 DATE REVISED APRIL 1983

U. S. DEPARTMENT OF AGRICULTURE
SOIL CONSERVATION SERVICE
NATIONAL SOIL SURVEY LABORATORY
LINCOLN, NEBRASKA

THAILAND

GENERAL METHODS 1B1A, 2A1, 2B

-1- -2- -3- -4- -5- -6- -7- -8- -9- -10- -11- -12- -13- -14- -15- -16- -17- -18- -19- -20-

SAMPLE NO.	HZN NO.	DEPTH (CM)	HORIZON	TOTAL CLAY LT .002	TOTAL SILT .002 -.05	TOTAL SAND .05 -2	TOTAL FINE LT .0002	CLAY CO3 LT .002	SILT FINE .002 -.02	SILT COARSE .02 -.05	SAND VF .05 -.10	SAND F .10 -.25	SAND M .25 -.50	SAND C .5 -1	SAND VC 1 -2	COARSE FRACTIONS (MM) HEIGHT 2 -5	5 -20	20 -75	.1- 75	(>2MM) WT PCT OF WHOLE SOIL
				<- - - - - - - - - - - - PCT OF <2MM							(3A1)	- - - - - - - - - - -				<- PCT OF <75MM (3B1) ->				SOIL
821932	1S	0- 28	A	11.9	35.4	52.7			10.3	25.1	40.8	11.6	0.3	—	—	—	—	—	12	—
821933	2S	28- 53	A2	9.4	22.8	67.8		TR	8.1	14.7	43.7	23.8	0.3	—	—	—	—	—	24	—
821934	3S	53- 73	C1	6.9	16.4	76.7			4.1	12.3	33.7	41.1	1.8	0.1	—	—	—	—	43	—
821935	4S	73- 84	C2	4.0	7.1	88.9			2.8	4.3	18.6	66.2	3.9	0.2	—	—	—	—		—
821936	5S	84-155	C3	8.1	20.1	71.8			6.9	13.2	40.7	30.4	0.6	0.1	—	—	—	—	31	—
821937	6S	155-200	C4	6.5	15.7	77.8			3.6	12.1	32.3	34.5	9.6	1.1	0.3	TR	—	—	45	—

SAMPLE NO.	HZN NO.	ORGN C 6A1C	TOTAL N 6B3A	NITR TOTAL P	S 6H3A	DITH-CIT EXTRACTABLE FE 6C2B	AL 6G7A	MN 6D2A	CEC 8D1	RATIO/CLAY 15 BAR 8D1	ATTERBERG LIMITS LL 4F1	PI 4F	BULK DENSITY FIELD MOIST 4A3A	1/3 BAR 4A1D	OVEN DRY 4A1H	COLE WHOLE SOIL 4D1	WATER CONTENT FIELD MOIST 4B4	1/10 BAR 4B1C	1/3 BAR 4B1C	15 BAR 4B2A	WRD WHOLE SOIL 4C1
		<- - - - - - - PCT OF <2MM - - - - - - - ->									PCT <0.4MM		<- - G/CC - - ->			CM/CM	<- - -PCT OF <2MM - ->				CM/CM
821932	1	0.79	0.062			1.0	0.1	TR	0.59	0.46	24	1		1.38	1.42	0.010			18.8	5.5	0.13
821933	2	0.37	0.029			0.9	0.1	TR	0.53	0.49				1.35	1.37	0.005			10.6	4.6	0.08
821934	3	0.22	0.015			0.8	0.1	TR	0.52	0.49				1.34	1.36	0.005			9.0	3.4	0.08
821935	4	0.17				0.8	0.1	TR	0.60	0.65				1.33	1.35	0.005			6.9	2.6	0.06
821936	5	0.24				0.9	0.1	TR	0.51	0.52				1.34	1.35	0.002			12.5	4.2	0.11
821937	6	0.24				0.8	0.1	TR	0.55	0.62				1.44	1.44	--			12.8	4.0	0.13

SAMPLE NO.	HZN NO.	NH4OAC EXTRACTABLE BASES CA 5B5A 6P2E	MG 5D5A 6Q2D	NA 5B5A 6P2B	K 5B5A 6Q2B	SUM BASES	ACID-ITY 6H5A	EXTR AL 6G9A	SUM CATS 5A3A	CEC NH4-OAC 5A8B	BASES + AL 5A3B	AL SAT 5G1	BASE SUM 5C3	SAT-NH4 OAC 5C1	CO3 AS CACO3 <2MM 6E1G	RES. OHMS /CM 8H1	SURFACE AREA EGME 7D2 HG/G	EGME 7D2 M2/G	PH CACL2 .01M 8C1F 1:2	PH H2O 8C1F 1:1
		<- - - - - - - - - - - - - - - - MEQ / 100 G - - - - - - - - - - - - ->										<- - - - -PCT - - - ->								
821932	1		0.7	—	0.2					7.0				100	3		16	56	7.5	7.7
821933	2		0.8	—	0.1					5.0				100	4		14	49	7.5	8.1
821934	3		0.6	—	0.1					3.6				100	3		10	35	7.6	8.2
821935	4		0.5	—	0.1					2.4				100	3		8	28	7.6	8.2
821936	5		0.9	—	0.1					4.1				100	3	7400	12	42	7.6	8.2
821937	6		0.9	—	0.1					3.6				100	3		9	32	7.7	8.2

SAMPLE NO.	HZN NO.	MINERALOGY CLAY X-RAY 7A2I	7A2I	7A2I	7A2I	DTA 7A3	7A3	VFS TOTAL 7B1A	DOM MINS WEATH 7B1A
		<- RELATIVE AMOUNTS ->				<- - - - -PCT - - - ->			
821932	1								
821933	2							73	PK17
821934	3							72	PK16
821935	4							70	PK15
821936	5								
821937	6							79	PK13

FAMILY CONTROL SECTION: DEPTH 25-100 PCT CLAY -- PCT .1-75MM --

ANALYSES: S= ALL ON SIEVED <2MM BASIS

MINERALOGY: KIND OF MINERAL PK POTAS-FELD

Series: Kampaeng Saen
Pedon No: S82PN-875-015 Date: 3/83
Taxonomy: Fine-loamy, mixed, isohyperthermic Fluventic Ustropepts.
Location: Kanchanaburi Province, Tha Muang District, Mu Nong Sua area, Wang Sala Village
Physiography: Terrace in river valley
Geomorphic Position:
Slope and Aspect: 1 pct planar Elevation:
Air Temp. Summer: Winter:
Precipitation: Ustic moisture regime.
Water Table: Not observed
Drainage: Well drained Permeability: Moderately slow
Stoniness:
Land Use: Cropland-banana
Erosion or Deposition: None
Parent Material: Alluvium
Described by: W. Silicheuchu, C. Changprai, C. Manotham, C. Niamskul

Ap 0 - 17 cm Pale brown (10YR 6/3) clay loam, brown to dark brown (10YR 4/3, moist); moderate medium to coarse subangular blocky parting to moderate fine to medium granular structure; hard, friable, slightly sticky; slightly plastic; common fine roots and common coarse roots; common worm casts; strongly effervescent; pH=8.0, moderately alkaline; clear wavy boundary.
82P1938

AB 17 - 32 cm Pale brown (10YR 6/3) clay loam, brown to dark brown (10YR 4/3, moist); moderate fine to medium subangular blocky structure; hard, friable, slightly sticky; slightly plastic; common fine roots and common coarse roots; common worm casts; strongly effervescent; pH=8.0, moderately alkaline; clear smooth boundary.
82P1939 Scattered alluvial artifacts.

Bt1 32 - 65 cm Light yellowish brown (10YR 6/4) clay loam, yellowish brown (10YR 5/4, moist); moderate medium to coarse subangular blocky structure; hard, friable, slightly sticky; slightly plastic; some thin patchy clay skins in channels and pores; a few very fine to fine roots; common worm casts and a few iron concretions; strongly effervescent; pH=8.0, moderately alkaline; gradual smooth boundary.
82P1940

Bt2 65 - 90 cm Pale brown (10YR 6/3) light clay loam, yellowish brown (10YR 5/4, moist); moderate fine to medium subangular blocky structure; hard, friable, slightly sticky; slightly plastic; some thin patchy clay skins in channels and pores; common medium roots; a few iron concretions; strongly effervescent; pH=8.0, moderately alkaline; gradual smooth boundary.
82P1941

Bt3 90 - 122 cm Light yellowish brown (10YR 6/4) light clay loam, yellowish brown (10YR 5/5, moist); weak fine to medium subangular blocky structure; friable, slightly sticky; slightly plastic; some clay skins in channels and pores; a few iron concretions; strongly effervescent; pH=8.0, moderately alkaline; diffuse smooth boundary.
82P1942

BC1 122 - 138 cm Yellow (10YR 7/6) light clay loam, yellowish brown (10YR 5/6, moist); weak fine to medium subangular blocky structure; a few iron concretions; strongly effervescent; pH=8.0, moderately alkaline; clear smooth boundary.
82P1943

BC2 138 - 160 cm Sandy clay loam, yellowish brown (10YR 5/8, moist); weak fine to medium subangular blocky structure; strongly effervescent; pH=8.0, moderately alkaline.
82P1944

