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STUDY ON SOIL PRODUCTIVITY OF PADDY FIELDS IN THAILAND

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ABSTRACT

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This study was carried out to analyse the production characteristics of paddy soils in Thailand in relation to soil fertility with a view to contributing to the advancement of rice production. For this purpose, observations of soil profiles were made to analyse the soil conditions of the paddy fields, which cover various kinds of soils in representative rice growing areas throughout the whole country. Physical, chemical and clay mineralogical analyses of the soil samples collected during the field observation of the profiles were conducted to identify the soil factors limiting rice production and/or the extent of possible soil damage among the various kinds of soil groups. Based on these results, several appropriate soil management and fertilization practices were suggested.

Index words: Soil fertility of tropical paddy soils, production capability classification, clay mineral, oxidative-reductive properties.

CONTENTS

Study on Soil Productivity of Paddy Fields in Thailand

I. Introduction

Thailand is located between 5° and 21° of north latitude and between 97° and 106° of east longitude, covering approximately 60 million hectares. Of the total area, farmland accounts for 22 percent, forest and grazing for 51 percent, and the rest includes urban areas, lakes, swamps, rivers, highways, railroad and so on. About 52 percent of the total farmland, that is 6.9 million hectares, is devoted to paddy rice cultivation. For the convenience of statistical consideration, Thailand is divided into four regions, namely the Central Plain with 35 provinces, the North-eastern Region with 15 provinces, the Northern Region with 7 provinces, and the Southern Region with 14 provinces.*

Though rice is grown in all the regions, the Central Plain which accounts for about 50–55 percent of the total production and about 38 percent of the total acreage of paddy fields, is frequently called the "rice bowl of Thailand." The soils and climatic conditions in this region are particularly suited to paddy rice cultivation. The rice fields in the North-eastern Region are the largest of the four regions of the country, amounting to about 2.7 million hectares. However, the soils are generally characterized by a low fertility and inadequate water supply. Approximately 30 percent of the total area of this region is not suitable for cropping due to shallow soils, low moisture holding capacity, low fertility, and erosion hazards. The Northern Region is chiefly mountainous and forested. Agriculture is limited to the valleys of the Chao Phraya river tributaries. Main rice cultivation areas are Chiang Mai, Lampang, Chiang Rai, Phrae and Nan Basins, totalling about one million hectares. The soils there are the most fertile in Thailand, and multiple cropping system is being promoted in the areas where irrigation water is available. The Southern peninsula is a region of narrow, rugged mountains. Rubber is widely grown on small holdings, but the yield is rather low, and the trees generally are in poor condition. Paddy rice, is also an important crop, but the cultivated area is only 0.5 million hectares.

In most of the country a monsoon type of climate with pronounced wet and dry seasons prevails. The average annual precipitation fluctuates between 1000 mm and 2000 mm, but the rainfall is usually concentrated in six months from May to October and the precipitation during this period often exceeds 85 percent of the total amount. However, the time of rainfall as well as the amount greatly varies from year to year. The delay in the onset of the rainy season frequently interferes with the time of rice planting and a high amount of rainfall often causes severe inundations over a considerable area, resulting in flood damage to rice plant. The average annual temperature ranges between 26°C and 28°C. Although April is the hottest month and January the coldest month, the fluctuations in monthly temperature are usually less than 5°C. With respect to the temperature rice cultivation in Thailand can take place all the year round.

Agriculture plays a major role in the economy of Thailand. Nearly one third of the Gross Domestic Product originates from the agricultural sector, and exports of the country have been mainly depending upon agricultural products, which account for

*Number of provinces: data from 1973

more than 60 percent of the total foreign exchange earnings. Especially, rice has been the most important export product. Thailand is exporting a quantity of rice amounting to 1.0 to 1.5 million metric tons annually in terms of milled rice. However, the increase in the population of Thailand with an annual growth rate of nearly 3 percent has resulted in the rapid expansion of domestic rice consumption. Coping with the population increase of nearly 3 percent, rice production had to be increased by more than 3 percent in order to maintain the same level of exports with a supply sufficient to meet the domestic requirements.

The total annual rice production steadily increased from 5.5 million metric tons in 1957 to 13.7 million metric tons in 1977 (12). This upward trend has mostly been caused by the expansion of rice fields. On the other hand, the average yield per unit area gradually decreased until 1960 presumably because the land has been cultivated without application of any fertilizers for many years. However, yield started to increase from 1961 due to the introduction of improved varieties, use of chemical fertilizers, and control of pests and diseases. Nevertheless, the average yield per unit area, which was estimated at about 1.7 metric tons per hectare in 1977 (12), is still low compared with that in other rice producing countries. Low yield may be ascribed to various factors such as climatic conditions, water supply system, fertilizer application technique, cultivation practices, varieties used, soil fertility and so on. Among those factors, variety improvement has significantly contributed to the increment in rice yield, but it should be emphasized that high yielding varieties are generally more exacting than the native ones in their requirements of fertility management.

A large part of the rice growing area in Thailand has been cultivated without the application of any fertilizers for many years as mentioned before. Consequently, most of the nutrients required for rice plant must be derived from the soil and irrigation water. Therefore, the enhancement of soil fertility is one of the prerequisites to high rice production. The fertility of paddy soils in Thailand varies from area to area as evidenced by the rice yield per unit area. For instance, based on the simple fertilizer trials carried out all over the country from 1964 to 1966, the average yeild following fertilization at the rate of about 95 kg of ammophos fertilizer per hectare, was about 2 tons per hectare in the North-eastern Region, 3 tons in the Central Plain, and 4 tons in the Northern Region, respectively (39). On the other hand, it has been reported that about 6 tons of paddy per hectare were producted in some areas of the Petchabun Province in the Central Plain even without any fertilizer application.

Soil fertility is closely related to the soil forming process including parent materials, the mode of deposition and physiographic position. The first systematic study of soils in Thailand was started by Pendelton in 1935 (64), and under his guidance soil surveys were carried out all over the country. These results have been comprehensively compiled by Montrakul (48). From 1962 onwards, a detailed reconnaissance soil survey has been organized to cover the whole country using aerial photographs and topographic maps under the guidance of FAO staff. A general soil map at a scale of 1,250,000 was prepared and printed in 1968 (49). Moormann and Rajanassonthon outlined the physiographic regions of Thailand and their main soil types, and also Komes (34) described some of the problem soils in this country and discussed methods by which their productivity may be increased. Thereafter, Kawaguchi and his colleagues conducted field studies and laboratory analyses with a view to characterizing paddy soils in Thailand in terms of their materials and fettility (7, 29, 30). Thus the knowledge on paddy soils in Thailand has been increasing both in quantity and quality. However, it is considered that the evaluation of physical, chemical, biological and mineralogical characteristics of paddy soils in relation to soil fertility is still insufficient to enable the introduction of advanced technology for high production of rice.

This study has been undertaken with the aim to clarify the following aspects:

1) Relationship between the physical, chemical and clay mineralogical properties of paddy soils as reflected by their taxonomic classification and their inherent content or deficiency in various nutrient-elements required for rice plant.

2) Evaluation of the soil limiting factors not only for rice production but also for the introduction of upland crops to paddy fields based upon the soil properties and the environmental conditions.

3) Get an insight into some soil management practices for the enhancement of soil fertility and/or improvement of soil conditions.

This study has been carried out under the cooperation research program between the Agriculture Department (former Rice Department), Ministry of Agriculture and Cooperatives, Thailand and the Tropical Agriculture Research Center, Ministry of Agriculture, Forestry and Fisheries, Japan.

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II. Pedogenetic Characteristics of Paddy Soils

Paddy rice in Thailand is grown mainly on alluvial lowlands and on the lower part of low terraces. Paddy fields are composed of a wide range of natural soils showing great variations in their morphology and physical and chemical properties. In this chapter, physiographical and morphological characteristics of paddy soils will be discussed through the field studies.

1. Methods and Locations

During the field studies, at the selected sites, a pit one meter deep, wherever possible, was dug so that the soil profile could be examined. The methods of profile examination have been described in a previous publication (58).

Several field trips to various parts of Thailand were made to analyse soil profiles of paddy fields and to take soil samples. The sites for field studies and soil sampling were selected so as to include various kinds of soil groups and to cover representative soils of paddy fields all over the country. Throughout the whole country, 71 profiles in the Central Plain, 44 profiles in the North-eastern Region, 37 profiles in the Northern Region, and 24 profiles in the Southern Region were studied. The names of the soil groups used in this study follow the terminology adopted in the report on "The Soils of the Kingdom of Thailand" pubiished by Mooremann and Rajanasoonthon (50).

2. Physiography and Parent Materials of Soils

Mainly based upon the similarity of internal landform and climatic conditions, Pendelton (64) divided Thailand physiographically into the following four regions as shown in Fig. 1.

1) Central Valley

The major parts of the Central Valley are covered with Quaternary Alluvium. The Central Valley is subdivided into three physiographic sub-regions, that is, Bangkok Plain, Upper Plain and Marginal Plain.

The Bankgkok Plain has two main physiographic units, namely recent alluvial plains and semi-recent terraces. The surface deposits of the Bangkok Plain are derived from riverine alluvium in the northern part and from marine alluvium in the southern part with a transition to brackish water in the central part. The recent alluvial plains have very few topographic features except for natural levees along the river channels. The semi-recent terraces formed by the rivers are located on the upper part of the Central Valley. In general, the landform of the semi-recent terraces is flat to slightly undulating.

In the Upper Plain and Marginal Plain, five main physiographic units are distinguished: recent alluvial plains, semi-recent terraces, low terraces, high terraces and hills. The recent alluvial plains and semi-recent terraces are formed by the sediments transported from the Chao Phraya, the Mae Klong, the Pasak and the Prachin rivers and their landform is flat to gently undulating. The lower part of the low terraces has a flat to slightly undulating landform. The high terraces and hills are fairly high above the recent alluvial plains, having an undulating or rolling topography. The hills consist of various kinds of rocks, varying from granite and quatzite to andesite and limestone. Paleozoic limestone also covers a considerable part of the western mountains and the eastern valley. Granite, gneiss and schist occurring in the catchment area of the Ping and the Wang rivers are the source of

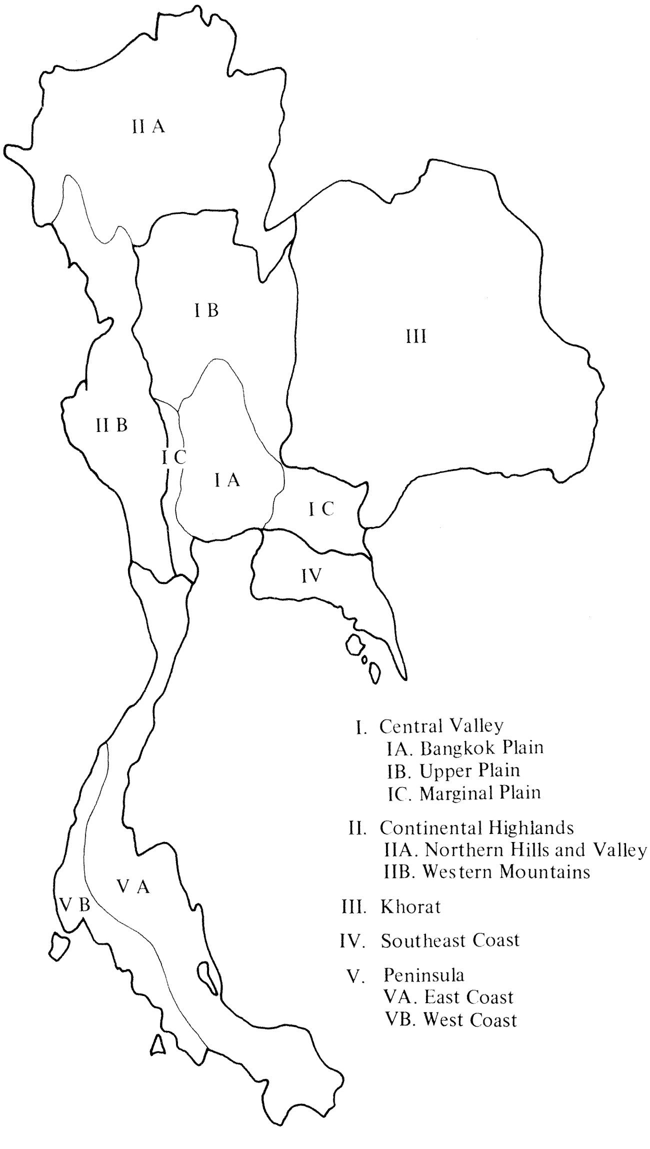


Figure 1. Physiographic Regions of Thailand, after R. L. Pendelton.

the muscovite fragments found in the levees of the Central Valley. Some effusion rocks (rhyolite, andesite and basalt) also are found in the eastern part of the Central Valley.

Important paddy field areas in Thailand cover most of the Central Valley, and both broadcast and transplanted rice is grown.

2) Continental Highlands

Structurally this region is a part of the extension of the Himalaya folded mountain system into Southeast Asia and divided into two sub-regions, that is, Northern Hills and Valley, and Western Mountains.

In the Northern Hills and Valley, there are five physiographic units: recent alluvial plains, semi-recent terraces, low terraces and hills.

The recent alluvial plains are situated in the lowest part of the flat lands along the Ping, the Yom, the Wang and the Nan rivers. The materials of these basins are composed mainly of fine-textured sediments from those rivers, but in some places, more coarser, mica-containing materials are deposited, reflecting the nature of the parent rocks. The semi-recent terraces extend between the recent alluvial plains and low terraces. The low terraces are subdivided into higher and lower parts. The lower part of the low terraces is flat to slightly undulating or gently sloping towards the recent alluvial plains. The higher portion of the low terraces is in contact with either the higher terraces or hills. The materials of the semi-recent terraces are loamy to clayey in the surface layer and a little heavier in the lower layer. The hills have three sub-regions, namely inter-mountain plateau, incised mountain plateau, and steep mountain land. The rocks in the hills include both igneous and sedimentary rocks that have undergone locally varying degree of metamorphism. Older granite and gneiss predominate among the igneous rocks. The sedimentary rocks consist of the Silurian-Devonian Kanchanaburi Formation containing mainly shale, sandstone and phyllite.

Paddy fields are mostly on the recent alluvial plains and semi-recent terraces, and scattered on the lower part of the low terraces.

3) Khorat

The landform in the Khorat region consists of alluvial plains, terraces of three levels (low, middle, and high) and hills and mountains.

The alluvial plains stretch as a narrow strip along the Mun, the Chi and the Mekong Rivers. The low terraces which are mostly found in this region, are flat to slightly undulating. The middle terraces are mainly seen in the northern part of the Khorat plateau. The topography of the middle terraces is generally undulating. The high terraces occur in small areas. Hills are scattered throughout the region. The bed rocks belong to the Mesozoic Khorat series characterized by a continental sequence of sandstone, siltstone, shale and conglomerate. Limestone occurs as a minor inclusion and basalt crops out near Buri Ram and elsewhere.

Paddy fields are concentrated in the present river alluvium and in the low terraces throughout the region. The lower part of the undulating middle terraces is also used for rice, whereas the higher areas are usually cultivated with field crops.

4) Peninsula

The Peninsula in Thailand is divided into two physiographic sub-regions, that is, East Coast and West Cost, being bordered by the hilly uplands and mountains located in the center of the peninsula.

The East Coast along the Gulf of Thailand has a smooth shoreline backed by broad coastal plains and marine terraces. The plains occur between the terraces and the tidal flats associated with the estuaries or lagoons. The topography of the coastal plains is generally flat. The tidal flats and swamps are fringing the lagoons and estuaries. A small area of recent brackish water alluvium is found in spots along the muddy estuaries and the lagoons.

The West Coast along the Andaman Sea is characterized by the existence of drowned rivers or estuaries, rocky headlines and off-shore islands. As a result of the presence of extensive hill ranges in close proximity of the present shoreline, marine and river terrace formations are restricted to narrow strips between the hills. In places, narrow coastal plains occur between the low terraces and tidal flats. Sandy beach formations are of limited occurrence compared with the eastern coast.

The geology of the Peninsula is more complicated than that of the other regions. The main rocks are igneous and sedimentary rocks. The predominant form of granite in the Peninsula is referred to as young granite in Thailand, and is thought to have intruded in the Later Cretaceous of Early Tertiary era. The sedimentary rocks are composed of the Phuket series, Kanchanaburi series, Ratchaburi series and Korat series.

Limited rice cultivation is practiced in the plains and lower terraces.

3. Morphological Characteristics of Paddy Soils

According to Moormann and Rajanasoonthon (50), most of the soils used for rice cultivation in Thailand belong to two soil groups, namely Alluvial Soils and Low Humic Gley Soils. And, only locally are Humic Gley soils, Regosols, Gray Podzolic Soils, Non-Calcic Brown Soils, and Grumusols cultivated for paddy rice. Soils cultivated for rice are kept submerged either naturally or artificially at least three to four months a year during the growing period of rice plant. Thus, soils that have long been cultivated with rice are known to have acquired special morphological features and to show special physical and chemical changes induced by cultivation (44, 51, 57, 67, 89). The morphological characteristics of each soil group used for rice cultivation are briefly outlined as follows:

1) Alluvial Soils

Alluvial Soils are formed on recent alluvium and are found in flooded plains and valleys throughout the country. They are sub-divided into three subgroups based upon the kinds of materials deposited by water, that is, Marine Alluvial Soils, Brackish Water Alluvial Soils and Fresh Water Alluvial Soils.

(1) Marine alluvial Soils: Marine Alluvial Soils derived from marine sediments occur on the tidal flats which are regularly inundated by sea water during high tide, on the slightly higher parts of the tidal flats and on the estuarine area which are never, or hardly flooded by sea water. They also occur on the more inland part of the Chao Phraya river which is now free of tidal flooding. Marine Alluvial Soils are usually very fine-textured soils with an Apg-Cg horizon sequence. The Apg horizons are composed of brownish black to brownish gray heavy clay with common, distinct iron mottles along root channels overlying dark to brownish gray, plastic and sticky heavy clay with few to common, faint yellowish spotty or cloudy iron mottles and sometimes with manganese mottles. Although the area of Marine Alluvial Soils is flooded for several months during the year, typical gley horizons are usually not recognized within a depth of 1 meter from the surface in the dry season, but dark olive gray mud-clay occurs at a depth of more than 1 meter in many places. In some places, the Cg horizons contain some gypsum needles. There are also many deep cracks in

the dry season and slickensides are common in the Cg horizons. Ped faces and pore wall of the Cg horizons often have clay coatings, some of which showing clear signs of clay movement.

(2) Brackish Water Alluvial soils: Brackish Water Alluvial Soils are formed on brackish water alluvium in former tidal flats, or in depressions behind beach ridges. They are distributed widely in the Central Plain and seldom occur in the Southern Region. Brackish Water Alluvial Soils are characterized by strongly acid heavy clay soils with "straw yellow" mottles, so called cat-clay, starting at a depth of about 30 cm from the surface. The profiles have an Apg-(Bg)-Cg horizon sequence. The Apg horizons are black to brownish black with few to common, distinct reddish brown to brown iron mottles along root channels. The Bg horizons consist of brownish gray heavy clay with common, prominent red, yellowish brown and dark brown iron mottles and "straw yellow" mottles, where the Bg horizons are present. The Cg horizons consist of grayish brown or gray nearly unripen heavy clay with common to few, prominent red and/or yellowish brown and "straw yellow" mottles. Neither manganese mottles nor concretions are present throughout the profiles. In some places, gypsum needles occur in the subsoils. Many wide and deep cracks are formed during the dry season. Slickensides and clay coating are observed in the subsoils.

(3) Fresh Water Alluvial Soils: Fresh Water Alluvial Soils are formed on fresh water alluvium (mainly riverine deposits, in some places lacustrine sediments), in the river basin area of flooded plains and valleys, and on the levees bordering the rivers. They are widely found all over the country, but show great variations in physical and chemical features, reflecting the nature of the parent materials in the catchment area of the river. Fresh Water Alluvial Soils in the Central Plain, the Northern Region and the Southern Region are usually fine-textured soils with an Apg-(Bg)-Cg horizon sequence, but those in the North-eastern region are commonly coarse-textured soils except the soils along the Mun and the Mekong rivers, which are usually clayey. Soil color of the Apg horizon greatly varies with the location, the hue ranging from 5YR to 5Y, and the soil color generally becomes more grayish with the depth. The Apg horizons have common, distinct brown to yellowish brown, reddish brown or bright brown spotty or cloudy iron mottles with often common to many manganese concretions. Occasionally, slickensides are present in the lower parts of the Bg horizons and in the Cg horizons, especially when the soil texture is heavy.

2) Low Humic Gley Soils

Low Humic Gley Soils are predominantly formed on semi-recent alluvium or old alluvium and situated on semi-recent terraces, low terraces and on lowlying depressions of middle terraces throughout the country.

There are considerable differences in their morphological characteristics depending on the age of the alluvial sediments on which they were formed. They are usually deep soils with an Apg-Bg-Cg horizon sequence, but in some places, they are shallow due to the presence of semi-consolidated and/or consolidated iron-manganese stones which occur within a depth of 50 cm from the surface. Such shallow soils are found in the North-eastern Region. Texture of this soil group ranges from clay to loamy sand. Generally speaking, the soil texture is fine to very fine in the Central Plain, fine to medium in the Northern Region and medium to coarse in the North-eastern Region. The subsoils become usually more clayey than the surface soils, indicating signs of textural B horizon formation. At the present stage, it is considered that a cambic horizon is present but not an argillic one. Soil color of the Apg horizons mostly is 10 YR or 7.5 YR in hue, but chroma and value show considerable variations. Soil color of the subsoils ranges from 5 Y to 5 YR in hue, 1 to 6 in chroma and 2 to 7 in value. In general, Low Humic Gley Soils in the North-eastern Region have higher value in both chroma and value than those in the other regions. They are mottled throughout the profiles with a shade of yellowish, brownish and reddish color. In many places, ferro-manganese concretions are present in the Bg and/or Cg horizons. In the soils on older alluvium, lateritic concretions occur in the subsoils, mostly as individual concretions but sometimes as large sheets which become very hard when exposed to the air.

3) Humic Gley Soils

Humic Gley Soils in Thailand are formed on semi-recent alluvium derived from calcareous rocks, on flooded plains and low terraces of inter-mountainous valleys. They are distributed to a small extent in the Chiang Rai basin. They are characterized by a black or brownish gray Apg horizon overlying a brownish gray or gray Bg horizon. They are usually fine-textured soils throughout the profile. Common, distinct yellowish brown or bright brown iron mottles occur throughout the profile and iron-manganese concretions may be present in the subsoils. Soil structure develops moderately to strongly. Well developed crumb or granular structure is observed along the root residuals and moderate, medium prismatic structure in the Bg horizon. In the dry season, the soils show deep cracks.

4) Regosols

Regosols are formed on old alluvium on higher part of low terraces or lower part of middle terraces. They are distributed mainly in the North-eastern Region. They are sandy in texture to a considerable depth. The profile is composed of Ap and C horizons. A horizons consist of light brown or greyish brown loamy sand overlying AC or C horizon made of light brown or light reddish brown loamy sand. Mottles usually are limited to the surface. This soil group was formerly called Regosolic Low Humic Gley Soils (11), and thereafter named Hydromorphic Regosols by Kittayarak (32). In some places, a white crust of salts appears on the surface soil in the dry season, due to the presence of salt deposits in the substratum.

5) Gray Podzolic Soils

Gray Podzolic Soils are only sporadically used for paddy cultivation. They are formed on semi-recent alluvium or colluvium derived from coarse-textured materials such as granite or sandstone on low terraces. Their profiles are rather uniform with a very weak horizon differentiation. The majority of these soils have a medium to coarse texture, namely sandy loam or loamy sand in the surface horizon, showing a light gray color when dry and changing to a (dark) grayish brown color when moist. The subsoil usually is yellowish brown. Few to common, faint yellowish brown iron mottles are present in some places. A weak compacted layer is commonly found beneath the A horizon.

6) Non-Calcic Brown Soils

Non-Calcic Brown Soils are formed on semi-recent alluvium and are situated on semi-recent terraces, on the transitional area between river levees and the relatively higher part of semi-recent terraces, and on the border between the present flooded plains and the semi-recent terraces. Their topography is almost flat to slightly undulating. These soils are scattered in every region.

Non-Calcic Brown Soils have a loamy to clayey texture with an Apg-Bg-Cg horizon sequence. The subsurface texture is finer than that of the surface due to the formation of a textural B horizon. Soil color is deep dark gray, grayish brown, or dark grayish brown in the Apg horizon and dark grayish brown, grayish brown or dark brown in the Bg horizon. Common distrinct yellowish brown iron mottles occur in the Apg horizon along root channels and commmon to many, distinct dark brown, yellowish brown, bright brown, and locally reddish brown spotty iron mottles in the Bg horizon. Sometimes manganese concretions are present in the Bg horizon. There is a weak to moderate development of clay coating in the Bg horizon.

7) Grumusols

Grumusols used for the cultivation of paddy rice are limited to the Lop Buri province in the Central Plain. Grumusols are formed on alluvium or colluvium derived from limestone and occur on semi-recent terraces associated with limestone hills. The profile of Grumusols is characterized by heavy clay containing predominantly montmorillonitic clay minerals with an Ap-C horizon sequence. Most commonly, Ap horizons are black or very dark grayish brown in color to a considerable depth. When dry, wide and deep crakcs appear being often over 4 cm in width. The first few rains in the beginning of the rainy season may be percolated fairly rapidly, but once the clay swells, further precipitation has little or no chance to penetrate through the soil column. This shrink-swell pattern of the clays is evidenced by the slickensides and pressure faces occuring in the subsoils. Lime concretions are present throughout the profile, but neither iron nor manganese mottles are usually observed.

4. Correlation of Paddy Soil Classification

Several soil classification systems have been established in many countries in the past, and it is quite probable that more will be proposed in the future.

The soils of Thailand have been classified so far in various ways. Among them, soil groups are generally used as soil classification units in reconnaissance soil survey. This system is fundamentally based upon the predominant parent materials and the soil characteristics in association with the physiographic position (50). At present, the Soil Survey Staff of the Soil Survey Divison, Department of Land Development in Thailand, have been adopting the soil series as the mapping units in semi-detailed soil surveys. So far more than 150 soil series have been identified all over the country including upland soils (9).

In Japan, since the 1930s, many attempts have been made to classify paddy soils (26, 28, 41, 42, 60, 85, 92). At present, arable land in Japan has been classified into sixteen soil groups in considering diagnostic horizons such as gleyed horizon, gray-colored horizon, volcanic ash horizon in the profile, parent materials and mode of deposition and so forth (2).

On the other hand, a new system of soil classification, "A Comprehensive System, 7th Approximation" has been officially adopted by USDA. Based upon the presence or absence of diagnostic horizons, there are ten soil orders in this system. (86, 87, 88)

As these systems greatly differ in their classification criteria each soil group classified in a given system needs to be correlated for a better understanding of the soils. For this purpose, soil groups or subgroups used in Thailand are correlated with the great group of the USDA system and major soil groups in Japan as shown in Table 1. In addition, names of soil series employed in the Soil Survey Division, Department of Land Development are indicated when identified.

Table 1. Correlation of Soil Groups in Paddy Soil among Three Classification Systems

Thailand's system	USDA system	Japanese system
Marine Alluvial Soils	Tropaquent.	Gray Lowland Soils, partly Gley Soils.
Brackish Water Alluvial Soils	Tropaquent, partly Tropaquept.	Gray Lowland Soils.
Fresh Water Alluvial Soils	Tropaquept, Tropaquent.	Gray Lowland Soils, Brown Lowland Soils.
Low Humic Gley Soils	Tropaquept, partly Plintaquult.	Gray Lowland Soils, Brown Lowland Soils, partly Yellow Soils.
Humic Gley Soils	Tropaquept.	Gray Lowland Soils.
Hydromorphic Regosols	Ustipsamment, Psammaquent.	Brown Lowland Soils, Yellow Soils.
Hydromorphic Gray Podzolic Soils	Dystropaquept.	Gray Lowland Soils, Gray Upland Soils.
Hydromorphic Non-Calcic Brown Soils	Tropaqualf.	Brown Lowland Soils. Gray Lowland Soils.
Grumusols	Pellustert.	—

All of the Marine Alluvial Soils investigated in this study belong to the Tropaquents in the USDA system because there is no distinct pedogenetic horizon due to the lack of time to develop a diagnostic horizon. But, in some areas, the formation of a plow-sole is observed and cambic horizons are weakly developed. According to the classification system of Japan, most of the Marine Alluvial Soils are classified as Gray Lowland Soils and partly as Gley Soils. Based on the presence or absence of gypsum, color of mottles and texture, Marine Alluvial Soils examined here were grouped into the following soil series; Bang Leng (presence of gypsum), Bang Khen (presence of gypsum and red iron mottles), Samut Prakan (presence of reduced layer), and Bang Lamun (coarse texture).

Brackish Water Alluvial Soils are classified as Tropaquents or Tropaquepts in the USDA system, but most of them belong to the Tropaquents. In the Japanese system, all the Brackish Water Alluvial Soils are classified as Gray Lowland Soils. According to the presence or absence of gypsum and the depth of the cat-clay layer, Brackish Water Alluvial Soils are grouped into the following soil series; Ongkarak (cat-clay layer appears within a depth of less than 30 cm from the surface), Rangsit (cat-clay layer is present deeper) and Ayuthaya (presence of gypsum).

Fresh Water Alluvial Soils are classified as Tropaquents or Tropaquepts in the USDA system according to the degree of horizon differentiation. Although there are no significant illuvial or eluvial horizons, a sign of development of argillic horizon is found in some places. In the Japanese system, Fresh Water Alluvial Soils are classified as Gray Lowland Soils and Brown Lowland Soils according to the color of the subsoil. Fresh Water Alluvial Soils are grouped into the following soil series based on the soil color of subsoils, texture, parent materials and so on; Phimai (gray subsoil), Chai Nat (visible presence of mica flakes), Pa Sak, Si Songkram (coarse texture), Mae Chan, and Chiang Mai.

Low Humic Gley Soils are classified as Tropaquepts and Plintaquults in the USDA system according to the presence of diagnostic horizons. Although silicate clays tend to accumulate in the subsoils in most places, the presence of an argillic horizon is not clear. Therefore, most of the Low Humic Gley Soils can be classified as Inceptisols. Low Humic Gley Soils which are classified as Ultisols, have a fairly well developed argillic horizon and predominant plinthitic iron concretions in the lower parts. According to the Japanese system, this soil group is classified as Gray Lowland Soils.

Based on the presence of plinthite, soil color of subsoil, texture and parent materials and so on, Low Humic Gley Soils are grouped into the following soil series: Hing Khong, Tha Lat, Phen (presence of unconsolidated plinthite), Roi Et, Nakhon Phanom, Tha Thum, On (presence of consolidated plinthite), Mae Sai, Lampang, Hong Dong, Nan, Klaeng, Chanburi and Bangnara.

Humic Gley Soils are classified as Tropaquepts because of the lack of distinct argillic horizon. In the Japanese system, they are classified as Gray Lowland Soils. They belong to the Mae Khan series.

Regosols are classified as Ustipsamments and Psamaquents in the USDA system. In the Japanese system, they are classified as Brown Lowland soils, and Yellow Soils. According to the presence of salt accumulation and soil color of subsoils, they are grouped into the following soil series; Ban Khai, Ubon and Udon (slat accumulation).

Gray Podzolic soils are classified as Dystropaquepts in the USDA system. In the Japanese system, they are classified as Gray Lowland Soils. According to the parent materials, they are grouped into the San Pa Thong and Nam Krachai series.

Non-Clacic Brown Soils mainly belong to the Tropaqualfs in the USDA system. In the Japanese system, they are classified as Gray Lowland Soils. They are grouped into the following series; Manorom, Nakhon Pathom and Kamphaen Saen.

Grumusols are classified as Pellusterts in the USDA system. In Japan, this kind of soil has not been identified. Grumusols used for the cultivation of paddy mainly belong to the Lop Buri series, but in the area bordering the other soil groups, there are some other soil series, for example, Bang Mi series.

5. Summary

About 20 percent of the total area of Thailand (about 60 million hectares) is cultivated. Of this cultivated area, 6.9 million hectares are devoted to rice cultivation. Paddy rice is cultivated on alluvial plains or on alluvial lowlands and the lower part of low terraces under flooded conditions. The soils used for rice cultivation belong mainly to two soil groups, namely Alluvial Soils and Low Humic Gley soils. Only sporadically are Humic Gley Soils, Regosols, Gray Podzolic Soils, Non-Calcic Brown Soils and Grumusols cultivated for paddy rice.

Alluvial Soils are formed on recent alluvium and are still youg soils. They have an Apg-Cg horizon sequence. They are sub-divided into three sub-groups based upon the kind of water-deposited materials, namely Marine Alluvial Soils, Brackish Water Alluvial Soils and Fresh Water Alluvial Soils. Marine Alluvial Soils are derived from marine sediments and are generally heavy-textured soils. Soil color is brownish black to brownish gray. Common, distinct or faint iron mottles, and sometimes manganese mottles are recognized in the whole profile. In some places the Cg horizon contains some gypsum crystals. Slickensides are common in the Cg horizon. These soils are distributed mainly in the Bangkok Plain and the Peninsula. Brackish Water Alluvial Soils are derived from brackish water alluvium. They are characterized by the presence of strongly acid heavy clay with "straw yellow" mottles, so-called cat-clay. They are distributed widely in the Central Plain and less in the Peninsula. Fresh Water Alluvial Soils are derived from fresh water alluvium and occur mainly on the river basins and valley bottoms. They are found all over the country. Their morphology greatly differs

according to the parent materials. In the Central Plain, Northern Region, and Southern Region, they are usually fine-textured soils, while coarse-textured soils predominate in the North-eastern Region except along the Mun and the Mekong rivers. Soil color greatly varies ranging from 5YR to 5Y in hue. Iron and/or manganese mottles are commonly found throughout the profile.

Low Humic Gley Soils are derived from semi-recent alluvium or old alluvium and occur on semi-recent terraces and low terraces. They are usually deep soils with an Apg-Bg-Cg horizon sequence. In general, the soils in the Central Plain have a fine texture, fine to medium in the Northern Region, coarse in the North-eastern Region and various kinds of textures in the Southern Region, but the subsoils are more clayey than the surface soils. Soil color greatly varies ranging from 5YR to 5Y in hue. There are mottles of iron/or manganese throughout the profile. In some places, lateritic concretions are found in the subsoil.

Humic Gley soils are derived from semi-recent alluvium originating from limestone. They are narrowly distributed in the Chiang Rai basin. They are fine-textured soils with a black or brownish gray Apg horizon and brownish gray or gray Bg horizon. Soil structure develops moderately to strongly.

Regosols are derived from old alluvium on the higher part of low terraces. They are distributed mainly in the North-eastern Region. They are deep sandy soils. Mottles usually are limited to the surface. In some places, a white crust of salt appears on the surface in the dry season.

Gray Podzolic Soils are derived from semi-recent alluvium. They are scattered in the Northern Region. Soil color is light gray in the surface horizon, changing to yellowish brown in the subsoil.

Non-Calcic Brown Soils are derived from semi-recent alluvium. They are scattered in every region. They are medium- to fine-textured soils. Soil color is dark gray to dark grayish brown in the Apg horizon and grayish brown to dark brown in the Bg horizon. Oxidative sediments of iron and manganese are found in the profile. Grumusols are derived from marls and alluvium originating from limestone. Grumusols used for paddy cultivation are limited to the Lop Buri Province. They are characterized by a black or dark gray Ap horizon. Because of the presence of montmorillonitic heavy clay, they crack deeply in the dry season. There are distinct slickensides in the subsoils. Neither iron nor manganese mottles are present.

III. Physical Properties of Paddy Soils

Physical properties of a soil greatly influence plant growth. The penetration of plant roots, drainage and retention of available water and plant nutrients are primarily linked with the physical conditions of soil. Physical properties also influence the chemical and biological behavior of the soil. The importance of the physical properties of paddy soils, however, had not been properly recognized up to this time. A possible reason for this is the fact that paddy soils are kept submerged during the growing period of rice plant. Recently, it has been reported that the technology to achieve high yield of rice is based on the assumption that drainage and irrigation can be carried out any time when necessary (10, 62, 69). It has also been emphasized that the diversification of paddy fields is of fundamental importance for the agricultural development of Thailand. Moreover, the introduction of mechanized farming for promoting labor efficiency is closely related to the physical properties of paddy soils. Under such conditions, the physical behavior of paddy soils should be more emphasized in the near future.

The physical properties greatly depend upon the amount, size, shape, arrangement, and clay mineral composition of soil particles; kind and amount of organic matter; and the volume and form of pores and the way they are occupied by water and air at a particular time.

Of the important physical properties of paddy soils, particle size distribution (mechanical analysis or soil texture), distribution of three-phase, bulk density, sedimentation volume, dispersion ratio, water-holding capacity and moisture equivalent will be discussed in this chapter.

1. Materials and Methods

Analytical methods for the physical properties analysed in this study were described in a previous publication (58). Soil samples for the analysis were taken from each genetic horizon concurrently with the profile examination.

2. Results and Discussion

1) Particle Size Distribution

The particle size distribution or the mechanical composition of a soil is the most stable property of a soil, and is little affected by soil management. It reflects the nature of the parent materials, degree of weathering, and pedological and geological process that affected it. The retention of plant nutrients and available water and water permeability conditions are greatly influenced by the particle size distribution. In dealing with soil fertility, particle size distribution is one of the most fundamental soil properties. Soil texture refers to the relative proportion of sand, silt and clay fractions; coarse sand, 2-0.2 mm; fine sand 0.2-0.02 mm, silt, 0.02-0.002 mm; and clay, less than 0.002 mm in diameter, following the definition of the International Soil Science Society.

The results of mechanical analysis of paddy soils in every region were plotted in a triangular graph in terms of sand, silt and clay content, as shown in Fig. 2. And also, the mean and standard deviation of coarse sand, fine sand, silt and clay content for each soil group are tabulated in Table 2.

As seen from the figure, the soils from the Central Plain were concentrated in the upper right corner of the triangles which corresponds to the area with high clay content. The greater part of the soils from this region had a HC texture. In contrast with the soils in the Central Plain, the soils from the North-eastern Region are seen in the lower left corner which corresponds to the area with a high content of sand fraction. Of the 43 profiles analysed in the North-eastern Region, 39 profiles were FSL to L in textural class. Fine sand fraction of the coarser-textured soils often accounted for more than 60% and sometimes for more than 80%. This sand fraction is mainly derived from continental sandstone, shale and conglomerates of Triassic and Jurassic age. However, along the Mekong and the Mun rivers and their tributaries, fine-textured soils were found sporadically. The soils from the Northern Region are observed toward the lower right side of the triangle, indicating that silt fraction in this region is the predominant component. Accordingly, LiC and SiC in textural class were prevalent, especially in the Phrae, Nan and Lampang basins. In other words, soils on lower or young terraces were definitely heavier in soil textures than those on higher or older terraces. The soils from the Southern Region were scattered in the triangular diagram. In other words, a wide variety of soil texture is seen in the soils from this region, ranging from HC to SL in textural class depending upon the parent materials and physiographic position on which the soils developed. As a rule, soils on higher elevations or at the foot of the mountains were coarse-textured, while those on lower flat plains were fine-textured.