KANPANG SANN

CLASSIFICATION: FINE-LOAMY, MIXED, ISOHYPERTHERMIC FLUVENTIC USTROPEPT

S 82PH-875 -015 SAMPLE NOS. 82P1938 - 1944 DATE REVISED APRIL 1983

U. S. DEPARTMENT OF AGRICULTURE
SOIL CONSERVATION SERVICE
NATIONAL SOIL SURVEY LABORATORY
LINCOLN, NEBRASKA

THAILAND

GENERAL METHODS 1B1A, 2A1, 2B

-1- -2- -3- -4- -5- -6- -7- -8- -9- -10- -11- -12- -13- -14- -15- -16- -17- -18- -19- -20-

SAMPLE NO.	HZN NO.	DEPTH (CM)	HORIZON	TOTAL CLAY LT .002	TOTAL SILT .002 -.05	TOTAL SAND .05 -2	TOTAL FINE .0002	CLAY CO3 LT .002	SILT FINE .002 -.02	SILT COARSE .02 -.05	SAND VF .05 -.10	SAND F .10 -.25	SAND M .25 -.50	SAND C .5 -1	SAND VC 1 -2	COARSE FRACTIONS (MM) HEIGHT 2 -5	5 -20	20 -75	.1-75MM (.5B1)	PCT OF WHOLE SOIL
				<- PCT OF <2MM (3A1)												<- PCT OF <75MM (5B1) ->				
821938	1S	0- 17	AP	26.0	35.1	38.9	8.7	TR	19.4	15.7	18.5	14.2	3.0	2.2	1.0	1	TR	—	21	1
821939	2S	17- 32	AB	26.7	34.2	39.1	9.5		18.1	16.1	19.7	13.6	2.6	2.1	1.1	1	TR	—	20	1
821940	3S	32- 65	BT1	27.0	34.9	38.1	12.3	1	17.2	17.7	17.7	13.4	2.7	2.5	1.8	TR	—	—	20	TR
821941	4S	65- 90	BT2	25.5	33.3	41.2	8.6	1	17.7	15.6	19.2	13.7	3.1	2.5	2.7	2	—	—	24	2
821942	5S	90-122	BT3	21.4	32.1	46.5	7.4		15.6	16.5	22.1	16.0	3.8	2.9	1.7	2	1	—	27	3
821943	6S	122-138	BC1	15.5	25.9	58.6	6.5		12.2	13.7	22.9	18.3	6.7	6.0	4.7	7	12	8V	53	27
821944	7S	138-160	BC2	16.7	28.0	55.2	7.3		12.6	15.4	26.6	20.0	3.7	3.0	1.8	2	1	—	31	3

SAMPLE NO.	HZN NO.	ORGN C 6A1C	TOTAL N 6B3A	NITR P	TOTAL S 6B3A	DITH-CIT EXTRACTABLE FE 6C2B	AL 6G7A	MN 6D2A	RATIO/CLAY C/N 8D1	15 BAR 8D1	ATTERBERG LIMITS LL 4F1	PI 4F	BULK DENSITY FIELD MOIST 4A3A	1/3 BAR 4A1D	OVEN DRY 4A7B	COLE WHOLE SOIL 4D1	WATER CONTENT FIELD MOIST 4B4	1/10 BAR 4B1C	1/3 BAR 4B1C	15 BAR 4B2A	HZD WHOLE SOIL 4C1
		<- PCT OF <2MM ->									PCT <0.4MM		<- G/CC ->			CM/CM	<- PCT OF <2MM ->				CM/CM
821938	1	0.83	0.072			1.3	0.1	0.1	0.42	0.40	32	13		1.47	1.61	0.031			19.8	10.5	0.14
821939	2	0.56	0.057			1.3	0.1	0.1	0.42	0.40				1.45	1.56	0.025			19.3	10.6	0.13
821940	3	0.44	0.049			1.4	0.1	0.1	0.40	0.37				1.46	1.56	0.022			19.4	9.9	0.14
821941	4	0.41	0.043			1.2	0.1	0.1	0.44	0.39	29	11		1.39	1.48	0.021			19.3	9.9	0.13
821942	5	0.34				1.1	0.1	0.1	0.48	0.41				1.45	1.45	—			15.6	8.7	0.10
821943	6	0.22				1.1	0.1	0.1	0.48	0.42				1.53	1.58	0.009			15.6	6.5	0.12
821944	7	0.24				1.0	0.1	0.1	0.47	0.41	25	7		1.49	1.55	0.013			13.7	6.9	0.10

SAMPLE NO.	HZN NO.	NH4OAC EXTRACTABLE BASES CA 5B5A 6B2B	MG 5B5A 6G2D	NA 5B5A 6P2B	K 5B5A 6Q2B	SUM BASES	ACID-ITY 6H5A	EXTR AL 6G9A	SUM CATS 5A3A	CEC NH4-OAC 5A8B	BASES + AL 5A3B	AL SAT 5G1	BASE SUM 5C3	SAT-NH4 OAC 5C1	CO3 AS CACO3 <2MM 6E1G	SURFACE AREA EGME 7D2 M2/G	EGME 7D2 M2/G	COND. MMHOS /CM 8A1	PH CACL2 .01M 8C1F 1:2	PH H2O 8C1F 1:1
		<- MEQ / 100 G ->										<- PCT ->								
821938	1		1.9	—	0.3					11.0				100	6	27	94	0.32	7.8	8.1
821939	2		1.9	—	0.3					11.1				100	6	29	101	0.24	7.9	8.2
821940	3		1.1	—	0.3					10.9				100	4	29	101	0.21	7.8	8.2
821941	4		1.4	TR	0.3					11.3				100	7	28	98	0.21	7.8	8.2
821942	5		1.7	—	0.3					10.3				100	8	27	94	0.22	7.9	8.2
821943	6		1.8	TR	0.2					7.4				100	6	20	70	0.17	7.9	8.3
821944	7		2.2	TR	0.2					7.9				100	7	20	70	0.17	7.9	8.3

SAMPLE NO.	HZN NO.	TOTAL ANALYSIS 7C3 CLAY K2O 6Q3A	Fe 6C7A	MINERALOGY CLAY X-RAY <2U 7A2X	7A2X	7A2X	7A2X	DTA <2U 7A3	7A3	WPS TOTAL <2U 7B1A	DOM RES 7B1A	DOM WEATH 7B1A
		<- PCT ->		<- RELATIVE AMOUNTS ->				<- PCT ->				
821938	1	2.8	5.7	HI 3	KK 2	HT 2		KK15			72	PK22
821939	2											
821940	3	2.9	6.4	HI 3	KK 2	HT 1		KK14			74	PK17
821941	4										75	PK15
821942	5	2.5	6.0	HI 3	KK 2	HT 2		KK13				
821943	6											
821944	7	2.5	6.2	HI 3	KK 2	HT 2		KK16			76	PK12

FAMILY CONTROL SECTION: DEPTH 32- 82 PCT CLAY 26 PCT .1-75MM 22

MMHOS/CM OF 1:2 WATER EXTRACT (8I) FOR LAYERS 2, 3, 4, 5, 6, 7,

ANALYSES: S= ALL ON SIEVED <2MM BASIS V= 75-20MM FROM VOLUME ESTIMATES

MINERALOGY: KIND OF MINERAL HI MICA KK KAOLINITE HT MONTMORILL PK POTAS-FELD

RELATIVE AMOUNT 6 INDETERMINATE 5 DOMINANT 4 ABUNDANT 3 MODERATE 2 SMALL 1 TRACE

Series: Namphong
Pedon No: S82FN-875-016 Date: 3/83
Taxonomy: siliceous, isohyperthermic Typic Ustipsamments.
Location: 9 km stone Tha Rua to Phra Tham Dong Rang. kanchanaburi Pro. Tha Ma Ka Dist, Phra Than Dong Rang area.
Physiography: Upland ridge in level to undulating uplands
Geomorphic Position:
Slope and Aspect: 0 pct planar Elevation:
Air Temp. Summer: Winter:
Precipitation: 120 cm Ustic moisture regime.
Water Table: Not observed
Drainage: Well drained Permeability: Rapid
Stoniness:
Land Use: Forest, ungrazed (Dipterocarp)
Erosion or Deposition: Slightly eroded
Parent Material: Residual material from non-calcerous sandstone
Described by: W. Silicheuchu, C. Changprai, C. Manotham, C. Niamskul

A 0 - 15 cm Light brownish gray (10YR 6/2) sand, dark grayish brown (10YR 4/2, moist); structureless; soft, very friable, non-sticky; non-plastic; a few very fine to fine roots; pH=6.5, slightly acid; clear smooth boundary.
82P1945

C1 15 - 28 cm Light gray (10YR 7/2) sand, light brownish gray (10YR 6/2, moist); structureless; soft, very friable, non-sticky; non-plastic; a few very fine to fine roots; a few iron concretions; pH=8.0, moderately alkaline; gradual smooth boundary.
82P1946

C2 28 - 53 cm White (10YR 8/2) sand, pinkish white (7.5YR 8/2, moist); structureless; soft, very friable, non-sticky; non-plastic; common medium distinct dark yellowish brown (10YR 4/4) iron coats on ped faces; a few very fine to fine roots; a few iron concretions; pH=8.0, moderately alkaline; gradual smooth boundary.
82P1947

C3 53 - 87 cm White (10YR 8/2) sand, pinkish white (7.5YR 8/2, moist); structureless; soft, very friable, non-sticky; non-plastic; a few very fine to fine roots; a few iron concretions; pH=8.0, moderately alkaline; gradual smooth boundary.
82P1948 Weakly cemented by iron.

C4 87 - 130 cm White (10YR 8/2) loamy sand, pinkish white (7.5YR 8/2, moist); structureless; soft, very friable, non-sticky; non-plastic; a few very fine to fine roots; a few iron concretions; pH=8.0, moderately alkaline.
82P1949 Strong cementation by iron in material below this horizon

NAMPHONG

CLASSIFICATION: SILICEOUS, ISOHYPERTHERMIC TYPIC USTIPSAMMENT — REVISED

S 82PH-875 -016 — SAMPLE NOS. 82P1945 - 1949 — DATE APRIL 1983

U. S. DEPARTMENT OF AGRICULTURE
SOIL CONSERVATION SERVICE
NATIONAL SOIL SURVEY LABORATORY
LINCOLN, NEBRASKA

THAILAND

GENERAL METHODS 1B1A, 2A1, 2B

SAMPLE NO.	HZN NO.	DEPTH (CM)	HORIZON	TOTAL CLAY LT .002	TOTAL SILT .002 -.05	TOTAL SAND .05 -2	CLAY FINE LT .0002	CLAY CO3 LT .002	SILT FINE .002 -.02	SILT COARSE .02 -.05	SAND VF .05 -.10	SAND F .10 -.25	SAND M .25 -.50	SAND C .5 -1	SAND VC 1 -2	COARSE FRACTIONS (MM) WEIGHT 2 -5	5 -20	20 -75	.1- 75	(>2MM) WT PCT OF WHOLE SOIL
				<- PCT OF <2MM												<- PCT OF <75MM (3B1) ->				
821945	1S	0- 15	A	0.8	17.7	81.4			6.5	11.2	15.5	33.6	18.8	9.3	4.2	TR	—	—	66	TR
821946	2S	15- 28	C1	2.0	16.6	81.3			6.4	10.2	14.6	35.5	18.6	7.2	3.3	TR	—	—	65	TR
821947	3S	28- 53	C2	2.0	17.0	80.8			6.4	10.6	15.6	35.1	18.5	7.4	4.2	1	—	—	66	1
821948	4S	53- 87	C3	2.8	20.1	77.0			8.4	11.6	16.0	33.7	16.4	6.5	4.3	1	—	—	61	1
821949	5S	87-130	C4	4.4	18.2	77.3			8.0	10.2	15.3	34.9	15.2	6.2	4.5	1	—	—	61	1

SAMPLE NO.	HZN NO.	ORGN C 6A1C	TOTAL N 6B3A	EXTR P	TOTAL S 6R3A	EXTRACTABLE FE 6C2B	AL 6G7A	MN 6D2A	RATIO/CLAY CEC CO1	15 BAR 8D1	ATTERBERG LIMITS LL 8F1	PI 8F	BULK DENSITY FIELD MOIST 4A3A	1/3 BAR 4A1D	OVEN DRY 4A1H	COLE WHOLE SOIL 4D1	WATER CONTENT FIELD MOIST 4B4	1/10 BAR 4B1C	1/3 BAR 4B1C	15 BAR 4B2A	WRD WHOLE SOIL 4C1
		<- PCT OF <2MM									PCT <0.4MM		<- G/CC			CM/CM	<- PCT OF <2MM				CM/CM
821945	1	0.40	0.018			0.1	TR	TR	1.63	1.25				1.71	1.71	—			3.4	1.0	0.04
821946	2	0.27	0.010			0.1	—	—	0.25	0.40				1.70	1.70	—			0.9	0.8	TR
821947	3	0.14	0.005			TR	—	—	0.10	0.35				1.73	1.73	—			3.2	0.7	0.04
821948	4	0.10				TR	—	—	0.07	0.25				1.75	1.75	—			2.8	0.7	0.04
821949	5	0.10				TR	—	—	0.02	0.16				1.90	1.90	—			4.6	0.7	0.07

SAMPLE NO.	HZN NO.	NH4OAC EXTRACTABLE BASES CA 5B5A 6N2E	MG 5B5A 6Q2D	NA 5B5A 6P2B	K 5B5A 6Q2B	SUM BASES	ACID-ITY 6H5A	EXTR AL 6G9A	CEC SUM CATS 5A3A	NH4-OAC 5A8B	BASES + AL 5A3B	AL SAT 5G1	BASE SUM 5C3	BASE SAT NH4 OAC 5C1	CO3 AS CACO3 <2MM 6E1G	RES. OHMS /CM 8H1	SURFACE AREA EGME 7D2 MG/G	EGME 7D2 M2/G	PH CACL2 .01M 8C1F 1:2	H2O 8C1F 1:1
		<- MEQ / 100 G										<- PCT								
821945	1	2.0	0.3	—	TR	2.3	0.1		2.4	1.3			96	100	—		3	11	6.9	7.3
821946	2	0.8	0.1	0.1	TR	1.0	—		1.0	0.5			100	100			3	11	6.1	6.6
821947	3	0.4	0.1	—	TR	0.5	0.1		0.6	0.2			83	100			5	18	5.8	6.3
821948	4	0.3	0.1	—	TR	0.4	0.1		0.5	0.2			80	100			6	21	5.6	6.0
821949	5	0.4	TR	—	TR	0.4	—		0.4	0.1			100	100		31000			5.2	6.1

SAMPLE NO.	HZN NO.	MINERALOGY CLAY X-RAY 7A2I	7A2I	7A2I	7A2I	VFS 7A3	7A3	TOTAL 7B1A	DOM HRS WEATH 7B1A
		<- RELATIVE AMOUNTS ->				<- PCT ->			
821945	1							93	PK 6
821946	2								
821947	3							93	PK 6
821948	4							89	PK 11
821949	5							94	PK 5

FAMILY CONTROL SECTION: DEPTH 25-100 PCT CLAY 3 PCT .1-75MM 63

ANALYSES: S= ALL ON SIEVED <2MM BASIS

MINERALOGY: KIND OF MINERAL PK POTAS-FELD

Series: Lat Ya
Pedon No: S82FN-875-017 Date: 3/83
Taxonomy: Fine-loamy, siliceous, isohyperthermic Ustoxic Palehumults.*
Location: 39 km to Erawan falling. Kanchanaburi Province, Lat Ya District, Wang Dong village, Wang Dong Subdistrict.
Physiography: Fan in level to undulating uplands
Geomorphic Position:
Slope and Aspect: 2 pct convex Elevation:
Air Temp. Summer: Winter:
Precipitation: Ustic moisture regime.
Water Table: Not observed
Drainage: Well drained Permeability: moderate
Stoniness:
Land Use: Forest, ungrazed
Erosion or Deposition: Slightly eroded
Parent Material: Alluvium
Described by: W. Silicheuchu, C. Changprai, C. Manotham, C. Niamskul

*Ustoxic subgroup is proposed for this pedon.

Ap 0 - 20 cm Brown to dark brown (7.5YR 4/4) clay loam, dark brown (7.5YR 3/4, moist); weak medium subangular blocky parting to moderate fine subangular blocky structure; hard, friable, slightly sticky; slightly plastic; many very fine to fine roots; pH=6.0, slightly acid; clear smooth boundary.
82P1950 Some pockets of Bt material.

BA 20 - 42 cm Strong brown (7.5YR 5/6) clay loam, reddish brown (5YR 4/4, moist); moderate medium to coarse subangular blocky structure; hard, friable, slightly sticky; slightly plastic; some thin patchy clay skins on faces of peds and some thin patchy clay skins in channels and pores; common fine roots and a few coarse roots; pH=5.0, strongly acid; gradual smooth boundary.
82P1951

Bt1 42 - 66 cm Reddish yellow (7.5YR 6/8) clay loam, (7.5YR 3/6, moist); moderate medium to coarse subangular blocky structure; hard, friable, slightly sticky; slightly plastic; a few very fine to fine roots; a few large tubular pores; pH=4.0, extremely acid; gradual smooth boundary.
82P1952

Bt2 66 - 96 cm Strong brown (7.5YR 4/6) and reddish yellow (5YR 6/8) clay loam, yellowish red (5YR 4/8, moist); moderate medium to coarse subangular blocky parting to moderate fine subangular blocky structure; hard, friable, slightly sticky; slightly plastic; some thin patchy clay skins on faces of peds and a few thick patchy clay skins in channels and pores; a few very fine to fine roots; pH=4.0, extremely acid; abrupt smooth boundary.
82P1953

2C 96 - 127 cm Extremely gravelly clay; structureless; a few clay skins on gravels; a few fine roots.
82P1954