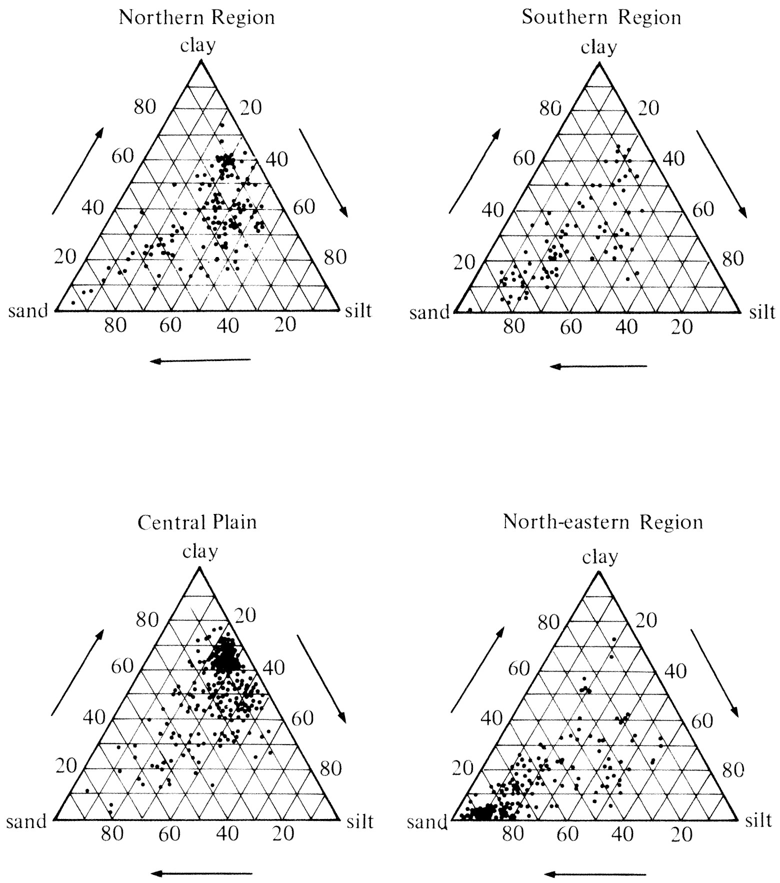


Figure 2. Particle Size Distribution in Triangular Diagram

Table 2. Particle Size Distribution by Soil Group

Soil group	Layer*	CoS (%) mean	CoS (%) S.D.	FS (%) mean	FS (%) S.D.	Silt (%) mean	Silt (%) S.D.	Clay (%) mean	Clay (%) S.D.
Marine Alluvial Soils	I	0.3	0.4	8.2	4.3	28.5	5.3	63.0	8.0
(n:14)	II	0.9	1.6	9.2	5.5	28.6	5.7	61.3	10.2
	III	1.6	1.3	12.2	7.7	25.7	4.9	60.5	9.7
Brackish Water Alluvial Soils	I	1.0	1.2	8.1	6.5	32.5	6.9	58.4	11.0
(n:9)	II	2.2	2.8	8.3	4.9	30.0	8.2	59.5	6.8
	III	3.2	3.6	8.6	4.0	30.9	6.5	57.3	7.7
Fresh Water Alluvial Soils	I	4.7	6.1	24.3	19.7	34.5	13.4	36.5	16.5
(n:34)	II	7.4	13.7	21.9	17.9	31.5	12.8	39.2	16.1
	III	6.3	8.4	21.6	19.3	31.0	12.0	41.1	14.5
Low Humic Gley Soils	I	5.8	6.7	38.3	25.3	31.5	15.0	24.4	17.2
(n:80)	II	6.8	7.0	35.3	22.5	30.2	13.3	27.7	17.7
	III	8.6	8.5	32.4	19.9	27.0	12.0	32.0	16.0
Humic Gley Soils	I	1.4	0.2	8.7	2.2	31.0	0.9	58.9	3.2
(n:2)	II	2.9	1.7	6.4	0.3	30.4	0.5	60.3	1.4
	III	1.8	0.6	6.7	2.0	26.6	4.3	64.9	6.4
Regosols	I	17.4	14.0	69.8	19.9	7.8	4.9	5.0	4.3
(n:11)	II	19.9	15.5	66.4	20.8	9.6	5.0	4.1	3.8
	III	18.7	17.2	67.6	17.5	9.4	4.5	4.3	3.6
Gray Podzolic Soils	I	18.6	13.8	51.7	6.1	18.3	5.9	11.4	2.9
(n:4)	II	19.5	15.4	48.2	6.1	19.2	6.9	13.1	8.8
	III	17.4	15.1	40.0	10.0	21.6	9.3	21.0	12.8
Non-Calcic Brown Soils	I	2.5	2.5	32.3	19.9	30.8	8.0	34.4	15.5
(n:4)	II	1.9	1.8	32.1	19.0	30.1	8.2	35.9	16.3
	III	0.6	0.3	13.8	7.8	24.7	3.9	60.9	11.3
Grumusols	I	4.6	2.6	12.3	6.5	28.5	11.1	54.6	10.7
(n:4)	II	8.0	7.3	12.8	5.9	23.3	5.4	55.9	13.2
	III	6.9	4.0	11.6	5.6	24.1	5.5	57.4	11.4

* I: Surface soils, II: Subsurface soils, III: Subsoils.

Of the 16 soil profiles from Marine Alluvial Soils, 14 sites had a HC soil texture throughout the profile. The clay content of these soils often exceeded 60%.

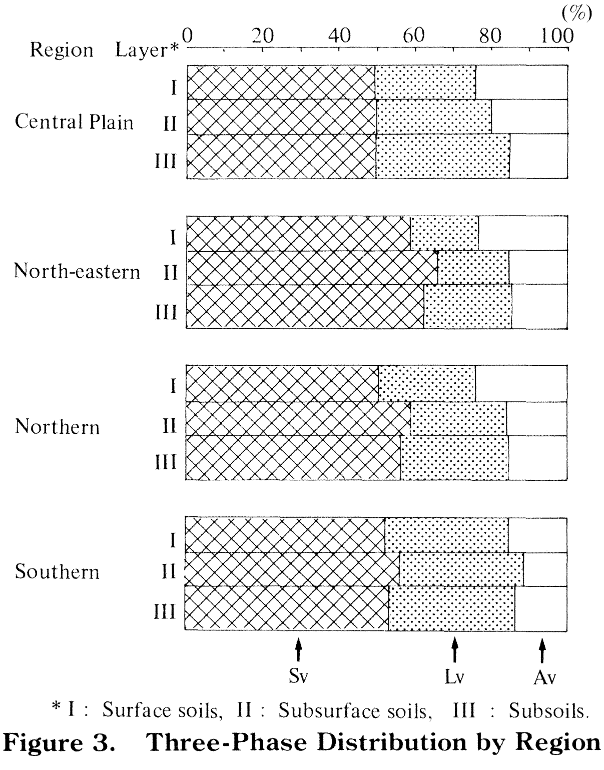
In the Marine Alluvial soils, downward movement of clay in the profile did not occur often, so that the soil texture was nearly uniform throughout the profile. In the Brackish Water Alluvial Soils, both the silt and clay fractions were slightly more abundant than in the Marine Alluvial Soils, which brought about a relative decrease in the sand fraction. The distribution of particle size was nearly uniform throughout the profile as in the Marine Alluvial Soils. In the Fresh Water Alluvial Soils, clay content decreased and fine sand fraction was more conspicuous compared with the Marine Alluvial Soils and Brackish Water Alluvial Soils. Soil texture in this soil group varied with the sites, ranging from HC to LFS. A greater part of the Fresh Water Alluvial Soils in the Central Plain were HC to LiC in soil texture, while those in the North-eastern Region showed a coarse texture except the soils derived from riverine alluvium of the Mekong and the Mun rivers and their tributaries. In this soil group, the clay fraction commonly increased more or less with the depth, suggesting a downward movement of the clay fraction. In the Low Humic Gley Soils, the clay content decreased and fine sand content increased compared with the Fresh Water Alluvial Soils. Of the 12 profiles from the Low Humic Gley Soils in the Central Plain, only one profile had a soil texture with HC and the other soils were characterized by textures ranging from LiC to L. Most of the Low Humic Gley Soils from the North-eastern Region were coarse-textured soils, (FSL to CL). Since the silt fraction generally predominated in the soils of this group in the Northern Region, as seen in Fig. 3, LiC and SiC textures prevailed. In the Southern Region, the soil texture of the Low Humic Gley Soils greatly varied from HC to SL. The clay fraction clearly increased with the depth, indicating the formation of an argillic horizon. In the Humic Gley Soils, soil texture was HC. The clay fraction slightly increased with the depth. In the Regosols, the fine sand fraction was prevalent throughout the profile, as implied from the name of this soil group. Soil texture of the Gray Podzolic Soils was SL in the surface soils but ranged from CL to LiC in the subsoil. Soil texture of the Non-Calcic Brown Soils was LiC in surface soils and HC in subsoils. Grumusols were HC in soil texture throughout the profile and showed no variation with the depth.

2) Three-Phase Distribution

Three-phase distribution of a soil is defined as the relative ratio of solid, liquid and air phases by which a unit volume of the soil is occupied.

Three-phase distribution of the undisturbed soil samples of the whole profiles examined is delineated in Fig. 3. And also, the mean and standard deviations of solid phase (Sv), liquid phase (Lv) and air phase (Av) for each soil group are tabulated in Table 3.

Soil samples were taken in the dry season, although the climatic conditions at sampling time varied. Accordingly, although it is very difficult to make a thorough comparison among the regions or soil groups, data obtained are as follows. Solid



* I : Surface soils, II : Subsurface soils, III : Subsoils.

Figure 3. Three-Phase Distribution by Region

Table 3. Three-Phase Distribution by Soil Group

Soil group	Layer*	Solid phase (%) mean	Solid phase (%) S.D.	Liquid phase (%) mean	Liquid phase (%) S.D.	Air phase (%) mean	Air phase (%) S.D.
Marine Alluvial Soils	I	44.7	7.1	36.4	10.9	18.9	9.3
(n:10)	II	45.2	4.8	38.2	9.3	16.6	9.2
	III	46.2	3.2	44.5	10.1	9.3	5.4
Brackish Water Alluvial Soils	I	44.6	6.3	33.6	8.5	21.8	11.0
(n:7)	II	47.1	4.9	36.2	5.2	16.7	5.9
	III	44.1	2.4	40.1	7.6	15.8	7.5
Fresh Water Alluvial Soils	I	50.4	7.5	23.2	8.7	26.4	9.7
(n:25)	II	53.7	7.6	26.9	6.1	19.4	7.8
	III	51.9	7.8	29.2	6.3	18.9	7.9
Low Humic Gley Soils	I	54.6	7.7	24.5	9.2	20.9	8.7
(n:73)	II	60.6	8.7	24.7	8.6	14.7	8.1
	III	57.8	7.7	27.9	7.5	14.3	7.3
Humic Gley Soils	I	40.0	2.9	31.4	0.5	28.6	3.4
(n:2)	II	49.3	2.9	33.9	0.1	16.8	3.0
	III	48.4	8.8	33.5	1.9	18.1	1.2
Regosols	I	58.7	3.2	20.6	6.4	20.7	5.2
(n:10)	II	64.3	9.1	20.2	7.1	15.5	6.9
	III	66.9	6.4	23.0	6.3	10.1	5.5
Gray Podzolic Soils	I	59.0	5.9	28.9	8.1	12.1	7.0
	II	62.9	9.1	25.2	9.6	11.9	6.8
(n:4)	III	59.5	8.1	23.2	5.8	17.3	4.0
Non-Calcic Brown Soils	I	47.7	4.4	21.7	11.6	30.6	15.9
	II	54.4	6.7	25.2	9.4	30.4	7.0
(n:3)	III	53.2	5.1	31.4	0.3	15.4	5.4
Grumusols	I	42.4	1.9	31.6	3.7	26.0	1.9
(n:2)	II	42.2	1.7	32.3	1.5	30.5	1.5
	III	41.5	2.5	33.0	1.8	25.5	0.7

* I: Surface soils, II: Subsurface soils, III: Subsoils.

phase occupied the largest portion in a unit volume of the soils regardless of regions or soil groups. Solid phase had the highest value in the North-eastern Region where sandy soils are widely distributed, and the lowest value in the Central Plain where clayey soils predominate. In every region, the solid phase showed the highest value in the subsurface soils except in the Central Plain where vertical changes in the solid phase were negligible. Liquid phase in surface soils had the highest value in the Southern Region and the lowest in the North-eastern Region. Most commonly, the value of the liquid phase increased with the depth, except for the soils from the Southern Region where the value of the liquid phase remained unchanged throughout the profile. This is probably due to the fact that the ground water table was high at the time of sampling in the Southern Region. Air phase had the lowest value in the Southern Region as in the other regions. Value of air phase, as a rule, abruptly decreased with the depth.

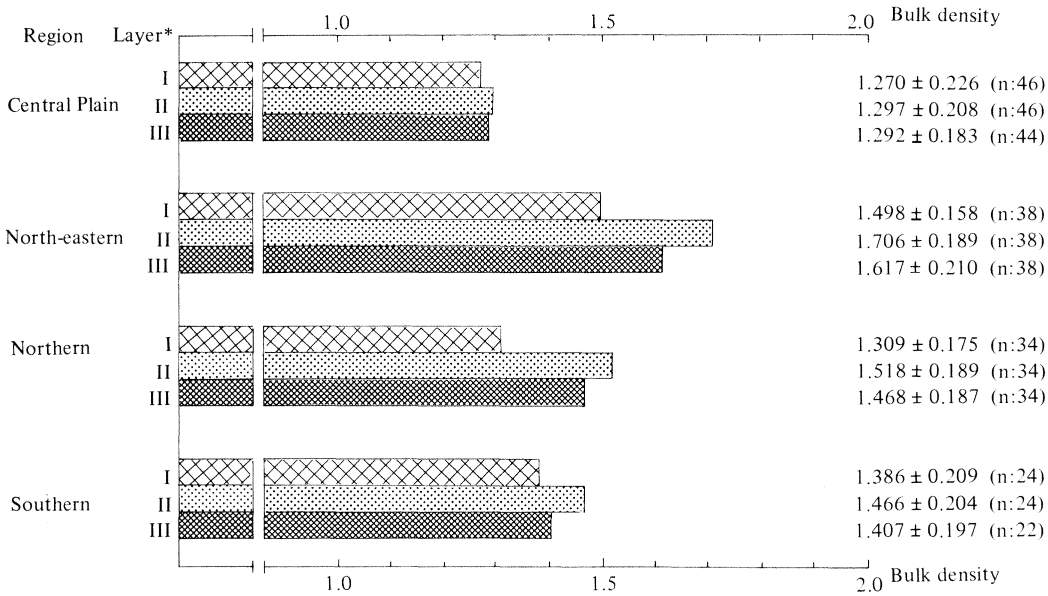
As for the soil groups, the following features are described: Solid phase had the highest value in the Regosols and the lowest in the Grumusols. The value of the solid phase in the subsurface soils was the highest in the profile except for the Marine Alluvial Soils and the Grumusols which showed nearly the same value throughout the profile, suggesting the formation of a plow-sole. The variations of the values of the liquid phase with the soil groups were rather small, but the Regosols had the lowest value probably due to the fact that the water holding capacity is very low in this soil group. Value of the liquid phase usually increased with the depth. This was especially evident in the Alluvial Soils. Value of the air phase in the Grumusols remained high even in the subsoils due to the formation of many deep cracks at the time of sampling in dry season. Value of the air phase usually declined with the depth, in contrast with the increase of the values of the liquid phase in deeper soils.

Since the surface soils of paddy fields are puddled before transplanting, the three-phase distribution of the surface soils does not appear to be important. However, the pattern of the three-phase distribution of the subsoils is one of the important factors for water permeability, particularly in relation to the water infiltration, aeration, or water retention properties when upland crops are introduced to paddy fields.

3) Bulk Density

Bulk density or apparent density is defined as the weight of a dry soil in a unit volume and is usually expressed as grams per cm^3. Average bulk density of surface soils, subsurface soils and subsoils in the undisturbed samples are represented in the histogram shown in Fig. 4 by region. The mean and the standard deviations in both the undisturbed and disturbed samples for every soil group are listed in Table 4.

The average values of bulk density of the undisturbed surface soils were 1.270 ranging from 0.963 to 1.753 in the Central Plain, 1.498 ranging from 1.053 to 1.813 in



* I : Surface soils, II : Subsurface soils, III : Subsoils.

Figure 4. Bulk Density by Region

Table 4. Bulk Density by Soil Group

Soil group	Layer*	Undisturbed samples			Disturbed sampled		
		No. of samples	Bulk density mean	S.D.	No. of samples	Bulk density mean	S.D.
Marine Alluvial Soils	I	11	1.163	0.178	13	1.141	0.062
	II	11	1.184	0.121	13	1.217	0.049
	III	11	1.205	0.081	12	1.196	0.047
Brackish Water Alluvial Soils	I	8	1.168	0.153	8	1.082	0.062
	II	8	1.226	0.119	8	1.140	0.043
	III	8	1.160	0.069	8	1.162	0.047
Fresh Water Alluvial Soils	I	28	1.304	0.207	39	1.117	0.139
	II	28	1.388	0.187	38	1.179	0.110
	III	27	1.358	0.195	33	1.191	0.118
Low Humic Gley Soils	I	74	1.415	0.194	78	1.210	0.167
	II	74	1.587	0.224	79	1.289	0.132
	III	73	1.514	0.194	79	1.271	0.111
Humic Gley Soils	I	2	1.040	0.074	2	0.997	0.021
	II	2	1.286	0.072	2	1.102	0.026
	III	2	1.256	0.020	2	1.128	0.029
Regosols	I	10	1.528	0.081	11	1.419	0.126
	II	10	1.681	0.246	11	1.467	0.107
	III	9	1.740	0.163	9	1.464	0.136
Gray Podzolic Soils	I	4	1.546	0.160	4	1.272	0.135
	II	4	1.649	0.099	4	1.346	0.036
	III	4	1.576	0.216	4	1.295	0.051
Non-Calcic Brown Soils	I	3	1.365	0.173	5	1.223	0.107
	II	3	1.449	0.142	5	1.297	0.124
	III	2	1.386	0.132	3	1.196	0.032
Grumusols	I	2	1.102	0.048	4	1.129	0.064
	II	2	1.077	0.025	4	1.161	0.076
	III	2	1.081	0.067	4	1.144	0.059

* I: Surface soils, II: Subsurface soils, III: Subsoils.

the North-eastern Region, 1.309 ranging from 0.966 to 1.587 in the Northern Region, and 1.386 ranging from 1.055 to 1.795 in the Southern Region, respectively. These values appeared to be high compared with those of Japanese paddy soils (59). Among the soil groups, the Humic Gley Soils, Grumusols and Brackish Water Alluvial Soils which have a relatively high content of organic matter, showed a relatively low bulk density, the value for the surface soils being 1.040, 1.102 and 1.168, respectively. In contrast, the Gray Podzolic soils, Regosols, and Low Humic Gley Soils from the North-eastern Region which are very poor in organic matter had a relatively high bulk density, the value in the surface soils being 1.566, 1.524 and 1.522, respectively. In fact, a high correlation between organic matter content and bulk density of the surface soils could be recognized, as shown in Fig. 5. Bulk density in relation to organic matter content is calculated in Table 5 for reference.

Bulk density is also expected to be considerably affected by the soil texture. In general, the higher the sand fraction content, the higher the bulk density, as shown

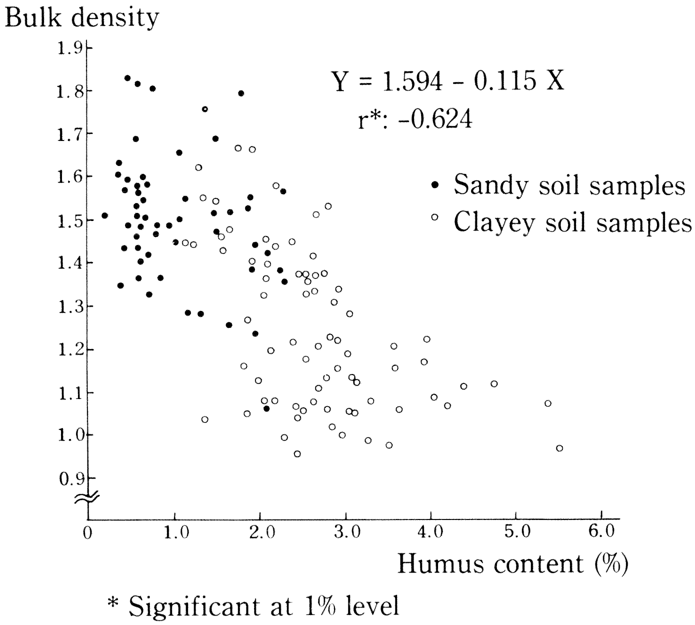


Figure 5. Relationship between Organic Matter Content and Bulk Density

Table 5. Bulk Density in Relation to Organic Matter Content

Organic matter % (air-dried soil basis)	No. of samples	Bulk density mean	Bulk density S.D.
less than 0.49	123	1.618	0.215
0.50 — 1.00	123	1.459	0.210
1.01 — 1.99	149	1.373	0.203
2.00 — 3.99	84	1.229	0.168
more than 4.00	6	1.128	0.142

in Table 6. Shaykewich, et al. (71) have observed that organic matter was the soil component most closely related to the bulk density, next to the clay content, and fine sand plus silt and that the interaction of clay and organic matter was less but approximately equally related to the bulk density.

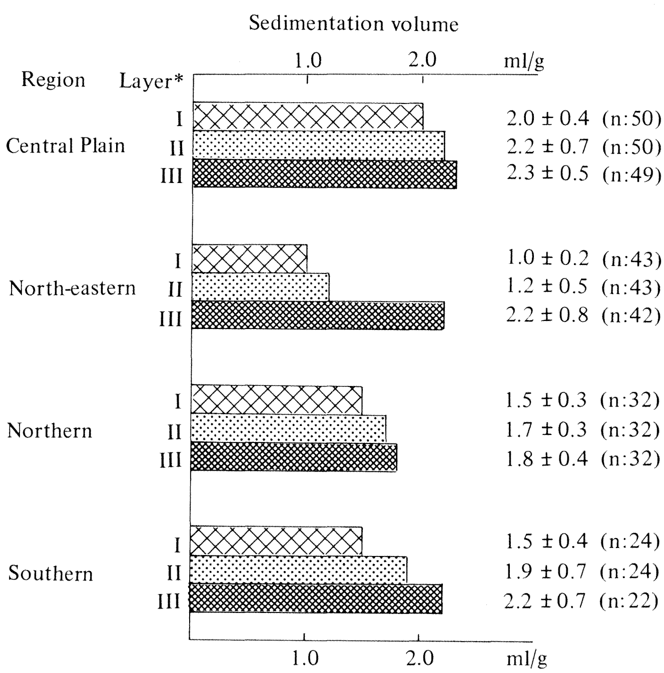
Air-dried fine soils, in other words, disturbed samples, had a lower bulk density than the undisturbed soil samples almost without any exception. The average values were 1.109 in the Central Plain, 1.370 in the North-eastern Region, 1.092 in the Northern Region, and 1.189 in the Southern Region, respectively. The difference in bulk density between the undisturbed samples and the air dried fine soil samples may indicate that the paddy soils in Thailand have a tendency to be packed more compactly under field conditions. Soil compaction was observed more clearly in the soils where the silt fraction predominated, as seen in Table 6.

When soil particles of uniform size are packed into a definite volume, the bulk density depends only on the type of packing, regardless of the size of the soil particles. There are two typical packing systems, the hexagonal (close packing), and

Table 6. Bulk Density in Relation to Textural Class

g/c.c.

Textural class	Undisturbed samples			Disturbed samples			(A)/(B)
	No. of samples	Bulk density mean (A)	S.D.	No. of samples	Bulk density mean (B)	S.D.	
Heavy clay	179	1.237	0.171	205	1.140	0.098	1.085
Silty clay	32	1.409	0.183	37	1.112	0.096	1.267
Light clay	93	1.437	0.183	106	1.223	0.111	1.175
Sandy clay	2	1.547	0.047	6	1.269	0.036	1.219
Silty clay loam	8	1.547	0.178	12	1.247	0.076	1.241
Clay loam	41	1.565	0.190	38	1.312	0.103	1.119
Sandy clay loam	18	1.625	0.210	15	1.373	0.065	1.183
Silty loam	4	1.608	0.184	7	1.216	0.065	1.322
Loam	13	1.627	0.207	13	1.380	0.049	1.179
Sandy loam	53	1.656	0.129	62	1.381	0.106	1.199
Loamy sand	13	1.627	0.129	13	1.436	0.079	1.133
Fine sand	23	1.663	0.169	27	1.505	0.091	1.105



* I : Surface soils, II : Subsurface soils, III : Subsoils.

Figure 6. Sedimentation Volume by Region

Table 7. Sedimentation Volume by Soil Group

ml/g

Soil group	Layer*	No. of samples	Sedimentation volume mean	S.D.
Marine Alluvial Soils	I	11	2.3	0.3
	II	11	2.9	1.2
	III	11	2.7	0.7
Brackish Water Alluvial Soils	I	9	2.1	0.3
	II	9	2.2	0.2
	III	9	2.3	0.2
Fresh Water Alluvial Soils	I	28	1.7	0.4
	II	28	1.9	0.5
	III	27	2.0	0.5
Low Humic Gley Soils	I	76	1.4	0.4
	II	76	1.6	0.5
	III	76	2.2	1.3
Humic Gley Soils	I	2	1.7	0.2
	II	2	2.1	0.1
	III	2	2.2	0.1
Regosols	I	11	0.9	0.2
	II	11	1.0	0.3
	III	9	1.1	0.2
Gray Podzolic Soils	I	4	1.1	0.1
	II	4	1.4	0.4
	III	4	1.6	0.5
Non-Calcic Brown Soils	I	4	1.7	0.3
	II	4	1.8	0.3
	III	4	2.5	0.2
Grumusols	I	4	2.6	0.1
	II	4	2.5	0.2
	III	4	2.6	0.2

* I: Surface soils, II: Subsurface soils, III: Subsoils.

the cubic (open packing). The closest packing occurs when soil particles are packed according to the hexagonal system. In this case the mean density of the system will be 2.0/cm^3. On the other hand, in the case of the open packing system, the mean bulk density will be 1.41 g/cm^3. Some of the Thai paddy soils exceeded 2.0 in bulk density. Yokoi (93) disclosed that the bulk density of three fraction systems in soil particles amounted to 2.41 in the open packing state, and 2.65 in the closest packing state. On the other hand, Terasawa (82) reported that the existence of a bulk density of less than 1.41 (theoretical value) in the open packing system may be ascribed to the aggregate formation of soil particles.

According to Kawaguchi and Kyuma (29), the high bulk density observed in the Thai paddy soils is due to various soil properties such as the paucity of soil organic matter, the strong association of highly humified organic matter with clay and the characteristics of the clay itself, as well as to cyclic drying and wetting of very heavy clayey soils.

4) Sedimentation Volume of Soil in Water

Sedimentation volume of a soil is the volume of soil particles contained in water.

Average values of the sedimentation volume of the Thai paddy soils are listed in Fig. 6 by region. The mean and the standard deviations for each soil group are indicated in Table 7.

The average values of the sedimentation volume of the surface soils were 2.0 ml per one g of dry soils on a dry basis in the Central Plain, 1.0 ml in the North-eastern Region, 1.5 ml in the Northern Region and 1.5 ml in the Southern Region, respectively. Marine Alluvial Soils, Brackish Water Alluvial Soils, Humic Gley Soils and Grumusols had higher values than the other soil groups. In general, the higher the clay content of clay, the higher the value of sedimentation volume, as might be expected. When the clay contents are nearly identical, the soils containing chiefly montmorillonitic minerals have higher values than kaolinitic soils, as reported by Abe and Arrake (1). Sedimentation volume generally increased with the depth. For instance, Profile Nos. 115 (Ubon Ratchathani, Khuan Nai), 125 (Buri Ram, Prakhon Chai) had a very high sedimentation volume in the subsoils compared with that in the surface soils.

In the Marine Alluvial Soils, Brackish Water Alluvial Soils, and Grumusols, the soil particles in water were readily flocculated, while in the other samples they occurred in a well dispersed state for a long period of time. The sedimentation volume gradually decreased with time in the former soil groups and gradually increased in the latter. This is probably due to the difference in the kind and amount of exchangeable cations adsorbed on soil particles and hydration degree of soil colloids. Calcium ion is likely to flocculate soil particles whereas sodium ion tends to disperse soil particles. But, excessive amount of salts is liable to flocculate soil particles. Thus the sedimentation volume of a soil in water is markedly

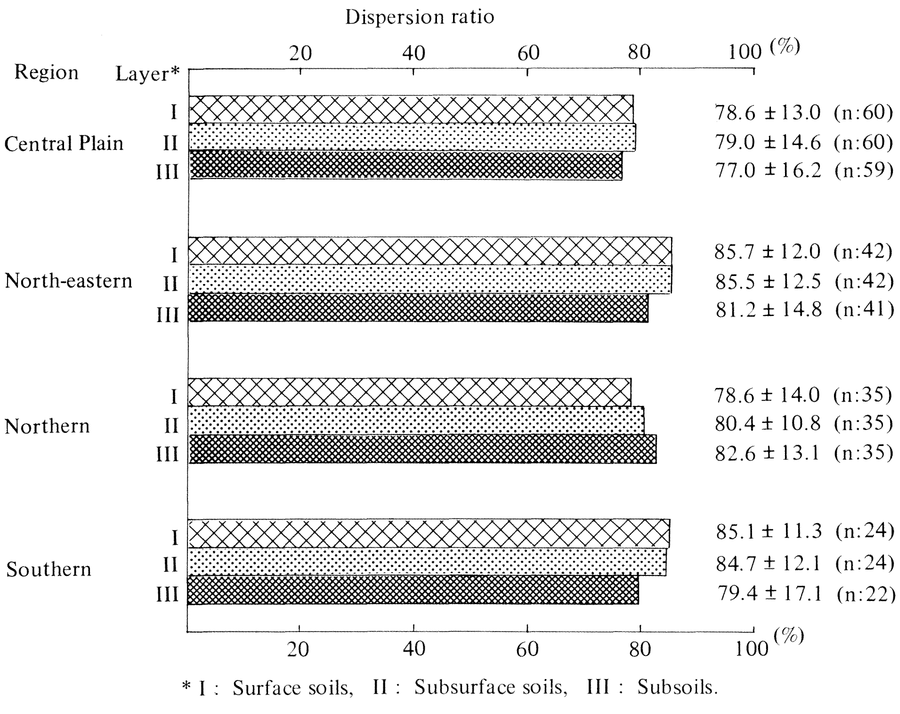


Figure 7. Dispersion Ratio by Region

influenced by the physico-chemical properties of soil such as electric charge carried on soil particles, kind and amount of exchangeable bases absorbed on the surface of soil particles and the degree of hydration of the soil.

Although the relationship between sedimentation volume and other physical properties is not sufficiently documented, it is considered that there is a relationship with the solid phase, moisture equivalent and so on. Middleton (43) showed that the sedimentation volume is closely related to the amount of colloids, organic matter, moisture equivalent and the ratio of silica to alumina. And also, it has been reported that the soils with high values of sedimentation volume show a low water permeability (53). Therefore, the sedimentation volume is regarded as one of the indices of the physical properties acquired during the soil forming process (77).

5) Dispersion Ratio

As shown in Fig. 7, the average values of the dispersion ratio of the surface soils were 78.6% in the Central Plain, 85.7% in the North-eastern Region, 78.6% in the Northern Region and 85.1% in the Southern Region, respectively. Great variations with the depth were not recognized. The soils on which a granular structure was

Table 8. Dispersion Ratio by Soil Group

(%)

Soil group	Layer*	No. of samples	Dispersion ratio mean	S.D.
Marine Alluvial Soils	I	14	82.1	9.2
	II	14	85.5	9.6
	III	14	86.2	7.1
Brackish Water Alluvial Soils	I	9	69.9	10.9
	II	9	64.8	11.2
	III	9	68.6	5.2
Fresh Water Alluvial Soils	I	35	78.5	13.5
	II	35	78.2	14.4
	III	34	75.4	16.7
Low Humic Gley Soils	I	78	85.5	10.7
	II	78	84.9	11.5
	III	78	84.5	12.0
Humic Gley Soils	I	2	53.9	3.7
	II	2	70.5	4.2
	III	2	71.9	4.7
Regosols	I	11	79.8	15.0
	II	11	82.1	10.3
	III	9	73.0	17.6
Gray Podzolic Soils	I	4	88.2	14.6
	II	4	86.8	9.3
	III	4	68.3	20.8
Non-Calcic Brown Soils	I	4	79.3	12.9
	II	4	86.0	7.8
	III	4	78.6	5.1
Grumusols	I	2	55.1	15.0
	II	2	55.0	19.4
	III	2	66.1	7.0

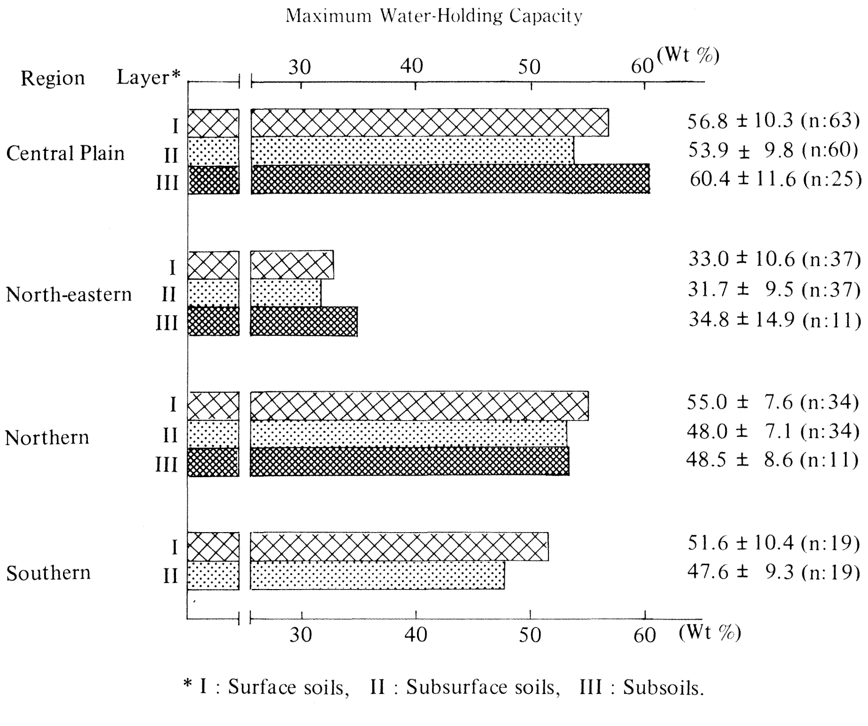
* I: Surface soils, II: Subsurface soils, III: Subsoils.

developed under the field conditions tended to have a lower value of the ratio. For instance, as seen in Table 8, the ratios of the surface soils were 55.1% in the Grumusols and 53.9% in the Humic Gley Soils. These ratios, however, increased in the subsoils. However, significant differences among other soil groups were not evident. These values seem to be fairly high compared with those of paddy soils in Japan (53).

Dispersion ratio is obtained by dividing the amount of silt plus clay that is easily suspended in pure water by the total quantity of silt plus clay. The larger this ratio, the more easily the soil can be dispersed. It is considered that the dispersion ratio of a soil is an index of the soil structure in relation to water stable aggregate formation. A negative correlation has been observed between the dispersion ratio and aggregate index (82). Accordingly, the high dispersibility of the Thai soils may indicate that water stable aggregate formation is very poor even in the surface layer probably due to the low organic matter content. It is very important that a soil crust be readily produced in the surface layer since the soil particles are easily dispersed by rain drops when paddy fields are used for the cultivation of upland crops, because the soil crust is liable to cause a significant resistance to infiltration of rain water or irrigation water, resulting in the decrease of available water storage.

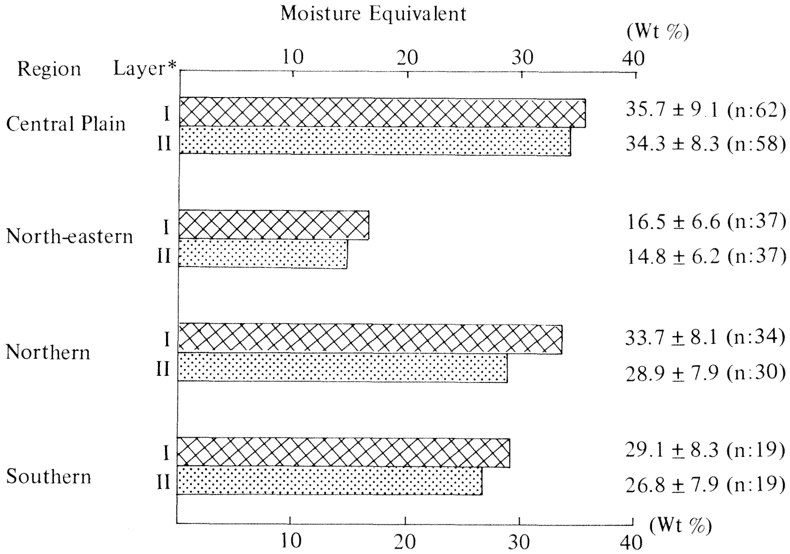
6) Maximum Water-Holding Capacity and Moisture Equivalent

Maximum water-holding capacity and moisture equivalent were measured to determine the characteristics of water retention of a soil. The former is defined as the average moisture content when all the pores in a soil are replaced by water and



* I : Surface soils, II : Subsurface soils, III : Subsoils.

Figure 8. Maximum Water-Holding Capacity by Region



* I : Surface soils, II : Subsurface soils.

Figure 9. Moisture Equivalent by Region

the latter as the water retained in a soil against a centrifugal force equivalent to 1,000 g.

Average values of maximum water-holding capacity and moisture equivalent are listed in Figs. 8 and 9 by region, respectively. The mean and the standard deviations for each soil group are tabulated in Table 9. The average values of maximum water-holding capacity of the surface soils were 56.8% in the Central Plain, 33.0% in the North-eastern Region, 55.0% in the Northern Region and 51.6% in the Southern Region, respectively. On the other hand, moisture equivalent was 35.7%, 16.5%, 33.0% and 29.1%, respectively.

Maximum water-holding capacity as well as moisture equivalent were closely related to the textural class of soils, as shown in Table 10. In fact, a significantly high positive correlation between clay content and maximum water-holding capacity and moisture equivalent was recognized, with the correlation coefficients being 0.850 and 0.858, respectively. It is, therefore, natural that these values were high in the Central Plain where the clay fraction predominates and very low in the North-eastern Region where the sand fraction is prevalent. For an identical clay content, montmorillonitic soils have higher values of both maximum water-holding capacity and moisture equivalent than kaolinitic soils, as in the case of the Grumusols. In the same textural class, the higher the organic matter content, the higher the values of both maximum water-holding capacity and moisture equivalent. For example, there was a significantly high positive correlation between organic matter content and maximum water-holding capacity and moisture equivalent in soils belonging to the light clay textural class. The correlation coefficients were 0.823 in the former and 0.922 in the latter, respectively.

Table 9. Maximum Water-Holding Capacity and Moisture Equivalent by Soil Group

(Wt. %)

Soil group	Layer*	Max. water-holding capacity No. of samples	mean	S.D.	Moisture equivalent No. of samples	mean	S.D.
Marine Alluvial Soils	I	13	62.4	5.5	12	44.4	5.5
	II	12	60.6	6.6	11	43.2	5.3
	III	9	67.8	8.6	—	—	—
Brackish Water Alluvial Soils	I	8	61.7	4.1	8	40.8	2.9
	II	8	58.1	4.9	8	38.9	1.9
	III	4	62.8	4.2	—	—	—
Fresh Water Alluvial Soils	I	35	55.5	8.8	35	34.6	7.7
	II	33	51.2	8.5	32	31.8	7.6
	III	11	54.0	10.0	—	—	—
Low Humic Gley Soils	I	73	46.5	12.9	73	25.9	9.1
	II	73	42.9	10.5	72	23.5	8.3
	III	14	47.4	8.9	—	—	—
Humic Gley Soils	I	2	64.5	0.2	2	42.0	2.0
	II	2	52.0	0.3	—	—	—
	III	1	51.9	—	—	—	—
Regosols	I	10	27.4	6.2	10	12.9	4.3
	II	10	24.6	5.2	10	10.8	3.3
	III	4	18.2	3.0	—	—	—
Gray Podzolic Soils	I	4	39.0	6.7	4	18.3	4.1
	II	3	37.4	3.6	4	15.7	4.3
	III	2	31.9	0.3	—	—	—
Non-Calcic Brown Soils	I	4	50.8	3.9	4	30.1	5.2
	II	4	47.2	3.9	4	27.7	5.4
	III	2	53.2	5.3	—	—	—
Grumusols	I	3	74.2	4.5	3	48.8	1.6
	II	3	70.1	5.4	3	45.1	1.9
	III	2	73.7	2.5	—	—	—

* I: Surface soils, II: Subsurface soils, III: Subsoils.