LAT YL

CLASSIFICATION: FINE-LOAMY, SILICEOUS, ISOHYPERTHERMIC USTOXIC PALEHUMULT

* 82PN-875 -017 SAMPLE NOS. 82P1950 - 1954 DATE REVISED APRIL 1983

U. S. DEPARTMENT OF AGRICULTURE
SOIL CONSERVATION SERVICE
NATIONAL SOIL SURVEY LABORATORY
LINCOLN, NEBRASKA

THAILAND

GENERAL METHODS 1B1A, 2A1, 2B

SAMPLE NO.	HZN NO.	DEPTH (CM)	HORIZON	TOTAL CLAY LT .002	TOTAL SILT .05 -.05	TOTAL SAND -2	TOTAL FINE .0002	CLAY CO3 LT .002	CLAY FINE .002 -.02	SILT COARSE .02 -.05	SILT VF .05 -.10	SAND F .10 -.25	SAND M .25 -.50	SAND C .5 -1	SAND VC 1 -2	COARSE FRACTIONS (MM) 2 -5	5 -20	20 -75	.1- 75	(>2MM) WT PCT OF WHOLE SOIL
				<- - - - - - - - - - - - - - - - - PCT OF <2MM (3A1) - - - - - - - - - - - - - - - - - ->												<- PCT OF <75MM (3B1) ->				
821950	1S	0- 20	AP	22.0	35.4	42.6	11.3		23.7	11.7	11.3	13.3	8.9	5.8	3.3	1	—	—	32	1
821951	2S	20- 42	BA	25.1	33.3	41.6	19.5		23.9	9.4	11.1	13.1	8.6	5.6	3.2	1	TR	—	31	1
821952	3S	42- 66	BT1	30.3	35.6	34.1	18.0		19.7	15.9	8.7	10.1	7.3	4.4	3.6	2	TR	—	27	2
821953	4S	66- 96	BT2	36.5	34.8	28.7	24.2		19.7	15.1	7.3	7.6	5.8	4.3	3.7	3	TR	—	24	3
821954	5S	96-127	2C	45.4	26.0	28.6	27.7		15.3	10.7	3.3	3.0	2.5	3.9	15.9	23	38	1	72	62

SAMPLE NO.	HZN NO.	ORGN C 6A1C	TOTAL N 6B3A	NITR P	TOTAL S 6B3A	DITH-CIT EXTRACTABLE FE 6C2B	AL 6G7A	MN 6D2A	RATIO/CLAY CEC 8D1	15 BAR 8D1	ATTERBERG LIMITS LL 4F1	PI 4F	BULK DENSITY FIELD MOIST 4A3A	1/3 BAR 4A1D	OVEN DRY 4A1H	COLE WHOLE SOIL 4D1	WATER CONTENT FIELD MOIST 4B4	1/10 BAR 4B1C	1/3 BAR 4B1C	15 BAR 4B2A	WRD WHOLE SOIL 4C1
		<- - - - - - - PCT OF <2MM - - - - - - ->									PCT <0.4MM		.<- - G/CC - - ->			CM/CM	<- - -PCT OF <2MM - ->				CM/CM
821950	1	1.62	0.097			1.5	0.2	TR	0.41	0.32	26	10		1.33	1.38	0.012			14.2	7.1	0.09
821951	2	1.41	0.085			1.9	0.2	TR	0.30	0.32				1.40	1.45	0.012			15.8	8.1	0.11
821952	3	0.54	0.050			2.3	0.3	—	0.23	0.31	30	13		1.39	1.44	0.012			18.2	9.3	0.12
821953	4	0.44	0.050			2.5	0.3	TR	0.23	0.32				1.41	1.48	0.016			19.8	11.8	0.11
821954	5	0.21				5.4	0.5	0.1	0.27	0.32										14.6	

SAMPLE NO.	HZN NO.	NH4OAC EXTRACTABLE BASES CA 5B5A 6N2B	MG 5B5A 6O2D	NA 5B5A 6P2B	K 5B5A 6Q2B	SUM BASES	ACID-EXTR ITY 6H5A	AL 6G9A	CEC SUM CATS 5A3A	NH4-OAC 5A6B	BASES + AL 5A3B	AL SAT 5G1	BASE SUM 5C3	SAT- NH4 OAC 5C1	CO3 AS CACO3 <2MM 6H1G	BES. OHES /CM 8E1	SURFACE AREA EGME 7D2 MG/G	EGME 7D2 M2/G	PH CACL2 .01M 8C1F 1:2	H2O 8C1F 1:1
		<- - - - - - - - - - - - - -MEQ / 100 G - - - - - - - - - - - ->										<- - - - -PCT - - - ->								
821950	1	2.0	1.4	TR	0.2	3.6	7.8	0.9	11.4	9.0	4.5	20	32	40					4.3	4.9
821951	2	0.8	0.9	TR	0.2	1.9	9.0	2.2	10.9	7.6	4.1	54	17	25					4.2	4.8
821952	3	0.2	0.3	TR	0.1	0.6	8.7	3.8	9.3	6.9	4.4	86	6	9					3.9	4.7
821953	4	0.3	0.6	TR	0.1	1.0	9.9	4.6	10.9	8.4	5.6	82	9	12					4.1	4.7
821954	5	1.1	2.0	0.2	0.2	3.5	10.5	4.2	14.0	12.3	7.7	55	25	28		23000			4.2	4.9

SAMPLE NO.	HZN NO.	TOTAL ANALYSIS 7C3 CLAY K2O 6Q3A	Fe 6C7A	MINERALOGY CLAY X-RAY <2U 7A2I	7A2I	7A2I	7A2I	DTA <2U 7A3	7A3	TOTAL 7E1A	DOM WEATH 7B1A
		<- - - - - - - PCT - - - - - - ->		<- RELATIVE AMOUNTS ->				<- - - - -PCT - - - ->			
821950	1	2.6	6.4	HI 3	KK 2	GE 1		KK22			
821951	2	2.7	6.7	KK 2	HI 2	GE 1		KK16			
821952	3	2.7	6.9	KK 3	HI 3	GE 1		KK40		96	FK 3
821953	4	2.7	6.7	KK 3	HI 3	GE 1		KK35		94	FK 5
821954	5	2.6	7.0	KK 3	HI 3	GE 1		KK35			

FAMILY CONTROL SECTION: DEPTH 42- 92 PCT CLAY 34 PCT .1-75MM 25

ANALYSES: S= ALL ON SIEVED <2MM BASIS

MINERALOGY: KIND OF MINERAL HI MICA KK KAOLINITE GE GOETHITE FK POTAS-FELD

RELATIVE AMOUNT 6 INDETERMINATE 5 DOMINANT 4 ABUNDANT 3 MODERATE 2 SMALL 1 TRACE

Series: Muak Lek
Pedon No: S02FN-875-018 Date: 3/83
Taxonomy: Loamy-skeletal, siliceous, isohyperthermic Ultic Paleustalfs.
Location: Kanchanaburi Province, Si Sawat District, Erawan falling area.
Physiography: Hillside in mountains-plateaus
Geomorphic Position: On middle third hillside backslope
Slope and Aspect: 50 pct convex Elevation:
Air Temp. Summer: Winter:
Precipitation: Ustic moisture regime.
Water Table: Not observed
Drainage: Well drained Permeability: Slow
Stoniness:
Land Use: Forest, ungrazed
Erosion or Deposition: Slightly eroded
Parent Material: Colluvium
Described by: W. Silicheuchu, C. Changprai, C. Manotham, C. Niamskul

A 0 - 24 cm Dark gray (10YR 4/1) gravelly clay loam, very dark gray (10YR 3/1, moist); weak medium to coarse subangular blocky parting to moderate fine granular structure; slightly hard, friable, slightly sticky; slightly plastic; many fine roots and many coarse roots; pH=6.5, slightly acid; clear smooth boundary.
82P1955

BA 24 - 46 cm Brown to dark brown (7.5YR 4/2) very gravelly clay loam, dark brown (7.5YR 3/2, moist); moderate fine subangular blocky structure; loose, friable, slightly sticky; slightly plastic; some clay skins; a few; pH=6.0, slightly acid; clear wavy boundary.
82P1956

Bt1 46 - 75 cm Brown to dark brown (7.5YR 4/4) very gravelly clay loam, reddish brown (5YR 4/4, moist); structureless; loose, friable, slightly sticky; slightly plastic; many thick clay skins on gravels; many fine roots and common medium roots; pH=5.5, strongly acid; gradual smooth boundary.
82P1957

Bt2 75 - 120 cm Brown to dark brown (7.5YR 4/4) very gravelly clay loam, yellowish red (5YR 4/6, moist); structureless; loose, friable, slightly sticky; slightly plastic; many thick clay skins on gravels; many fine roots; pH=6.0, slightly acid.
82P1958

SOAK LEK

CLASSIFICATION: LOAMY-SKELETAL, SILICEOUS, ISOHYPERTHERMIC ULTIC PALEUSTALF

REVISED

S 82PH-875 -018 SAMPLE NOS. 82P1955 - 1958 DATE APRIL 1983

U. S. DEPARTMENT OF AGRICULTURE
SOIL CONSERVATION SERVICE
NATIONAL SOIL SURVEY LABORATORY
LINCOLN, NEBRASKA

THAILAND

GENERAL METHODS 1B1A, 2A1, 2B

SAMPLE NO.	HZN NO.	DEPTH (CM)	HORIZON	TOTAL CLAY LT .002	TOTAL SILT .002 -.05	TOTAL SAND .05 -2	TOTAL FINE LT .0002	CLAY CO3 LT .002	SILT FINE .002 -.02	SILT COARSE .02 -.05	SAND VF .05 -.10	SAND F .10 -.25	SAND M .25 -.50	SAND C .5 -1	SAND VC 1 -2	COARSE FRACTIONS (MM) WEIGHT 2 -5	5 -20	20 -75	.1- 75	(>2MM) WT PCT OF WHOLE SOIL
				<- - - - - - - - - - - - PCT OF <2MM (3A1) - - - - - - - - - - - - - ->												<- PCT OF <75MM (3B1) ->				
821955	1S	0- 24	A	15.9	25.0	59.1	6.7		11.3	13.7	17.9	20.5	6.5	5.1	9.1	2	0	14	55	24
821956	2S	24- 46	BA	21.0	27.6	51.4	7.0		13.2	14.4	17.0	16.1	5.1	3.9	9.3	14	22	32	79	68
821957	3S	46- 75	BT1	29.5	31.1	39.4	11.5		16.0	15.1	11.1	7.3	2.5	4.3	14.2	26	29	23	84	78
821958	4S	75-120	BT2	45.8	28.1	26.1	22.7		15.3	12.8	9.0	5.3	2.2	3.3	6.3	18	34	28	83	80