Although the moisture content available to plant cannot be estimated from these data only, sandy soils poor in organic matter are likely to have very low content of available water, resulting in severe drought damage in the dry season when upland crops are introduced to paddy fields.

3. Summary

The Thai paddy soils have a great variety of textural classes. The soils from the Central Plain mostly are classified as heavy clay soils except the soils on low terraces in the marginal areas. Clay content of the Marine Alluvial Soils, Brackish Water Alluvial Soils and Fresh Water Alluvial Soils in some places often exceeded 65%. In contrast, the soils from the North-eastern Region had a coarse texture ranging from fine sand to sandy loam. Fine sand content of Regosols often exceeded 70%. Along the Mekong River, silt fraction was prevalent in some areas. In the Northern Region, the silt fraction often predominated, and silty clay to light clay textures were typical. In the Southern Region

Table 10. Maximum Water-Holding Capacity and Moisture Equivalent in Relation to Textural Class

(Wt. %)

Textural class	Max. water-holding capacity			Moisture equivalent		
	No. of samples	mean	S.D.	No. of samples	mean	S.D.
HC	147	60.7	8.4	95	38.3	6.6
SiC	26	53.8	6.6	23	32.0	6.3
LiC	54	51.0	6.9	48	32.0	6.8
SC	4	43.4	1.3	—	—	—
SiCL	6	40.4	3.3	4	16.1	3.1
CL	22	43.8	7.8	19	26.0	3.6
SCL	8	39.7	3.1	3	13.1	2.7
SiL	6	38.0	4.7	5	20.6	6.1
L	11	37.9	6.9	11	19.8	4.3
SL	43	34.6	8.1	40	16.4	4.2
LS	14	29.0	4.8	12	13.1	2.2
FS	24	22.2	3.9	17	10.2	2.5

the textural class varied considerably depending upon the parent materials and physiographic position.

Of the three phases, the solid phase accounted for the largest portion regardless of soil groups, ranging from 35.8% to 70.2% in the surface soils. Values of the solid phase were the lowest in the Central Plain and the highest in the North-eastern Region. Values of the liquid phase were the highest in the Southern Region and the lowest in the Northern Region. Air phase values were the highest in the North-eastern Region and the lowest in the Southern Region.

The bulk density was generally high irrespective of textural grades, the average values in the surface soils being 1.270 in the Central Plain, 1.498 in the North-eastern Region, 1.309 in the Northern Region and 1.386 in the Southern Region.

The average values of the sedimentation volume of the surface soils were 2.0 ml/g in the Central Plain, 1.0 ml/g in the North-eastern Region, 1.5 ml/g in the Northern Region and 1.5 ml/g in the Southern Region, respectively.

Dispersion ratio was rather high regardless of the soil groups, indicating that soils can be washed away by heavy rain.

The average values of the maximum water-holding capacity of the surface soils were 56.8% in the Central Plain, 33.0% in the North-eastern Region, 55.0% in the Northern Region and 51.6% in the Southern Region. Moisture equivalent was 35.7%, 16.5%, 33.7% and 29.1%, respectively. These data may indicate that severe drought damage may take place on sandy soils low in organic matter when upland crops are introduced.

IV. Chemical Properties of Paddy Soils

Soil is the medium for plant growth. The majority of essential elements for plant growth are largely supplied by the soil. Soil is the source of 13 of the 16 elements essential for plant growth. These elements originate from the parent rock from which the soil is developed. Another source of plant nutrients is the organic matter contained in the soil. In this connection, the physical, chemical and microbiological factors mutually influence the release of some essential elements.

The supplying capacity of plant nutrients in the soil is of fundamental importance to economic production of crop. Fertilizers and manures basically are only used as supplements. Thus, the plant nutrient supplying power of a soil can be considered to reflect the fertility of the soil in a narrow sense.

In this chapter, the supplying power and availability of plant nutrients in paddy soils will be discussed in relation to their chemical properties such as soil reaction, total organic carbon content, cation exchange capacity, status of exchangeable bases and so on.

1. Materials and Methods

Analytical methods of the chemical properties examined in this study have been described in a previous publication (58). Soil samples for the analysis were taken from each horizon of the profile concurrently with the profile examination. Air-dried fine soils passed through a 2 mm sieve were used for the chemical analysis.

2. Results and Discussion

1) Soil Reaction

Soil reaction of paddy soils in Thailand varied widely from strongly acid to alkaline, depending upon the parent materials from which the soils were developed. Fig. 10 shows the frequency distribution of the pH values of the whole soil samples when measured in a water suspension of air dried soils. pH of most of the soils fluctuated between 5.5 and 6.0 in the Central Plain, between 4.0 and 5.0 in the North-eastern Region, between 5.0 and 6.0 in the Northern Region, and between 4.5 and 5.0 in the Southern Region, respectively.

The average pH values are listed in Fig. 11 by region. The mean and the standard deviations for each soil group are tabulated in Table 11.

The average pH values of the surface soils were 5.49 ranging from 4.00 to 8.25 in the Central Plain, 5.04 ranging from 4.10 to 8.05 in the North-eastern Region, 5.70 ranging from 4.15 to 7.90 in the Northern Region, and 4.97 ranging 3.95 to 6.35 in the Southern Region, respectively. The pH values of the subsurface soils and subsoils were slightly higher than those of the surface in every region.

The average pH values of the Marine Alluvial Soils were 5.18 in the surface soils, 5.88 in the subsurface soils and 6.25 in the subsoils. The surface soils tended to have a lower pH value than the subsurface soils and subsoils, and some of them showed fairly low pH values (for example, Profile Nos. 12, 20 and 159) because of the persistent influence of marine deposits.

In the Brackish Water Alluvial Soils, the soil reaction was very strongly acidic throughout the profile, the average pH values being 4.38 in the surface soils, 4.10 in the subsurface soils and 4.00 in the subsoils, respectively. In fact, the exchange acidity referred to as Y_1 was very high in the Brackish Water Alluvial Soils, the

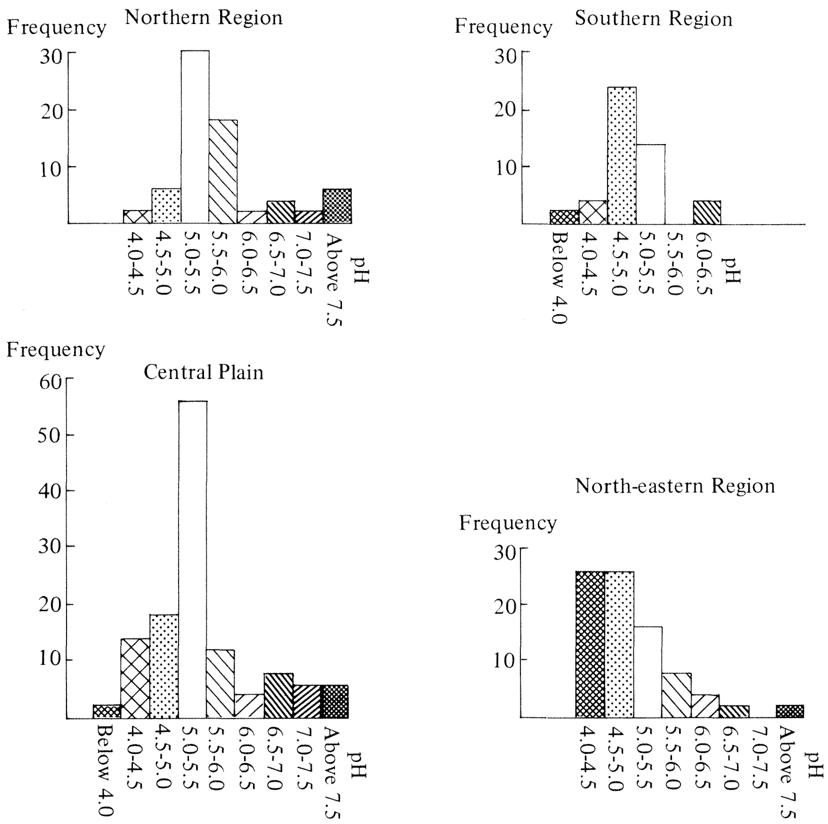
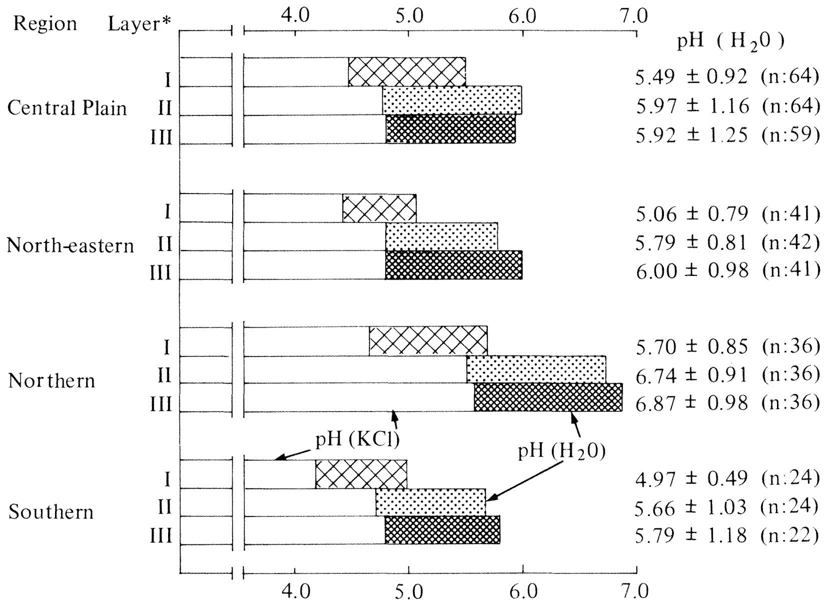


Figure 10. Frequency Distribution of Soil pH



* I : Surface soils, II : Subsurface soils, III : Subsoils.

Figure 11. pH Values by Region

Table 11. Soil pH Values by Soil Group

Soil group	Layer*	No. of samples	pH (H_2O) mean	pH (H_2O) S.D.	pH (KCl) mean	pH (KCl) S.D.
Marine Alluvial Soils	I	14	5.26	0.47	4.46	0.45
	II	14	5.95	0.89	5.06	0.79
	III	14	6.38	1.20	5.46	1.17
Brackish Water Alluvial Soils	I	9	4.38	0.31	3.71	0.33
	II	9	4.33	0.42	3.50	0.35
	III	9	4.03	0.30	3.42	0.89
Fresh Water Alluvial Soils	I	38	5.66	0.93	4.56	0.91
	II	38	6.39	1.01	5.12	0.95
	III	33	6.33	0.96	5.08	0.89
Low Humic Gley Soils	I	79	5.25	0.64	4.29	0.63
	II	80	6.02	0.95	4.85	0.87
	III	80	6.22	1.08	4.91	1.00
Humic Gley Soils	I	2	7.75	0.10	7.15	0.15
	II	2	8.05	0.20	6.68	0.03
	III	2	8.03	0.08	6.50	0.10
Regosols	I	11	4.80	0.64	4.40	0.32
	II	11	5.72	0.70	4.95	0.15
	III	9	5.69	0.71	4.93	0.76
Gray Podzolic Soils	I	4	5.35	1.12	4.80	0.32
	II	4	6.06	1.18	5.01	1.15
	III	4	6.03	1.62	4.83	1.55
Non-Calcic Brown Soils	I	4	6.09	1.32	5.31	1.21
	II	4	6.66	1.46	5.40	1.03
	III	4	6.30	1.00	5.18	1.38
Grumusols	I	4	6.65	0.74	5.65	0.67
	II	4	6.90	0.88	5.71	0.66
	III	4	6.91	1.05	5.91	0.87

* I: Surface soils, II: Subsurface soils, III: Subsoils.

average values being 19.9 ml in the surface soils, 31.6 ml in the subsurface soils and 40.8 ml in the subsoils, respectively. The high acidity of the Brackish Water Alluvial Soils was caused by the oxidation of sulfur compounds, mainly pyrites and jaroisite during their maturation process as paddy soils (5, 63, 68). But, the soil pHs were fairly higher than those of acid sulfate soils in Malaysia, where soil pHs in this kind of soil were commonly below 4.0 (27).

The average pH values of the Fresh Water Alluvial Soils and Low Humic Gley Soils were 5.66 and 5.25 in the surface soils, respectively. But, the pH values differed considerably from one area to another. Soils derived from calcareous or basic rocks, as a rule, showed a high pH while soil originating from igneous rock or sandstone had a low pH. In the surface soils the pH values tended to decrease, especially in the well-drained soils. It should be noted that this tendency appeared more clearly in the North-eastern Region. The high acidity of the Fresh Water Alluvial Soils and Low Humic Gley Soils may result in the strong leaching of bases.

Regosols which were mainly distributed in the North-eastern Region in Thailand, showed very low pH values, due to the abundance of sandy, acidic parent materials that have undergone severe weathering and leaching. Among them, there were the so-called salty or saline soils which had a salt accumulation on the surface. It is interesting to point out that these soils showed a rather acidic reaction not only in the surface layers but also in the deeper layers (for example, Profiles Nos. 56 and 57). This was a peculiar property compared with the normal saline soils which usually have a high pH value (6).

Humic Gley Soils and Grumusols derived from calcareous parent material showed high pH values throughout the profile. Both the Gray Podzolic Soils and Non-Calcic Soils had a wide range of soil pH.

The soil reaction is actually the most important fertility factor of a soil. The soil pH largely regulates not only the chemical reactions but also the activity of the microorganisms in the soil. For instance, Matsuguchi et al. (40) reported that soils low in pH had a decreased capacity of fixation of atmospheric nitrogen. The availability of essential nutrients and the amount of toxic substances in the soil depend also upon the soil reaction. In general, an acidic soil is poor in plant nutrients, has a strong ability in phosphate fixation, and is liable to cause aluminum, iron and manganese toxicity while an alkaline soil may indicate possible deficiency of minor elements. Rice crop is relatively highly tolerant of strong acidity. In addition, the pH value of paddy soils is generally close to neutrality during the growing season as a result of water-logging, as will be discussed later. Thus, the low pH value recorded in the air-dried soil samples did not appear to be a serious limiting problem for rice cultivation. However, in the Brackish Water Alluvial Soils or sandy soils which are poor in organic matter, pH increase after submergence was maintained for a relatively long period compared with the other clayey soils. Furthermore, soils low in pH commonly are deficient in bases such as calcium and magnesium. Therefore, in strongly acid soils it is preferable to raise the soil reaction to a desired pH by liming. However, it should be emphasized that overliming may induce deficiency of minor elements or other undersirable changes of soils. Accordingly, close attention should be paid to the correction of the soil reaction.

The amount of lime required to raise the soil reaction to a desired pH or lime requirement is determined by several factors such as the nature of soils, chemical and physical properties of liming materials. Although the actual quantity required under field conditions differs from the values obtained in the laboratory, it may be estimated from the buffer curve of the soil. Fig. 12 shows an example of buffer curve of different soils. The acidity of all of the soils decreased when bases were added, but the buffering capacity differed with each soil. From the figure, it appears that the buffering capacity was high in the clayey soils, while low in the sandy soils. The amount of lime required to raise the soil reaction to pH 6.5 was 0.5 meq for 10 g of Klong Luang soil (Brackish Water Alluvial Soils), 0.15 meq for the Phrae soil (Fresh Water Alluvial Soils), and 0.04 meq for the Ubon soil (Regosols), respectively.

2) Total Carbon, Total Nitrogen and Carbon Nitrogen Ratio

Tables 12 and 13 show data on total carbon, total nitrogen and carbon nitrogen ratio of the soil in every region and in every soil group, respectively.

The average values of total carbon content of the surface soils were 1.424% in the Central Plain, 0.434% in the North-eastern Region, 1.459% in the Northern Region and 1.366% in the Southern Region, respectively. These values were more or less comparable with those of the soils from other Southeast Asian countries, except for the North-eastern Region, according to Kawaguchi and Kyuma (30). The average

Soils	Klong Luang	Phrae	Ubon
Clay %	54.7	15.1	1.0
Silt %	37.0	52.1	7.6
Sand %	8.3	32.8	75.8
Texture	HC	SiCL	FS
Humus %	2.52	1.08	0.34

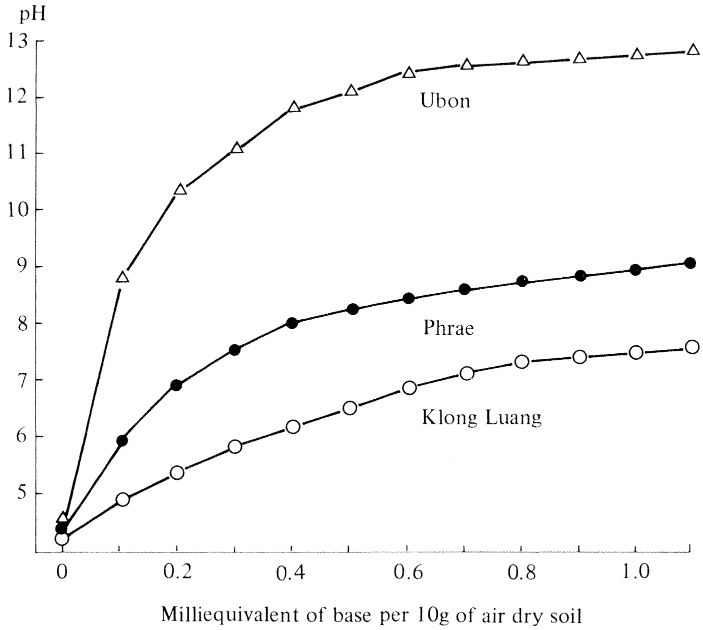


Figure 12. Buffer Curve of pH in Different Soils

values of total nitrogen content of the surface soils were 0.118% in the Central Plain, 0.043% in the North-eastern Region, 0.133% in the Northern Region and 0.118 in the Southern Region, respectively.

As a rule, the total carbon contents were higher in the following order among the soil groups: Humic Gley Soils, Brackish Water Alluvial Soils, Grumusols, Marine Alluvial Soils, Fresh Water Alluvial Soils, Non-Calcic Brown Soils, Low Humic Gley Soils, Gray Podzolic Soils and Regosols. On the other hand, the total nitrogen contents were nearly identical with the total carbon contents, except for the Grumusols which had a rather high organic carbon content.

It should be pointed out that the total carbon as well as the total nitrogen contents of the soils from the North-eastern Region were very low especially in the case of the Regosols and Low Humic Gley Soils, which were widely distributed in this region, presumably because most of these soils were coarse-textured, resulting in a much reduced capacity to accumulate organic matter on account of the very low active surface area of the soil particles. Brackish Water Alluvial Soils had

Table 12. Total Carbon, Total Nitrogen and C:N Ratio by Region

Region	Layer*	No. of samples	T-C (%) mean	T-C (%) S.D.	T-N (%) mean	T-N (%) S.D.	C/N mean	C/N S.D.
Central Plain	I	64	1.424	0.440	0.118	0.037	12.1	2.2
	II	64	0.988	0.393	0.082	0.033	12.2	2.1
	III	59	0.586	0.234	0.053	0.020	11.1	2.6
North-eastern	I	43	0.434	0.220	0.043	0.023	10.1	2.6
	II	43	0.299	0.153	0.031	0.017	9.6	2.0
	III	42	0.214	0.107	0.023	0.012	9.3	1.9
Northern	I	35	1.459	0.583	0.133	0.048	11.0	1.3
	II	35	0.788	0.334	0.074	0.029	10.6	1.3
	III	35	0.579	0.275	0.056	0.031	10.3	1.4
Southern	I	24	1.366	0.682	0.118	0.050	11.6	1.9
	II	24	0.676	0.376	0.062	0.027	10.9	1.8
	III	22	0.405	0.248	0.038	0.017	10.7	1.8

* I: Surface soils, II: Subsurface soils, III: Subsoils.

Table 13. Total Carbon, Total Nitrogen and C:N Ratio by Soil Group

Soil group	Layer*	No. of samples	T-C (%) mean	T-C (%) S.D.	T-N (%) mean	T-N (%) S.D.	C/N mean	C/N S.D.
Marine Alluvial Soils	I	14	1.521	0.351	0.128	0.026	11.9	1.4
	II	14	1.155	0.359	0.094	0.027	12.3	1.5
	III	14	0.532	0.299	0.051	0.021	10.4	2.1
Brackish Water Alluvial Soils	I	9	1.975	0.531	0.155	0.026	12.7	1.5
	II	9	1.093	0.381	0.090	0.028	12.1	1.1
	III	9	0.727	0.257	0.065	0.022	11.2	1.1
Fresh Water Alluvial Soils	I	38	1.271	0.494	0.116	0.044	11.0	1.6
	II	38	0.787	0.300	0.074	0.030	10.6	1.5
	III	33	0.608	0.304	0.058	0.032	10.5	2.1
Low Humic Gley Soils	I	79	0.022	0.607	0.093	0.053	11.0	2.2
	II	79	0.577	0.320	0.055	0.029	10.5	1.9
	III	79	0.389	0.200	0.038	0.018	10.2	1.8
Humic Gley Soils	I	2	2.984	0.208	0.239	0.012	12.5	0.3
	II	2	1.350	0.298	0.109	0.020	12.4	0.6
	III	2	0.868	0.037	0.068	0.001	12.8	0.7
Regosols	I	11	0.351	0.262	0.034	0.020	10.3	2.4
	II	11	0.260	0.220	0.028	0.021	9.3	2.0
	III	9	0.131	0.063	0.014	0.005	9.4	1.7
Gray Podzolic Soils	I	4	0.902	0.316	0.078	0.026	11.6	0.4
	II	4	0.443	0.222	0.041	0.020	10.8	1.2
	III	4	0.186	0.092	0.019	0.008	9.8	1.1
Non-Calcic Brown Soils	I	5	1.056	0.356	0.086	0.023	12.3	1.8
	II	5	0.642	0.348	0.050	0.019	12.8	3.5
	III	3	0.451	0.172	0.044	0.007	10.3	2.1
Grumusols	I	4	1.613	0.139	0.095	0.011	17.0	1.1
	II	4	0.968	0.259	0.058	0.015	16.7	0.4
	III	4	0.538	0.192	0.033	0.011	16.3	1.9

* I: Surface soils, II: Subsurface soils, III: Subsoils.

higher contents of both total carbon and nitrogen than the Marine Alluvial Soils or Fresh Water Alluvial Soils distributed in the area adjacent to the Brackish Water Alluvial Soils. This is probably due to the rather slow decomposition of organic matter caused by the strong acidity of the soil reaction. In fact, ammonium nitrogen released from soil nitrogen after anaerobic incubation was considerably low as will be discussed later.

Carbon nitrogen ratios in the paddy soils of Thailand varied from one region to another, but most commonly ranged from 9 to 13. The average values of the carbon nitrogen ratio of the surface soils were 12.1 in the Central Plain, 10.1 in the North-eastern Region, 11.0 in the Northern Region, and 11.6 in the Southern Region. These values nearly coincided with those reported by Kawaguchi and Kyuma (29). It appears that the carbon nitrogen ratio in the North-eastern Region was lower than that in the other regions throughout the profile. The carbon nitrogen ratio in the North-eastern Region was also reported by Montakul (48), to be as low as 7.23. Undoubtedly carbon nitrogen ratios also varied with the soil groups. Grumusols had the highest ratio of 17.1 and the lowest one was found in the Regosols, the value being 9.1.

As might be expected, both total carbon and nitrogen contents of the deeper layer were generally much lower than those of the superficial layers, since most of the organic residues are incorporated in or deposited on the surface. In general, the carbon nitrogen ratio became lower in the subsoils than in the corresponding surface soils.

Organic matter content in a soil is one of the most important characteristics of the soil affecting its fertility. Organic matter in the soils comprises the nutrients needed by growing plants, including some of the minor elements. Upon the decomposition of organic matter, most of the plant nutrients are released and become available to the plants. Thus, organic matter acts as a reservoir of plant nutrients in the soil. Organic matter also plays an important role in the formation of soil aggregates and consequently in the physical properties such as adequate tillage, water infiltration and water retention. Most of the soil micro-organisms derive their energy for life and multiplication from the soil organic matter. Thus, the inherent capacity of a soil to produce rice crop is closely and directly related to its organic matter and nitrogen contents, especially in the case of cultivation without fertilizer application as in the tropical region. However, satisfactory levels of these two constituents are difficult to maintain in the majority of the farm soils, especially in tropical regions. Because organic matter added to the soil is rapidly decomposed due to the high temperature and high activity of the soil micro-organisms under the tropical conditions (3), the methods of organic matter application and preservation should receive special consideration in all soil management programs.

3) Cation Exchange Capacity and Exchangeable Bases

The data on cation exchange capacity (CEC) and exchangeable bases by region and by soil group are summarized and listed in Tables 14 and 15 respectively.

The average values of CEC of the surface soils were 22.6 meq per 100 g of soils on a dry basis ranging from 1.7 meq to 58.7 meq in the Central Plain, 4.8 meq ranging from 0.4 meq to 21.9 meq in the North-eastern Region, 11.8 meq ranging from 2.7 meq to 21.6 meq in the Northern Region, and 7.8 meq ranging from 2.7 meq to 27.8 meq in the Southern Region. The cation exchange capacity was higher in the following order among the various soil groups: Grumusols, Marine Alluvial Soils,

Table 14. Cation Exchange Capacity and Exchangeable Bases by Region

(meq/100g)

Region	Layer*	No. of samples	CEC mean	CEC S.D.	Ex-Ca mean	Ex-Ca S.D.	Ex-Mg mean	Ex-Mg S.D.	Ex-Na mean	Ex-Na S.D.	Ex-K mean	Ex-K S.D.
Central Plain	I	60	22.55	11.39	11.84	13.05	6.74	6.21	2.46	2.95	0.55	0.37
	II	44	24.21	11.94	12.59	13.03	7.04	6.45	3.01	3.48	0.56	0.40
	III	43	24.42	10.85	14.29	16.74	7.25	6.43	3.80	4.36	0.57	0.42
North-eastern	I	31	4.77	4.13	3.50	9.85	0.83	1.26	1.04	1.57	0.12	0.09
	II	31	5.12	4.29	3.16	4.66	1.07	1.14	0.76	0.55	0.11	0.08
	III	31	8.32	5.61	3.96	3.19	1.31	1.40	1.09	0.95	0.15	0.10
Northern	I	34	11.80	5.11	8.89	10.03	2.38	1.40	0.83	0.61	0.27	0.13
	II	29	10.55	4.96	7.44	4.93	2.55	1.76	0.69	0.50	0.19	0.09
	III	29	11.79	4.89	8.00	5.38	2.94	1.99	0.79	0.49	0.22	0.21
Southern	I	24	7.78	5.59	2.93	3.42	1.85	3.99	0.60	1.10	0.21	0.23
	II	24	7.78	4.58	3.66	3.65	1.97	3.72	0.80	1.23	0.15	0.25
	III	22	8.93	5.05	4.07	3.87	2.18	3.79	1.01	1.42	0.18	0.34

* I: Surface soils, II: Subsurface soils, III: Subsoils.

Table 15. Cation Exchange Capacity and Exchangeable Bases by Soil Group

(meq/100g)

Soil group	Layer*	No. of samples	CEC mean	CEC S.D.	Ex-Ca mean	Ex-Ca S.D.	Ex-Mg mean	Ex-Mg S.D.	Ex-Na mean	Ex-Na S.D.	Ex-K mean	Ex-K S.D.
Marine Alluvial Soils	I	13	29.76	5.20	10.88	3.77	17.10	5.73	7.17	3.40	1.08	0.34
	II	10	29.91	5.76	11.04	4.22	16.88	6.49	8.57	3.47	1.17	0.34
	III	10	28.36	5.17	11.88	4.38	17.16	5.27	10.55	4.24	1.23	0.43
Brackish Water Alluvial Soils	I	7	25.25	5.64	8.25	3.15	5.81	2.85	1.43	0.89	0.51	0.22
	II	6	24.63	7.00	7.19	3.14	5.94	3.13	1.67	1.30	0.49	0.29
	III	6	24.18	6.47	6.65	4.23	5.32	2.56	1.86	1.41	0.45	0.21
Fresh Water Alluvial Soils	I	37	16.73	8.29	10.31	10.51	3.85	2.34	0.86	0.66	0.29	0.19
	II	25	15.83	8.89	10.20	8.77	4.09	2.96	0.87	0.61	0.22	0.20
	III	24	16.52	8.66	10.97	10.97	3.80	2.58	1.21	1.07	0.22	0.19
Low Humic Gley Soils	I	70	8.53	5.78	3.78	3.59	1.54	1.25	0.81	0.57	0.26	0.21
	II	67	8.91	5.91	4.48	4.31	1.73	1.50	0.84	0.65	0.21	0.17
	III	67	10.67	5.83	5.25	4.43	2.19	2.39	1.03	0.88	0.24	0.22
Humic Gley Soils	I	2	20.66	0.88	46.22	4.19	0.59	0	1.37	0.84	0.26	0
	II	1	20.71	—	20.56	—	0.92	—	0.48	—	0.15	—
	III	1	24.05	—	23.57	—	2.38	—	0.46	—	0.15	—
Regosols	I	7	1.72	1.43	0.72	0.37	0.24	0.18	2.15	2.98	0.08	0.07
	II	5	2.09	1.76	0.86	0.25	0.30	0.29	0.63	0.78	0.05	0.03
	III	5	1.30	0.94	0.72	0.38	0.25	0.25	0.68	0.77	0.05	0.04
Gray Podzolic Soils	I	4	4.86	1.91	2.68	2.72	0.59	0.28	0.27	0.17	0.18	0.11
	II	4	4.59	1.37	2.50	1.12	0.80	0.60	0.52	0.17	0.06	0.01
	III	4	5.24	3.00	1.65	0.55	0.86	0.35	0.84	0.44	0.08	0.04
Non-Calcic Brown Soils	I	4	13.06	6.32	7.93	6.53	1.78	0.99	1.07	0.44	0.20	0.09
	II	4	14.59	6.81	9.22	7.78	2.02	1.16	1.63	1.44	0.15	0.02
	III	3	21.88	2.98	13.12	5.43	4.34	3.14	2.85	2.08	0.15	0.01
Grumusols	I	4	45.43	10.81	51.02	17.34	7.33	3.34	1.62	0.57	0.50	0.13
	II	4	44.99	13.03	23.35	17.60	6.33	4.00	2.00	0.58	0.39	0.14
	III	4	44.06	10.22	51.35	24.04	5.72	3.96	2.66	1.08	0.36	0.09

* I: Surface soils, II: Subsurface soils, III: Subsoils.

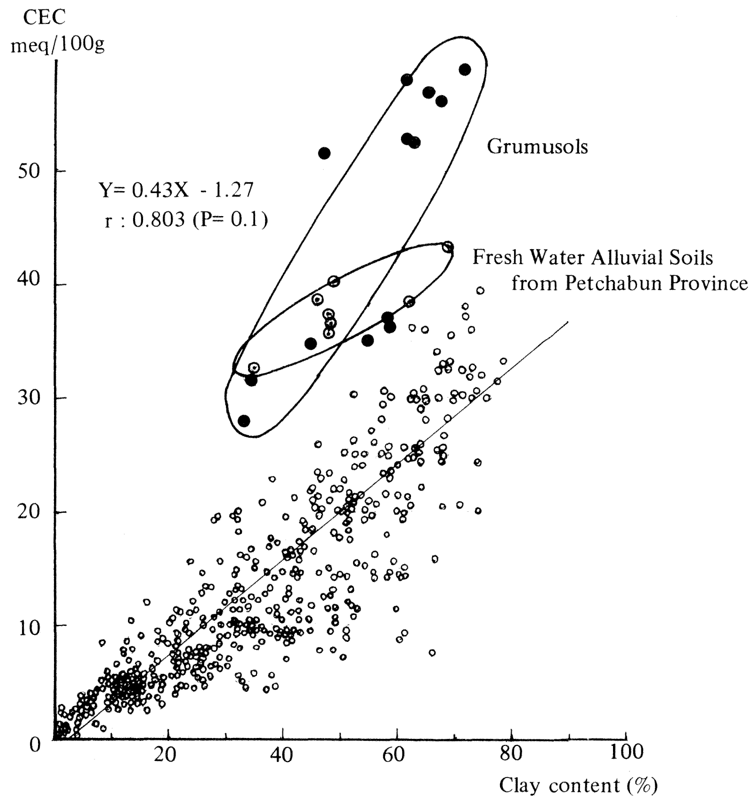


Figure 13. Relationship between CEC and Clay Content

Brackish Water Alluvial Soils, Humic Gley Soils, Fresh Water Alluvial Soils, Non-Calcic Brown Soils, Low Humic Gley Soils, Gray Podzolic Soils, Regosols.

It is well known that the cation exchange capacity greatly depends upon the kind and amount of clay fraction contained. In general, the more clay in a soil, the higher the cation exchange capacity. This fact is clearly demonstrated in Fig. 13. Significant correlation at 0.1% level was recognized between cation exchange capacity and clay content, the coefficient being 0.803. However, there were still large fluctuations of CEC values for the same amount of clay fraction. For example, the soils from the Central Plain, had much higher values of CEC compared with those from the other regions, presumably due to the difference in clay mineralogical composition. The soils with high CEC values are usually composed of montmorillonitic clay minerals, wheras those with a low CEC value contain kaolinitic clay minerals. Indeed, Grumusols in the Central Plain had the highest value among the various soils in Thailand, the average value being 45.3 meq. In these soils montmorillonite dominates the clay composition, as will be discussed later.

Another main constituent contributing to the soil CEC is the content in organic matter. Several studies have suggested that the cation exchange capacity of the soil is due as much to the content of organic matter as to that of clay (16). However, Piyapongse (65) pointed out that the contribution to CEC of organic matter content in the Brackish Water Alluvial Soils and Marine Alluvial Soils in Thailand was negligible. Kawaguchi and Kyuma (29) also reported that only small portions of the cation exchange sites in organic matter were actually operating under field conditions.

Of the exchangeable cations, calcium and magnesium prevailed in the composition of the sorptive complex in most of the Thai paddy soils examined. The average values of exchangeable Ca and Mg of the surface soils were 11.84 meq and 6.74 meq per 100 g soil on a dry basis in the Central Plain, 3.50 meq and 0.83 meq in the North-eastern Region, 8.89 meq and 2.38 meq in the Northern Region, and 2.93 meq and 1.85 meq in the Southern Region, respectively. Exchangeable sodium and potassium were present in the sorptive complex in relatively small amounts, for instance, 2.46 meq and 0.55 meq in the Central Plain, 1.04 meq and 0.12 meq in the North-eastern Region, 0.83 meq and 0.27 meq in the Northern Region, and 0.60 meq and 0.21 meq in the Southern Region, respectively. However, some characteristic features in the composition of exchangeable bases were found in several soil groups. Marine Alluvial Soils are characterized by the predominance of exchangeable magnesium, reflecting their origin from marine deposits. By contrast, Grumusols, Humic Gley Soils and the soils derived from calcareous materials had a high content of exchangeable calcium. In some cases, the exchangeable Ca exceeded the cation exchange capacity, owing to the presence of soluble Ca compounds such as $CaCO_3$. In the so-called saline soils which are distributed mainly along the coastal area of the Central Plain and the Peninsula, and in the North-eastern Region, sodium was the predominant exchangeable cation, and sometimes its content exceeded the cation exchange capacity, for example in the case of the Profiles Nos. 50 and 56, due to the presence of large amounts of water soluble sodium.

The base saturation degree of the soils fluctuated from one area to another, depending upon the parent materials, as mentioned before. Most commonly, the base saturation degree increased with the depth of the profile, indicating that bases leached down from the surface soils. In most of the Marine Alluvial Soils, the base saturation degree exceeded the cation exchange capacity probably due to the presence of water soluble cations. Although the Brackish Water Alluvial Soils are considered to contain water soluble cations as in the case of the Marine Alluvial Soils, the base saturation degree was rather low, ranging from 34.2% to 73.5% with an average value of 62.1%. This fact may indicate that hydrogen ion predominates in the sorptive complex of the soils. In the Fresh Water Alluvial Soils, Low Humic Gley Soils, Regosols, Gray Podzolic Soils and Non-Calcic Brown Soils base unsaturation was present except in the soils derived from calcareous materials, the average values being 83.0%, 72.3%, 71.9%, 49.7% and 71.9%, respectively. The soils from the Northern Region had generally a relatively high base saturation value, while the soils from the North-eastern Region had very low saturation values. As already mentioned above, in the Grumusols and Humic Gley Soils, base saturation exceeded the cation exchange capacity owing to the presence of free calcium compounds such as $CaCO_3$.

The cation exchange capacity is one of the most important chemical characteristics of a soil. In fact, it is considered that the capacity of a soil to exchange cations is the best single index of soil fertility. The nature and content of exchangeable bases in a soil have an important bearing on its general properties. Soils with a high calcium base saturation offer suitable physical and chemical conditions and favorably influence the microbiological activities. A calcium-dominated soil is granular in structure and porous, and ensures good aeration and drainage, thus minimizing the unfavorable effect of a high clay content. In contrast

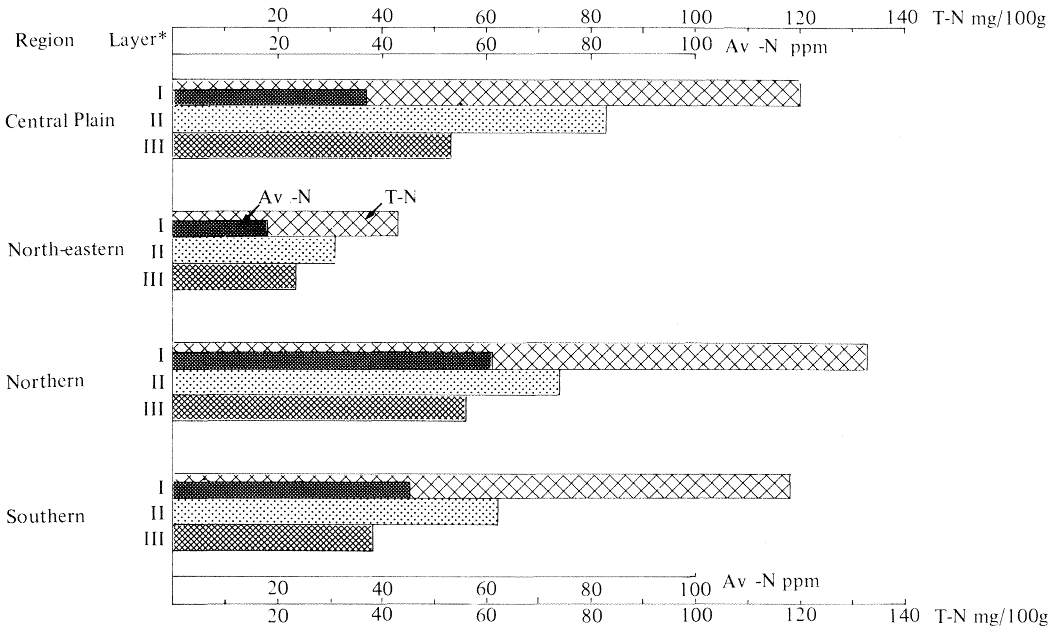
Na-clay is deflocculated, sticky, difficult to work and has poor drainage and poor aeration. Thus, excessive presence of sodium cation adversely affects normal plant growth as well as the physical properties of soil.