SAMPLE NO.	HZN NO.	ORGN C 6A1C	TOTAL N 6B3A	NITR P	TOTAL S 6A3A	DITH-CIT EXTRACTABLE FE 6C2B	AL 6G7A	MN 6D2A	CEC 8D1	RATIO/CLAY 15 BAR 8D1	ATTERBERG LIMITS LL 4F1	PI 4P	BULK DENSITY FIELD MOIST 4A3A	1/3 BAR 4A1D	OVEN DRY 4A1H	COLE WHOLE SOIL 4D1	WATER CONTENT FIELD MOIST 4B4	1/10 BAR 4B1C	1/3 BAR 4B1C	15 BAR 4B2A	MRD WHOLE SOIL 4C1
		<- - - - - - - PCT OF <2MM - - - - - - ->									PCT <0.4MM		<- - G/CC - - ->			CM/CM	<- - -PCT OF <2MM - ->			CM/CM	
821955	1	2.15	0.140			1.5	0.1	TR	0.72	0.45	28	9								7.2	
821956	2	1.01	0.088			1.9	0.2	TR	0.42	0.35										7.3	
821957	3	0.53	0.070			3.1	0.3	TR	0.30	0.33	30	14								9.6	
821958	4	0.50				2.7	0.2	TR	0.27	0.29										13.1	

SAMPLE NO.	HZN NO.	NH4OAC EXTRACTABLE BASES CA 5B5A	MG 5B5A	NA 5B5A	K 5B5A	SUM BASES 6H2B	ACID-EXTR ITY 6H5A	AL 6G9A	CEC SUM CATS 5A3A	NH4- OAC 5A8B	BASES + AL 5A3B	AL SAT 5G1	BASE SAT SUM 5C3	NH4 OAC 5C1	CACO3 <2MM 6E1G	CO3 AS RES. ORB3 /CM 8E1	SURFACE AREA EGME MG/G 7D2	EGME M2/G 7D2	PH CACL2 .01M 8C1F	H2O 8C1F
		<- - - - - - - - - - - - - MEQ / 100 G - - - - - - - - - - - - ->										<- - - - PCT - - - ->							1:2	1:1
821955	1	6.2	2.1	--	0.7	9.0	6.0		15.0	11.5			60	78					5.3	5.8
821956	2	2.4	1.2	--	0.4	4.0	6.3	0.8	10.3	8.8	4.8	17	39	45					4.6	5.1
821957	3	3.3	1.4	--	0.6	5.3	5.3	0.7	10.6	8.9	6.0	12	50	60					4.5	5.2
821958	4	5.9	2.3	--	0.7	8.9	5.9	0.3	14.8	12.4	9.2	3	60	72		9000			4.8	5.4

SAMPLE NO.	HZN NO.	TOTAL ANALYSIS 7C3 CLAY K2O 6Q3A	Fe 6C7A	MINERALOGY CLAY X-RAY 7A2I	7A2I	7A2I	7A2I	DTA 7A3	7A3	TOTAL SAND RES 7B1A	HEATH 7B1A
		<- - - - - - - PCT - - - - - ->		<- RELATIVE AMOUNTS ->				<- - - - -PCT - - - ->			
821955	1	3.4	3.6	HI 2	KK 2	QZ 1					
821956	2									99	FK 1
821957	3	4.2	5.0	HI 3	KK 3	QZ 1		KK 10		99	FK 1
821958	4									99	FK 1

FAMILY CONTROL SECTION: DEPTH 25-100 PCT CLAY 33 PCT .1-75MM 82

ANALYSES: S= ALL ON SIEVED <2MM BASIS

MINERALOGY: KIND OF MINERAL HI MICA KK KAOLINITE QZ QUARTZ FK POTAS-FELD

RELATIVE AMOUNT 6 INDETERMINATE 5 DOMINANT 4 ABUNDANT 3 MODERATE 2 SMALL 1 TRACE

Series: Bang Len
Pedon No: S82FN-875-019 Date: 3/83
Taxonomy: Fine, montmorillonitic, isohyperthermic Typic Pelluderts.
Location: 10 km stone Don Yai Hom to Bang Phee, Nakhonpathom Province, Muag Dist., Don Yai Ham vill. and Subdist.
Physiography: Floodplain in river valley
Geomorphic Position:
Slope and Aspect: 0 pct planar Elevation:
Air Temp. Summer: Winter:
Precipitation: Aquic moisture regime.
Water Table: 136 cm Apparent
Drainage: Poorly drained Permeability: Slow
Stoniness:
Land Use: Cropland-paddy rice.
Erosion or Deposition: None
Parent Material: Alluvium
Described by: W. Silicheuchu, C. Manothan, P. Teamprateep

In February, 1983 cracks were less than 1 cm wide at 50 cm.

Ap 0 - 10 cm Dark gray (10YR 4/1) clay; a few fine distinct brownish yellow (10YR 6/6) mottles; strong fine to medium subangular blocky structure; very hard, firm, very sticky; plastic; many fine roots; pH=7.0, neutral; clear smooth boundary.
82P1959

Ag 10 - 28 cm Very dark gray (10YR 3/1) clay; a few fine distinct olive brown (2.5Y 4/4) mottles; strong medium to coarse angular blocky structure; very hard, firm, very sticky; plastic; some pressure faces; a few fine roots; pH=7.5, mildly alkaline; gradual smooth boundary.
82P1960

Bg1 28 - 46 cm Black (N 2/0) clay; a few fine faint olive brown (2.5Y 4/4) mottles; strong medium to coarse angular blocky structure; very hard, firm, very sticky; plastic; some pressure faces; a few fine roots; a few fine gypsum concentrations; pH=8.0, moderately alkaline; diffuse smooth boundary.
82P1961

Bg2 46 - 74 cm Black (N 2/0) clay; a few fine faint olive brown (2.5Y 4/4) mottles; strong medium to coarse subangular blocky structure; hard, firm, very sticky; plastic; some slickensides; common fine gypsum concentrations; pH=8.0, moderately alkaline; gradual smooth boundary.
82P1962 Slickensides intersect.

Bg3 74 - 116 cm Dark gray (N 4/0) clay; common fine faint olive brown (2.5Y 4/4) and a few fine distinct dark yellowish brown (10YR 4/4) mottles; strong coarse subangular blocky parting to strong fine to medium subangular blocky structure; hard, firm, sticky; plastic; many fine gypsum concentrations; pH=8.0, moderately alkaline; abrupt smooth boundary.
82P1963 Slickensides intersect.

BCg 116 - 136 cm Gray (10YR 5/1) clay; many medium faint dark yellowish brown (10YR 4/4) and many coarse distinct brown to dark brown (7.5YR 4/4) mottles; weak fine to medium subangular blocky structure; friable, slightly sticky; slightly plastic; a few fine cylindrical iron-manganese concretions; pH=8.0, moderately alkaline; diffuse smooth boundary.
82P1964

Cg 136 - 160 cm Light brownish gray (10YR 6/2) clay; many medium faint dark yellowish brown (10YR 4/4) and many medium distinct olive brown (2.5Y 4/4) mottles; weak medium platy structure; friable, slightly sticky; slightly plastic; some thin skeletans on faces of peds; pH=8.0, moderately alkaline.
82P1965

BANG LEM

CLASSIFICATION: FINE, MONTMORILLONITIC, ISOHYPERTHERMIC TYPIC PELLUDERT

S 82PH-875 -019 SAMPLE NOS. 82P1959 - 1965 DATE REVISED APRIL 1983

U. S. DEPARTMENT OF AGRICULTURE
SOIL CONSERVATION SERVICE
NATIONAL SOIL SURVEY LABORATORY
LINCOLN, NEBRASKA

THAILAND

GENERAL METHODS 1B1A, 2A1, 2B

SAMPLE NO.	HZN NO.	DEPTH (CM)	HORIZON	TOTAL CLAY LT .002	TOTAL SILT .002 -.05	TOTAL SAND .05 -2	CLAY FINE LT .0002	CLAY CO3 LT .002	SILT FINE .002 -.02	SILT COARSE .02 -.05	SILT VF .05 -.10	SAND F .10 -.25	SAND M .25 -.50	SAND C .5 -1	SAND VC 1 -2	COARSE FRACTIONS (MM) 2 -5	COARSE FRACTIONS (MM) 5 -20	COARSE FRACTIONS (MM) 20 -75	COARSE FRACTIONS (MM) .1- 75	>2MM PCT OF WHOLE SOIL
				<- - - - - - - - - - - - - - PCT OF <2MM (3A1) - - - - - - - - - - - - - ->												<- PCT OF <75MM (3B1) ->				
821959	1S	0- 10	AP	51.6	46.1	2.3	33.6		27.1	19.0	1.7	0.4	0.2	—	—	—	—	—	1	—
821960	2S	10- 28	AG	54.4	43.4	2.2	34.3		26.1	17.3	1.5	0.5	0.2	—	—	—	—	—	1	—
821961	3S	28- 46	BG1	57.5	40.8	1.7	34.5		26.0	14.8	1.3	0.4	--	—	—	—	—	—	TR	—
821962	4S	46- 74	BG2	60.0	38.0	2.0	32.6		23.2	14.8	1.5	0.4	0.1	—	—	—	—	—	TR	—
821963	5S	74-116	BG3	54.9	42.8	5.3	15.2		24.6	18.2	4.2	0.9	0.2	—	—	—	—	—	1	—
821964	6S	116-136	BCG	24.5	37.2	38.3	11.5		9.8	27.4	25.4	8.7	2.2	0.8	1.2	—	—	—	13	—
821965	7S	136-160	CG	28.6	42.9	28.5	14.4		13.9	29.0	26.6	1.5	0.4	—	—	—	—	—	2	—