The exchangeable bases are the primary source of calcium, magnesium and potassium in plant nutrition. But the exchangeable bases are always susceptible to leaching away from the surface soils with the downward movement of irrigation water or rain water. Thus the surface soils are always likely to be in a state of base unsaturation. Soils with base unsaturation are prone to acidity due to the predominance of exchangeable hydrogen. Low soil pH in the North-eastern Region was caused by the low degree of base saturation.

Owing to the property of base exchange capacity soluble inorganic fertilizer applied to a soil is not washed away from the soil. For example, when ammonium sulfate or potassium chloride are added to a soil, ammonium and potassium ions are absorbed on the surface of the soil colloids by cation exchange reaction. Exchangeable ammonium and potassium ions are directly available to the plant. When a large amount of nitrogen fertilizer is applied to a soil with a low CEC value, a large portion of the fertilizer may be leached away with irrigation water or may be denitrified and lost. In sandy soils poor in organic matter or soils with a low CEC value, it is necessary to increase the efficiency of the fertilizer. Soil management such as soil dressing, deep ploughing, application of organic matter are considered to be useful practices for such a purpose. Also, split application of fertilizer is necessary depending on the stage of plant growth in soils with a low CEC.

4) Macronutrients

(1) Nitrogen



* I : Surface soils, II : Subsurface soils, III : Subsoils,

Figure 14. Total and Available Nitrogen by Region

Table 16. Total and Available Nitrogen by Soils Group

Soil group	Layer*	No. of samples	T-N mg/100g average	T-N mg/100g S.D.	Av-N ppm average	Av-N ppm S.D.	% of T-N average	% of T-N S.D.
Marine Alluvial Soils	I	14	128	26	53.8	19.8	4.2	1.3
	II	14	94	27	—	—	—	—
	III	14	51	21	—	—	—	—
Brackish Water Alluvial Soils	I	9	155	26	37.6	28.8	2.5	1.9
	II	9	116	27	—	—	—	—
	III	9	65	22	—	—	—	—
Fresh Water Alluvial Soils	I	38	116	44	40.9	32.6	3.5	1.7
	II	38	74	30	—	—	—	—
	III	33	58	32	—	—	—	—
Low Humic Gley Soils	I	79	93	53	38.7	25.3	4.4	1.9
	II	79	55	29	—	—	—	—
	III	79	38	18	—	—	—	—
Humic Gley Soils	I	2	239	12	79.8	7.1	3.4	0.2
	II	2	109	20	—	—	—	—
	III	2	68	1	—	—	—	—
Regosols	I	11	34	20	11.5	9.1	3.2	1.1
	II	11	28	21	—	—	—	—
	III	9	14	5	—	—	—	—
Gray Podzolic Soils	I	4	78	26	21.1	14.0	4.7	1.4
	II	4	41	20	—	—	—	—
	III	4	19	8	—	—	—	—
Non-Calcic Brown Soils	I	4	98	5	38.5	1.6	4.0	0.3
	II	4	50	19	—	—	—	—
	III	3	44	17	—	—	—	—
Grumusols	I	4	95	11	27.5	10.6	3.1	1.4
	II	4	58	15	—	—	—	—
	III	4	33	11	—	—	—	—

* I: Surface soils, II: Subsurface soils, III: Subsoils.

Total and available nitrogen contents are represented by a histogram shown in Fig. 14 by region. The average and standard deviations of total and available nitrogen in the soil groups are listed in Table 16.

Total nitrogen content of the surface soils ranged from 30 mg to 170 mg per 100 g of soil on a dry basis with an average value of 120 mg in the Central Plain, from 16 mg to 107 mg with an average value of 43 mg in the North-eastern Region, from 31 mg to 179 mg with an average value of 133 mg in the Northern Region, and from 49 mg to 198 mg with an average value of 118 mg in the Southern Region, respectively. Total nitrogen contents were higher in the following order among the various great soil groups: Humic Gley Soils, Brackish Water Alluvial Soils, Marine Alluvial Soils, Fresh Water Alluvial Soils, Low Humic Gley Soils, Grumusols, Non-Calcic Brown Soils, Gray Podzolic Soils and Regosols. Total nitrogen abruptly decreased with the depth in any soil groups.

Nitrogen in soils is mostly present in the organic form and is not immediately available to rice plant. The determination of available nitrogen is most essential for the evaluation of the fertility of a paddy soil. Although several methods for the determination of available nitrogen have been proposed (15, 38, 96) the anaerobic incubation method is commonly used in Japan (83). As an index of nitrogen availability, the average values of ammonium nitrogen produced after 4 weeks' anaerobic incubation of air-dried fine soils at 30°C, were 37.3 ppm in the Central Plain, 18.2 ppm in the North-eastern Region, 60.9 ppm in the Northern Region and 44.5 ppm in the Southern Region, respectively. It is, of course, natural for the amount of ammonium nitrogen produced to be quite different among the soil groups. The highest value of 165 ppm was obtained in the Mae Chan soil (Profile No. 152) in Chiang Rai Province, which belongs to the Fresh Water Alluvial Soils and the lowest one in the Maha Sarakam soil (Profile No. 51) which belongs to the Regosols, the value being 2.6 ppm. In other words, the amount of available nitrogen was higher in the following order among the various soil groups: Humic Gley Soils, Marine Alluvial Soils, Fresh Water Alluvial Soils, Low Humic Gley Soils, Brackish Water Alluvial Soils, Non-Calcic Brown Soils, Grumusols, Gray Podzolic Soils, and Regosols. This order coincided with that of total nitrogen contents except for the Brackish Water Alluvial Soils and Grumusols.

It can be assumed from the data available that the average nitrogen contents of grain and straw of rice plant after harvest in Thailand amount to 1.4% and 0.5% respectively, and straw grain ratio is about 1.8. Since the average yield of paddy rice per hectare was 3 tons for the Central Plain, 2 tons for the North-eastern Region and 4 tons for the Northern Region according to the results of simple fertilizer trials (39), the total amount of nitrogen taken up by rice plant may be estimated at 69 kg, 46 kg and 92 kg, respectively. The amount of nitrogen released under anaerobic incubation corresponded to the 54.1%, 39.6% and 66.6% of these figures, respectively.

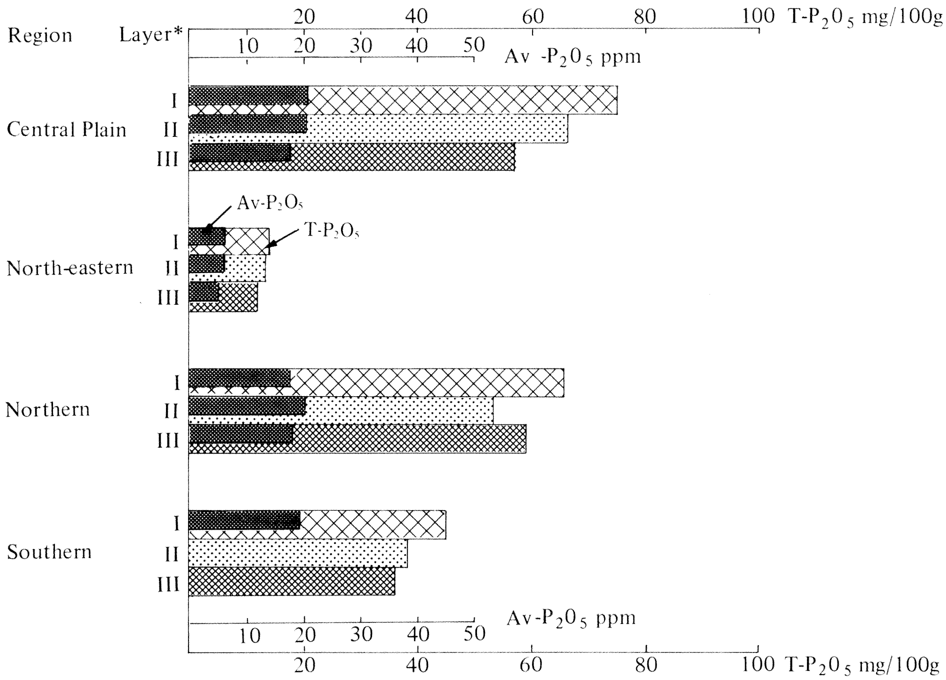
The average values of ammonification rate (the percentage of ammonium nitrogen produced to the total nitrogen) were 3.2% in the Central Plain, 4.4% in the North-eastern Region, 4.7% in the Northern Region and 4.0% in the Southern Region, respectively. According to Kawaguchi and Kyuma (30), the total nitrogen content in the Thai paddy soils is comparable to that of the other South Asian paddy soils, but both available nitrogen and ammonification rate were quite low, especially in the Brackish Water Alluvial Soils and typical Grumusols (Profile Nos. 23 and 71), the value being 2.5% and 1.7%, respectively. This may indicate that organic matter in the Thai paddy soils is in a more advanced stage of humification.

From the viewpoint of nitrogen status, it may be considered that the fertility of the Thai paddy soils is high in the Humic Gley Soils, moderate in the Marine Alluvial Soils, moderate to low in the Brackish Alluvial Soils, Fresh Water Alluvial Soils, Low Humic Gley Soils, Non-Calcic Brown Soils, and low to very low in the Gray Podzolic Soils, Grumusols and Regosols.

(2) Phosphorus

The data on total and available phosphorus contents are summarized and represented by a histogram in Fig. 15, by region. The average value and standard deviation of total and available phosphorus for each soil group are listed in Table 17.

Total phosphorus content of the surface soils ranged from 6.9 mg to 208.3 mg with an average value of 75.2 mg per 100 g soil on a dry basis as P_2O_5 in the



* I : Surface soils, II : Subsurface soils, III : Subsoils,

Figure 15. Total and Available Phosphorus by Region

Central Plain, from 2.3 mg to 101.3 mg with an average value of 14.1 mg in the North-eastern Region, from 17.9 mg to 129.4 mg with an average value of 66.0 mg in the Northern Region and from 20.4 mg to 82.1 mg with an average value of 45.3 mg in the Southern Region, respectively. In other words, total phosphorus content was higher in the following order among the various soil groups: Humic Gley Soils, Fresh Water Alluvial Soils, Brackish Water Alluvial Soils, Grumusols, Marine Alluvial Soils, Low Humic Gley Soils, Non-Calcic Brown Soils, Gray Podzolic Soils and Regosols.

Many attempts have been made to assess the level of available phosphorus in soils. But, no single method is fully reliable at present. Shiga (73) reported that dilute acidic solutions such as the Bray No. 2 or 2.5% acetic acid solutions could probably be used to estimate the phosphorus supplying ability of paddy soils. The Olsen-EDTA method was found to be applicable for the determination of phosphorus availability in the soils with a wide range of pH and characteristics (47). In this study, Bray No. 2 solution was used for the determination of available phosphorus. The average values of available phosphorus of the surface soils were 16.4 ppm as P_2O_5 in the Central Plain, 6.6 ppm in the North-eastern Region, 17.7 ppm in the Northern Region and 19.8 ppm in the Southern Region, respectively. Among the various soil groups, available phosphorus content was higher in the following order: Humic Gley Soils, Fresh Water Alluvial Soils, Brackish Water Alluvial Soils, Grumusols, Marine Alluvial Soils, Low Humic Gley Soils, Non-Calcic Brown Soils, Gray Podzolic Soils and Regosols.

Table 17. Total and Available Phosphorus by Soil Group

Soil group	Layer*	No. of samples	$T\text{-}P_2O_5$ mg/100g average	S.D.	No. of samples	$Av\text{-}P_2O_5$ ppm average	S.D.
Marine Alluvial Soils	I	14	57.2	17.5	14	15.3	5.0
	II	14	58.1	20.6	12	16.7	6.6
	III	14	74.0	37.1	11	22.4	10.4
Brackish Water Alluvial Soils	I	9	63.6	22.9	9	18.9	8.2
	II	9	51.2	23.0	8	18.2	9.7
	III	9	40.4	9.3	8	14.8	6.5
Fresh Water Alluvial Soils	I	39	91.5	57.4	38	21.8	13.3
	II	39	71.1	48.3	31	23.3	15.7
	III	30	68.9	40.7	25	20.2	14.5
Low Humic Gley Soils	I	77	37.8	28.5	77	12.8	9.6
	II	79	33.3	27.6	30	13.2	9.5
	III	79	32.4	29.3	29	11.2	7.5
Humic Gley Soils	I	2	129.3	0.2	2	32.2	0.5
	II	2	94.3	6.8	2	28.4	7.7
	III	2	85.7	0.6	2	21.1	3.6
Regosols	I	11	15.6	21.6	11	10.7	11.3
	II	11	13.4	21.3	4	6.7	6.1
	III	9	10.3	15.4	4	4.9	3.1
Gray Podzolic Soils	I	4	24.5	11.1	4	17.9	5.5
	II	4	17.6	6.5	2	8.9	0.6
	III	4	7.2	12.1	2	10.4	1.7
Non-Calcic Brown Soils	I	4	37.3	16.7	4	15.1	11.0
	II	4	35.7	17.0	2	8.9	0.6
	III	3	25.5	13.7	2	10.4	1.7
Grumusols	I	4	63.1	10.1	4	29.6	10.6
	II	4	46.2	18.8	4	32.0	17.4
	III	4	28.6	9.9	4	16.8	9.3

* I: Surface soils, II: Subsurface soils, III: Subsoils.

Both total and available phosphorus contents in the Fresh Water Alluvial Soils and Low Humic Gley Soils which are widely distributed throughout the whole country varied significantly with the regions, as shown in Table 18.

In the Fresh Water Alluvial Soils the highest values of both total and available phosphorus were found in soils from the Central Plain, next to those from the Northern Region whereas soils from the North-eastern Region and Southern Region had the lowest amounts of total phosphorus, the value being nearly identical, but available phosphorus content was higher in the Southern Region in the North-eastern Region.

In the Low Humic Gley Soils, the highest value of total phosphorus was found in soils from the Northern Region, followed by those from the Central Plain, Southern Region, and North-eastern Region. Soils from the North-eastern Region had an extremely low value of 12.0 mg per 100 g of dry soil. On the other hand, the highest value of available phosphorus was found in the soils from the Southern Region, followed by those of the Northern Region, the Central Plain, which had nearly the same value, and the lowest value of available phosphorus was found in soils from the North-eastern Region.

Table 18. Total and Available Phosphorus in Fresh Water Alluvial Soils and Low Humic Gley Soils by Region

Region	Layer*	T-P_2O_5 mg/100g No. of samples	average	S.D.	Av-P_2O_5 ppm No. of samples	average	S.D.
Fresh Water Alluvial Soils							
Central Plain	I	22	115.1	53.4	22	25.9	14.8
	II	22	99.3	45.9	22	25.6	16.8
	III	16	80.2	41.3	16	21.8	16.4
North-eastern	I	6	31.3	32.1	5	9.0	3.3
	II	6	29.1	30.0	3	10.8	2.3
	III	6	19.4	15.7	3	7.6	3.4
Northern	I	8	94.4	42.9	8	20.1	8.3
	II	8	72.0	27.1	6	21.0	11.5
	III	8	74.4	25.0	6	22.2	7.7
Southern	I	3	32.1	6.1	3	17.2	3.1
	II	3	24.1	5.6	—	—	—
	III	3	20.2	7.5	—	—	—
(Total)	I	39	91.5	57.4	38	21.8	13.3
	II	39	71.1	48.3	31	23.3	15.7
	III	33	68.9	40.7	25	20.2	14.5
Low Humic Gley Soils							
Central Plain	I	14	48.1	32.5	14	15.4	8.6
	II	14	44.6	31.2	14	13.3	7.5
	III	14	37.7	22.6	14	10.8	6.3
North-eastern	I	25	12.4	10.4	26	5.7	6.0
	II	27	12.9	14.2	6	2.8	1.7
	III	27	12.4	11.7	5	3.5	2.5
Northern	I	24	53.0	25.4	24	15.8	10.5
	II	24	45.8	27.0	10	19.2	9.5
	III	24	52.4	41.4	10	15.7	7.2
Southern	I	14	46.9	19.4	14	18.1	6.6
	II	14	39.7	17.8	—	—	—
	III	14	39.0	18.9	—	—	—
(Total)	I	77	37.8	28.5	77	12.8	9.6
	II	79	33.3	27.6	30	13.2	9.5
	III	79	32.4	29.3	29	11.2	7.5

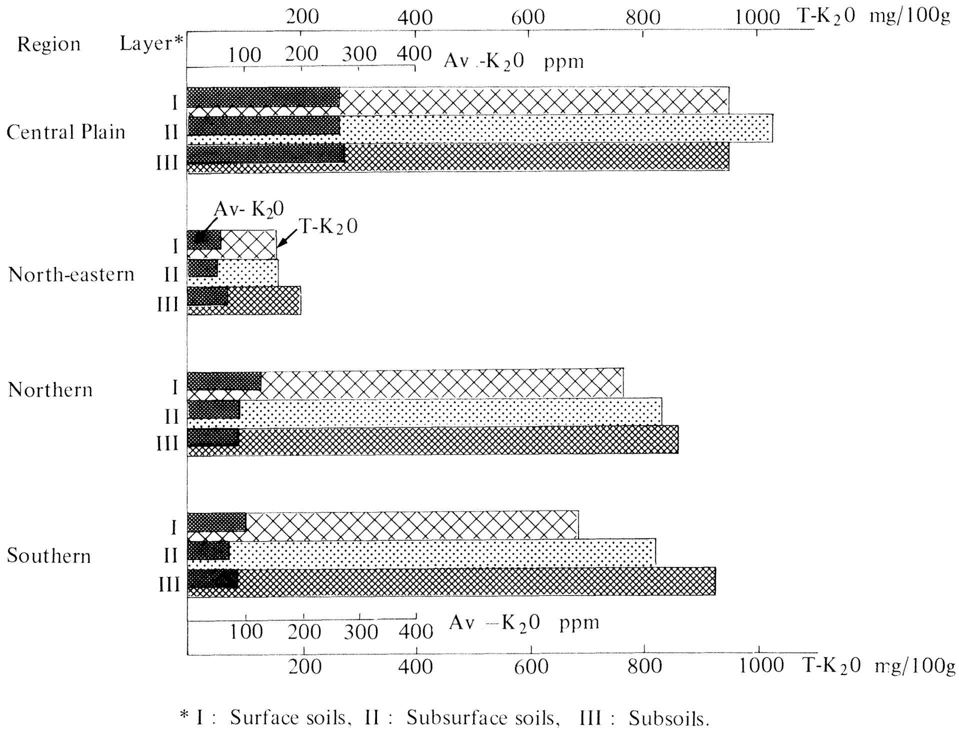
* I: Surface soils, II: Subsurface soils, III: Subsoils.

Assuming that the average phosphorus content of grain and straw of rice plant after harvest is 0.5% and 0.1%, respectively, the total amount of phosphorus taken up by rice plant per hectare may be estimated at 20.4 kg for the Central Plain, 13.6 kg for the North-eastern Region and 27.2 kg for the Northern Region, respectively. The amount of available phosphorus extracted with the Bray No. 2 solution corresponded to the 100%, 46% and 65% of these figures, respectively.

However, in general, both total and available phosphorus amounts were insufficient for normal growth of rice plant in the Thai paddy soils. Especially, the sandy soils of the North-eastern Region were extremely deficient in phosphorus as well as in other nutrients. Although the Brackish Water Alluvial Soils had rather high values of total and available phosphorus in Thailand, rice plants grown on these soils exhibited symptoms of severe phosphorus deficiency when phosphatic fertilizer was not applied especially the improved varieties (37). Phosphorus can be found in soils in several chemical forms, namely organic phosphorus, calcium phosphate, aluminum phosphate and iron phosphate, a part of which is occluded by iron oxides. In some soils, organic phosphorus constitutes a major portion of the total phosphorus, and it is the main source of phosphorus available to plants. Because of the paucity of organic matter in most of the Thai paddy soils, calcium, aluminum and iron phosphates are considered to be by far the most important sources of forms available to crop. Cholitkul and Tyner (8) reported that surface-bonded iron phosphate and reductant-soluble phosphate (occluded phosphate) were the most abundant inorganic phosphorus fractions accounting for 35 and 19 percent, respectively, of the mean total phosphorus and that aluminum phosphate and calcium phosphate accounted for about 5 and 4 per cent, respectively, of the mean total phosphorus. Kawaguchi and Kyuma (30) also reported nearly the same results, but they pointed out that Grumusols contained more than 50% of calcium phosphate.

(3) Potassium

The data on total and available potassium contents are summarized and represented by a histogram in Fig. 16, by region. The average values and



* I : Surface soils, II : Subsurface soils, III : Subsoils.

Figure 16. Total and Available Potassium by Region

Table 19. Total and Available Potassium by Soil Group

Soil group	Layer*	No. of samples	$T\text{-}K_2O$ mg/100g average	S.D.	No. of samples	$Av\text{-}K_2O$ ppm average	S.D.
Marine Alluvial Soils	I	14	1284	321	13	508	168
	II	14	1343	311	10	549	161
	III	14	1260	347	10	580	205
Brackish Water Alluvial Soils	I	9	1123	395	7	240	102
	II	9	1049	391	6	232	135
	III	9	1344	684	6	211	97
Fresh Water Alluvial Soils	I	38	876	567	37	137	90
	II	38	919	632	25	105	96
	III	32	799	474	25	103	89
Low Humic Gley Soils	I	76	526	460	70	124	96
	II	78	602	510	67	97	82
	III	78	616	476	66	107	87
Humic Gley Soils	I	2	831	11	2	123	0
	II	2	849	28	1	91	—
	III	2	1019	20	1	71	—
Regosols	I	11	92	143	7	35	32
	II	11	89	144	4	21	13
	III	9	75	151	4	19	17
Gray Podzolic Soils	I	4	396	229	4	83	51
	II	4	481	362	4	28	7
	III	4	598	522	3	39	21
Non-Calcic Brown Soils	I	4	589	298	4	92	40
	II	4	999	855	3	69	11
	III	3	1231	1037	2	68	2
Grumusols	I	4	301	152	4	233	60
	II	4	210	76	4	182	64
	III	4	185	71	4	169	45

* I: Surface soils, II: Subsurface soils, III: Subsoils.

standard deviation of total and available potassium for each soil group are listed in Table 19.

Total potassium content of the surface soils ranged from 144 mg to 2111 mg per 100 g of dry soil with an average value of 948 mg in the Central Plain; from 10 mg to 1030 mg with an average value of 154 mg in the North-eastern Region; from 55 mg to 1512 mg with an average value of 764 mg in the Northern Region; and from 64 mg to 1994 mg with an average value of 687 mg in the Southern Region, respectively.

In the Central Plain, Alluvial Soils had the highest value, and no significant difference among soils of marine, brackish or riverine origin was recognized, the average value being 1280 mg, 1123 mg and 1100 mg, respectively. Grumusols had the lowest value of 301 mg. In the North-eastern Region, Phimai soil (Profile No. 42), Si Chiang Mai soil (Profile No. 48) and Nakhon Phanom soil (Profile No. 108) contained more than 500 mg of total potassium. However, total potassium in the soils from the North-eastern Region had a critical level which was generally low, especially in the Regosols. In the Northern Region, total

Table 20. Total and Available Potassium in Fresh Water Alluvial Soils and Low Humic Gley Soils by Region

Region	Layer*	T-K_2O mg/100g No. of samples	average	S.D.	Av-K_2O ppm No. of samples	average	S.D.
Fresh Water Alluvial Soils							
Central Plain	I	21	1100	613	22	166	99
	II	21	1195	671	11	167	113
	III	15	981	516	10	154	116
North-eastern	I	6	453	348	4	93	42
	II	6	393	282	4	50	26
	III	6	400	317	4	67	42
Northern	I	8	792	292	8	108	61
	II	8	793	347	7	65	35
	III	8	819	355	7	71	27
Southern	I	3	379	67	3	66	7
	II	3	450	122	3	39	20
	III	3	635	118	3	43	11
(Total)	I	38	876	567	37	137	90
	II	38	919	632	25	105	96
	III	32	799	474	25	103	89
Low Humic Gley Soils							
Central Plain	I	14	584	279	13	265	99
	II	14	673	350	12	224	97
	III	14	662	218	12	244	98
North-eastern	I	24	129	150	21	58	42
	II	26	151	162	21	55	41
	III	26	208	163	21	77	48
Northern	I	24	773	419	22	139	61
	II	24	865	471	20	99	40
	III	24	884	406	19	95	47
Southern	I	14	761	548	14	124	96
	II	14	920	544	14	50	26
	III	14	868	621	14	51	25
(Total)	I	76	526	460	70	124	96
	II	78	602	510	67	97	82
	III	78	616	476	66	107	87

* I: Surface soils, II: Subsurface soils, III: Subsoils.

potassium contents of Low Humic Gley Soils were relatively high compared with those in the other regions, as shown in Table 20. The soils from the Southern Region were characterized by a low content of total potassium in the Fresh Water Alluvial Soils which contained an average of 312 mg of total potassium, as shown in Table 20.

The amount of exchangeable potassium has been regarded as an index of potassium availability. The average values of available potassium of the surface soils were 263 ppm in the Central Plain, 56 ppm in the North-eastern Region, respectively. Available potassium content was higher in the following order among the various soil groups: Marine Alluvial Soils, Brackish Water Alluvial Soils, Grumusols, Fresh Water Alluvial Soils, Low Humic Gley Soils, Non-Calcic Brown Soils and Regosols. It is interesting to note that the amount of available potassium of the Fresh Water Alluvial Soils in the Central Plain was lower compared to the total potassium content, while the amount of available potassium of the Grumusols and Low Humic Gley soils was higher compared to the total content.

Assuming that the average content of potassium of grain and straw after harvst is 0.3% and 1.6%, the total amount of potassium taken up by rice plant may be estimated at 95 kg per hectare for the Central Plain, 64 kg for the North-eastern Region, and 127 kg for the Northern Region. As the available potassium per hectare amounted to 263 kg in the Central Plain, 56 kg in the North-eastern Region, 128 kg in the Northern Region and 100 kg in the Southern Region, these figures seem to be suitable for normal growth of rice plant. Also it should be emphasized that irrigation water plays an important role in the potassium supply to rice crop. According to Kobayashi (33), the average content of potassium in the Thai rivers was 10.7 ppm although the concentration gretly differed depending on the nature of the catchment area. If the water requirement for a single rice crop is considered to be 1000 mm, the total supply of K_2O from the irrigation water would be about 130 kg per hectare, which is a large enough figure to be taken into account when fertilizers are applied. In fact, simple fertilizer trials (39) indicated that rice plant did not respond to potassium fertilizer. However, the soils in the North-eastern Region were generally very poor in available potassium. Potassium deficiency is likely to take place when rice growth is promoted by the adoption of improved cultivation practives such as the introduction of high yielding varieties, N, P fertilizer application, etc.

It is generally recognized that potassium is present in four forms in soil, namely soluble potassium, exchangeable potassium, non-exchangeable potassium and mineral potassium. These four forms are in equilibrium with one another. Soluble potassium is found in the soil solution, but the amount is usually very small. Exchangeable potassium can be replaced by other cations and is readily available to plant. Non-exchangeable potassium cannot be replaced and is not available to plant. But, when exchangeable potassium is taken up by plant, the non-exchangeable form is gradually released to replenish the exchangeable site. Mineral potassium can also become available to plant through weathering. In the tropical regions, mineral potassium contributes a great deal to the increase of the content of available potassium through accelerated weathering.

In short, potassium nutrition to rice plant was rather good in the Thai paddy soils except in the soils from the North-eastern Region, which have a very low content in both total and available potassium.

5) Micronutrients and Available Silica

(1) Available Micronutrients

Of the micronutrients, the content of available iron, manganese, copper and zinc was determined in this study. The data on these elements are summarized by region, as shown in Fig. 17. The average value and standard deviation for each soil group are listed in Table 21.

The average values of available iron extracted with *N*-ammonium acetate

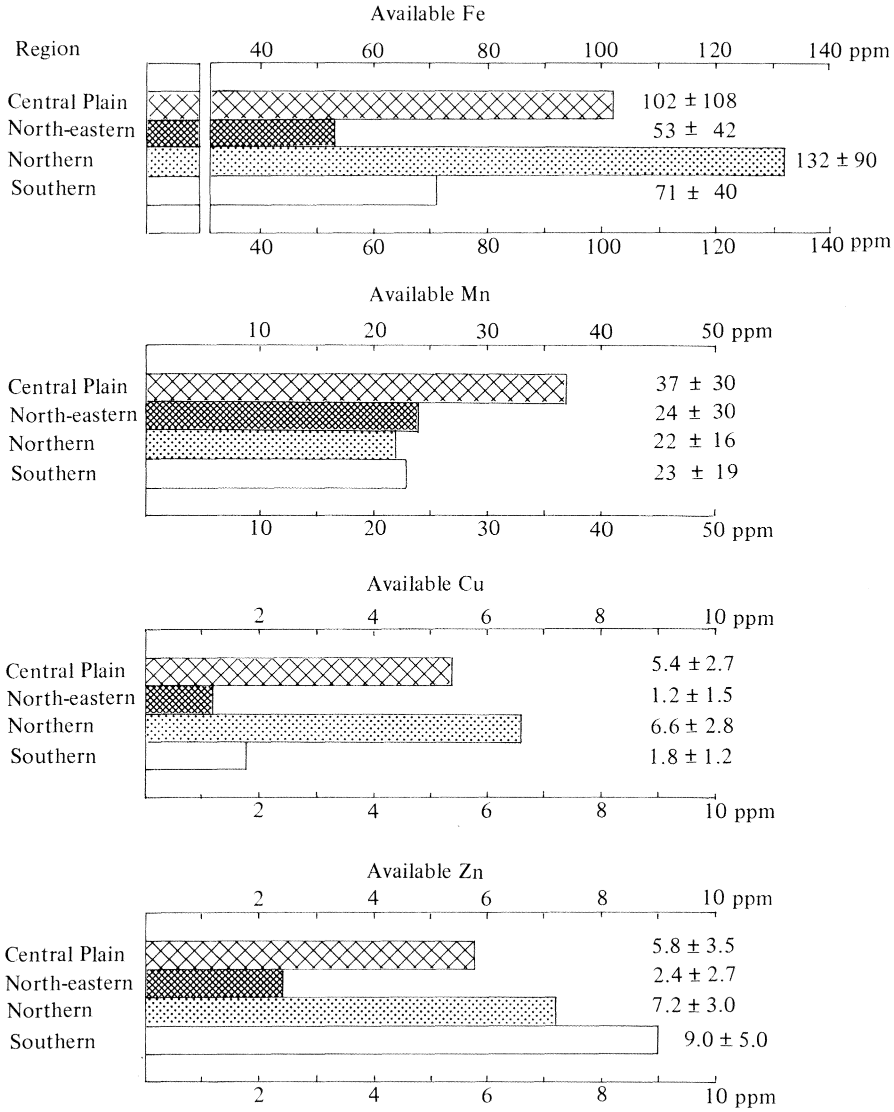


Figure 17. Available Fe, Mn, Cu and Zn in Surface Soils by Region

solution at pH 4.8 were 102 ppm as Fe ranging from 4 ppm to 550 ppm in the Cental Plain, 54 ppm ranging from traces to 210 ppm in the North-eastern Region, 132 ppm ranging from traces to 380 ppm in the Northern Region and 72 ppm ranging from traces to 145 ppm in the Southern Region, respectively.

Marine Alluvial Soils were very poor in available iron, although they had a fairly high content of easily reducible iron oxides, as will be discussed later. The figures were comparable to those found in the Regosols in the North-eastern Region. Brackish Water Alluvial Soils were comparatively rich in extractable iron. The average values of the Fresh Water Alluvial Soils and Low Humic Gley Soils were 104 ppm and 92 ppm, respectively, but these values varied among

Table 21. Available Iron, Manganese, Copper and Zinc in Surface Soils by Soil Group

ppm

Soil group		No. of samples	Fe average	Fe S.D.	Mn average	Mn S.D.	Cu average	Cu S.D.	Zn average	Zn S.D.
Marine Alluvial Soils		7	16	8	32	18	3.2	1.1	6.4	4.6
Brackish Water Alluvial Soils		8	141	166	31	21	5.3	2.9	5.0	1.8
Fresh Water Alluvial Soils										
Region	Central Plain	7	109	52	58	34	7.4	2.8	8.2	3.0
	North-eastern	6	79	42	54	46	2.5	2.4	2.9	1.5
	Northern	5	131	133	24	23	6.1	3.6	7.1	3.4
	Southern	3	98	27	8	6	1.3	0.4	6.7	2.4
	(Total)	21	104	78	41	39	4.8	3.7	6.2	3.5
Low Humic Gley Soils										
Region	Central Plain	10	134	78	37	31	5.3	2.5	5.9	4.8
	North-eastern	26	52	26	23	25	1.2	1.2	2.5	3.1
	Northern	20	139	75	24	12	6.9	2.5	7.0	2.8
	Southern	14	70	40	27	19	1.9	1.4	10.1	5.0
	(Total)	70	92	68	26	22	3.5	3.1	5.8	4.7
Humic Gley Soils		1	116	—	2	—	8.3	—	11.0	—
Regosols		9	23	18	11	9	0.7	1.2	2.4	1.7
Gray Podzolic Soils		4	54	54	26	21	2.3	0.6	7.6	2.7
Non-Calcic Brown Soils		2	135	85	8	3	1.3	0.1	2.2	1.0
Grumusols		1	4	—	2	—	7.0	—	4.0	—

the regions. In the North-eastern Region, the higher the clay content, in general, the higher the available iron content. The soils from the Northern Region had a relatively high content of available iron. In the Southern Region, available iron contents were also high. Grumusols had the lowest available iron contents among the various soil groups.

The average values of available manganese extracted with pH 7.0 *N*-ammonium acetate solution were 77 ppm as Mn ranging from 7 ppm to 110 ppm in the Central Plain, 24 ppm ranging from traces to 120 ppm in the North-eastern Region, 22 ppm ranging from traces to 66 ppm in the Northern Region, and 23 ppm ranging from traces to 75 ppm in the Southern Region, respectively.

In the Central Plain, available manganese contents were slightly higher in the Fresh Water Alluvial Soils than in the other soil groups. No significant difference was observed among the Marine Alluvial Soils, Brackish Water Alluvial Soils and Low Humic Gley Soils, the average values being 32 ppm, 31 ppm and 37 ppm, respectively. Grumusols were very poor in available manganese as well as iron. In the North-eastern Region, the Regosols were poor in available manganese. In some locations in the North-eastern Region, the contents of available manganese exceeded those of available iron (for example, Profiles Nos. 42, 48, 43, 100). The soils from both the Northern and Southern Regions were relatively low in available manganese in every soil group.

The average values of copper extracted with 0.1 *N* NCl solution were 5.4 ppm as Cu ranging from 2.0 ppm to 10.7 ppm in the Central Plain, 1.2 ppm ranging from traces to 7.2 ppm in the North-eastern Region, 6.6 ppm ranging from 1.8 ppm to 13.0 ppm in the Northern Region, and 1.8 ppm ranging from traces to 13.0 ppm in the Southern Region, respectively.

There was no distinctive feature regarding the available copper contents among the soil groups because of the large variations which could be found even within the same soil group. However, the soils from the North-eastern and Southern Regions seemed to have much lower contents of available copper than those from the Central Plain and the Northern Region in every soil group.

The average values of available zinc extracted with 0.1 *N* HCl solution were 5.8 ppm as Zn ranging from 3.0 ppm to 13.0 ppm in the Central Plain, 2.4 ppm ranging from traces to 7.4 ppm in the North-eastern Region, 7.2 ppm ranging from 3.3 ppm to 11.0 ppm in the Northern Region, and 9.0 ppm ranging from 3.2 ppm to 23.6 ppm in the Southern Region, respectively. According to Yoshida (95), the critical concentration of zinc in soils was 4 ppm, when zinc was extracted with EDTA-$(NH_4)_2CO_3$ solution. Extraction with 0.1 *N* HCl solution used in this study was assumed to dissolve zinc more than the method proposed by Yoshida (95). The soils from the North-eastern Region had much lower contents of available zinc in every soil group compared with those of the other regions. It is interesting to note that the available zinc level was the highest in the Southern Region in the whole country.

These figures which were obtained from air-dried fine samples seemed to be somewhat inadequate as an index of the availability of the elements to rice plant, since these elements are likely to become more soluble to be readily available to rice plant when the soil reduction is more or less developed during the rice growing period. Also, Tanaka (81) states that zinc deficiency is usually related to the alkaline reaction of the soils, which could apply to many other minor elements.

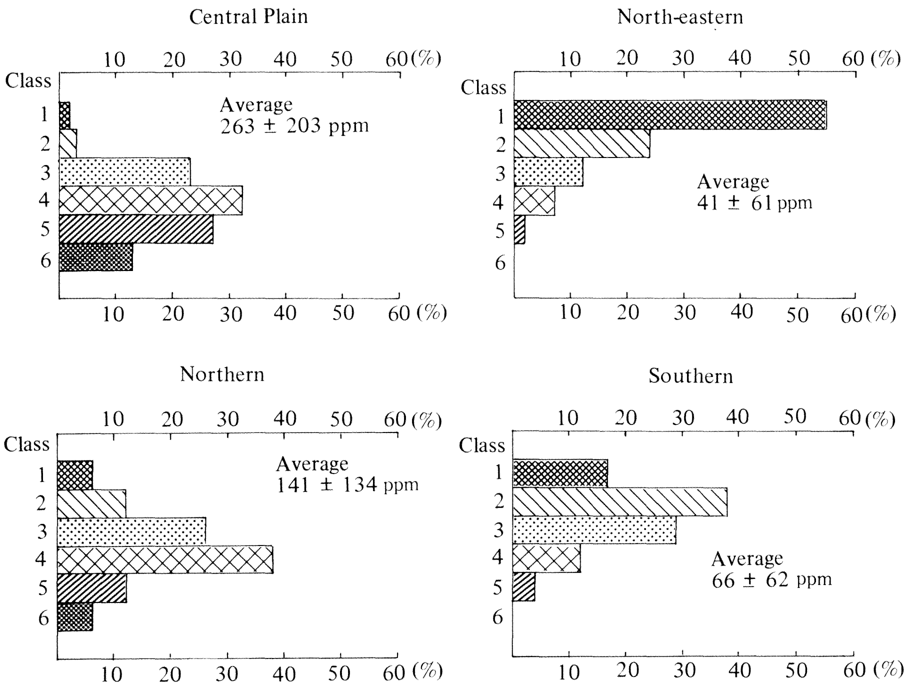
(2) Available Silica

The importance of silica as a plant nutrient has not been entirely documented yet. However, it is evident that silica is essential for high production of rice. With regard to the role of silica in rice growth, the following two aspects should be emphasized (24): 1) it contributes to the increase of the resistance of rice to diseases, 2) it increases the resistance of rice to lodging at high rate of nitrogen fertilizer application. The latter function is considered to enhance the absorption of solar energy by the plant, with beneficial effects on yield.

Analytical results on the content of available silica extracted with *N*-ammonium acetate at pH 4.8 are presented in Fig. 18 and Table 22.

The average values of available silica of surface soils were 223 ppm in terms of SiO_2 ranging from 16 ppm to 952 ppm in the Central Plain, 40 ppm ranging from 5 ppm to 389 ppm in the North-eastern Region, 141 ppm ranging from 18 ppm to 722 ppm in the Northern Region, and 66 ppm ranging from 11 ppm to 322 ppm in the Southern Region, respectively.

In the Central Plain, the contents of the Grumusols and Marine Alluvial Soils in available silica were extremely high, the average values being 732 ppm and 312 ppm, respectively. Fresh Water Alluvial Soils had an available silica level close to the average value for this region, but the soils originating from the Pasak river deposits (Profile Nos. 72 and 73) had a significantly higher content in available silica than the other soils from the same group. Available silica



Class : Available SiO_2 ppm

1 : 0-25, 2 : 26-50, 3 : 51-100, 4 : 101-200, 5 : 201-400, 6 : more than 401.

Figure 18. Histogram of Available Silica Content of Surface Soils in Each Region

level of Brackish Water Alluvial Soils and Low Humic Gley Soils showed fairly lower figures compared to the average value for this region, namely 146 ppm and 90 ppm, respectively. The soils from the North-eastern Region were poor in available silica, even the clayey soils except for the Si Chiang Mai soils (Profile No. 48) developed along the Mekong river, which contained 389 ppm of available silica. The coarse-textured soils were generally poor in available silica, especially the Regosols, the value being only 11 ppm, ranging from 5 ppm to 21 ppm.

In the Northern Region, Humic Gley Soils were rich in available silica and the value was comparable to that of the Grumusols in the Central Plain. The available silica content of the Fresh Water Alluvial Soils in the Northern Region was lower than that of the soils in the Central Plain. However, the average silica content of Low Humic Gley Soils was similar to that for the corresponding soil groups of the Central Plain. As a rule, the Chiang Mai and Chiang Rai basins seemed to have higher available silica content than the Lampang, Phare or Nun basins.

The soils from the Southern Region, exclusive of the Marine Alluvial Soils, were not as low in available silica as the soils from the North-eastern Region, but the content was considered to be insufficient for normal growth of rice plant.

Yoshida and Imaizumi (94) reported that a positive response could be

Table 22. Available Silica Content in Surface Soils by Soil Group

Soil group		n	SiO_2 ppm average	S.D
Marine Alluvial Soils		13	335	184
Brackish Water Alluvial Soils		9	142	46
Fresh Water Alluvial Soils				
Region	Central Plain	21	219	127
	North-eastern	6	111	129
	Northern	7	135	67
	Southern	3	55	8
	(Total)	37	172	126
Low Humic Gley Soils				
Region	Central Plain	14	103	64
	North-eastern	26	34	27
	Northern	24	110	62
	Southern	14	56	36
	(Total)	78	74	59
Humic Gley Soils		2	600	123
Regosols		9	11	6
Gray Podzolic Soils		4	35	19
Non-Calcic Brown Soils		2	42	23
Grumusols		4	732	185

expected from the application of silica-containing fertilizer to a soil if the available silica content of the surface soil was less than 105 ppm. Kawaguchi and Kyuma (5) suggested that the same criterion may not be applicable to tropical paddy soils because the rate of silica release from soil minerals or weathering intensity seems to be higher in the tropics and they recognized that soils with a value of less than 40 ppm of available silica are deficient in silica.

Judging from these criteria, most of the soils of the North-eastern Region were extremely deficient in available silica, and such soils were scattered in every region.

6) Absorption Coefficients of Phosphorus and Nitrogen

It is a well known fact that when phosphatic fertilizers are added to a soil, the plant may absorb only 2 to 25 per cent of the phosphorus added (83) since most of the phosphorus is tied up in relatively insoluble compounds with iron, aluminum, calcium and organic matter. The phosphorus absorption coefficient is a relative measure of the capacity of a soil to make applied phosphorus unavailable to crop.

Analytical results are presented in Fig. 19 and Table 23. The average values of the phosphorus absorption coefficients of the surface soils were 1063 mg per 100 g on a dry basis in terms of P_2O_5 in the Central Plain, 251 mg in the North-eastern Region, 675 mg in the Northern Region, and 553 mg in the Southern Region, respectively. These values did not change with the depth.

Grumusols had the highest coefficient amounting to 2498 mg. This value was comparable to that in the Andosols which have a high capacity of phosphorus absorption (36). This soil contained high amounts of exchangeable calcium, which may account for the high phosphorus absorption coefficient. Marine Alluvial Soils

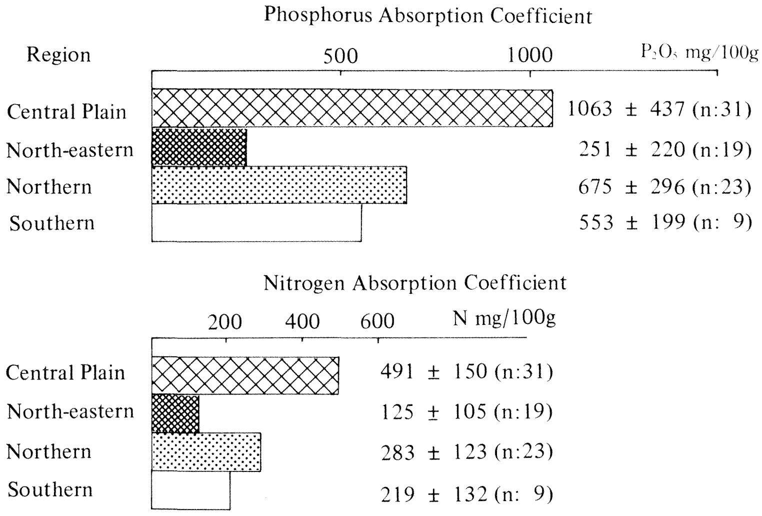


Figure 19. Absorption Coefficient of Phosphorus and Nitrogen by Region

Table 23. Absorption Coefficient of Phosphorus and Nitrogen by Soil Group

mg/100g

Soil group		No. of samples	Phosphorus as P_2O_5 average	Phosphorus as P_2O_5 S.D.	Nitrogen as N average	Nitrogen as N S.D.
Marine Alluvial Soils		10	1195	303	572	110
Brackish Water Alluvial Soils		4	1209	107	497	87
Fresh Water Alluvial Soils						
Region	Central Plain	8	1080	374	490	129
	North-eastern	4	470	278	231	130
	Northern	7	854	341	362	128
	Southern	2	520	25	194	24
	(Total)	21	835	406	396	84
Low Humic Gley Soils						
Region	Central Plain	7	727	327	339	107
	North-eastern	9	205	143	119	65
	Nothern	14	556	199	245	106
	Southern	5	524	86	187	79
	(Total)	35	495	278	223	121
Humic Gley Soils		1	1143	—	381	—
Regosols		5	71	21	29	9
Gray Podzolic Soils		2	278	34	134	26
Non-Calcic Brown Soils		3	821	238	433	149
Grumusols		1	2498	—	805	—

and Brackish Water Alluvial Soils had also a relatively high coefficient, the average values being 1261 mg and 1210 mg, respectively. In the North-eastern Region, the phosphorus absorption coefficient was generally very low, especially in the Regosols, because of the predominance of coarse-textured soils. In the Northern Region, Humic Gley Soils had a relatively high coefficient. Fresh Water Alluvial Soils and Low Humic Gley Soils from the Northern and Southern Regions had a much lower coefficient of phosphorus absorption than those from the Central Plain for the same textural class.

The average values of the nitrogen absorption coefficient of the surface soils were 491 mg per 100 g of soil on a dry basis in terms of N in the Central Plain, 125 mg in the North-eastern Region, 283 mg in the Northern Region, and 219 mg in the Southern Region, respectively. Grumusols, Marine Alluvial Soils, Brackish Water Alluvial Soils and Fresh Water Alluvial Soils from the Central Plain had a relatively high nitrogen absorption coefficient. By contrast, the soils from the North-eastern Region had a much lower absorption coefficient.

The amount of ammonium absorption in a soil is directly related to the amount and kind of clay present. As a rule, the higher the clay content, the higher the nitrogen absorption coefficient as well as phosphorus absorption. The absorbed ammonium is not necessarily fixed. Some of the ammonium is readily available to plant, but some is held as non-exchangeable (fixed) ammonium on the soil colloid. The higher the percentage of clay of the expanding-lattice type (montmorillonite), the higher the amount of fixed ammonium.

3. Summary

The characteristics of the chemical properties of Thai paddy soils can be summarized as follows:

Soil reaction in the Marine Alluvial Soils was rather acidic in the surface soils, but neutral or slightly alkaline in the subsoils. The soil pH in the Brackish Water Alluvial Soils was very low throughout the profile, ranging from 3.5 to 4.5. Fresh Water Alluvial Soils and Low Humic Gley Soils had quite different pH values ranging from a very acid to an alkaline reaction depending upon the parent materials. In the North-eastern Region, a rather strongly acidic reaction was present, even in the so-called saline soils. Grumusols and Humic Gley Soils showed a slightly alkaline reaction throughout the profile.

Organic carbon contents were very low compared to those in the temperate regions, the average values being 1.42% in the Central Plain, 0.43% in the North-eastern Region, 1.46% in the Northern Region, and 1.37% in the Southern Region. Carbon nitrogen ratios were 12.3 in the Central Plain, 10.1 in the North-eastern Region, 11.1 in the Northern Region, and 11.5 in the Southern Region.

In the Central Plain, the cation exchange capacity (CEC) was 27 meq/100 g in the Marine Alluvial Soils, 25 meq in the Brackish Water Alluvial Soils, 20 meq in the Low Humic Gley Soils and 45 meq in the Grumusols. In the Northern Region, CEC was fairly lower than that of the corresponding soil groups in the Central Plain, the average values being 14 meq in the Fresh Water Alluvial Soils, 6 meq in the Low Humic Gley Soils, and 21 meq in the Humic Gley Soils, CEC of the soils from the North-eastern Region was very low, the average values being 10 meq in the Fresh Water Alluvial Soils, 5 meq in the Low Humic Gley Soils, and 1 meq in the Regosols. In the Southern Region, the average values were 9 meq in the Fresh Water Alluvial Soils and 6 meq in the Low Humic Gley Soils.

Of the exchangeable cations, calcium and magnesium predominated in the composition of the sorptive complex. Marine Alluvial Soils were characterized by the predominance of exchangeable magnesium. By contrast, Grumusols, Humic Gley Soils and the soils derived from calcareous materials had a very high content of exchangeable calcium. In the so-called saline soils, sodium was the predominant cation.

The average values of the base saturation degree of the surface soils were 88.1% in the Central Plain, 68.2% in the North-eastern Region, 94.2% in the Northern Region, and 62.9% in the Southern Region. In the Marine Alluvial Soils, the base saturation degree generally exceeded the cation exchange capacity due to the presence of water soluble cations. Brackish Water Alluvial Soils had a rather low base saturation degree, which ranged from 34.2% to 73.5%. Fresh Water Alluvial Soils, Low Humic Gley Soils, Regosols, Gray Podzolic Soils and Non-Calcic Brown Soils were characterized by the presence of base unsaturation except for the soils derived from calcareous materials.

Total nitrogen content of the surface soils ranged from 0.03% to 1.17% in the Central Plain, from 0.016% to 0.107% in the North-eastern Region, from 0.021% to 0.071% in the Northern Region, from 0.047% to 0.198% in the Southern Region. Ammonium nitrogen produced under anaerobic incubation (which is considered to correspond to the available nitrogen) was 34.7 ppm in the Central Plain, 18.2 ppm in the North-eastern Region, 60.7 ppm in the Northern Region and 44.5 ppm in the Southern Region. Ammonification rate (percentage of ammonium nitrogen produced to the total nitrogen) was very low compared with that in other rice-producing countries.

Total phosphorus content of the surface soils was 75 mg/100 g in terms of P_2O_5 in the Central Plain, 14 mg in the North-eastern Region, 66 mg in the Northern Region, and 45 mg in the Southern Region. Available phosphorus extracted with Bray No. 2 solution was 16 ppm in the Central Plain, 7 ppm in the North-eastern Region, 18 ppm in the Northern Region and 20 ppm in the Southern Region. These figures seemed to be low for normal growth of rice plant.

Supplying power of potassium was rather high except in the sandy soils from the North-eastern Region.

The average values of available iron extracted with *N*-ammonium acetate solution at pH 4.8 were 99 ppm in the Central Plain, 54 ppm in the North-eastern Region, 132 ppm in the Northern Region, 71 ppm in the Southern Region. The average values of available manganese extracted with a neutral *N*-ammonium acetate solution were 37 ppm in the Central Plain, 24 ppm in the North-eastern Region, 23 ppm in the Northern Region, and 21 ppm in the Southern Region. The average values of available copper extracted with 0.1 *N* hydrochloric acid were 5.4 ppm in the Central Plain, 1.2 ppm in the North-eastern Region, 6.7 ppm in the Northern Region, and 1.8 ppm in the Southern Region. The average values of available zinc extracted with 0.1 *N* hydrochloric acid were 5.7 ppm in the Central Plain, 2.4 ppm in the North-eastern Region and 9.9 ppm in the Southern Region.

The average values of available silica extracted with *N*-ammonium acetate solution at pH 4 were 223 ppm in the Central Plain, 40 ppm in the North-eastern Region, 141 ppm in the Northern Region, and 66 ppm in the Southern Region.

The average values of phosphorus absorption coefficient were 1063 mg in the Central Plain, 251 mg in the North-eastern Region, 675 mg in the Northern Region, and 553 mg in the Southern Region. Grumusols had a high coefficient of 2498 mg. The average values of the nitrogen absorption coefficient were 491 mg in the Central Plain, 125 mg in the North-eastern Region, 282 mg in the Northern Region, and 219 mg in the Southern Region.

V. Clay Mineralogical Properties of Paddy Soils

The composition of clay minerals in a soil is closely associated with the physical and chemical properties as well as the genesis of the soil. Therefore, both clay content and its mineralogical composition play an important role in the soil productivity. In fact, it has been reported that, in Japan, soils with a predominance of montmorillonitic clay have a higher yield potential and show a higher response to nitrogen fertilizer in rice cultivation than those with kaolinitic clay or allophane (13). Clay mineralogical characteristics are often used as an index of the nature of the soil parent materials. For example, in the USDA soil classification system, clay mineralogy is adopted as one of the criteria for differentiating soil families (88).

Concerning the clay mineral composition of soils in Thailand, Sorasith et al. (76) conducted a pioneer study in 1962. Later, some detailed studies were carried out by Hattori et al. (17) and Kawaguchi and Kyuma (29) with a view to clarifying the general clay mineralogical characteristics of paddy soils. Furthermore, Hattori (18, 20—22) studied the clay minerals of Thai soils in more detail in relation to the genesis and physiography of the Quaternary deposits in the Northern Basin and the Central Plain. Charoen (7) attempted to establish a clay mineral classification of paddy soils based on the contents of different clay mineral species along with correlations with the parent materials and fertility studies.

In this chapter, some experiments have been carried out to get a better insight into the clay mineralogical characteristics of paddy soils in Thailand with special reference to the soil forming process.

1. Materials and Methods

1) Materials

Soils for clay mineralogical analysis were selected to cover each soil group from each region. Surface soils and subsoils taken from the same profile, (31 profiles in total) were used for X-ray diffraction analysis.

2) X-ray Diffraction Analysis

For a quantitative determination of the clay mineral composition, several methods have been proposed (4, 25, 91), but they are rather complex and laborious. In this report, the method used by Hattori et al. (17) was adopted with some modifications for a semi-quantitative assessment of the clay mineral composition.

3) Estimation of the Clay Mineral Composition

The relative abundance of the layer silicate clay minerals in the clay fraction was approximately determined in the Mg-clay air dried specimens by measuring the intensity of diffraction peaks at $2\theta=12^\circ$, 8.8° and $6\text{–}5^\circ$, which corresponded, respectively, to the basal spacing of kaolinites with 7Å layer, mica clay minerals (10Å) and 14Å minerals. In this report, however, some modifications were made by correcting the relative intensity of diffraction peaks using an intensity ratio, R, (for example, R: I(15Å Mt)/I(10Å Mc)=3, I(17Å Mt)/I(10Å Mc)=4, I(14Å Ch)/I(10Å Mc)=1, I(14Å Ch)/I(10Å Mc)=1, I(14Å Ch)/I(10Å)=1, I(7Å Kt)/[I(10Å Mc)=3], as reported by Wada (90). Otherwise, in particular the amount of 10Å minerals seemed to be underestimated. The 14Å minerals, which comprised various kinds of 2:1 or 2:2 type minerals, were conveniently grouped into montmorillonite, vermiculite, Al-interlayered minerals, chlorites and interstratified mixed layered minerals in this report. The relative abundance of 14Å minerals was expressed by the symbols (+++,

++, +, ±, -) according to the changes in the intensities and positions of X-ray diffraction peaks after the various treatments. The symbols show the relative abundance of clay species only within the same clay fraction of each sample, as follows: +++; abundant, ++; moderate, +; low, ±; very low, -; not detected.

2. Results and Discussion

1) Soils from the Central Plain

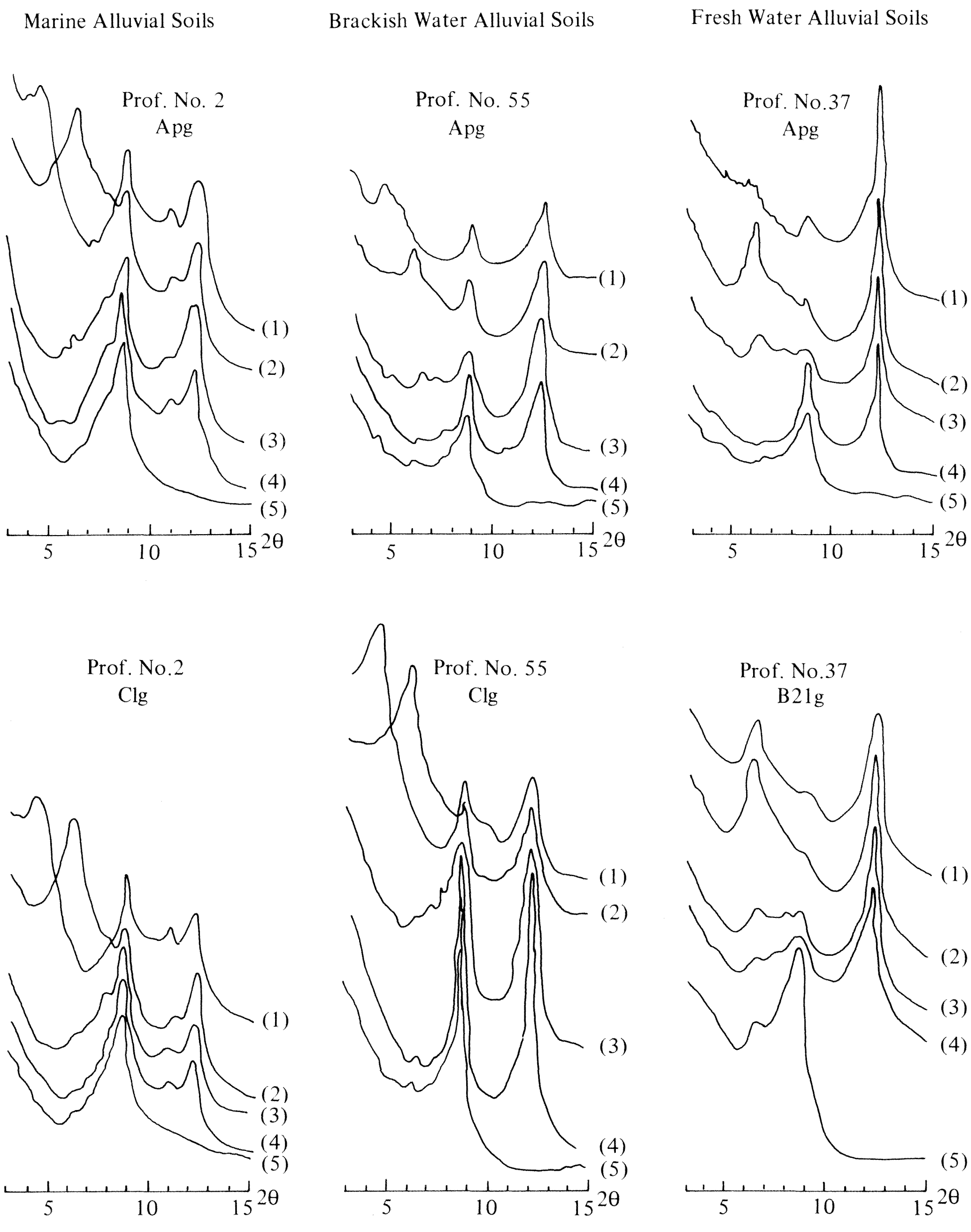
Clay mineral composition of paddy soils from the Central Plain is summarized in Table 24. Some typical X-ray diffraction patterns are illustrated in Figs. 20 and 21.

Table 24. Clay Mineral Composition of Paddy Soils in the Central Plain

				Relative Abundance								
No.	Location	Horizon	Deptch	7 Å	10 Å	14 Å						
			cm	(%)	(%)	(%)	Mt	Ver	Al-int	Ch	Int
2.	Phra Nakhon	Apg	0-15	30	45	25	+++	+	±	±	±
	Bang Khen.	C1g	50-65	25	40	35	+++	+	±	±	+
12.	Samut Prakan,	Apg	0-15	30	50	20	+++	+	±	-	+
	Bang Phli.	C1g	35-55	25	40	35	+++	+	-	-	+
55.	Pathum Thani,	Apg	0-17	40	40	20	++	+	±	+	-
	Klong Luang.	C1g	35-65	35	30	35	++	+	±	+	+
37.	Pitsanulok,	Apg	0-14	60	15	25	±	++	+	±	±
	Muang.	B21g	25-50	55	5	40	-	++	+	±	+
73.	Petchabun,	Apg	0-17	20	15	65	++	++	±	+	+
	Lom Sak.	B22g	38-52	30	15	55	++	++	+	+	±
140.	Sukhothai,	Apg	0-10	25	60	15	+	++	+	+	±
	Si Samrong.	Cg	24-60	25	55	20	+	++	+	++	±
3.	Saraburi,	Apg	0-12	65	10	25	+	++	+	+	±
	Muang.	B2g	25-55	60	5	35	+	++	+	+	±
132.	Nakhon Nayok,	Apg	0-13	65	15	20	+	++	+	±	±
	Muang.	B21g	20-60	70	10	20	+	++	+	±	±
135.	Chachengsao,	Apg	0-14	45	25	30	+	++	++	-	-
	Phanom Sarakham.	Cg	29-68	40	25	35	+	++	+	-	-
138.	Kamphaeng Phet,	Apg	0-18	55	40	5	-	++	±	-	-
	Kong Khlung.	Cg	38-70	55	40	5	-	++	-	-	-
6.	Suphan Buri,	Apg	0-15	45	50	5	±	+	+	+	-
	Muang.	B2g	25-40	45	45	10	+	+	+	+	-
11.	Nakhon Pathom,	Apg	0-15	30	65	5	+	+	±	-	-
	Muang.	B1g	15-45	30	60	10	+	+	±	-	-
23.	Lop Buri,	Ap	0-13	15	0	85	+++	±	±	-	-
	Muang.	A13	13-60	15	0	85	+++	±	±	-	-

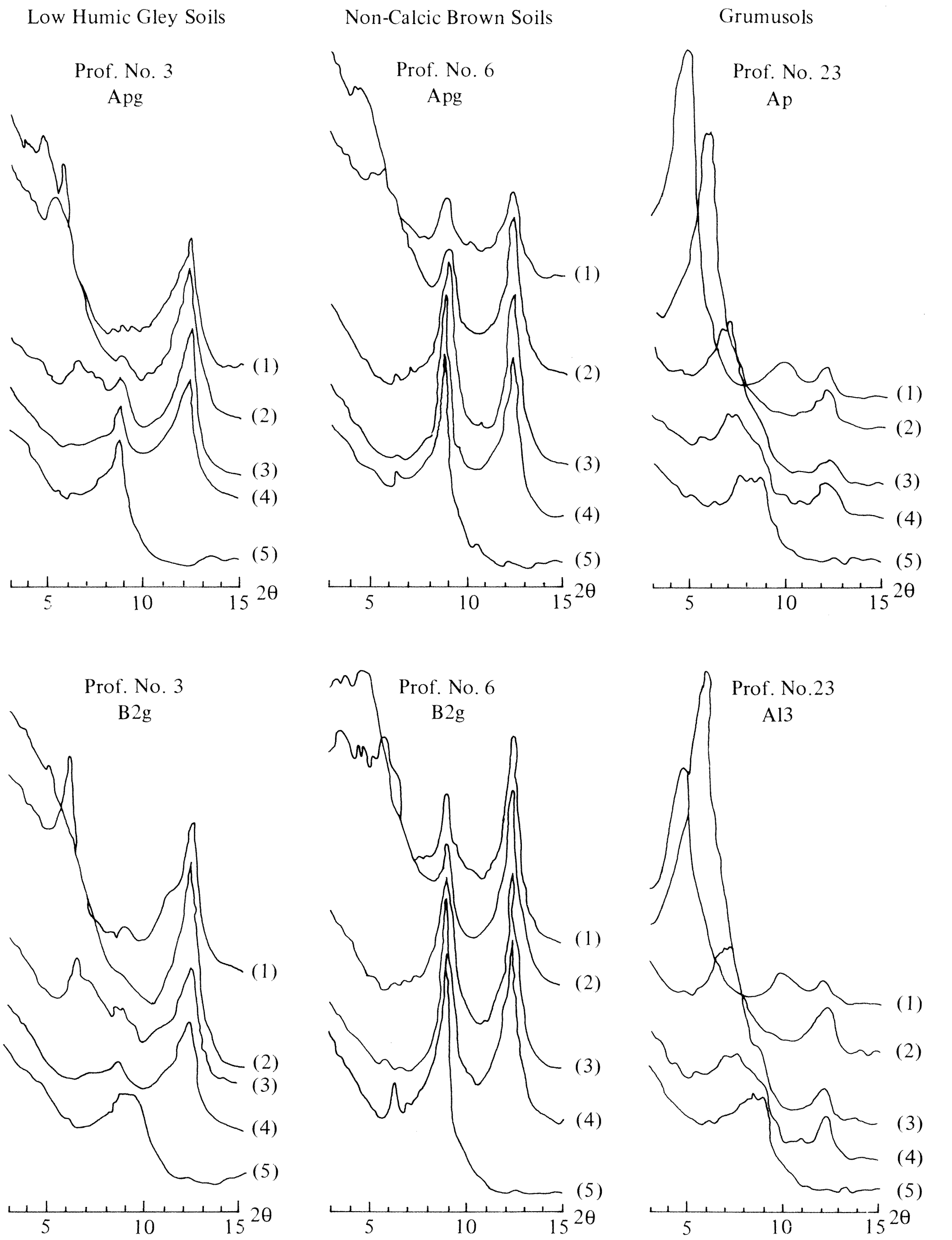
Composition: 7 Å, kaolinite minerals; 10 Å, mica clay minerals, Mt, montmorillonite, Ver, vermiculite; Al-int, aluminum interlayered minerals; Ch, chlorite; Int, interstratified mixed layer minerals.

Abundance: +++, abundant; ++, moderate; +, low; ±, very low; -, not detected.



(1) Mg-glycerol, (2) Mg-air-dried, (3) K-air-dried, (4) K-clay heated at 300 °C, (5) K-clay heated at 550°C

Figure 20. X-Ray Diagrams of Some Paddy Soils in the Central Plain



(1) Mg-glycerol, (2) Mg-air-dried, (3) K-air-dried, (4) K-clay heated at 300°C, (5) K-clay heated at 550°C

Figure 21. X-Ray Diagrams of Some Paddy Soils in the Central Plain

The clay fraction of the Marine Alluvial Soils was composed of mica clay minerals, kaolinite minerals and 14Å minerals in nearly even quantity. The 14Å minerals consisted of a large amount of montmorillonite and a small amount of vermiculite and mixed layered minerals. Brackish Water Alluvial Soils had nearly the same clay mineral composition as that of the Marine Alluvial Soils, except for the presence of a small amount of chlorites, which exhibited a low peak at 14Å for the K-clay after heating at 600°C.

Clay mineral composition of the Fresh Water Alluvial Soils greatly varied with the location depending on the nature of the parent materials. For example, the soils of Profile No. 37 (Pitsanulok, Muang) derived from the fresh water deposits of the Nan river, contained a large amount of kaolinitic minerals, while the soils of Profile No. 140 (Sukhothai, Si Samrong) derived from the fresh water sediments of the Yom river were composed predominantly of 10Å minerals and showed a rather clear peak at 14Å for the K-clay specimens heated at 600°C, particularly in the subsoil. On the other hand, the soils of Profile No. 73 (Petchbun, Lom Sak) derived from the fresh water deposits of the Pasak river were characterized by a large amount of 14Å minerals, which consisted mainly of montmorillonite and vermiculite, and by a relatively low content of both kaolinitic minerals and mica clay minerals. The peak intensity in X-ray diffraction of the specimens from this profile was weak and rather broad, indicating that clay minerals were low in crystallinity, especially for the surface soils presumably due to their younger pedogenetic age.

Most of the soils taken from Low Humic Gley Soils were composed predominantly of kaolinites. In these soils both mica clay minerals and 14Å minerals showed marked fluctuations ranging from 5% to 40% and from 5% to 35%, respectively. The 14Å minerals contained large amounts of vermiculite and a small amount of Al-interlayered minerals and montmorillonite.

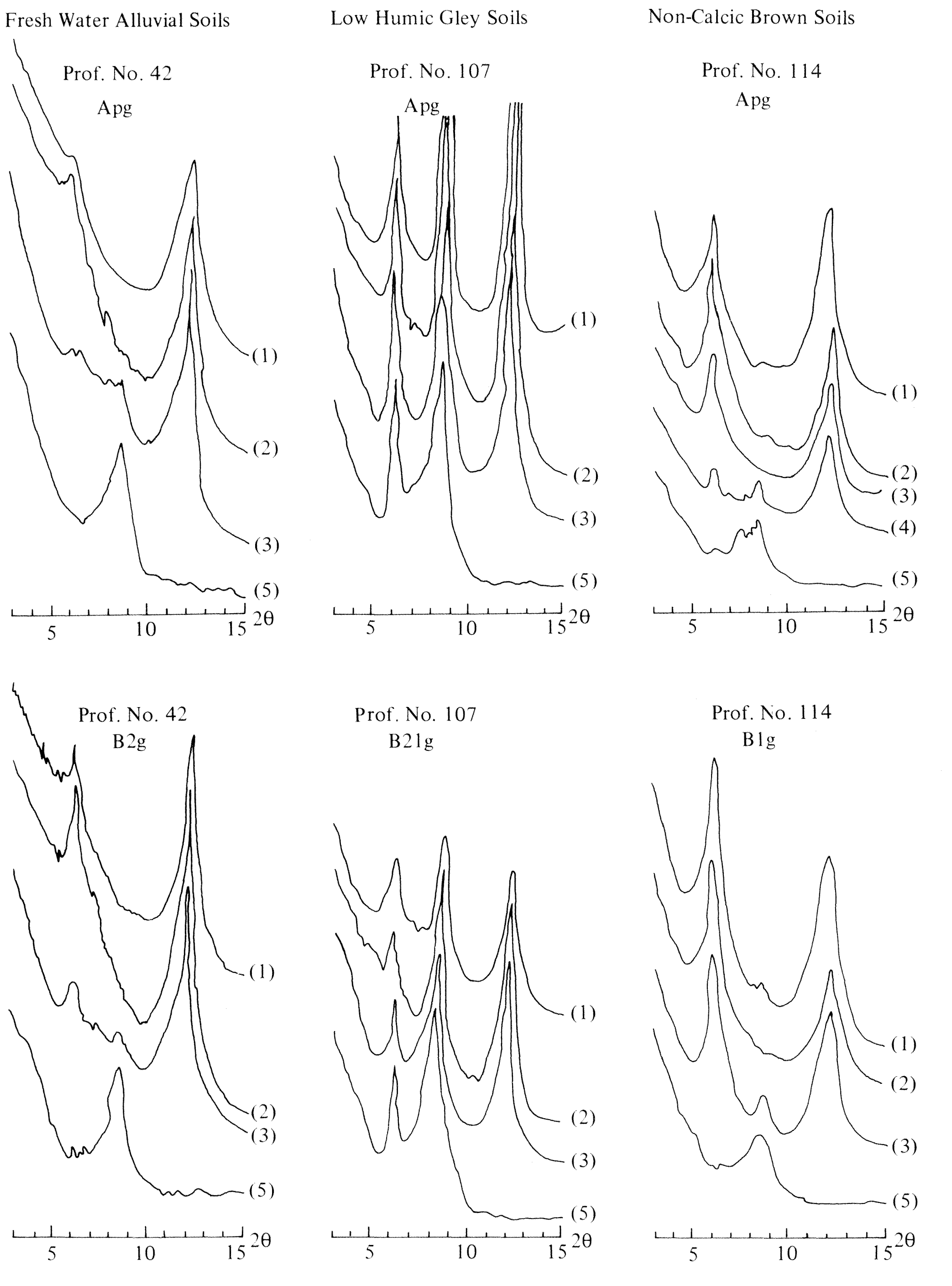
Non-Calcic Brown Soils in the Central Plain showed a comparatively high content of both mica clay minerals and kaolinitic minerals, and few 14Å minerals, which consisted mainly of vermiculite and partly of chlorite. The clay fraction of Profile No. 23 (Lop Buri, Muang) belonging to Grumusols developed on marly sediments was highly montmorillonitic (roughly 85%) in its clay mineral composition.

2) Soils from the North-eastern Region

Soils distributed along the Mekong river in this region could be clearly distinguished by their clay mineral composition from the other soils from this region, as readily seen in Table 25. Some typical X-ray diffraction patterns are shown in Fig. 22.

The soils of Profile No. 45 (Nong Khai, Si Chiang Mai) belonging to Fresh Water Alluvial Soils derived from the fresh water sediments of the Mekong river were characterized by large amounts of mica clay minerals and by an abundance of chlorites among the 14Å minerals. The soils of Profile No. 107 (Nong Khai, Muang) developed on the old levee of the Mekong river, which belonged to Low Humic Gley Soils, had nearly the same clay mineralogical characteristics as those of Profile No. 45, but the peak intensity at 14Å indicating the presence of chlorite was more striking. Hattori (19) pointed out that Cambodian paddy soils derived from recent Mekong sediments also contained a high amount of illite (corresponding to mica clay minerals).

In contrast, soils which were not considered to be affected by the sediments of the



(1) Mg-glycerol, (2) Mg-air-dried, (3) K-air-dried, (4) K-clay heated at 300°C, (5) K-clay heated at 500°C

Figure 22. X-Ray Diagrams of Some Paddy Soils in the North-eastern Region

Table 25. Clay Mineral Composition of Paddy Soils in the North-eastern Region

No.	Location	Horizon	Depth	7 Å	10 Å	Relative Abundance 14 Å					
			cm	(%)	(%)	(%)	Mt	Ver	Al-int	Ch	Int
42.	Nakhon Ratchasima,	Apg	0–15	80	0	20	–	+	++	–	±
	Phimai.	B2g	40–75	75	0	25	–	+	++	±	±
45.	Nong Khai,	Apg	0–15	30	55	15	±	+	±	++	±
	Si Chiang Mai.	Cg	30–55	30	40	20	±	+	±	++	±
48.	Khon Kaen,	Apg	0–10	50	5	40	–	++	++	–	+
	Chum Phae.	Cg	40–75	50	5	40	–	++	++	–	+
107.	Nakhom Phanom,	Apg	0–12	30	45	25	–	+	+	+++	±
	Muang.	B21g	23–42	30	50	20	–	+	+	+++	±
114.	Ubon Ratchathani,	Apg	0–10	50	5	45	–	++	+++	±	+
	Muang.	B1g	15–23	50	0	50	–	++	+++	±	+

Legends are the same as in Table 24.

Mekong river, were characterized by very low mica clay mineral contents and by abundant Al-interlayered minerals among the 14Å minerals, irrespective of the soil groups.

3) Soils from the Northern Region

As a rule, the clay mineral composition of the paddy soils from the Northern Region was characterized by a high amount of either kaolinitic or mica clay minerals and rather low contents of 14Å minerals, which consisted mainly of vermiculite, as tabulated in Table 26. Some typical X-ray diffraction patterns are shown in Fig. 23.

Soils with a predominance of kaolinitic minerals were distributed in the Chiang Mai and Chiang Rai basins, while soils with a predominance of mica clay minerals in the Nan and Phrae basins. The soils of Profile No. 154 located at Lampang, Muang, which belonged to Low Humic Gley Soils, contained a relatively large amount of 14Å minerals, which consisted chiefly of montmorillonite.

The clay fraction of the Humic Gley Soils (Profile No. 31, Chiang Rai, Mae Sai) was composed of kaolinitic minerals and mica clay minerals in nearly even quantity, and the amount of 14Å with a predominance of vermiculite was rather small.

4) Soils from the Southern Region

Clay mineralogical characteristics of paddy soils from the Southern Region were quite different from those of soils from the other three regions. Clay mineral composition of the soils in this region is tabulated in Table 27. As seen from the X-ray diffraction patterns shown in Fig. 24, they were characterized by a predominance of kaolinite minerals, irrespective of the soil groups, along with a small amount of mica clay minerals and by traces of 14Å minerals such as vermiculite and Al-interlayered minerals.

5) Classification of Clay Mineral Composition

The clay mineral composition of paddy soils in Thailand was classified into 10 classes based on the relative abundance of 7Å, 10Å and 14Å minerals according to the method proposed by Kawaguchi and Kyuma (30). Table 28 gives the profile

Table 26. Clay Mineral Composition of Paddy Soils in the Northern Region

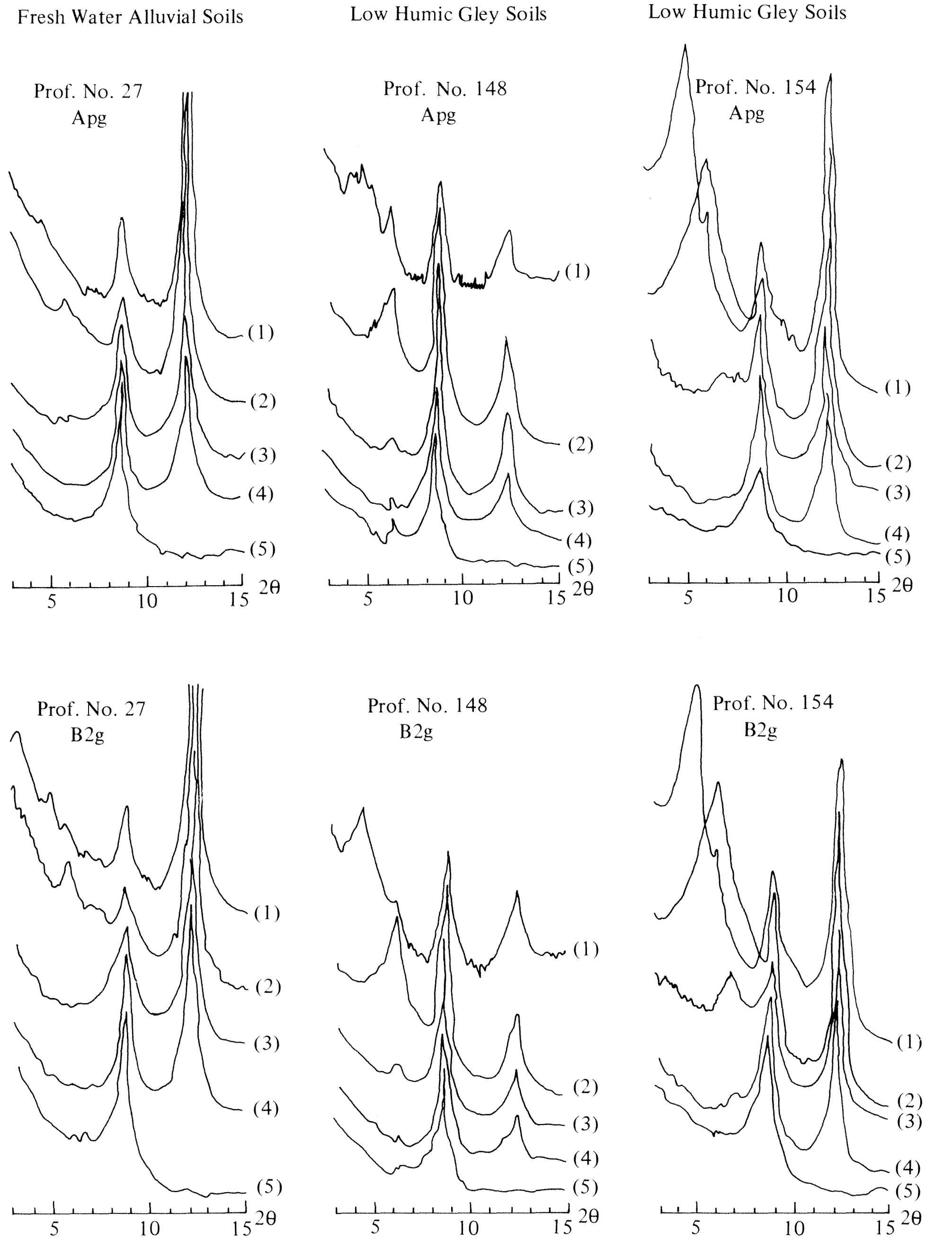
No.	Location	Horizon	Depth	7 Å	10 Å	Relative Abundance 14 Å					
			cm	(%)	(%)	(%)	Mt	Ver	Al-int	Ch	Int
27.	Chiang Mai,	Apg	0–15	65	30	5	±	++	±	-	±
	Sam Kampheng.	B21g	30–65	65	30	5	±	++	±	-	±
146.	Nan,	Apg	0–10	35	50	15	+	++	+	-	±
	Muang.	Cg	23–65	35	45	20	+	++	+	-	±
152.	Chiang Rai,	Apg	0–15	55	35	10	++	+	++	-	±
	Mae Chan.	B22g	25–40	55	35	10	++	+	+	-	±
26.	Chiang Mai,	Apg	0–15	40	55	5	+	+	-	-	-
	Mae Taeng.	B21g	25–45	40	55	5	+	+	-	-	-
33.	Chiang Rai,	Apg	0–15	50	30	20	±	++	±	+	±
	Phan.	B22g	45–65	50	25	25	±	++	±	±	-
148.	Phrae,	Apg	0–13	20	60	20	+	+	±	+	±
	Song.	B2g	23–65	20	55	25	++	+	±	+	+
154.	Lampang,	Apg	0–8	45	25	30	+++	+	±	-	-
	Muang	B2g	15–50	40	20	40	+++	+	±	-	-
158.	Chiang Rai,	Apg	0–15	50	40	10	±	++	±	-	-
	Fang, Ping Tam.	Blg	20–30	30	60	10	±	++	±	-	-
31.	Chiang Rai,	Apg	0–15	50	40	10	±	++	+	+	±
	Mae Sai.	B2g	40–60	45	40	15	±	++	+	+	±

Lengends are the same as in Table 24.