SAMPLE NO.	HZN NO.	ORGN C 6A1C	TOTAL N 6B3A	NITR P	TOTAL S 6K3A	DITH-CIT EXTRACTABLE FE 6C2B	DITH-CIT EXTRACTABLE AL 6G7A	DITH-CIT EXTRACTABLE MN 6D2A	CEC 8D1	RATIO/CLAY 15 BAR 8D1	ATTERBERG LIMITS LL 4F1	ATTERBERG LIMITS PI 4F	BULK DENSITY FIELD MOIST 4A3A	BULK DENSITY 1/3 BAR 4A1D	BULK DENSITY OVEN DRY 4A1H	COLE WHOLE SOIL 4D1	WATER CONTENT FIELD MOIST 4B4	WATER CONTENT 1/10 BAR 4B1C	WATER CONTENT 1/3 BAR 4B1C	WATER CONTENT 15 BAR 4B2A	MED WHOLE SOIL 4C1
		<- - - - - - -PCT OF <2MM - - - - - - ->									PCT <0.4MM		<- - G/CC - - ->			CM/CM	<- - -PCT OF <2MM - ->				CM/CM
821959	1	1.37	0.130			1.0	0.1	TR	0.61	0.36	54	30		1.42	1.97	0.115			28.3	18.6	0.14
821960	2	0.99	0.103			1.0	0.1	TR	0.60	0.33				1.47	1.99	0.106			26.2	17.7	0.13
821961	3	0.83	0.087			1.1	0.1	TR	0.61	0.33				1.46	1.99	0.109			26.8	19.2	0.11
821962	4	0.75	0.080			1.0	0.1	TR	0.60	0.35	62	37		1.42	1.98	0.117			29.9	21.0	0.13
821963	5	0.39				0.8	0.1	TR	0.46	0.37				1.48	1.91	0.089			27.8	19.3	0.13
821964	6	0.15				3.6	0.1	0.2	0.48	0.47				1.44	1.54	0.023			21.4	11.5	0.14
821965	7	0.15				0.6	TR	TR	0.47	0.39	35	17		1.43	1.55	0.027			22.1	11.2	0.16

SAMPLE NO.	HZN NO.	NH4OAC EXTRACTABLE BASES CA 5B5A	NH4OAC EXTRACTABLE BASES MG 5B5A	NH4OAC EXTRACTABLE BASES NA 5B5A	NH4OAC EXTRACTABLE BASES K 5B5A	NH4OAC EXTRACTABLE BASES SUM BASES 6Q2B	ACIDITY 6H5A	CEC SUM CATS 5A3A	CEC NH4-OAC 5A8B	BASE SAT 5D2 PCT	BASE SAT 5E	BASE SATURATION SUM NH4OAC 5C3	BASE SATURATION 5C1	CO3 AS CACO3 <2MM 6E1G PCT	RES. OHMS /CM 6E1	CASO4 AS GYPSUM <2MM 6F1A	CASO4 AS GYPSUM <20MM 6F4	PH SAT PASTE 8C1B	PH CACL2 .01M 8C1F 1:2	PH H2O 8C1F 1:1
		<- - - - - - - - - - -MEQ / 100 G - - - - - - - - - - ->								PCT		<- -PCT- >		PCT		<- -PCT ->				
821959	1	22.0	7.2	0.9	0.5	30.6	7.2		31.6	2	2	97				—		5.9	5.5	5.7
821960	2	23.0	7.1	1.0	0.5	31.6	4.0		32.7	2	2	97				—		6.7	6.6	6.7
821961	3	26.6	8.2	1.9	0.5	37.2	2.2		34.8	4	3	100		—		—		7.2	7.1	7.2
821962	4	35.9	9.3	3.0	0.5	48.7	2.4		36.1	5	4	100				1		7.2	7.2	7.1
821963	5	102.9	7.4	3.6	0.4	114.3	2.2		23.7	7	6	100		—	480	3		7.2	7.1	7.0
821964	6	8.5	4.1	2.7	0.3	15.6	1.2		11.8	10	8	100		--		—		7.8	7.1	7.0
821965	7	8.3	4.7	3.1	0.4	16.5	0.7		13.3	11	9	100				—		7.3	7.0	6.9

SAMPLE NO.	HZN NO.	WATER EXTRACTED FROM SATURATED PASTE CA 6N1B	MG 6O1B	NA 6P1B	K 6Q1B	CO3 6I1B	HCO3 6J1B	CL 6K1C	SO4 6L1C	NO3 6M1C	H2O 8A	TOTAL SALTS EST. 8D5	ELEC. COND. 8A3A	MINERALOGY CLAY <2U 7A2I	MINERALOGY CLAY <2U 7A2I	MINERALOGY CLAY <2U 7A2I	MINERALOGY X-RAY 7A2I	MINERALOGY DTA 7A3	MINERALOGY DTA 7A3	TOT ANL CLAY K2O 6Q3A	TOT ANL CLAY Fe 6C7A
		<- - - - - - - - - - - - - - -MEQ / LITER - - - - - - - - - - - ->									<- -PCT ->		/CM	<- RELATIVE AMOUNTS ->				<- - - - -PCT - - - ->			
821959	1	6.2	2.5	3.8	0.1	—	0.5	5.0	6.6	—	66.8	TR	1.21	HT 4	KK 3	HI 2		KK27		2.1	5.1
821960	2	5.0	1.9	4.4	0.1	—	0.8	2.9	7.0	—	67.1	TR	1.09								
821961	3	9.1	3.4	8.4	0.1	—	1.0	6.2	12.7	—	73.7	0.1	1.85	HT 4	KK 3	HI 2		KK26		2.0	5.0
821962	4	28.1	10.2	16.8	0.1	—	1.0	10.1	40.6	—	75.2	0.2	4.01	HT 4	KK 3	HI 2	QZ 1	KK19		2.0	4.7
821963	5	28.0	12.5	25.1	0.2	—	0.9	16.5	45.1	—	74.6	0.3	4.94	HT 4	KK 3	HI 3	QZ 1	KK19		2.0	4.8
821964	6	16.0	8.3	28.0	0.2	—	0.4	24.9	23.0	--	54.8	0.2	4.49	HT 3	KK 3	HI 2	GE 1	KK21		1.8	11.0
821965	7	17.0	10.0	21.6	0.4	—	0.8	30.4	24.9	—	52.9	0.2	4.97	HT 4	KK 3	HI 3	QZ 1	KK24		2.0	5.2

FAMILY CONTROL SECTION: DEPTH 25-100 PCT CLAY 56 PCT .1-75MM 1

ANALYSES: S= ALL OR SIEVED <2MM BASIS

MINERALOGY: KIND OF MINERAL HT MONTMORILL KK KAOLINITE HI MICA QZ QUARTZ GE GOETHITE

RELATIVE AMOUNT 6 INDETERMINATE 5 DOMINANT 4 ABUNDANT 3 MODERATE 2 SMALL 1 TRACE

Pedon No. 20

Series	:	Tha Mai
Taxonomy	:	
Latitude	:	Longitude
Location	:	About 100 m. East of Tha Mai - Chanthaburi Road (at Km 15.1) Amphoe Tha Mai, Chanthaburi province.
MLRA	:	
Physiography	:	Foothill slope
Geomorphic Position	:	
Slope and Aspect	:	4 pct
Elevation	:	30 m.
Microrelief	:	
Air Temp	:	26.4°C Summer
Summer	:	-
Winter	:	-
Precipitation	:	3014.0 mm.
Water Tables	:	-
Drainage	:	well drained
Permeability	:	slow
Stoniness	:	-
Land Use	:	Rambutan, durian and rubber
Erosion or Deposition	:	-
Parent Material	:	Basalt
Described by	:	

A_1 0 - 20 Dark reddish brown (5YR 3/3) clay; weak fine granular structure; very friable, slightly sticky, slightly plastic; many fine and medium roots; strongly acid (pH 5.5); diffuse, smooth boundary.

B_{21} 20 - 50 Dark reddish brown (5YR 3/4) clay; weak fine subangular blocky structure; very friable, slightly sticky, slightly plastic; many fine and medium roots; strongly acid (pH 5.5); diffuse, smooth boundary.

B_{22} 50 - 95 Dark reddish brown (5YR 3-4/4) clay; weak fine and medium subangular blocky structure; very friable, slightly sticky, slightly plastic; common fine and medium roots; strongly acid (pH 5.5); diffuse, smooth boundary.