Table 27. Clay Mineral Composition of Paddy Soils in the Southern Region

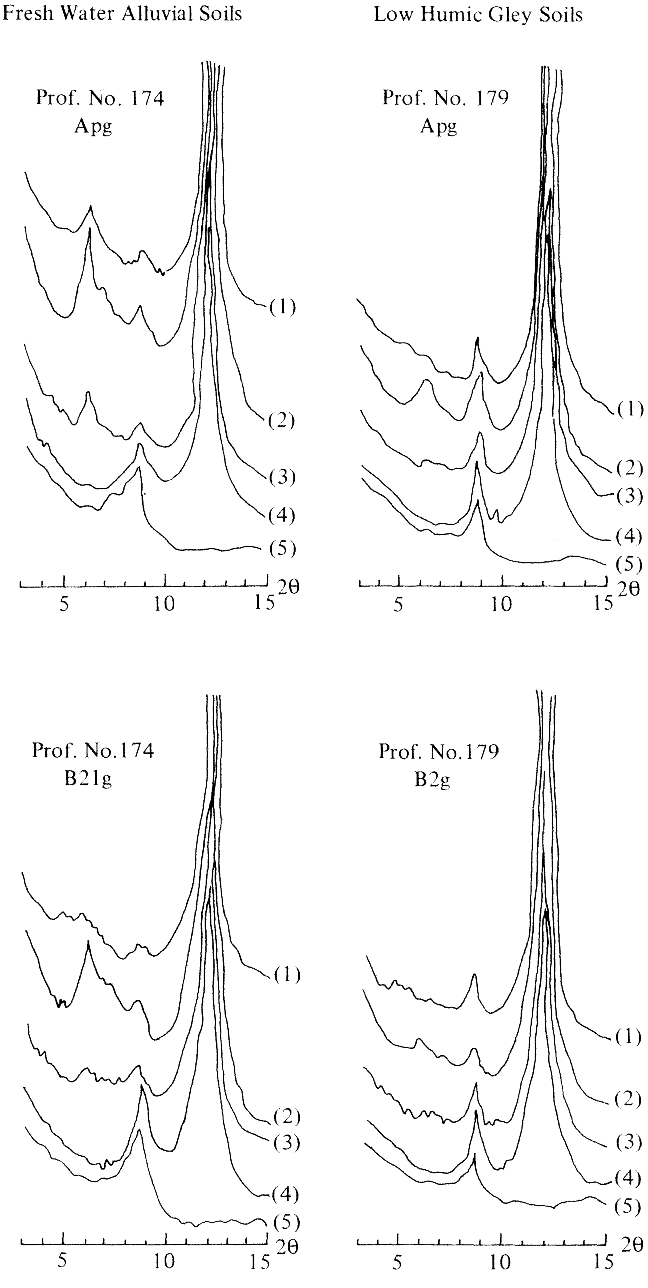
No.	Location	Horizon	Depth	7 Å	10 Å	Relative Abundance 14 Å					
			cm	(%)	(%)	(%)	Mt	Ver	Al-int	Ch	Int
174.	Phattalung,	Apg	0–17	75	10	15	-	+	++	-	-
	Khuan Khanum.	B21g	30–60	80	10	10	+	++	+	-	-
176.	Satun,	Apg	0–17	60	35	5	±	+	±	-	-
	Muang.	B2g	28–70	65	30	5	±	+	±	-	-
179.	Patthani,	Apg	0–12	75	20	5	±	+	±	-	-
	Khok Pho.	B2g	23–35	80	15	5	±	+	±	-	-
182.	Narathiwat,	Apg	0–15	80	15	5	±	+	±	-	-
	Muang.	B2g	30–40	80	20	5	±	+	±	-	-
		IICg	60–90	70	25	5	±	+	±	-	-

Lengends are the same as in Table 24.



(1) Mg-glycerol, (2) Mg-air-dried, (3) K-air-dried, (4) K-clay heated at 300°C, (5) K-clay heated at 550°C

Figure 23. X-Ray Diagrams of Some Paddy Soils in the Northern Region



(1) Mg-clay glycerol saturated, (2) Mg-clay air-dried, (3) K-clay air-dried,
(4) K-clay heated at 300℃, (5) K-clay heated at 550℃

Figure 24. X-Ray Diagrams of Some Paddy Soils in the Southern Region

Table 28. Clay Mineralogical Classes of Paddy Soils in Thailand

	Clay mineral composition	Central Plain		North-eastern Region		Northern Region		Southern Region	
		Surface	Subsoil	Surface	Subsoil	Surface	Subsoil	Surface	Subsoil
7 Å-dominant type	7 Å			○ 42	○ 42			○ 174 ● 179 ● 182	○ 174 ● 179 ● 182
	7-10 Å	● 138	● 138			○ 27 ○ 152 ● 33 ● 158 △ 31	○ 27 ○ 152 ● 33 △ 31	● 176	● 176
	7-14 Å	● 3 ● 37 ● 132 ● 135	● 3 ● 37 ● 132 ● 135	● 48 ▼ 114	● 48 ▼ 114	● 154	● 154		
10 Å-dominant type	10 Å								
	10-7 Å	□ 12 ■ 55 ○ 140 ▼ 6 ▼ 11	○ 140 ▼ 6 ▼ 11	● 45 ● 107	● 45 ● 107	○ 146 ● 26	○ 146 ● 26 ● 158		
	10-14 Å					● 148	● 148		
14 Å-dominant type	14 Å	▲ 23	▲ 23						
	14-7 Å	○ 73	○ 73						
	14-10 Å								
7-10-14 Å even type		□ 2	□ 2 □ 12 ■ 55						

□ Marine Alluvial Soils,
○ Fresh Water Alluvial Soils,
△ Humic Gley Soils,
▼ Non-Calcic Brown Soils
□ Brackish Water Alluvial Soils,
● Low Humic Gley Soils,
▲ Grumusols,

number corresponding to each class for each region.

As seen from the table, more than half of the soils examined here corresponded to the 7Å mineral dominant types. However, the 10Å mineral dominant types also were widely distributed especially in the Central Plain and the Northern Region. The experimental results showed that mica clay mineral content was much higher than that obtained by Hattori et al. (17), and Kawaguchi and Kyuma (29), who had reported that the Thai paddy soils, in general, were characterized by a high amount of kaolinite minerals and a low content of illite. This discrepancy is probably due to differences in the estimation of mica clay minerals, that is, the relative intensity of the diffraction peak at 14Å was adjusted by using an intensity ratio, "R" in this report, as described before. With regard to soil fertility, the presence of a high content of mica clay minerals in the Thai paddy soils plays an important role as one of the sources of plant nutrients, especially potassium, during the weathering process of these minerals.

Another difference from the results reported by Kawaguchi and Kyuma (29) was the presence of chlorites. The chlorites were commonly found in the soils along the Mekong river in the North-eastern Region and in various soil groups from other regions except for the Southern Region. Mitsuchi (45) suggested that the formation of chlorites from vermiculite in the plowed layer of paddy soils was regulated by the seasonal cycle of reduction and oxidation during rice cultivation. Inoue et al. (23) revealed the possible occurrence of chlorites from montmorillonite caused by acidic irrigation water. However, it is assumed that the chlorites in the Thai paddy soils did not result from the paddy soil forming process, but from inheritance of the parent materials.

The clay mineralogical characteristics of a soil are closely related to the characteristics of the parent materials and the clay mineral composition reflects the weathering history of the soil. Among the various types, the 7Å mineral dominant type may be regarded as the most highly weathered soil, the 14Å mineral dominant type and especially the 10Å mineral dominant type as the least weathered and the type with 7-10-14Å minerals in equal amounts as being intermediate between the former two. In this regard, the soils from the North-eastern Region except those affected by the sediments of the Mekong river and the Southern Region were considered to be highly weathered. In such soils, Al-interlayered minerals were predominant among the 14Å minerals. In the Central Plain, and the North-eastern Region, soils containing a large amount of kaolinitic minerals were commonly found in the Low Humic Gley Soils developed on low terraces derived from old alluvium. On the other hand, soils of the 10Å and 14Å mineral dominant types were found in low-lying areas in the Central Plain and basins in the Northern Region. Most of these soils were enriched each year by flooded water containing a large amount of soil particles. The 14Å minerals of these soils were mainly montmorillonite and/or vermiculite.

3. Summary

Clay mineralogy of the Thai paddy soil was, in general, characterized by a large amount of 7Å minerals, but some distinctive characteristics were recognized among both the different soil groups and different regions. Marine Alluvial Soils were composed of mica clay minerals, kaolinite minerals and 14Å minerals in nearly even quantity. Clay minerals of the Brackish Water Alluvial Soils were not different from those of the Marine Alluvial Soils, except for the presence of a small amount of chlorites. The clay mineral composition of the Fresh Water Alluvial Soils and Low Humic Gley Soils varied markedly with the regions. In the Central Plain various types ranging from 7Å to 14Å mineral dominant types were found. Soils from the North-eastern Region were characterized by a high amount of 7Å minerals, but in the soils along the Mekong river mica clay minerals predominated and chlorite was the main component 14Å minerals. Soils from the Northern Region were either of the 7Å or 14Å mineral dominant types. Soils from the Southern Region were more kaolinitic than those of the other three regions.

VI. Oxidative-Reductive Properties of Paddy Soils

Paddy soils are under flooded conditions during the growing period of rice plant. Consequently aerobic micro-organisms at first consume molecular oxygen in water, then oxygen loosely bounded with other compounds and organic matter in soil, and finally anaerobic bacteria utilize other oxides like iron, sulfate, etc. as electron acceptors. Takai (79) clearly described the stepwise reduction pathways in a flooded soil in conjunction with changes in corresponding microbial activities. A series of drastic changes in physical, chemical and biological properties that take place during this process, undoubtedly influence to a great extent the growth of rice plant. In some cases, soil reduction is beneficial to growth owing to the increasing availability of plant nutrients in the soil such as nitrogen, phosphorus, silica, etc. (66, 72, 73). In contrast, in other cases, it brings about serious disadvantages for healthy growth. One of the possible reasons for this is the fact that rice roots are easily damaged by the accumulation of harmful substances such as hydrogen sulfide, methane, organic acid and so on, which are readily produced under strongly reduced conditions (46). Accordingly, it may be said that oxidative-reductive properties of paddy soils are very closely associated with rice production.

Herein, oxidative-reductive characteristics of paddy soils in Thailand will be discussed with regard to the changes in soil pH, redox potential, ammonia production and ferrous iron formation under anaerobic incubation. And also, some aspects of soil management will be briefly taken up in relation to the development of soil reduction in this chapter.

1. Materials and Methods

1) Soil Samples

The soil samples used in this experiment were surface soils collected from paddy fields, that is, 63 samples from the Central Plain, 42 samples from the North-eastern Region, 34 samples from the Northern Region and 24 samples from the Southern Region, which were thought to cover the various types of paddy soils in Thailand.

2) Analytical Methods

Sixty grams of air-dried fine soil were placed into 100 ml polyethylene bottle and mixed thoroughly after addition of 60 ml of distilled water. The flooded soil samples were anaerobically kept in an incubator at 30°C for 4 weeks.

Soil pH and redox potential before and after incubation were measured using a glass electrode and a platinum electrode, respectively. Redox potential was expressed as mV at pH 6.0 (Eh_6). Ferrous iron produced during the incubation was determined by the 2,2'-dipyridyl method after extraction with 0.2% $AlCl_3$ solution (55), and also ammonium nitrogen was determined by the Kjeldahl method after extraction with 10% KCl solution. At the time of the measurement of ferrous iron and ammonium nitrogen, a given weight of wet soil was used after removing the oxidized surface soil and mixing the reduced subsoil.

2. Results and Discussion

1) Changes in Physico-chemical Properties under Submergence

When a soil is water-logged, the color usually changes from yellowish brown or grayish brown to gray or bluish gray. At the same time, the chroma value is lower.

Table 29. Changes in Soil pH, Redox Potential and Ferrous Iron Formation by Anaerobic Incubation

Soil group		No. of samples	Soil pH Before average	Soil pH Before S.D.	Soil pH After average	Soil pH After S.D.	Redox Potential (Eh_6) mV Before average	Before S.D.	After average	After S.D.	Fe(II) ppm average	Fe(II) ppm S.D.
Marine Alluvial Soils		16	5.26	0.47	6.53	0.47	472	52	122	70	2691	1143
Brackish Water Alluvial Soils		9	4.38	0.31	5.62	0.62	502	46	173	56	2035	1943
Fresh Water Alluvial Soil												
Region	Central Plain	20	5.71	0.76	6.51	0.37	509	42	108	90	2918	1545
	North-eastern	6	5.46	1.26	6.31	0.73	457	45	184	70	1159	897
	Northern	7	5.57	0.81	6.84	0.15	487	64	94	58	3771	2683
	Southern	3	5.23	0.12	6.57	0.05	423	12	104	6	2787	339
	(Total)	(36)	5.66	0.93	6.55	0.44	488	54	117	82	2779	1873
Low Humic Gley Soils												
Region	Central Plain	14	5.34	0.60	6.30	0.40	539	50	130	71	2186	1252
	North-eastern	26	5.07	0.63	5.98	0.50	496	57	189	74	1142	981
	Northern	24	5.48	0.59	6.80	0.24	446	47	68	54	4106	1503
	Southern	14	4.93	0.49	6.44	0.29	431	33	133	63	2011	1326
	(Total)	(78)	5.25	0.64	6.37	0.57	477	62	131	78	2398	1693
Humic Gley Soils		2	7.75	0.10	6.85	0.30	502	28	99	11	2637	68
Regosols		10	4.80	0.64	5.12	0.63	484	52	329	58	228	278
Gray Podzolic Soils		3	5.35	1.12	6.48	0.47	448	21	196	67	1187	804
Non-Calcic Brown Soils		5	6.09	1.32	6.53	0.55	508	28	151	65	2224	1204
Grumusols		4	6.65	0.74	6.89	0.34	522	31	225	64	823	636

It was already demonstrated that the changes in soil color taking place under submergence are closely related to the process of ferrous iron formation (52).

However, as the incubation period proceeds, the soil color of the surface again becomes yellowish or reddish brown due to the oxidation of ferrous iron.

Table 29 shows the changes in soil pH, redox potential, and the amount of ferrous iron produced under anaerobic conditions for 4 weeks.

In most of the soil samples, the soil pH increased more or less and the final values ranged between 6.0 and 7.0. On the other hand, soils with an alkaline reaction showed a slight decrease of pH or no significant change. The magnitude and rate of the change in soil pH greatly varied according to the soil properties. Generally speaking, major changes occurred in soils with a high content in organic matter. For example, soil samples from the North-eastern Region which were very poor in organic matter, showed minor changes in soil pH, while the Alluvial Soils from the Central Plain and the Northern Region which have a relatively high content in organic matter showed conspicuous changes. However, only a small pH elevation after anaerobic incubation was recognized in the Brackish Water Alluvial Soils in spite of the rather high content of organic matter. This is probably caused by the low microbiological activity due to the low pH value of the soil. However, it should be noted that soil pH after flooding fairly increased with the growing stages of rice under the field conditions (56).

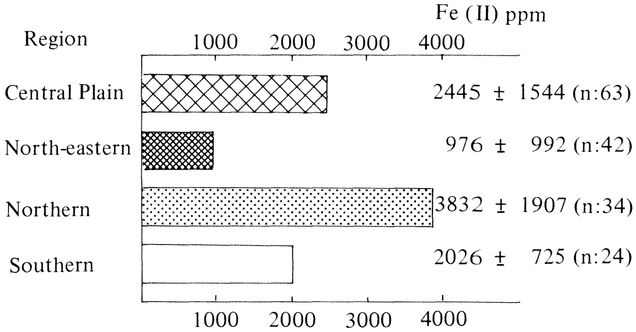


Figure 25. Fe(II) Production in Submergence

The decrease in redox potential was the most striking electrochemical change induced by flooding. After 4 weeks' anaerobical incubation, the redox potential fell in all of the samples without any exception. According to Ponnamperuma (66), the sequence of changes in redox potential varies depending upon the nature and amount of organic matter and the kind and content of oxidized soil components, especially the content of active manganese and iron. Soils low in organic matter from the North-eastern Region showed fairly high Eh_6 values even after 4 weeks' incubation. On the other hand, the Eh_6 value decreased appreciably in the soils relatively high in organic matter in the Central Plain and the Northern Region. Although it is considered that the lower the redox potential, the more pronounced the soil reduction, it should be noted that the redox potential is a measure of the intensity of reduction but does not give any indication of the concentration of the reduction products. Therefore, to analyse the oxidation-reduction characteristics of paddy soils more accurately, it is necessary to combine the intensity factor of reduction (redox potential) with the capacity of reduction factor which may involve the whole concentration of reduction products.

The most important chemical change that takes place in a flooded soil is the reduction of iron and the concurrent increase in its solubility. As shown in Fig. 25, the average amounts of ferrous iron produced under anaerobic conditions were 2445 ppm in the Central Plain, 976 ppm in the North-eastern Region, 3832 ppm in the Northern Region and 2026 ppm in the Southern Region, respectively. But, these values varied considerably among the soil groups. In other words, ferrous iron concentration after 4 weeks' anaerobic incubation was higher in the following order: Fresh Water Alluvial Soils, Marine Alluvial Soils, Humic Gley Soils, Low Humic Gley Soils, Non-Calcic Brown Soils, Brackish Water Alluvial Soils, Gray Podzolic Soils, Grumusols, Regosols, as shown in Table 29. Ferrous iron production generally increased with the content in organic matter. However, ferrous iron concentration was much lower in the soils from the Central Plain than in those from the Northern Region where organic matter content in the soil had nearly the same value. This is probably due to the difference in clay mineral composition. According to previous studies (54), soils with 2:1 type of clay minerals contain much less active and much more inactive and non-exchangeable ferrous iron forms than the soils with 1:1 type of clay minerals. Ferrous iron extracted with 0.2% $AlCl_3$ solution is considered to belong to the active form of ferrous iron (54). Accordingly, the soils of the Central Plain which contain relatively high amounts of montmoril-

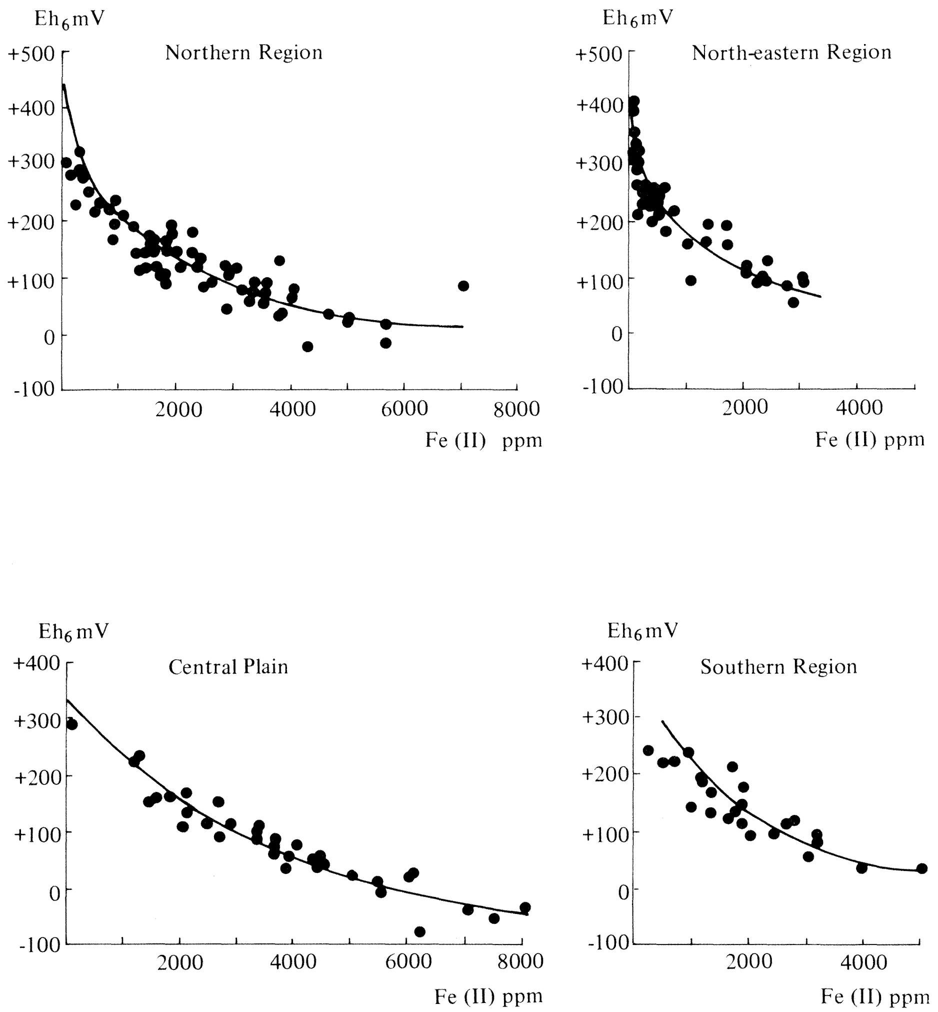


Figure 26. Relationship between Redox Potential and Amount of Fe(II) Produced.

lonitic clay minerals may show rather low values of ferrous iron extracted with 0.2% $AlCl_3$ solution.

Fig. 26 shows the relationship between the redox potential and the amount of ferrous iron produced. It is evident from this figure that the lower the redox potential, the larger the amount of ferrous iron produced. In other words, it may be suggested that the redox potential parallels the formation of ferrous iron.

Another important chemical change taking place in flooded soils is the mineralization of organic nitrogen in the soil. Ammonium nitrogen released from soil nitrogen is most advantageous for rice plant under flooded conditions. Ammonia production under anaerobic conditions has already been discussed in Chapter IV.

As seen from Fig. 27, a significantly high correlation was recognized between the amount of ferrous iron and ammonium nitrogen produced in anaerobic incubation.

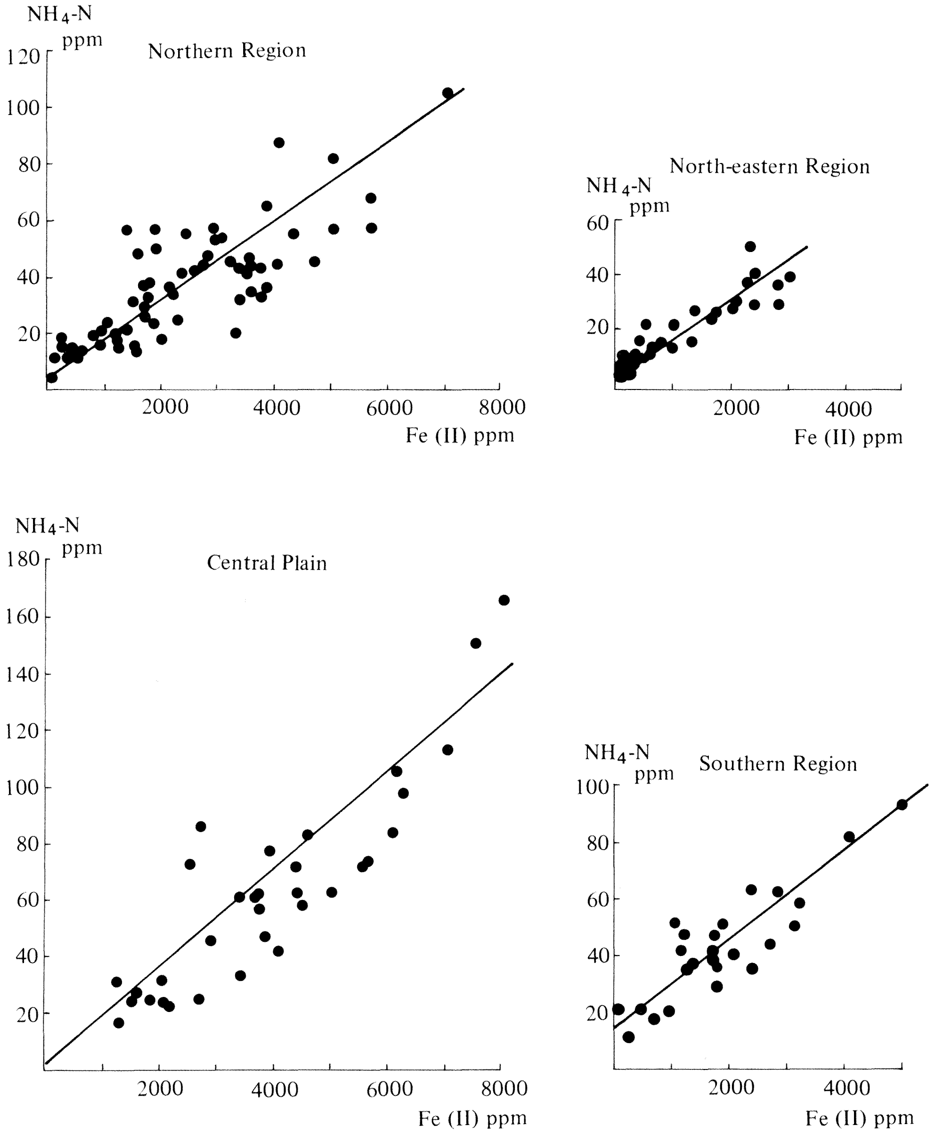


Figure 27. Relationship between Amount of Fe(II) and NH_4-N Produced under Anaerobic Incubation.

2) Effect of Liming on Soil Reduction

In the previous paragraph, it was pointed out that the development of soil reduction was markedly retarded in the Brackish Water Alluvial Soils presumably because microbiological activities were remarkably depressed by the low soil pH. Therefore, the current experiment was conducted to analyse the effect of liming on soil reduction. The experiments were carried out at three different locations under field conditions. After liming, the surface soil was well mixed and water-logging was maintained. The measurements were done 3 weeks after flooding.

The experimental results are summarized in Table 30.

In the case of the Klong Luang soil which belongs to the Brackish Water Alluvial

Table 30. Effect of Liming on Soil Reduction

Items	Lime Application			
	No Liming	2.5t/ha	3.75t/ha	5.0t/ha
		Bang Khen Soil*		
pH	6.66	6.84		6.99
Eh_6 mV	+ 29	+ 4		- 2
Fe(II) ppm	2813	3246		3443
NH_4-N ppm	40.3	53.6		62.4
		Klong Luang Soils**		
pH	4.86	5.83		6.00
Eh_6 mV	+ 287	+ 160		+ 130
Fe(II) ppm	419	803		1027
NH_4-N ppm	17.2	23.2		24.2
		Sakon Nakhon Soils***		
pH	6.11		9.14	
Eh_6 mV	+ 232		+ 258	
Fe(II) ppm	174		217	
NH_4-N ppm	6.5		14.3	

* Marine Alluvial Soils
** Brackish Water Alluvial Soils (Acid Sulfate Soils)
*** Regosols

Soils, so-called acid sulfate soils, the pH value of the air dried fine soil was 4.2. Without liming, the soil showed minor changes in soil pH and redox potential after flooding. But, liming caused a significant increase in soil pH and a clear decrease in redox potential. Also, liming seemed to promote ferrous iron formation. Thus, soil reduction indicated by the redox potential and ferrous iron formation was conspicuously enhanced in strongly acid soils by liming. It should be pointed out that the amount of ammonium nitrogen released from soil nitrogen increased with the amount of lime applied.

The same results were obtained in the Bang Khen soil which belongs to the Marine Alluvial Soils with intergrading of Brackish Water Alluvial Soils. Soil reaction was slightly acid in the surface. Liming also brought about an increase of soil pH and a decline of redox potential, but the magnitude of the change was not so pronounced. However, liming had a beneficial effect on ammonia production.

In the case of the Sakon Nakhon soil which belongs to the Regosols, following the application of lime at the rate of 3.75 tons per hectare, the soil pH developed a strongly alkaline reaction, because of the very weak buffer capacity of soil. This soil was characterized by a high content of sand fraction. A significant difference in redox potential by liming was not detected, but a large difference in ammonia production took place, namely the ammonia concentration in the limed soil was more than twice compared with that in the control.

From these results, it may be concluded that the correction of soil reaction by liming promoted soil reduction, especially in strongly acid soils as well as the availability of soil nitrogen. Such effects are beneficial to the growth of rice plant.

3) Effect of Organic Matter on Soil Reduction

The development of soil reduction is greatly affected by microbiological activities (66, 78). Consequently, the magnitude and the rate of soil reduction depend to a large extent upon soil properties related to microbiological activities, mainly upon the quantity and quality of organic matter in the soil. The sandy soils very poor in organic matter in the North-eastern Region, showed rather high values of redox potential even after 4 weeks' anaerobic incubation, as already mentioned before. Therefore, experiments were carried out to analyse the effect of the application of organic matter on soil reduction at Bang Khen and Surin Rice Experiment Stations where the soil conditions are different from one another.

As organic matter sources, city compost and rice straw were applied at the rate of 6 tons per hectare. Total amount of organic matter was introduced 3 weeks before transplanting, incorporated and mixed well with the plowed layer.

Tables 31 and 32 give analytical data on the soil conditions when organic matter was applied. These data were obtained from the Surin field (wet season 1971) and from the Bang Khen soil (dry season 1972), respectively. The soil was sampled just before basal fertilizer application, at the maximum tillering stage of rice (just before drainage), at the flowering stage (Bang Khen field) or at the heading stage (Surin field) and after harvesting.

Surin soil did not show a clear development of reduction indicated by changes in soil pH, redox potential, and ferrous iron content. However, the application of

Table 31. Effect of Application of Organic Matter on Soil Reduction in Surin Field, Wet Season, 1971

Treatment	Air-dried Soil	June 21*	July 21**	Sept. 15***	Oct. 15****
			Soil pH		
Control	5.65	6.25	6.30	6.40	6.35
City compost		6.60	6.32	6.55	6.42
Rice straw		6.43	6.46	6.68	6.55
			Redox potential (Eh_6, mV)		
Control	+ 462	+ 163	+ 157	+ 145	+ 136
City compost		+ 36	+ 127	+ 107	+ 191
Rice straw		+ 62	+ 90	+ 113	+ 111
			Ferrous iron, ppm		
Control	0	437	339	341	445
City compost		811	745	823	416
Rice straw		720	706	876	512
			Ammonium nitrogen, ppm		
Control	0	3.7	5.5	6.0	3.6
City compost		8.1	14.5	14.2	4.8
Rice straw		3.5	6.8	8.4	4.1

* Before basal fertilizer application
** Maximum tillering stage
*** Heading stage
**** After harvesting

Table 32. Effect of Application of Organic Matter on Soil Reduction in Bang Khen Field, Dry Season, 1972

Treatment	Air-dried Soil	Feb. 4*	Mar. 3**	Mar. 31***	May 10****
			Soil pH		
Control	5.20	6.68	6.78	6.68	5.90
City compost		6.74	6.80	6.87	6.30
Rice straw		6.68	6.90	6.88	5.95
			Redox potential (Eh_6, mV)		
Control	+ 425	+ 98	+ 88	+ 44	+ 313
City compost		+ 72	+ 49	+ 36	+ 225
Rice straw		+ 51	+ 31	+ 37	+ 354
			Ferrous iron, ppm		
Control	13	2,786	2,284	3,105	88
City compost		3,384	3,339	3,789	528
Rice straw		3,379	3,431	4,393	92
			Ammonium nitrogen, ppm		
Control	0.3	33.9	18.8	16.7	3.7
City compost		43.6	36.7	31.3	4.2
Rice straw		25.3	19.7	26.8	4.9

* Before basal fertilizer application
** Maximum tillering stage
*** Flowering stage
**** After harvesting

organic matter brought about an increase in soil pH, a decline in redox potential and acceleration of ferrous iron formation as a result of the stimulation of micro-organism activity.

Ammonium concentration in soil was slightly lower in the rice straw plot, but higher in the city compost plot than that of the control at the early stages, presumably due to differences in the carbon-nitrogen ratio between both types of organic matter. But, the ammonium concentration of all plots increased with the growing stages of rice.

On the other hand, in the Bang Khen soil, reduction was developed even without the application of organic matter. Therefore, the effect of organic matter on the development of soil reduction was not clear, but a slight increase in ferrous iron concentration was observed following the application of organic matter.

Thus the application of organic matter sometimes brings about a pronounced reduction in soil. In this case, appropriate water management such as drainage or intermittent irrigation was effective in removing the harmful substances and in recovering a suitable oxidation-reduction status surrounding the root zone.

4) Effect of Intermittent Drainage on Oxidation-Reduction State

It is essential to keep an adequate oxidation-reduction state in soils for optimum growth of rice throughout the whole growing period. Intermittent drainage of surface irrigation water is considered to be one of the most common soil management practices for this purpose (10, 62, 69). Experiments were carried out to evaluate the changes of some physico-chemical properties of the soils consecutive to intermittent drainage, using different soils at two different stations, Surin and

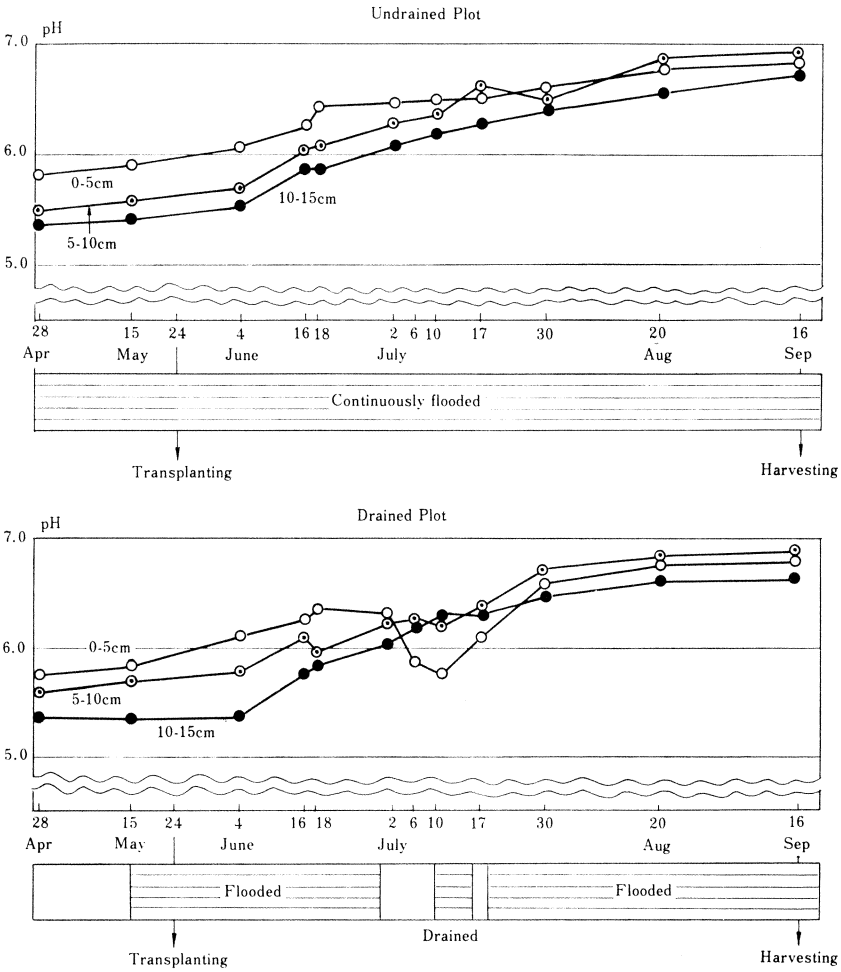


Figure 28. Changes in Soil pH in Bang Khen Field, Wet Season, 1970

Bang Khen. The intermittent drainage treatment was performed in draining off the surface irrigation water for 7 days or 10 days at the end of the effective tillering stage and for 3 days at the IPP stage.

The soil pH and redox potential measured periodically during the whole growing period in Bang Khen Station in the wet season of 1970 are shown in Fig. 28 and Fig. 29, respectively.

As shown in Fig. 28, a gradual increase in soil pH was observed during the growing period, and the value of the soil pH reached about 7.0 at the end of the period. Soil pH of the uppermost layer (0–5 cm) apparently was higher at the beginning of flooding than that of the following layers, but the values became closer as the growing period proceeded. During intermittent drainage of irrigation water, the soil pH of the uppermost layer decreased, but that in the lower part remained still at a high level.