B_{23} 95 - 180 Dark reddish brown (5YR 3-4/4) clay; weak medium subangular blocky structure; very friable, slightly sticky, slightly plastic; few fine roots; strongly acid (pH 5.5).

Micromorphological description of Thai Mai series.
20 - 50 cm. depth.

Plasma is dark brown, inundulic plasmic fabric grade to agglomero plasmic fabric, plasma is low birefringent; peds separate to micro-peds, presence of oxic horizon; some small iron oxide nodules; skeleton grains are rare and are silt size quartz with small pseudomorphic altered pyroxene (hightly weathered of augite); few root fragment.

0 - 90 cm. depth.

As above but plasma is more light and with slightly increase of small flake of augite as groundmass and small augite grains, with depth.

SOIL CLASSIFICATION-

SERIES - - - - - - - -THAMAI (TI)

SOIL NO - - - - - - - S78PN-000-004 COUNTY - - - THAILAND

GENERAL METHODS- - -1A,1B1B,2A1,2B SAMPLE NOS. 78P1736-78P1741

U. S. DEPARTMENT OF AGRICULTURE
SOIL CONSERVATION SERVICE, NTSC
NATIONAL SOIL SURVEY LABORATORY
LINCOLN, NEBRASKA

APRIL 1979

DEPTH CM	HORIZON	SAND 2-.05	SILT .05-.002	CLAY LT .002	FINE CLAY LT .0002	VCOS 2-1	CORS 1-.5	MEDS .5-.25	FNES .25-.10	VFNS .10-.05	COSI .05-.02	FNSI .02-.002	VFSI .005-.002	SAND 2-.10	INTR II .2-.02	FINE CLAY TO CLAY PCT	NON-CO3-CLAY PCT	RATIO 8D1 15-BAR TO CLAY
		(- - -	- - -	- - -	- - -	- - -	- - -	PCT LT 2MM	- - -	- - -	- - -	- - -	- - -	- - -	- - -)			
0-20	A1	3.6	20.2	76.2		1.1	.5	.5	.8	.7	6.9	13.3		2.9				.39
20-50	B21OX	3.6	21.8	74.6		1.0	.5	.4	.8	.9	8.7	13.1		2.7				[illegible]
50-95	B22OX	3.9	22.6	73.5		.7	.5	.5	1.2	1.0	8.3	14.3		2.9				[illegible]
95-125	B23OX	3.0	18.2	78.8		.5	.6	.4	.8	.7	5.4	12.8		2.3				[illegible]
125-155	B23OX	2.5	19.9	77.6		.5	.4	.3	.7	.6	6.3	13.6		1.9				.39
155-180	B23OX	2.5	18.3	79.2		.6	.4	.3	.6	.6	5.5	12.8		1.9				.39

(PARTICLE SIZE ANALYSIS, MM, 3B, 3B1, 3B2) (BULK DENSITY) (- - - -WATER CONTENT- - - -) CARBONATE (- -PH - -)

DEPTH CM	VOL. GT 2 PCT	WEIGHT GT 75 PCT	75-20	20-5	5-2	LT .074	20-2 PCT LT20	4A1D 1/3-BAR G/CC	4A1H OVEN DRY G/CC	4D1 COLE	4B1C 1/10 BAR PCT	4B1C 1/3-BAR PCT	4B2 15-BAR PCT	4C1 WRD CM/CM	6E1B LT 2 PCT	3A1A LT .002 PCT	8C1A 1/1 H2O	8C1F 1/2 CACL
			(- - - PCT LT 75	- - -)														
0-20													29.4				5.4	4.5
20-50													28.5				5.4	4.5
50-95													28.2				5.2	4.3
95-125													30.2				5.2	4.5
125-155													30.5				5.1	4.4
155-180													30.5				5.1	4.4

(ORGANIC MATTER) (- -EXTRACTABLE BASES 5B4A- -) (CAT EXCH) (BASE SAT)

DEPTH CM	6A1A ORGN CARB PCT	6B1A NITG PCT	C/N	IRON 6C2B EXT FE PCT	PHOS TOTL PCT	6N2E CA	6O2D MG	6P2B NA	6Q2B K	SUM EXTB	ACTY 6H1A BACL TEA	AL 6G1E KCL EXT	5A3A EXTB ACTY	5A6A NHAC	RATIO 8D1 NHAC TO CLAY	RATIO 8D3 CA TO MG	CA 5F1 SAT NHAC PCT	5C3 EXTB ACTY PCT	5C1 NHAC PCT
					(- - -	- - -	- - -	-MEQ	/ 100	G- - -	- - -	- - -	- - -	- - -)					
0-20	.68			9.0		2.0	.8	.4	.2	3.4	19.2	.7	22.6	12.6	.17	2.5	16	15	27
20-50	1.46			9.1		2.0	1.3	.4	.3	4.0	22.5	.7	26.5	14.9	.20	1.5	13	15	27
50-95	1.01			9.3		1.1	.6	.3	.1	2.1	23.7	1.7	25.8	13.7	.19	1.8	8	8	15
95-125	.60			9.4		2.1	.5	.1	TR	2.7	20.8	.7	23.5	13.1	.17	4.2	16	11	21
125-155	.35			9.4		1.6	.3	.1	.0	2.0	20.6	1.3	22.6	11.6	.15	5.3	14	9	17
155-180	.30			9.4		1.8	.4	.1	.0	2.3	20.2	1.1	22.5	11.6	.15	4.5	16	10	[illegible]

DEPTH CM	PH 8C1C KCL	CEC 5A7A NHCL MEQ / 100 G
0-20	4.5	6.4
20-50	4.4	
50-95	4.2	5.8
95-125	4.5	
125-155	4.3	6.7
155-180	4.4	

SAND MINERALOGY (7B1) PLACEMENT: SILICEOUS.
050-095 VFNS - RE97 QZ15 FE81 PO1 MS2 FK1 COS1 - RE99 QZ10 FE89 PO FK1
RELATIVE AMOUNTS: AS PERCENT
MINERAL CODE: RE = RESISTANT MINERALS MS = MUSCOVITE PO = PLANT OPAL QZ = QUARTZ FK = POTASSIUM FELDSPAR

APPENDIX I

The Fourth International Forum on Soil Taxonomy and Agrotechnology Transfer

7-24 February, 1983 Bangkok, Thailand

PROGRAMME

MONDAY, February 7

0900-1030	Opening Ceremony
	Chairman : Dr. S. Panichapong
	--- Mr. Anunt Komes, Director General, Land Development Department.
	--- Dr. H. Eswaran, Program Leader, Soil Mangement Support Services, USDA.
	--- Dr. H. Ikawa, Co-Principal Investigator, International Benchmark Sites Network for Agrotechnology Transfer.
	--- Hon. C. Leakpai, Minister of Agriculture.
1030-1100	Break
	Technical Session I --- Overview
1100-1130	Purpose of the course ---- H. Eswaran
1130-1230	Soil Taxonomy, a technical language of soil science --- A. Van Wambeke.
1230-1400	Lunch
	Technical Session II --- Soil Taxonomy
1400-1500	Principles of Soil Taxonomy --- A. Van Wambeke
1500-1600	Diagnostic horizon (surface) --- H. Eswaran
1600-1630	Break
1630-1730	Horizon Designation and Symbols --- H. Ikawa

TUESDAY, February 8

	Technical Session III --- Soil Taxonomy
0800-0900	Soil moisture and temperature regimes --- A. Van Wambeke
0900-1000	Diagnostic subsurface horizon --- H. Ikawa
1000-1030	Break
1030-1130	Soil Taxonomy, categories and nomenclature --- H. Eswaran.
1130-1230	Entisols and Inceptisols --- H. Ikawa
1230-1400	Lunch
1400-1500	Applications of soil survey and classificatior for tree crop development and improvement --- The malaysian experience --- Ng Siew Kee
1600-1630	Break
1630-1730	Excersises, how to classify --- H. Ikawa

WEDNESDAY, February 9

	Technical Session IV --- Soil Taxonomy
0800-0900	Alfisols and Ultisols --- S. Paramananthan
0900-1000	Vertisols --- H. Ikawa
1000-1030	Break
1030-1130	Physiography, geology and climate of Thailand --- L. Moncharoen
1130-1230	Soils of Thailand --- C. Changprai
1230-1400	Lunch
	Technical Session V --- Soil Survey Interpretation
1400-1730	Evaluation of soil resource inventories --- A. Van Wambeke

THURSDAY, February 10

	Technical Session VI --- Soil Survey Interpretation
0800-0900	Oxisols --- S. Paramananthan
0900-1000	Soil survey interpretations, principles --- M. Mausbach.
1000-1030	Break
1030-1130	Soil analysis --- M. Mausbach
1130-1230	Soil mineralogy --- H. Eswaran
1230-1400	Lunch
1400-1500	Soil survey interpretation --- M. Mausbach
1500-1600	Soil Families --- H. Ikawa
1600-1630	Break
1630-1730	Excercises, soils data --- M. Mausbach

FRIDAY, February 11

0700	Field Trip I Night in Kanchanaburi

SATURDAY, February 12

0730	Field Trip I Night in Bangkok

SUNDAY, February 13 ---- Free

MONDAY, February 14

	Technical Session VII --- Soil Survey Interpretations
0800-1000	Soil potential --- M. Mausbach
1000-1030	Break
1030-1230	Form 5 --- Mausbach

1230-1400	Lunch
1400-1700	Soil Taxonomy exercises --- H. Ikawa and F. H. Beinroth

TUESDAY, February 15

0730	Field Trip II Night in Khao Yai National Park

WEDNESAY, February 16

0730	Field Trip III Night in Nakorn Rachasima

THURSDAY, February 17

0730	Field Trip IV Night in Chantaburi

FRIDAY, February 18

0730	Field Trip V Night in Rayong

SATURDAY, February 19

	Field Trip VI Night in Bangkok

SUNDAY, February 20 --- Free

MONDAY, February 21

	Technical Session VIII --- Agro-ecological Zones
0800-0900	FAO Agro-ecological project --- M.F. Purnell
0900-1000	Potential population supporting capacities of land --- M.F. Purnell

1000-1030	Break
1030-1230	Excercises
1230-1400	Lunch
1400-1500	The Benchmark Soils Project principles --- F. H. Beinroth
1500-1600	The soils of BSP --- H. Ikawa
1600-1630	Break
1630-1730	Evaluation of BSP project --- F.H. Beinroth

TUESDAY, February 22

	Technical Session IX --- IBSNAT
0800-1000	Overview of IBSNAT --- F. H. Beinroth
1900-1000	Approaches to land evaluation and agrotechnology transfer --- H. Ikawa
1000-1030	Break
1030-1230	Exercises --- H. Ikawa and F. H. Beinroth
1230-1400	Lunch
	Technical Session X --- Soil-Crop Relations
1400-1500	Use of soil survey and fertility evaluation in Hevea cultivation --- E. Pushparajah
1500-1600	Soil-plant relationship : Sugarcane --- Preecha Suriyapan
1600-1615	Break
1615-1745	Characteristic and potential productivities of some major cassava soils --- Piya Duangpatra
1745-1815	A short report of corn in Thailand --- Takahiro Inove

WEDNESDAY, February 23

	Technical Session XI --- Soil-Crop Relations
0800-0900	Oil palm (Elalis guineensis) in Malaysia --- Hew Choy Kean

0900-1000	A proposed rice production philopsophy --- P. Prabuddham
1000-1030	Break
1030-1130	Management of acid sulphate soils for rice production --- Vo Tong Xuan
1130-1230	Soil conservation in Thailand --- S. Boonyarak
1230-1400	Lunch
	Technical Session XII --- Soils of the ASEAN Region
1400-1600	Discussion on problems in soil classification of ASEAN region --- H. Eswaran
1600-1630	Break
1630-1700	An evaluation and application of the concept of soil performance --- H. Eswaran

THURSDAY, February 24

	Technical Session XIII --- Panel Discussion
	Chairman : A. Van Wambeke
0900-1200	"An ASEAN Network of Banchmark Sites for Agrotechnology Transfer"
	Panel : Dr. S. Panichapong Dr. F.H. Beinroth Dr. A.H. Sharifuddin Dr. E. Pushparajah Dr. S. Rojanasoonthon
1200-1400	Lunch
1400-1500	Forum evaluation (participants) --- H. Eswaran
1500-1600	Recommendations --- H. Eswaran
1600-1630	Break
1630	Closing Ceremony
	Chairman : S. Panichapong

Presentation : A. Komes

--- Form in retroospect --- S. Rojanasoonthon

--- Vote of Thanks --- A. Van Wambeke

--- Closing Address --- A. Komes

APPENDIX II

The Fourth International Forum on Soil Taxonomy and Agrotechnology Transfer

LECTURERS

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APPENDIX III

The Fourth International Forum on Soil Taxonomy and Agrotechnology Transfer

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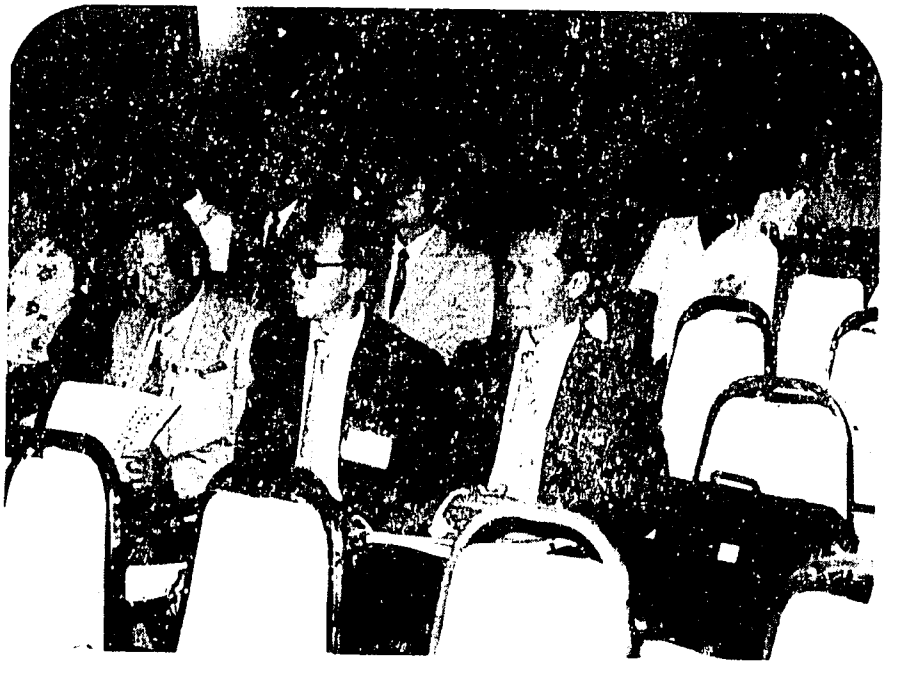
FORUM ACTIVITIES

Opening ceremony

Left to right Dr. H. Ikawa (IBSNAT), Dr. H. Eswaran (SMSS), H.E. Chuan Leekpai (Minister of Agriculture), Mr. A. Komes (Director General, DLD). Vacant seat-Dr. S. Panichapong (Director, Soil Survey Division)

H. E. Chuan Leekpai, Minister of Agriculture and Cooperatives delivers the opening address.



Participants at indoor sessions

Dr. Hari Eswaran (in pit) leads the discussion on the Namphong Series, a Siliceous, Isohyperthermic family of the Typic Ustipsamment, during the field tour.

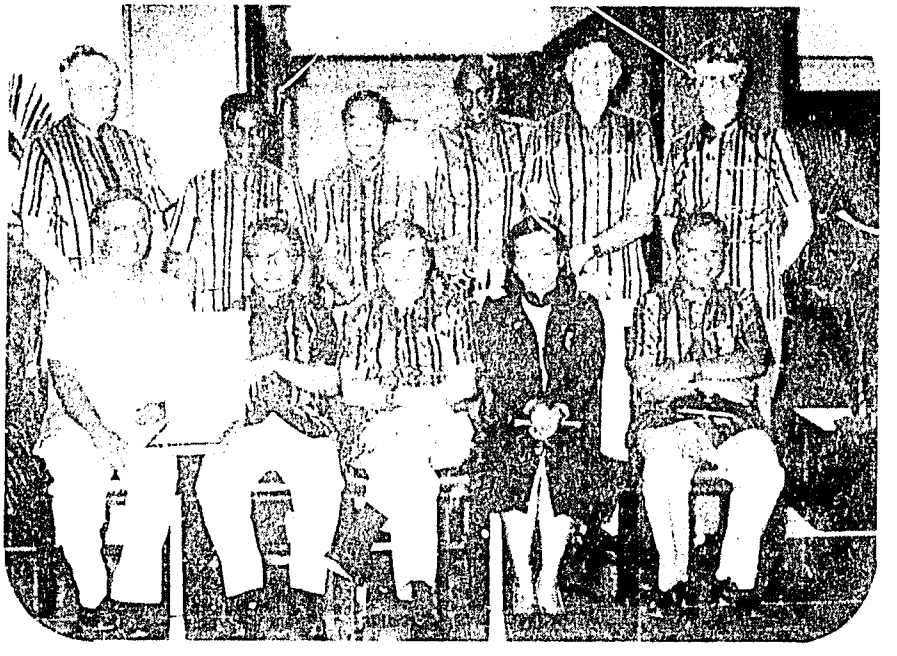
Dr. H. Ikawa and Mr. L. Moncharoen (foreground) search for clayskins during the field tour.

Mrs. Morakot

Participant of the Forum, receives her, a Certificate from Mr. Anunt Komes, Director General of the Land Development Department.

Closing Dinner

H. E. Chuan Leekpai (Minister of Agriculture, on far side of table) looks on as Ms. Carol Teasley, Deputy Director of USAID/Bangkok (pinkdress) and Dr. F. Beinroth (blue shirt) examine the plaque presented to SMSS.



Forum Resource Personnel

Front row, left to right : Dr. Hari Eswaran, Dr. Samarn Panichapong, Dr. Fred Beinroth, Mrs. Chālinee Niamskul Mr. Lek Moncharoen.

Back row, left to right : Dr. Armand Van Wambeke, Dr. Sinnathamby Paramanathan, Dr. Haryoshi Ikawa, Dr. Eliathamby Pushparajah, Dr. Frank Purnell, Dr. Maurice Mausbach.

(Dr. Panichapong holds the plaque presented by the Land Development Department to the Soil Management Support Services).

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