As expected, the redox potential decreased rather rapidly at the early stage of flooding, and then reached the constant Eh_6 value of 0 mV one month after transplanting. The potentials showed minimum values for the sub-surface layer

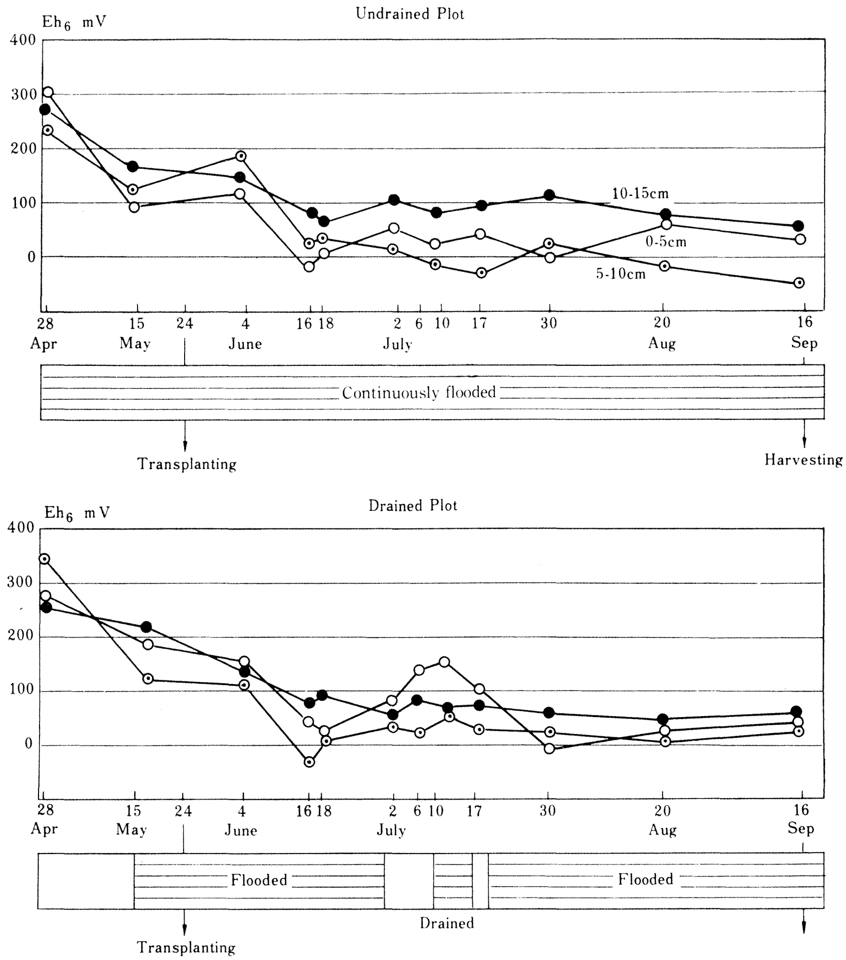


Figure 29. Changes in Redox Potential in Bang Khen Field, Wet Season, 1970

(5–10 cm) and maximum for the third layer (10–15 cm) during the whole period. In the drained plot, redox potential was decreasing in the same way as in the undrained plot until drainage started. However, the potential increased rapidly during the drainage period, namely, the Eh_6 value in the uppermost layer rose to +150 mV at the end of the drainage while that of the lower layer still remained at a low level. The redox potential decreased to a low Eh_6 value, after irrigation was resumed.

Effects of intermittent drainage of irrigation water on soil pH and redox potential seemed to be limited only to the uppermost layer. During the drainage period, wide cracks appeared and developed deeply with the drying up of the surface soil. The surface of the large cracks became easily oxidized by air, unlike the deeper parts which maintained a strongly reduced condition.

Changes in the three-phase distribution of soil are shown in Fig. 30. Due to drainage volumes of the solid phase of the soil in Bang Khen field gradually increased with a decrease in the values of the liquid phase, and the air phase increased steadily until it reached a constant value. Such changes were mainly

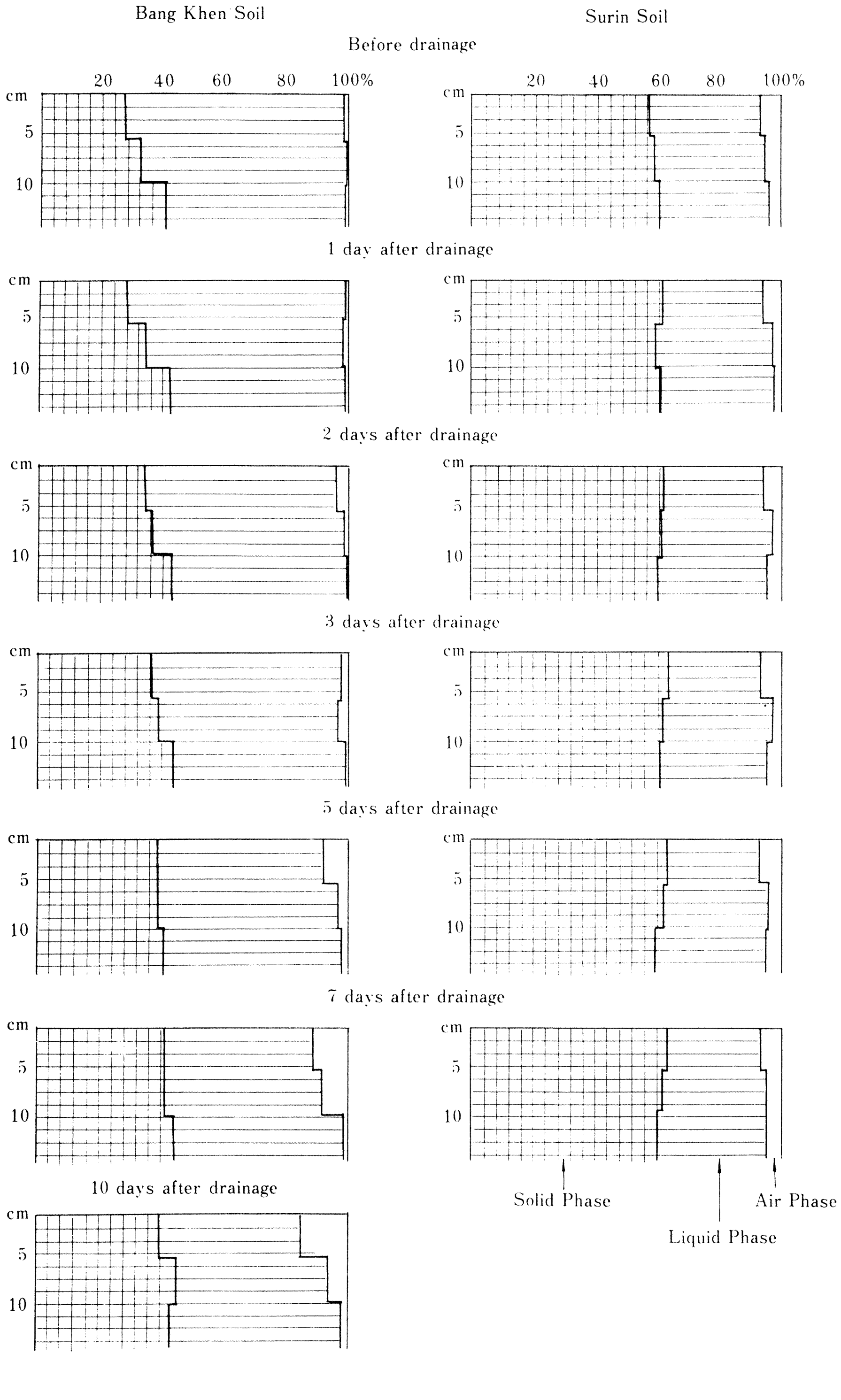


Figure 30. Changes in Three-Phase Distribution during Water Management

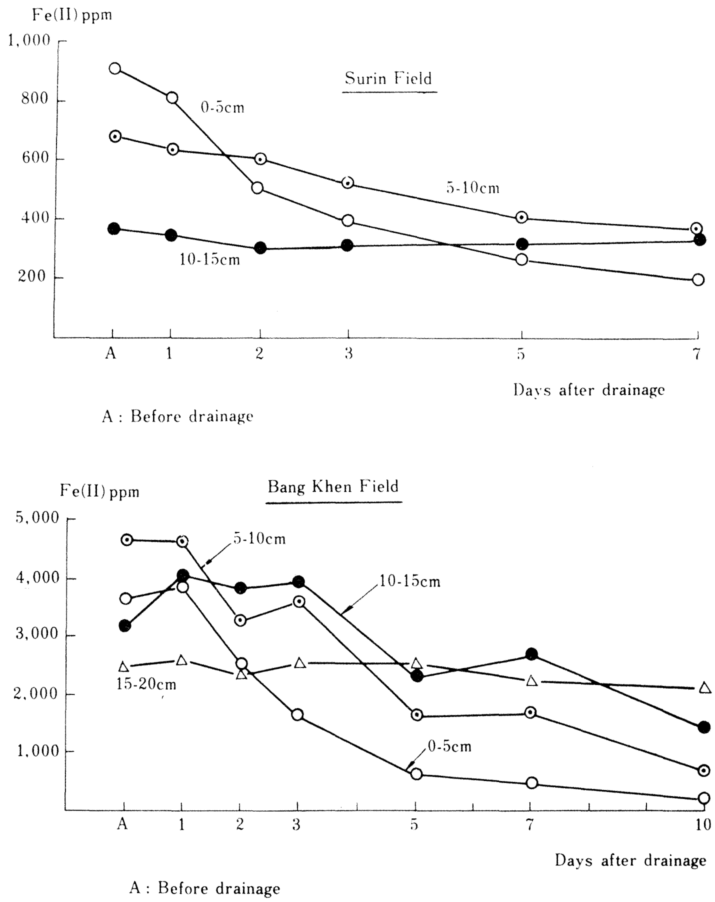


Figure 31. Changes in Fe(II) Content by Water Management

observed in the uppermost layer. Cracks began to appear 3 or 4 days after drainage, and strongly developed with the decrease in the values of the liquid phase. Bang Khen soil is a heavy-textured soil, with a predominance of montmorillonite followed by little kaolinite in its clay mineral composition. Accordingly, volume changes due to shrinkage amounted to almost 90%, suggesting that the soil volume decreased by nearly one-half of the original volume. Such a heavy shrinkage resulted in strong compaction of the soil.

Surin soil was in striking contrast to Bang Khen soil with regard to shrinkage. The values of the solid phase increased only slightly by drainage, but the air phase was kept almost unchanged during the whole period of the treatment. In fact, no cracks were observed during this treatment presumably due to the very narrow range between shrinkage limit and liquid limit on account of the very coarse texture of the soil.

Changes in the ferrous iron concentration during the drainage period are shown in Fig. 31. Ferrous iron content of the uppermost layer and of the second layer in the Bang Khen soil rapidly declined with time, that is, the ferrous iron concentration amounting to 3687 ppm or 4676 ppm in the uppermost layer and the following layer, respectively before the treatment decreased to 91 ppm or 672 ppm at the end of the

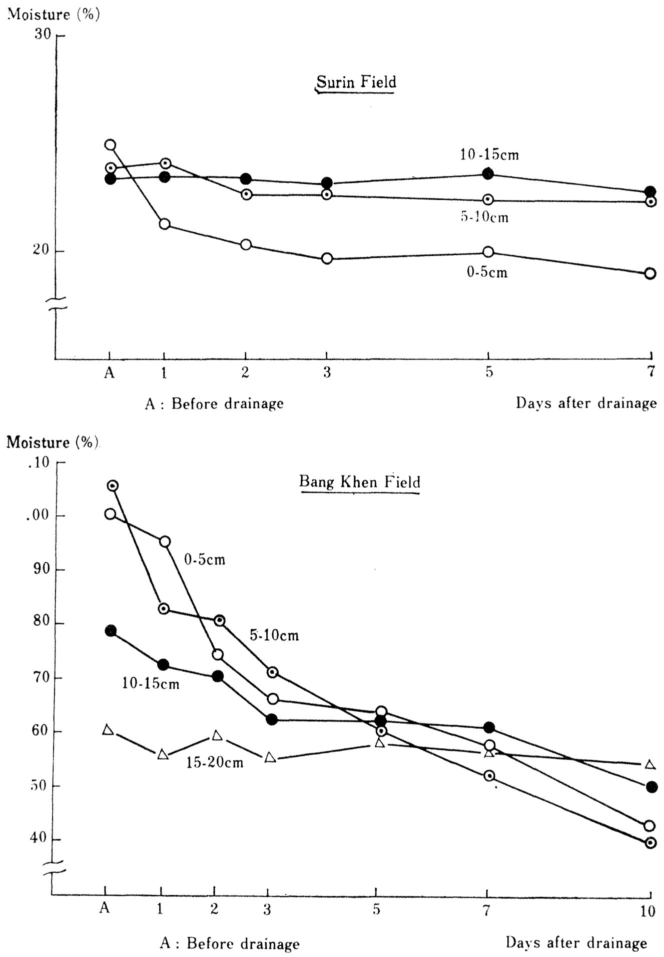


Figure 32. Changes in Moisture by Water Management

treatment. Ferrous iron concentration of the third layer, on the other hand, gradually decreased from 3155 ppm to 1363 ppm. And the changes in the ferrous iron content of the fourth layer were not evident, the values ranging between 2462 ppm and 1935 ppm throughout the treatment. Changes in the ferrous iron contents during the drainage treatment in the Surin soil showed the same tendency as those in the Bang Khen soil. However, the ferrous iron concentration was very low compared to that in Bang Khen soil.

Decrease in water content with drainage was evident for the first and second layers of Bang Khen soil, as shown in Fig. 32. However, a constant level of moisture was observed in the deepest layer (15–20 cm), ranging from 59.2% to 53.6%. In the case of Surin soil, changes in water content were limited only to the uppermost layer, ranging from 24.8% to 18.8%, and the moisture level in the following layers remained unchanged.

Fig. 33 shows the relationship between moisture and ferrous iron contents during the drainage period. As indicated in the figure, ferrous iron concentration was closely correlated with the moisture content, with a linear decrease as the moisture content decreased. Ohyama and Sakai (61) reported similar results. The increase in

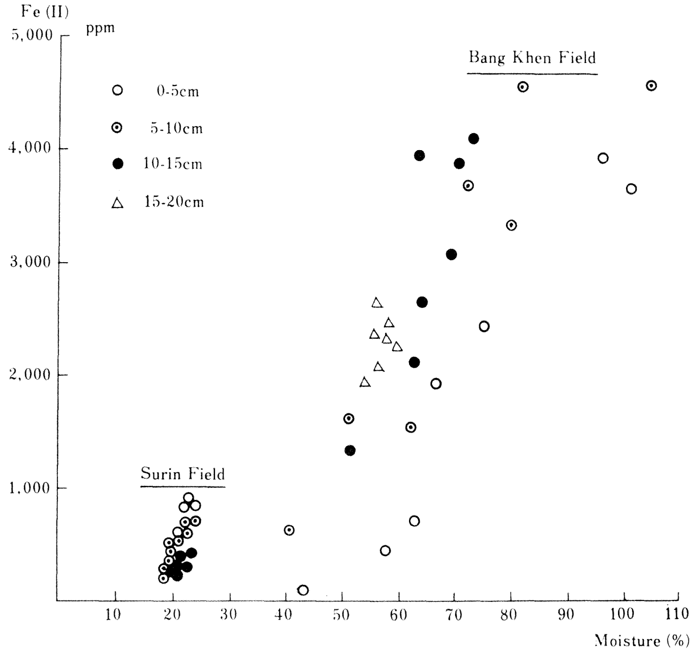


Figure 33. Relationship between Moisture and Ferrous Iron Content

the values of the air phase during the drainage treatment suggests that air penetrates into the soil from the surface or along the cracks formed by the soil shrinkage. Consequently, reduced substances such as ferrous iron may become oxidized. However, the formation of large cracks followed by shrinkage is likely to result in strong compaction of soil as already mentioned before. Therefore, to improve such strongly reduced soil condition by drainage treatment, it is important to improve the soil structure so that much air may easily reach the root zone. For this purpose, soil structure of the plowed layer should be improved to create as many small cracks as possible instead of a few large cracks.

3. Summary

Flooding of soil usually resulted in the rapid development of soil reduction, as shown by the increase in soil pH, the decrease in redox potential, and the formation of ferrous iron and ammonium.

As a rule, the higher the organic matter content in the soil, the more advanced the soil reduction. Soil reduction tended to be more pronounced in the Central Plain and Northern Region, in contrast with the North-eastern Region.

Marine Alluvial Soils, Fresh Water Alluvial Soils, Humic Gley Soils, and some of the Low Humic Gley Soils rich in organic matter showed a pronounced soil reduction.

Liming brought about the development of soil reduction, especially in the Brackish Water Alluvial Soils (Acid Sulfate Soils), resulting in high mineralization of soil nitrogen.

Accelerated development of soil reduction occurred by the application of organic matter, especially for the soils poor in organic matter.

Intermittent drainage treatment during the growing period changed more or less the soil condition from a reduced one to an oxidized one.

VII. Production Capability Classification of Paddy Soils

In order to increase rice production by improving soil management, it is essential to identify the soil factors limiting rice production. Recently, it has become necessary to introduce upland crops to paddy fields in order to increase farmers' income. Accordingly, it is important to determined whether the introduction of upland crops to paddy fields is suitable. For such purposes, the production capability classification seems to be a very effective method. Production capability classification is one of the interpretative soil classifications based upon soil surveys. It is a practical grading or grouping of soils based upon their limitations (management requirements and risks of damage) when used for crop production. Although the soils placed in the same class have limitations of about the same degree, the kind of limitation may vary considerably.

The production capability classification of paddy soils may indicate the kinds and the extent of soil limitations which impede rice production and concurrently may provide practical methods and/or techniques concerning the amelioration of the physical and chemical properties and enhancement of soil fertility. In other words, each soil class in the production capability classification may reflects the feasibility of soil improvement and fertilization. At the same time, the suitability for the introduction of upland crops to paddy fields may be suggested.

The soil survey staff of the Soil Survey Division, Department of Land Development have dealt with the problem of "Land Capability Classification" in reports on detailed reconnaissance soil surveys in each province (14, 31, 74, 75). However, these applied only to upland crops.

In this chapter, production capability classification of paddy soils in Thailand is attempted by using the methods which are generally applied in Japan (70, 80, 84).

1. Materials and Methods

1) Methods

In the production capability classification, the soils are classified into four classes, I, II, III and IV on the basis of the presence or absence of limiting factors for normal growth of crops and the extent of possible deterioration of the soils. The four classes are defined as follows:

- Class I: Soils that have no or only few limiting factors or hazards for crop production and/or risks of soil damage and are regarded as either naturally fertile or as having the greatest potential for crop production without any improvement practices.
- Class II: Soils that have some limiting factors or hazards and/or risks of soil damage and require some improvement practices.
- Class III: Soils that have many limiting factors or hazards and/or risks of soil damage and require fairly intensive improvement practices.
- Class IV: Soils that have greater natural limitations than those in class III, but can be cultivated with some crops under very careful management.

The capability classification is based on the evaluation of each standard factor (the inherent soil characters), which is determined by the combination of dependent factors (supplementary soil characters). The standard factors and the dependent factors used are as follows:

For paddy rice	For upland crops
Thickness of top soil (t)	Thickness of top soil (t)
Effective depth of soil (d)	Effective depth of soil (d)
Gravel content of top soil (g)	Gravel content of top soil (g)
Permeability (l)	Easiness of plowing (p)
Status of redox potential (r)	Wetness of land (w)
Inherent fertility (f)	Inherent fertility (f)
Content of available nutrients (n)	Content of available nutrients (n)
Presence of harmful substances (h)	Presence of harmful substances (h)
Frequency of accidents (a)	Frequency of accidents (a)

Standard factors are evaluated as I, II, III and IV by combining additional soil properties (dependent factors) which are individually ranked into four grades, 1, 2, 3 and 4. The production capability class of the soils is determined based on the lowest class value of the enumerated standard factors.

The detailed procedure of the production capability classification has been described in a previous publication (58).

2) Materials

Soil samples used for the production capability classification were selected so as to cover various kinds of soil groups in the representative paddy fields all over the country, that is, 71 profiles from the Central Plain, 44 profiles from the Northeastern Region, 37 profiles from the Northern Region, and 24 profiles from the Southern Region.

2. Results and Discussion

Some examples of the production capability classification of the soils are listed in Table 33. Based on the simplified code formula, the soil factors which limit considerably crop production could be identified. For example, the simplified code formula of IIrnh for paddy rice and IIIpIItwnh for upland crops corresponds to the soil of Profile No. 1 (Bang Khen soil). The code formula, IIrnh for paddy rice, indicates that, of nine standard factors, status of redox potential (r), content of available nutrients (n) and presence of harmful substances (h) are evaluated as class II and the other factors are placed in class I. In other words, the code suggests that there is a possible risk for rice to sustain moderate to strong root damage due to strong soil reduction, and that the content of available nutrients in soil is somewhat insufficient for adequate growth and production of paddy rice. Also, the code indicates that rice plants are slightly damaged by the presence of harmful substances. If the soils were to be used for the cultivation of upland crops, there is an indication that plowing operations of the soil may be very difficult due to the very fine texture of soil and due to the fact that the soil is very sticky when moist, very hard when dry, and that upland crops are susceptible to damage caused by excessive wetness.

The production capability classification of the soil groups is briefly summarized as follows:

1) Marine Alluvial Soils

Marine Alluvial Soils analysed here were placed in the capability class II. They were generally very poorly to poorly drained, and had a very fine texture. The plowing layer was about 15 cm thick and the effective depth of soil was more than 1 meter. In general, the inherent soil fertility was high and the content of available nutrients also was rather high except for phosphorus and nitrogen. The excessive

Table 33. Production Capability Classification

No.	Location	Simplified code formula	
		For Paddy	For Upland Crops
Marine Alluvial Soils			
1.	Phra Nakhon, Bang Khen St.	IIrnh	IIIpIItwnh
8.	Phetchaburi, Muang	IIrnh	IIIpIItwnh
12.	Samut Prakan, Bang Phli	IIIrIInh	IIIpwIItnh
46.	Thon Buri, Nong Khaem	IIIrIInh	IIIpwIItnh
Brackish Water Alluvial Soils			
22.	Pathum Thani, Klong Luang St.	IIInIIrfh	IIIpnIItwfh
74.	Nakhon Nayok, Ongkarak	IIInIIrfh	IIIpnIItwfh
94.	Songkhla Muang	IIrfnh	IIIdpwIIfnh
Fresh Water Alluvial Soils			
66.	Kanchanaburi, Tha Muang	IItrn	IIItpIIn
67.	Ratchaburi, Photharam	IIInIIf	IIIpnIItf
141.	Sukhothai, Si Satchanalai	IItrfn	IIItpIIwfn
48.	Nong Khai, Si Chiang Mai	IIrfn	IItpfn
98.	Khon Kaen, Nam Phong	IIIfnIIl	IIIfn(III)wIIt
27.	Chiang Mai, San Kamphaeng	IIrfn	IItpfn
83.	Chiang Rai, Mae Chan	IIfn	IIpfn
174.	Phattalung, Rice St.	IIrfn	IIIpIIwfn
Low Humic Gley Soils			
132.	Nakhon Nayok, Muang	IIIfIItrn	IIItpfIIn
161.	Lop Buri, Khok Samrong St.	IIInIIIf	IIInIItpf
43.	Khon Kaen, Rice St.	IIIfnIIl	IIIfn(III)wIIt
106.	Sakon Nakhon, Muang	IIIfnIIl	IIIfn(III)wIIt
107.	Nakhon Phanom, Muang	IIIfnIItr	IIItfn
53.	Surin, Rice St.	IIIfnIII	IIIfnIIt(II)w
89.	Chiang Mai, Doi Sa Ket	IIrfn	IIItIIdpwfn
28.	Lampang, Hang Chat	IIIfn	IIIfnIItpw
30.	Lampang, Ngao	IIrfn	IItpwfn
150.	Chiang Rai, Mae Chai	IItrfn	IIItIIpwfn
165.	Chumphon, Muang	IIIfnIIrl	IIIfnIIt
173.	Trang, Muang	IIrfn	IIIpIItfn
Humic Gley Soils			
31.	Chiang Rai, Mae Sai	IIrn	IIpwn
82.	Chiang Rai, Mae Sai	IIrn	IIpwn
Regosols			
57.	Sakon Nakhon, Rice St.	IIIlfnh	IIIfnh(III)wIIt
103.	Udon Thani, Nong Han	IIIlfn	IIIfn(III)wIIt
104.	Sakon Nakhon, Sawan Daen Din	IIIlfnIIt	IIItfn(III)w
119.	Roi Et, Muang	IIIlfn	IIItfn(III)w
120.	Roi Et, Chaturaphak Phiman	IIIlfn	IIIfn(III)wIIt
Grumusols			
71.	Lop Buri, Muang	IIn	IIIpIItwn
160.	Lop Buri, Muang	IIn	IIIpIItwn
163.	Lop Buri, Khok Samrong	IIn	IIIpIItwn

amounts of salts may adversely affect normal growth of rice plant. However, the most significant limitation of the soil seemed to be the strongly reduced condition caused by very poor drainage.

It would be very difficult to use such soils for upland crop cultivation in the wet season because they are among the poorest drained soils in Thailand. The damage caused by excessive wetness was likely to occur. However, in the dry season, upland crops could be introduced to some areas where irrigation water is available. In this case, plowing of the soil seemed to be very difficult, and there was a possible risk of excessive wetness when heavy rains occur.

2) Brackish Water Alluvial Soils

Most of the Brackish Water Alluvial Soils were grouped in the capability class III. They were very poorly to poorly drained, and very fine-textured soils. The plowing layer was about 15 cm thick and effective depth of soils was as thick as 1 meter. But, in some places, so-called cat clay layer appeared within 50 cm of the surface. This cat-clay layer seemed to impair the normal growth of crops because of the high content of sulfur compounds. The content of available nutrients was low, especially phosphorus and nitrogen. Because of the strong acidity, aluminum, iron or manganese might become toxic and impair the normal growth of rice plant. Soil reduction was not so pronounced as in the Marine Alluvial Soils, but there still remained a possibility of root damage.

If the soils were to be used for the cultivation of upland crops, the acidification of the soil might increase. Accordingly, the amendment of the soil reaction is one of the essential farming practices required for the introduction of upland crops.

3) Fresh Water Alluvial Soils

Fresh Water Alluvial Soils were grouped in the capability class II or III, and the soil limiting factors greatly varied with the soils. Low soil fertility was common in most of the Fresh Water Alluvial Soils. It is interesting, however, to point out that the soils formed on the riverine deposits from the Pasak river, were very fertile and had no special limitation except a weak risk of root damage.

In general, Fresh Water Alluvial Soils were moderately well to poorly drained soils with various grades of soil texture. In the poorly drained soils, root damage may occur. In some places, the thickness of the top soil (plowing layer) was unsuitable for adequate growth of rice plant.

Many kinds of upland crops can be cultivated when irrigation water is available, but it is necessary to apply organic matter and fertilizer that contain nitrogen and phosphorus to produce a reasonable yield. In coarse-textured soils, there is a high possibility of drought in the dry season.

4) Low Humic Gley Soils

Low Humic Gley Soils were grouped in the capability class III or II. As in the Fresh Water Alluvial Soils, both the inherent fertility and content of available nutrients were so low that crop production was severely limited. Especially, the soils of the North-eastern Region were extremely deficient in almost all of the nutrients necessary for the growth of plants. Drainage condition of this soil group greatly varied, mainly depending upon the physiographic position and soil texture. In the poorly drained soils, root damage was another limitation to normal production of paddy.

Many kinds of upland crops can be introduced both during the dry and wet seasons, when irrigation water is available. But, critical drought damage may take place in coarse-textured soils due to the very low available water-holding capacity.

It is obviously essential to supply organic matter as well as base rich materials and phosphorus to improve the soil fertility. Crop residues, and green manure crops should be returned to the soils, because they supply organic matter and increase the water-holding capacity.

5) Humic Gley Soils

Although it is possible that a deficiency in minor elements may occur due to the alkaline reaction, Humic Gley Soils in Thailand appeared to be fertile and could be classified in the capability class II. As their content in organic matter is comparatively high, soil reduction may take place, resulting in root damage. Humic Gley Soils were deep, very fine-textured soils, but the drainage condition was better than in the other fine-textured soils due to the presence of a well developed prismatic structure. Many kinds of upland crops can be safely introduced throughout the year, if irrigation water is available.

6) Regosols

Since the Regosols are very low in both inherent fertility and available nutrients, they were grouped in class III or IV. It is considered that their natural fertility is much lower than that of the Low Humic Gley Soils. As the soils were sandy and very poor in organic matter, soil reduction did not take place readily. In some places, high content of salts may hinder normal growth of rice plant. The soils were well drained to moderately well drained, very deep and coarse-textured. The top soils were about 15 cm thick, and effective depth of soil usually exceeded 1 meter. The soils had a high permeability, and were unable to hold much water. Consequently, the soils were likely to become much dry in the dry season. Both very poor physical and chemical soil conditions make it difficult for the Regosols to be cultivated with upland crops. Under intensive management, however, a reasonable level of production can be expected. Although the yield gradually increased when fertilizers were applied, much attention should be directed to the construction of irrigation facilities, to the increase of organic matter content, and the application of soil improvement materials that contain calcium, magnesium and phosphate.

7) Grumusols

Grumusols were fertile soils that were grouped in the capability class II. However, there was a slight risk of minor element deficiency due to the high value of soil pH. The development of soil reduction was not so strong as to cause root damage. The soils were poorly drained with a deep fine texture. The soils showed deep and wide cracks when dry, while the clay swelled to the point of preventing water from infiltrating soil in the rainy season. As the clay was very sticky and plastic when moist and very hard when dry, farming practices may become difficult.

3. Summary

Marine Alluvial Soils were classified in the capability class II. In general, the inherent fertility was relatively high and available nutrient contents were also rather high except for phosphorus and nitrogen. The most severe limitation of the soils seemed to be the strong reduced condition caused by very poor drainage, resulting in serious root damage.

Brackish Water Alluvial Soils were classified in the capability class III. The contents of available nutrients were low, especially phosphorus and nitrogen. Because of the strongly acidic soil reaction, aluminum, iron and manganese may become toxic and impair the normal growth of plant. Also phosphorus fixation capacity was very strong.

Soil reduction was not particularly strong, but there still remained a possibility of root damage.

Fresh Water Alluvial Soils were classified in the capability class II or III. Low soil fertility was common in most of the Fresh Water Alluvial Soils. In poorly drained soils, root damage may occur.

Low Humic Gley Soils were classified in the capability class III or II. Both the inherent fertility and contents of available nutrients were so low as to limit crop production. Especially, the soils from the North-eastern Region were extremely deficient in almost all of the nutrients necessary for normal growth of plant.

Humic Gley Soils were rather fertile soils in Thailand and classified in the capability class II. Because of the slightly alkaline reaction, there was a possibility that microelement deficiency may occur.

Regosols were classified in the capability class III or IV. Both the inherent fertility and contents of available nutrients were extremely low. In some places, high content of salt may impede normal growth of rice plant.

Grumusols were classified in the capability class II. They were fertile as well as the Humic Gley Soils, but there was a risk of minor element deficiency due to the high value of soil pH.

In general, the improvement of the soil physical properties such as water permeability, available water-holding capacity, tillage etc., is very difficult and requires large investments of capital. On the other hand, it is relatively easy to improve the chemical properties by application of fertilizer and/or soil improvement materials. In Thailand, heavy rainfall occurring during the wet season and the long duration of high temperature tend to promote leaching in soils. Soil fertility is always likely to be decreased. Therefore, much attention should be directed to maintain and to increase soil fertility. The use of commercial fertilizer alone, however, cannot solve the problem and liming, green manure application, and some other proper soil and water management practices are essential.

VIII. Summary and Conclusions

Thailand produces approximately 14 million metric tons of paddy annually and has a surplus of about 1.5 million metric tons of milled rice.

Taking into account the growing population and limited land availability for rice cultivation in Thailand the country must make its utmost efforts to increase rice production per unit area. Breeding of new varieties of rice would contribute significantly to the increase of yield, but it must be pointed out that the high yielding varieties usually require higher inputs and depend more heavily on soil management practices than the common local varieties. Therefore, it is essential to understand the importance of soil fertility and to adopt proper measures for soil management and improvement in order to increase crop production.

1. Morphological Characteristics of Paddy Soils

Of the total cultivated area, 6.9 million hectares are devoted to rice cultivation. The soils used for rice cultivation are the Marine Alluvial Soils, Brackish Water Alluvial Soils, Fresh Water Alluvial Soils and Low Humic Gley Soils. Only sporadically are the Humic Gley Soils, Regosols, Gray Podzolic Soils, Non-Calcic Brown Soils and Grumusols being cultivated with paddy rice.

Marine Alluvial Soils are still young soils with an Apg-Cg horizon sequence, which are derived from marine sediments. The clay contents of the soils were very high throughout the profile, the soil texture consisting of heavy clay. Brackish Water Alluvial Soils (Acid Sulfate Soils) are characterized by the presence of a so-called "cat-clay". The morphological characteristics of the Fresh Water Alluvial Soils varied considerably with the nature of the parent materials, but iron and/or manganese concretions were commonly found throughout the profile. Low Humic Gley Soils with an Apg-Bg-Cg horizon sequence are derived from semi-recent alluvium or old alluvium on semi-recent terraces. Soil color greatly varied ranging from 5YR to 5Y in hue, reflecting the parent materials. Iron and/or manganese concretions were commonly observed throughout the profile. Regosols which were widely distributed in the North-eastern Region were characterized by high amounts of fine sand. The horizon differentiation of this group was very poor. Grumusols were characterized by black or dark heavy clay containing chiefly montmorillonite with an Ap-C horizon sequence.

2. Characteristics of the Physical Properties of Paddy Soils

Although the importance of the physical properties of paddy soils for rice growth has not been properly recognized hitherto, much attention should be directed to the physical behavior of the soils to increase the agricultural potential of paddy fields.

The Thai paddy soils were grouped into a wide range of textural classes. As a rule, the soils from the Central Plain consisted of heavy clay. By contrast, most of the soils from the North-eastern Region were coarse-textured soils except for the soils distributed along the river. In the Northern Region, silt fraction sometimes predominated, the soil texture consisting of silty clay or light clay.

Of the three phases, the solid phase accounted for the largest portion regardless of soil groups or regions. An also, the bulk density was fairly high irrespective of the textural classes.

3. Characteristics of the Chemical Properties of Paddy Soils

The majority of the essential nutrients for plant growth are principally supplied by the soil and the supplying capacity of plant nutrients is closely related to the chemical properties of the soils such as soil reaction, organic matter contents, cation exchange capacity, etc.

The values of soil pH were quite different among the soil groups depending upon the parent materials from which the soils were derived. As a rule, the Marine Alluvial Soils were slightly acidic in the surface soils, but still remained neutral or slightly alkaline in the subsoils. Brackish Water Alluvial Soils showed very low pH values. Fresh Water Alluvial Soils and Low Humic Gley Soils had a wide range of pH values.

Organic matter contents were very low, compared with those in the temperate region, the average value for the whole country being 2.0%. Although the average value of the cation exchange capacity of the paddy soils was 14.8 meq/100 g for the whole country, the values varied considerably depending on the quantity and quality of clay contained. Of the exchangeable cations, calcium and magnesium predominated in the composition of the sorption complex. Marine Alluvial Soils were characterized by the predominance of exchangeable magnesium.

The average values of total nitrogen and available nitrogen were 0.118% and 34.7 ppm in the Central Plain, 0.023% and 18.2 ppm in the North-eastern Region, 0.133% and 60.7 ppm in the Northern Region, and 0.118% and 44.5 ppm in the Southern Region, respectively. These figures were very low compared with those in other rice growing countries. The average values of available phosphorus as P_2O_5 were 16.4 ppm in the Central Plain, 6.6 ppm in the North-eastern Region, 17.7 ppm in the Northern Region and 19.8 ppm in the Southern Region respectively. The figures seemed to indicate the existence of a severe deficiency in these elements resulting in the impairment of rice growth.

4. Clay Mineralogical Characteristics of Paddy Soils

The clay mineral composition of the Thai paddy soils was, in general, characterized by the presence of a large amount of 7Å minerals. However, some distinctive characteristics were recognized among the soil groups and regions.

Marine Alluvial Soils had a mineral composition characterized by equal amounts of 7-10-14Å minerals. Brackish Water Alluvial Soils had nearly the same composition as the Marine Alluvial Soils except for the presence of chlorite. The soils distributed along the Mekong River were characterized by the predominance of mica clay minerals. The soils from the Southern Region were much more kaolinitic than those from the other three regions. Grumusols derived from marly sediments were highly montmorillonitic in their clay mineral composition.

5. Reductive-Oxidative Characteristics of Paddy Soils

Paddy rice cultivation has been commonly performed under flooded conditions. Flooding of soil resulted in appreciable changes in the soils such as the increase of soil pH, decrease in redox potential, formation of ferrous iron, ammonia and harmful substances, etc. The higher the organic matter contents in the soils, the more progressive the soil reduction. Liming and application of organic materials to the soils accelerated the development of soil reduction. Intermittent drainage treatment resulted in the conversion of soils from a reductive state to an oxidative one during the growing period.

6. Productive Characteristics of Paddy Soils

Production capability classification of paddy soils was attempted to identify the soil factors limiting rice production and/or the extent of soil damage.

In the Central Plain, the most severe limitation in the paddy soils appeared to be the strongly reduced condition caused by very poor drainage. Brackish Water Alluvial Soils were placed in class III, because of the severe deficiency in available phosphorus and nitrogen and possible occurrence of iron and aluminum toxicity. Fresh Water Alluvial Soils were very low in soil fertility, and classified in class II or III. Low Humic Glay Soils were classified in class III or II, because of the low level of both inherent soil fertility and available nutrients, especially the soils from the North-eastern Region.

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In conclusion, the soils in the Central Plain had a moderate fertility. In the Central Plain, rice production was affected largely by the strongly reduced soil condition, resulting in serious root damage. And also, severe deficiency of phosphorus caused low rice yield in addition to nitrogen deficiency and possible toxicity of aluminum, iron and manganese, especially in the area with Brackish Water Alluvial Soils. In the marginal area of the Central Plain, available nutrients were not sufficient for normal growth of rice.

The increase in rice yield in the Central Plain, therefore, may be achieved by the maintenance of a suitable oxidation-reduction state through water management such as intermittent drainage treatment. However it is very difficult to carry out water management efficiently, especially in the rice season. It is important in the case of the Brackish Water Alluvial Soils to enhance the availability of soil phosphorus and to increase the efficiency of phosphorus fertilizer in order to increase yield.

In the North-eastern Region, the soil fertility was too low to enable the cultivation of rice, especially in the coarse-textured soils derived from well weathered sand stone. Analytical data indicated that the soils in this region are characterized by a low pH, low cation exchange capacity and an extremely low content of available nutrients as well as organic matter. It is likely that the deficiency in minor elements will become a problem when rice growth is improved by the introduction of better varieties, the application of fertilizer with three major elements, and so on. Under such conditions it is very difficult to increase soil fertility, which could be achieved, however, by continuous application of organic matter such as farm manure, green manure, rice straw, city compost etc., soil dreesing, suitable crop rotation including leguminous crops and so forth.

The soils in the Northern Region were relatively fertile as indicated by the average yield. In fact, chemical analyses showed that the contents of almost all the nutrients examined were higher in this region than in the other regions. However, continuous application of organic matter is necessary for improving and maintaining the soil fertility and productivity.

In the Southern Region, the soils were very complex and their fertility greatly varied depending upon the parent materials and physiographic position. Undoubtedly the soils were generally deficient in phosphorus and nitrogen.

Soil is the medium for plant growth and animal life, and a fertile soil is thus the basis of human prosperity. The importance of soil fertility should be more emphasized.

References

1) Abe, K. and Araake, M.: Clay mineral composition of paddy soils in Japan and its application to soil classification, Bull. Nat. Inst. Agri. Sci., B. 27, 61-127 (1975) (In Japanese with English summary)
2) Abe, K.: Present soil condition of cultivated land in Japan, Trop. Agri. Res. Series, No. 15, 97-103 (1982)
3) Araragi, M. et al.: Studies on microflora in tropical paddy and upland farm soils, Tech. Bull. Trop. Agri. Res. Center, No. 13, 1-89 (1979)
4) Barshad, I.: Thermal analysis techniques for mineral identification and mineralogical composition, In Black, C.A. (ed) Methods of soil analysis. Am. Soc. Agro., Madison Wis., 699-742 (1965)
5) Breemen, N. van: Genesis and solution chemistry of acid sulfate soils in Thailand, Centre for Agricultural Publishing and Documentation, Wageningen, (1976)
6) Buringh, P.: Introduction to the study of soils in tropical and subtropical regions, Centre for Agricultural Publishing and Documentation, p. 29-44 (1970)
7) Charoen, P.: Studies on parent materials, clay minerals, and fertility of paddy soils in Thailand, Doctoral dissertation, Kyoto Univ. (1974)
8) Chlitkul W. and Tyner, E. H.: Inorganic phosphorus fraction and relation to some chemical indices of phosphate availability for some lowland rice soils of Thailand, Pro. Inter. Symp. on Soil Fertility Evaluation, 1, 7-30, New Delhi (1971)
9) Cowie, J. D.: Key to soil series in Thailand, First Approximation, Soil Survey Division, Dep. Land Development and FAO, Bangkok (1969) (Mimeographed)
10) Dei, Y.: Water management in relation to growth of rice plant, Water Management for Rice Cultivation, p. 9-23, Tokyo (1968) (In Japanese)
11) Department of Land Development - USOM/PASA: Some characteristics, inferred quality, adapted plants, management problems and suitability interpretation of soils for north-eastern Thailand, Bangkok (1969)
12) Division of Agriculture Economics: Agricultural Statistics of Thailand, crop year 1976/1977, Agri. Stat. No. 72 (1977)
13) Egawa, T.: Clay mineral, fundamental studies of soils and fertilizers, Dojo Hiryo Zenpen (Soils and Fertilizers), Yokendo, Tokyo, p. 189-192 (1958) (In Japanese)
14) Gallup, D. L. et al.: Soil survey interpretation handbook for North-east Thailand, Part II. Land capability classification, Soil Survey and Land Classification Div., Report SSR-60, Bangkok (1967)
15) Harada, T.: The mineralization of native organic nitrogen in paddy soils and the mechanism of its mineralization, Bull. Nat. Inst. Agri. Sci., B. 9, 123-199 (1959) (In Japanese with English summary)
16) Harada, Y. and Inoko, A.: The relationship between cation exchange capacity and the degree of maturity of city refuse composts, Soil Sci. Plant Nutr., 26, 353-362 (1980)
17) Hattori, T. et al.: A few considerations on clay minerals in Thai paddy soils, Tonan Ajia Kenkyu (The Southeast Asian Studies) 3, 151-165 (1965) (In Japanese with English summary)
18) Hattori, T. et al.: Mineral composition of clay fraction in the Quaternary deposits in the Chao Phraya Basin, Central Thailand, ibid., 6, 911-916 (1969)
19) Hattori, T. et al.: The caly mineral composition of Cambodian paddy soils in relation to their weathering history, ibid., 7, 49-57 (1970) (In Japanese with

English summary)
20) Hattori, T.: Some properties of soils and substrata in the Lampan Basin, ibid., 7, 527-549 (1970)
21) Hattori, T.: The Quaternary stratigraphy in the northern basin of the Central Plain, Thailand, ibid., 9, 398-419 (1971)
22) Hattori, T.: Clay mineral composition of the soils and substrata of some Quaternary in Saraburi and Lop Buri area of the Central Plain of Thailand, ibid., 13, 481-492 (1975)
23) Inoue, K. et al.: Chloritization of paddy soils caused by acidic irrigation-water, J. Sci. Soil and Manure, Japan, 48, 193-200 (1977) (In Japanese)
24) Ishizuka, Y.: Nutrient deficiency of crops, ASPAC, Food & Fertilizer Technology Center, Taipei (1971)
25) Jackson, M. L.: Soil chemical analysis, Advanced course. Dept. of Soils, Univ. Wis. Madison, 171-250 (1965)
26) Kamoshita, Y.: Soil types on Tsugaru Plain, Aomori Prefecture, J. Sci. Soil and Manure, Japan, 10, 311-317 (1937) (In Japanese)
27) Kanapathy, K.: Studies on the reclamation of acid swamp soils, Malaysian Agri. J., 49, 33-46 (1971)
28) Kanno, I.: A new classification system of rice soils in Japan, Pedologist, 6, 2-10 (1962)
29) Kawaguchi, K. and Kyuma, K.: Lowland rice soils in Thailand, Reports on Research in Southeast Asia, Natural Science Series, N-4, The Center for Southeast Asian Studies, Kyoto Univ. (1969)
30) Kawaguchi, K. and Kyuma, K.: Paddy soils in tropical Asia — Their nature and fertility. The Center for Southeast Asian Studies, Kyoto Univ. (1977)
31) Kevie, W. van der and Yenmamas, B: Semi-detailed soil survey of a part of Central Plain, Report SSR-88, Soil Survey Div., Dept. Land Development, Bangkok (1972)
32) Kittayarak, S.: Soil series of the North East, Soil Survey Div., Dept Land Development, Bangkok (1971)
33) Kobayashi, J.: Chemical studies on the quality of the river water in the countries of Southeast Asia: Quality of water in Thailand, Nogaku Kenkyu, 6, 63-112 (1963) (In Japanese)
34) Komes, A.: The reclamation of some problem soils in Thailand, Tech. Bull, No. 14. ASPAC, Food & Fertilizer Technology Center, Taipei (1973)
35) Komoto, Y., et al.: Effect of phosphate fertilization on rice in the warm region, Part 1, Abstracts of the Annual Meeting of the Soc. Soil Sci. and Manure, Japan, 14, 94 (1968) (In Japanese)
36) Kosaka, J.: Volcanic Ash Soils in Japan, p. 107-109, ed. Ministry of Agriculture and Forestry, Japan (1964)
37) Koyama. T. et al.: Varietal difference of Thai rice in the resistance to phosphorus deficiency, Tech. Bull. TARC, Japan, No. 4, 1-22 (1973)
38) Koyama, T. and Shibuya, M.: Determination of nitrogen supplying capacity of soils using ^{15}N tracer technique, JARQ, 9, 84-86 (1975)
39) Lusanandana, B. et al.: Simple fertilizer trials in cultivators' field in Thailand, Bangkok (1968) (mimeographed)
40) Matsuguchi, T., Tangcham, B. and Patiyuth, S.: Free living nitrogen fixers and acetylene reduction in tropical rice fields, JARQ, 8, 253-256 (1974)
41) Matsuzaka, Y.: Study on the classification of paddy soils in Japan, Bull. Nat. Inst. Agri. Sci., B. 20, 155-349 (1969) (In Japanese with English summary)

42) Matsuzaka, Y.: Major soil groups in Japan, Proc. Inter. Seminar on Soil Environment and Fertility Management in Intensive Agriculture, p. 89-95 (1977)
43) Middleton, H. E. and Byers, H. G.: The settling volume of soils, Soil Sci., 37, 15-25 (1934)
44) Mitsuchi, M.: Pedogenic characteristics of paddy soils and their significance in soil classification, Bull. Nat. Inst. Agri. Sci., B25, 29-115 (1972) (In Japanese with English summary)
45) Mitsuchi, M.: Chloritization in lowland paddy soils, Soil Sci. Plant Nutr., 20, 107-116 (1974)
46) Mitsui, S.: Dynamic aspects of nutrient uptake, The Mineral Nutrition of Rice Plant, p. 52-63 Johns Hopkins Press, Maryland (1964)
47) Miyake, M.: Soil testing methods for available phosphorus in paddy soils of Indonesia, Japan. J. Trop. Agri., 22, 133-138 (1978)
48) Montrakul, S.: Agriculture and soils of Thailand, The Ministry of Agriculture, Bangkok (1964)
49) Moormann, F. R. and Rajanasoonthon, S.: Soils of Thailand, a reconnaissance Survey Report No. 72, Dept. Land Developemtn, Bankgkok, (1968) (mimeographed)
50) Moormann, F. R. and Rajanasoonthon, S.: The soils of the Kingdom of Thailand-Explanatory text of the general soil map, Report SSR-72A, Soil Survey Div. Dept. Land Development, Bangkok (1972)
51) Moorman, F. R. and Breemen, N. van: Rice, Soil, Water, Land, p. 83-102, IRRI, (1978)
52) Motomura, S. and Yamanaka, K.: Studies on gley formation, part 4., J. Sci. Soil Manure, Japan, 34, 428-432 (1963) (In Japanese)
53) Motomura, S.: Physical and chemical characteristics of fine textured soils of Japan, Annual report of the 2nd Div. of Soils, Nat. Inst. Agri. Sci., p. 1-58, (1969) (mimeographed)
54) Motomura, S.: Dynamic behavior of ferrous iron in paddy soils, JARQ, 3, 12-17 (1969)
55) Motomura, S.: Determination of ferrous iron of soil, p. 15-26 in Laboratory Manual for Soil Chemical Analysis ed. TARC (1973)
56) Motomura, S. et al.: Liming effect on growth and yield of paddy rice, Abst. Annual Meeting of Soc. Soil Sci. and Manure, Japan p. 77 (1975) (In Japanese)
57) Motomura, S.: Soil fertility of tropical paddy soils and soil management, Farming Japan, 10, 18-27 (1976)
58) Motomura, S. et al.: Field observation and laboratory analysis of paddy soils in Thailand, Nekken Shiryo, No. 45 (1979)
59) Nakaya, N. and Motomura, S.: Effects of organic and mineral fertilization on soil physical properties and hydrophobicity of soil organic matter, Organic Matter and Rice, p. 387-398, IRRI (1984)
60) Oyama, M.: A classification system of paddy rice field soils on their diagnostic horizons, Bull. Nat. Inst. Agri. Sci., B 12, 303-372 (1962) (In Japanese with English summary)
61) Ohyama, N. and Sakai, H.: Changes in oxidation-reduction state of plowed layer in paddy soils, J. Sci. Soil and Manure, Tokyo, 42, 349-354 (1971) (In Japanese)
62) Onikura, Y.: Soil characteristics concerned with the beneficial effect of water management in rice cultivation, Trop. Agri. Research Series, No. 9, 117-129 (1970)
63) Paul Vlek: Some morphological, physical and chemical aspects of acid sulfate soils

in Thailand, SSR-84, Soil Survey Div. Dept. Land Development, Bangkok (1971)
64) Pendelton, R. L.: Soils of Thailand, The Natural History Bull., Bangkok, 12, 33-74 (1940)
65) Piyapongse, P.: Cation exchange capacity of some paddy soils with high organic matter content, Annual Research Report of Rice Dept. in 1967, Bangkok, pp 215-220 (1970) (mimeographed)
66) Ponnanperuma, F. N.: Dynamic aspect of flooded soils and the nutrition of the rice plant, The Mineral Nutrition of the Rice Plant, p. 295-328, Johns Hopkins Press. Maryland (1964)
67) Ponnanperuma, F. N.: The chemistry of submerged soils, Advances in Agronomy, 24, 29-96 (1972)
68) Pons, L. J. and Kevie, W. van der: Acid sulfate soils in Thailand, SSR-81, Soil Survey Div. Dept. Land Development, Bangkok (1969)
69) Sakai, H.: Effect of water managment on paddy soil metabolism and its use in the growth control of rice plant, Trop. Agri. Research Series, No. 9, 139-151 (1975)
70) Sakayanagi, M. and Kawai, K.: Soil survey and land classification of paddy field for rice production increase in Japan, IRC 13th Session of Working Party on Soils, Water and Fertilizer Practices, Bangkok, (1972) (mimeographed)
71) Shaykewich, C. F. and Zwarich, M. A.: The relationship between soil physical constants and soil physical component of some Manitoba soils, Can. J. Soil Sci., 48, 199-204 (1968)
72) Shioiri, M.: Chemistry of paddy soils, Dainiponnokai, (1943) (In Japanese)
73) Shiga, H.: Effect of phosphorus fertility of soils and phosphate application on lowland rice, JARQ, 10, 12-16 (1976)
74) Scholten, J. J. and Doonyawat, W.: Detailed reconnaissance soil survey of the Northern part of Chiang Rai Province, SSR-86, Soil Survey Div., Dept. Land Developemtn, Bangkok (1971)
75) Scholton, J. J. and Doonyawat, W.: Detailed reconnaissance soil survey of Nan province, SSR-90, Soil Survey Div. Dept. Land Development, Bangkok (1972)
76) Sorasith, V. et al.: Characterization of selected Thai soils by means of X-ray diffraction, chemical and mineral. (1962) (mimeographed)
77) Sudo, S.: Fundamental aspect of soil structure, Bull. Nat. Inst. Agri. Sci., B. 12, 255-301 (1962)
78) Takai, Y. et al.: Microbial metabolism in reduction process of paddy soils, Soil and Plant Food, Tokyo, 2, 63-66 (1956)
79) Takai, Y.: The mechanism of reduction in paddy soil, JARQ, 4, 20-23 (1969)
80) Takijima, Y.: A tentative proposal for productivity classification of paddy soils in a detailed soil survey, Soil Sci. Plant Nutr., 13, 171-185 (1967)
81) Tanaka, A. and Yoshida, S.: Nutritional disorders of the rice plant in Asia, IRRI Tech. Bull. No. 10 (1970)
82) Terasawa, S.: Physical behavior of various great groups of paddy soils, Bull. Nat. Inst. Agri. Sci. B. 22, 85-210 (1970) (In Japanese with English summary)
83) TARC: Laboratory manual for soil chemical analysis, p. 7-10 (1973)
84) The Council on Agriculture, Forestry and Fisheries, Ministry of Agriculture and Forestry: Proposal on productivity and suitability classification of paddy field soils, Tokyo, (1964) (In Japanese)
85) Uchiyama, N.: Morphology of paddy soil, Chikyu Shuppan, Tokyo (1949) (In Japanese)
86) USDA: Soil classification, a comprehensive system 7th approximation, (1960)

87) USDA: Soil classification system, 7th approximation, 1964 supplement (1964)
88) USDA: Soil classification, 7th approximation, 1967 supplement (1967)
89) Wada, H. and Matsumoto, S.: Pedogenenic process in paddy soils, Pedologist, 17, 21-15 (1973)
90) Wada, K.: Qualitative and quantative determination of clay minerals, J. Sci. Soil and Manure, 37, 9-17 (1966) (In Japanese)
91) Whittig, L. D.: X-ray diffraction techniques for mineral identification and mineralogical composition, In Black, C. A. ed. Methods of Soil Analysis. Am. Soc. Agro. Madison, 671-698 (1965)
92) Yamazaki, K.: Studies on the pedogenetic classification of paddy soils in Japan, Bull. Toyama Pref. Agri. Exp. Station Special Report, 1, 1-105 (1960) (In Japanese)
93) Yokoi, H.: Theoretical analysis of particle size distribution of soil, Bull. Nat. Inst. Agri. Sci., B. 25, 1-28 (1974)
94) Yoshida, S. and Imaizumi, K.: Edaphological studies on silica supplying power of paddy fields, Bull. Nat. Inst. Agri. Sci., B.8, 261-304 (1958) (In Japanese with English summary)
95) Yoshida, S. et al.: Occurrence, diagnosis and correction of zinc deficiency of lowland rice, Soil Sci. Plant Nutr., 19, 83-93 (1973)
96) Yoshino, T. and Dei. Y.: Pattern of nitrogen release in paddy soils predicted by an incubation method, JARQ, 8, 137-141 (1974)

Appendix

1. Analytical Data on Physical Properties

Central Plain

Marine Alluvial Soils

No.	Location	Horizon	Depth (cm)	CoS (%)	FS (%)	Silt (%)	Clay (%)	Texture	Three phase (%) SV	LV	AV	Bulk density Field	Air-dried	Sedimentation volume (ml/g)	Dispersion ratio (%)	Max. water-holding capacity (%)	Moisture equivalent (%)
1.	Phra Nakhon,	Apg	0-15	0	4.4	24.1	71.5	HC	38.1	41.1	20.8	0.990	1.165	2.1	81.3	64.5	48.4
	Bang Khen,	A12g	15-30	0	3.2	18.2	78.6	HC	37.6	39.6	21.8	0.976	1.185	2.2	84.5	60.4	47.9
	Rice Ex. St.	AIICg	30-50	0.2	5.1	23.2	71.5	HC	42.7	41.5	15.8	1.111	1.202	2.2	84.2	66.9	-
		IIC1g	50-65	1.0	9.0	25.8	64.2	HC	44.6	44.8	10.6	1.161	1.200	2.2	92.7	68.3	-
		IIC2g	65-	0.5	9.7	26.2	63.6	HC	-	-	-	-	1.205	2.7	93.4	66.2	-
2.	Phra Hakhon,	Apg	0-15	0	5.9	26.2	67.9	HC	39.5	44.0	16.5	1.027	1.161	2.0	81.2	63.7	47.9
	Bang Khen,	A12g	15-30	0	6.5	24.1	69.4	HC	41.3	40.9	17.8	1.074	1.161	2.1	76.2	61.9	46.2
	Rice Ex. St.	AIICg	30-45	0.2	5.9	28.9	65.0	HC	43.0	40.4	16.6	1.117	1.158	2.1	72.2	66.3	-
		IIC1g	45-65	2.5	10.2	30.1	57.2	HC	47.2	43.3	9.5	1.226	1.208	2.2	92.5	64.9	-
									-	-	-	-	-		-	-	-
8.	Phetchaburi,	Apg	0-10/15	1.1	9.6	30.7	58.6	HC	50.2	32.6	17.2	1.330	1.222	2.1	71.5	57.4	33.9
	Muang	A12g	10/15-20	2.2	11.1	40.5	46.2	HC	53.2	35.5	11.3	1.410	1.218	2.2	75.5	55.8	33.4
		C1g	20-40	1.7	7.6	25.5	65.2	HC	51.5	37.7	10.8	1.339	1.200	2.3	88.7	67.9	-
		C2g	40-65	6.5	12.6	17.2	63.7	HC	48.9	43.8	7.3	1.271	1.196	2.3	80.6	65.8	-
9.	Samut Songkhram	Apg	0-10/15	0.4	3.0	22.2	74.4	HC	-	-	-	-	1.128	2.7	90.2	74.2	51.8
	Amphawa	A12g	10/15-20	0.4	2.8	24.8	72.0	HC	-	-	-	-	1.195	2.8	92.6	77.5	51.5
		C1g	20-43	0.4	3.1	23.4	73.1	HC	-	-	-	-	1.139	2.7	76.8	81.3	-
		C2g	43-65	0.6	4.1	23.8	71.5	HC	-	-	-	-	1.107	3.1	85.5	90.5	-
12.	Samut Prakan,	Apg	0-15	0.2	1.2	22.6	76.0	HC	47.2	42.7	10.1	1.220	1.100	2.4	90.3	59.7	-
	Bang Phli	ACg	15-35	0.6	1.5	24.1	73.8	HC	43.8	47.7	8.5	1.138	1.193	6.2	98.2	62.4	-
		C1g	35-55	0.7	1.9	25.1	72.3	HC	45.2	52.4	2.4	1.191	1.160	4.5	96.3	71.6	-
		C2g	55-65	1.3	2.1	23.7	72.9	HC	37.7	58.4	3.9	0.981	1.137	3.4	97.8	68.2	-
13.	Chachoengsao,	Apg-1	0-3	0.3	14.9	36.8	48.0	HC	43.5	18.4	38.1	1.153	1.199	2.0	82.6	50.2	38.1
	Bang Pakong	Apg-2	3-15	0.5	19.8	33.4	46.3	HC	-	-	-	-	-	2.1	96.2	49.7	36.8
		A12g	15-30	2.1	16.6	31.2	50.1	HC	47.5	22.3	30.2	1.235	1.223	2.1	92.1	59.2	-
		C1g	30-50	5.8	15.3	31.0	47.9	HC	44.8	43.4	11.8	1.165	1.165	2.3	86.2	64.3	-
		C2g	50-	1.2	17.2	29.7	51.9	HC	46.0	53.2	0.8	1.195	1.161	2.0	94.0	70.4	-
20.	Samut Sakhon,	Apg	0-15	0.1	16.4	28.7	54.8	HC	53.9	15.3	30.8	1.420	1.130	2.1	83.1	60.2	38.4
	Krathum Baen	A12g	15-25	0.4	17.0	32.7	49.9	HC	47.2	22.1	30.7	1.227	1.221	2.1	87.6	57.7	37.2
		Cg	25-65	3.7	21.0	32.3	43.0	LiC	52.7	27.0	20.3	1.370	1.247	2.3	75.2	54.8	-
58.	Thon Buri,	Apg	0-23	0	8.4	34.2	57.4	HC	40.8	38.8	20.4	1.079	1.065	-	72.1	62.9	42.5
	Nong Khaem	C1g	23-55	0.6	9.2	32.9	57.3	HC	45.6	38.8	15.6	1.208	1.288	-	75.9	-	-
		C2g	55-	0.7	29.6	23.0	46.7	HC	44.7	47.7	7.6	1.184	1.196	-	75.5	-	-
59.	Nakhon Pathom,	Apg	0-20	0.1	11.7	31.1	57.1	HC	-	-	-	-	1.012	-	71.6	-	-
	Nakhon Chaisi	BCg	20-50	0.2	11.8	28.3	59.7	HC	-	-	-	-	1.290	-	69.8	-	-
		C1g	50-60	0.4	17.5	16.3	65.8	HC	-	-	-	-	1.277	-	77.5	-	-
									-	-	-	-			-		

No.	Location	Horizon	Depth (cm)	CoS (%)	FS (%)	Silt (%)	Clay (%)	Texture	Three phase (%) SV	LV	AV	Bulk density Field	Air-dried	Sedimen-tation volume (ml/g)	Dis-persion ratio (%)	Max. water-holding capacity (%)	Moisture equiv-alent (%)
69.	Phetchaburi,	Apg	0-14	1.1	11.6	25.9	61.4	HC	-	-	-	-	1.081	-	68.3	62.7	43.2
	Muang	BCg	14-30	6.3	17.2	26.3	50.2	HC	-	-	-	-	1.124		76.9	53.8	40.4
		C1g	30-	1.1	21.1	31.5	46.3	HC	-	-	-	-	-	-	94.6	-	-
136.	Samut Prakan,	Apg	0-12	0.1	7.2	29.6	63.1	HC	40.5	51.5	8.0	1.054	1.163	2.5	92.5	59.2	41.0
	Bang Phli	A12g	12-30	0.1	8.1	30.3	61.5	HC	45.6	53.3	1.1	1.184	1.186	3.5	98.4	63.0	44.2
		C1g	30-52	0.5	8.1	30.4	61.0	HC	45.0	54.9	0.1	1.169	1.155	2.9	94.7	-	-
		C2g	52-82	1.3	17.1	27.1	54.5	HC	43.4	56.2	0.4	1.128	1.146	2.8	89.5	-	-
159.	Nakhon Pathom,	Apg	0-15	0.2	9.4	21.2	69.3	HC	58.5	34.7	6.8	1.520	1.175	2.2	74.6	62.7	48.6
	Sam Phran	A12g	15-40	0.2	10.3	24.0	65.5	HC	51.0	38.4	10.6	1.326	1.242	2.6	85.8	58.8	44.2
		ACg	40-55	2.6	8.4	15.3	73.7	HC	49.8	41.4	8.8	1.295	1.185	2.5	97.0	-	-
		Cg	55-75	3.5	12.2	19.4	64.9	HC	48.2	44.3	7.5	1.254	1.185	2.6	85.4	-	-
183.	Phra Nakhon,	Apg	0-15	0.1	6.1	26.3	67.5	HC	35.8	43.0	21.2	0.949	-	2.1	81.9	64.7	49.2
	Bang Khen,	A12g	15-32	0.2	5.3	25.4	69.1	HC	38.5	39.2	22.3	1.021	-	2.2	81.3	61.6	47.8
	Rice Ex. St.	ACg	32-50	1.2	5.5	25.6	67.7	HC	46.7	38.3	15.0	1.238	-	2.2	81.2	63.4	-
		Cg	50-	-	-	-	-	HC	47.4	49.1	3.5	1.256	-	2.4	-	-	-
Brackish Water Alluvial Soils																	
21.	Pathum Thani,	Apg	0-15	0.2	5.3	24.7	69.8	HC	41.8	32.2	26.0	1.086	1.160	2.0	63.1	62.0	40.9
	Thanyaburi,	A12g	15-30	0.7	4.8	24.5	70.0	HC	46.3	38.3	15.4	1.204	1.165	2.2	71.1	65.4	35.1
	Rangsit Rice	BCg	30-45	0.5	3.5	27.6	68.4	HC	43.6	42.7	13.7	1.135	1.193	2.3	78.7	63.0	-
	Ex. St.	Cg	45-85	0.9	2.3	29.1	67.7	HC	44.4	48.2	7.4	1.156	1.213	2.5	77.6	62.0	-
22.	Pathum Thani,	Apg	0-15	1.3	3.2	43.7	51.8	HC	51.2	29.1	19.7	1.330	1.132	1.7	67.8	64.2	36.9
	Klong Luang,	A12g	15-30/50	0.6	2.3	48.1	49.0	HC	56.6	33.8	9.6	1.473	1.174	1.7	63.2	50.9	37.3
	Rice Ex. St.	BCg	30/50-80	3.4	7.3	45.7	43.6	SiC	50.8	41.2	8.0	1.322	1.163	1.6	69.0	55.7	-
		Cg	80-100	8.1	3.1	43.0	45.8	HC	42.6	49.4	8.0	1.109	1.161	2.1	54.4	59.0	-
55.	Pathum Thani,	Apg	0-17	0.3	8.0	37.0	54.7	HC	51.0	30.0	19.0	1.326	1.178	2.1	67.0	52.5	36.2
	Klong Luang,	A12g	17-35	2.8	9.4	28.9	58.9	HC	51.5	34.8	13.7	1.338	1.125	2.2	55.7	61.2	39.2
	Rice Ex. St.	C1g	35-65	3.0	5.8	30.4	60.8	HC	42.4	44.9	12.7	1.102	1.142	2.4	59.2	68.9	-
		C2g	65-100	2.4	5.2	29.1	63.3	HC	41.4	57.7	0.9	1.069	1.115	2.4	69.9	69.3	-
74.	Nakhon Nayok,	Apg	0-17	0.4	5.3	39.6	54.7	HC	37.4	23.2	39.4	0.974	1.004	2.3	54.9	64.3	41.9
	Ongkharak	A12g	17-40	0.4	5.2	37.6	56.8	HC	44.7	31.0	24.3	1.161	1.081	2.2	55.8	59.0	40.0
		B21g	40-58	0.8	10.2	38.5	50.5	HC	44.0	35.5	20.5	1.144	1.106	2.4	59.4	57.1	-
		B22g	58-75	0.8	10.5	37.0	51.7	HC	42.2	38.0	19.8	1.097	1.060	2.4	66.9	64.2	-
		BCg	75-90	4.1	14.9	35.8	45.2	HC	44.7	52.6	2.7	1.163	1.120	2.3	68.0	57.4	-
		Cg	90-	3.0	12.0	30.8	54.2	HC	-	-	-	-	1.101	2.6	58.9	69.2	-
80.	Ayutthaya,	Apg	0-21	1.6	6.4	27.4	64.6	HC	46.1	30.8	23.1	1.221	1.040	2.1	55.7	58.9	40.6
	Wang Noi	A12g	21-35	4.0	7.1	26.1	62.8	HC	46.8	39.8	13.4	1.240	1.074	2.2	41.5	52.7	39.1
		C1g	35-52	16.1	13.4	22.5	48.0	HC	47.2	36.1	16.7	1.252	1.144	2.3	67.4	-	-
128.	Ayutthaya,	Apg	0-14	0.3	5.5	24.7	69.5	HC	37.4	48.0	14.6	0.973	1.040	2.3	75.4	61.4	45.4
	Muang	A12g	14-32	1.2	16.0	22.7	60.1	HC	41.8	38.7	19.5	1.086	1.164	2.2	72.5	55.1	39.4
		C1g	32-55	2.4	7.5	27.8	62.3	HC	47.2	36.5	16.3	1.228	1.139	2.4	56.9	-	-
		C2g	55-80	3.8	7.6	27.3	61.3	HC	43.8	34.5	21.7	1.139	1.149	2.1	78.1	-	-

No.	Location	Horizon	Depth (cm)	CoS (%)	FS (%)	Silt (%)	Clay (%)	Texture	Three phase (%) SV	Three phase (%) LV	Three phase (%) AV	Bulk density Field	Bulk density Air-dried	Sedimentation volume (ml/g)	Dispersion ratio (%)	Max. water-holding capacity (%)	Moisture equivalent (%)
129.	Ayutthaya,	Apg	0-10	0.3	4.5	32.8	62.4	HC	52.6	44.8	2.6	1.368	1.028	2.3	85.9	65.4	43.6
	Muang, Hantra,	ABg	10-25	0.3	4.1	35.7	59.9	HC	46.2	46.5	7.3	1.201	1.132	2.3	78.3	56.4	42.1
	Rice Ex. St.	B1g	25-57	0.7	5.8	30.1	63.4	HC	37.1	30.5	32.4	0.965	1.154	2.2	68.5	-	-
		B2g	57-90	0.2	6.8	30.1	62.9	HC	42.5	35.9	21.6	1.106	1.178	2.1	69.9	-	-
130.	Ayutthaya,	Apg	0-16	0.5	9.0	24.6	65.9	HC	-	-	-	-	-	2.6	72.2	65.1	41.1
	Wang Noi	A12g	16-35	0.5	9.5	23.0	67.0	HC	-	-	-	-	-	2.4	68.9	64.3	38.8
		ACg	35-63	1.9	16.1	21.7	60.3	HC	-	-	-	-	-	2.3	70.5	-	-
		Cg	63-	2.2	10.2	25.8	61.8	HC	-	-	-	-	-	2.5	69.0	-	-
Fresh Water Alluvial Soils																	
4.	Nakhon Sawan,	Apg	0-15	6.9	20.0	21.3	51.8	HC	50.2	19.1	30.7	1.306	1.134	1.8	88.7	54.2	28.3
	Phayuhakiri	B1g	15-25	8.2	24.2	20.4	47.2	HC	45.5	23.4	31.1	1.182	1.191	1.8	79.9	50.3	23.4
		B2g	25-50	5.8	23.4	17.3	53.5	HC	40.9	27.6	31.5	1.064	1.206	1.9	87.3	61.3	-
10.	Ratchaburi,	Apg	0-10/15	0.7	5.6	41.3	52.4	HC	-	-	-	-	1.144	1.9	66.8	57.5	28.4
	Muang	A12g	10/15-30	1.2	2.4	38.6	57.8	HC	-	-	-	-	1.127	2.0	58.1	54.0	28.0
		C1g	30-50	0.5	2.2	48.6	48.7	HC	-	-	-	-	1.178	2.0	68.1	50.9	-
		C2g	50-65	0.8	5.4	49.8	44.0	SiC	-	-	-	-	1.100	2.0	64.6	56.1	-
36.	Uttaradit,	Apg	0-12	2.5	12.5	45.8	39.2	SiC	-	-	-	-	0.933	2.0	94.1	50.5	39.1
	Muang	B1g	12-23	4.1	10.7	40.0	45.2	HC	-	-	-	-	1.109	2.2	83.5	48.9	36.4
		B21g	23-36	5.1	11.4	39.6	43.9	LiC	-	-	-	-	1.137	2.3	82.7	49.4	-
		B22g	36-60	2.4	10.3	42.2	45.1	HC	-	-	-	-	1.085	2.3	85.9	48.4	-
37.	Phitsanulok	Apg	0-14	8.2	35.7	22.9	33.2	LiC	-	-	-	-	1.233	1.8	45.1	50.1	33.2
	Muang,	B1g	14-25	11.9	36.1	12.0	40.0	LiC	-	-	-	-	1.236	2.0	29.0	48.5	30.3
	Rice Ex. St.	B21g	25-50	14.5	42.1	12.6	30.8	SC	-	-	-	-	1.265	2.1	28.4	45.0	
		B22g	50-70	16.0	47.5	7.3	29.2	SC	-	-	-	-	1.281	2.1	31.1	43.8	
61.	Suphan Buri,	Apg	0-15	2.0	9.6	37.4	51.0	HC	-	-	-	-	1.059	-	75.1	57.1	31.1
	U Thong	B21g	15-30	0.6	1.9	25.1	72.4	HC	-	-	-	-	1.217	-	78.1	-	-
		B22g	30-	0.5	2.9	31.4	65.2	HC	-	-	-	-	1.111	-	64.9	-	-
63.	Suphan Buri,	Apg	0-11	26.3	43.2	11.3	19.2	SCL	-	-	-	-	1.337	-	80.5	35.5	12.5
	Muang	Bg	11-25	21.8	36.0	14.7	27.5	SC	-	-	-	-	-	-	76.6	-	-
		BCg	25-	13.2	25.4	16.1	45.3	HC	-	-	-	-	-	-	87.3	-	-
68.	Ratchaburi,	Apg	0-20	5.0	32.4	48.0	14.6	SiL	-	-	-	-	1.213	-	91.3	42.7	31.5
	Pak Tho	Bg	20-45	5.7	32.1	38.7	23.5	CL	-	-	-	-	1.356	-	96.7	34.9	26.0
		IICg	45-	5.0	33.1	25.3	36.6	LiC	-	-	-	-	1.472	-	82.1	-	-
70.	Phetchaburi,	Apg	0-15	1.3	13.8	58.9	26.0	SiC	-	-	-	-	0.944	-	79.1	48.4	29.1
	Tha Yang	Bg	15-55	1.5	20.8	44.8	32.9	LiC	-	-	-	-	1.187	-	91.9	46.2	26.8
		Cg	55-	4.5	14.8	47.7	33.0	SiC	-	-	-	-	1.279	-	95.0	-	-

No.	Location	Horizon	Depth (cm)	CoS (%)	FS (%)	Silt (%)	Clay (%)	Texture	Three phase (%) SV	LV	AV	Bulk density Field	Air-dried	Sedimentation volume (ml/g)	Dispersion ratio (%)	Max. water-holding capacity (%)	Moisture equivalent (%)
72.	Phetchabun,	Apg	0-12	0.1	22.5	40.4	35.0	LiC	38.5	28.5	33.0	1.000	1.082	2.2	64.6	64.6	41.5
	Muang	B21g	12-37	0.2	11.7	39.5	48.6	HC	41.5	26.6	31.9	1.080	1.163	2.3	65.1	61.6	40.9
		B22g	37-57	0.4	3.9	33.2	62.5	HC	38.1	28.8	34.1	0.991	1.066	2.3	71.1	72.0	-
		BCg	57-	0.9	3.7	26.1	69.3	HC	39.2	34.3	26.5	1.020	1.080	2.4	67.4	76.6	-
73.	Phetchabun,	Apg	0-17	1.1	13.2	39.0	46.7	HC	43.0	22.2	34.8	1.117	1.012	2.2	59.7	74.6	44.5
	Lom Sak	B21g	17-38	1.9	13.9	34.6	49.6	HC	37.6	25.1	37.3	0.978	1.065	2.1	70.7	69.5	40.3
		B22g	38-52	2.9	19.6	29.4	48.1	HC	41.7	28.3	30.0	1.084	1.152	2.3	69.5	66.0	-
		B23g	52-	3.1	20.5	28.0	48.4	HC	43.3	27.1	29.6	1.126	1.176	2.4	80.0	63.7	-
76.	Nakhon Sawan	Apg	0-17	2.7	5.7	21.8	69.8	HC	40.0	28.7	31.3	1.059	1.081	1.8	68.2	55.4	30.2
	Phayuha Khiri	B1g	17-36	2.0	13.6	21.3	63.1	HC	47.9	36.3	15.8	1.269	1.076	1.9	68.8	55.1	28.3
		B2g	36-60	18.4	29.1	20.9	39.2	LiC	48.7	33.0	18.3	1.290	1.225	1.9	69.3	-	-
		BCg	60-	-	-	-	-	LiC	56.4	30.0	13.6	1.495	1.243	1.9	-	-	-
78.	Sing Buri,	Apg	0-19	0.3	37.9	36.4	25.4	LiC	55.0	24.3	20.7	1.458	1.135	-	71.8	53.0	25.4
	In Buri,	B21g	19-38	0.2	28.7	42.0	29.1	LiC	50.5	38.1	11.4	1.376	1.136	-	81.5	52.0	23.1
	Ponang Dum	B22g	38-64	0.2	18.7	46.2	34.9	SiC	54.1	44.7	1.2	1.434	1.096	-	90.4	-	-
79.	Ayutthaya,	Apg	0.18	1.1	19.4	43.0	36.5	LiC	54.4	27.0	18.6	1.442	1.078	-	74.6	54.2	31.7
	Maha Rat	Bg	18-33	2.5	23.5	40.7	33.3	LiC	52.9	22.4	24.7	1.401	1.088	-	89.7	50.1	29.6
		Cg	33-	1.2	5.3	33.7	59.8	HC	47.7	38.2	14.1	1.264	1.162	-	72.4	-	-
126.	Ang Thong,	Apg	0-10	1.3	14.8	38.9	45.0	HC	52.5	31.6	15.9	1.365	0.987	2.0	84.5	57.4	30.8
	Muang	B1g	10-37	1.6	33.6	34.5	30.3	LiC	55.1	33.9	11.0	1.432	1.025	1.5	75.1	49.6	29.3
		IIB21g	37-47	0.6	12.3	27.4	59.7	HC	50.0	39.1	10.9	1.299	1.095	2.0	80.5	-	-
		IIB22g	47-62	0.8	29.0	32.8	37.4	LiC	51.5	40.8	7.7	1.599	1.134	1.7	84.5	-	-
		IIICg	62-90	1.4	81.6	5.0	12.0	FSL	50.7	47.3	2.0	1.579	1.187	1.4	78.5	-	-
127.	Sing Buri,	Apg	0-13	0.3	3.5	43.8	52.4	HC	51.6	33.5	14.9	1.341	0.884	2.0	88.2	64.9	38.0
	Muang	B1g	13-33	0.9	6.8	38.5	53.8	HC	44.3	35.3	20.4	1.153	1.035	2.3	87.9	54.9	31.6
		B2g	33-68	1.8	6.9	38.3	53.0	HC	47.8	36.9	15.3	1.242	1.125	2.4	91.0	-	-
		B3g	68-90	2.9	8.3	43.2	45.6	HC	57.0	39.7	3.3	1.482	1.666	2.2	93.5	-	-
140.	Sukhothai,	Apg	0-10	0.2	4.2	39.0	56.6	HC	42.4	12.9	44.7	1.102	1.090	2.0	77.1	60.2	38.6
	Si Samrong	A12g	10-24	0.2	3.6	41.7	54.5	HC	61.6	28.0	10.4	1.600	1.109	2.2	82.5	58.4	34.6
		Cg	24-60	0.6	4.7	46.4	48.3	HC	56.4	26.2	17.4	1.465	1.096	2.3	85.8	-	-
141.	Sukhothai,	Apg	0-10	1.4	3.2	48.8	46.6	HC	46.9	7.4	45.7	0.958	1.047	1.9	89.9	57.8	33.9
	Si Satchanalai	A12g	10-25	2.1	4.5	42.9	50.5	HC	52.6	17.8	29.6	1.368	1.137	2.2	85.4	56.2	32.5
		Cg	25-50	2.1	1.4	38.2	58.3	HC	57.2	28.5	14.3	1.487	1.166	2.3	87.3	-	-
142.	Uttaradit,	Apg	0-15/19	1.5	6.7	41.9	49.9	HC	53.8	11.9	34.3	1.399	0.999	2.0	90.2	60.0	39.1
	Laplae	Cg	15/19-52	3.1	6.1	28.4	62.4	HC	56.0	34.5	9.5	1.457	1.082	2.4	93.3	57.9	36.8
Low Humic Gley Soils																	
3.	Saraburi,	Apg	0-12	4.8	1.3	56.2	37.7	SiC	50.2	19.1	30.7	1.431	1.151	1.9	73.4	47.3	23.4
	Muang	B1g	12-25	6.4	12.3	46.3	35.0	SiC	45.5	23.4	31.1	1.395	1.271	2.0	96.0	46.6	20.7
		B2g	25-55	3.0	8.5	39.3	49.2	HC	40.9	27.6	31.5	1.084	1.223	2.2	73.3	51.5	-
5.	Chai Nat,	Apg	0-15	0.9	8.0	27.9	63.2	HC	46.8	18.3	34.9	1.216	1.154	1.8	75.6	62.1	37.8
	Muang,	B21g	15-30	0.5	7.0	28.7	63.8	HC	49.3	32.4	18.3	1.282	1.225	2.0	77.0	56.9	35.4
	Rice Ex. St.	B22g	30-60	0.4	6.4	25.2	68.0	HC	46.8	38.1	15.1	1.217	1.229	2.0	88.5	54.6	-
7.	Ratchaburi,	Apg	0-15	13.8	9.2	35.4	41.6	LiC	49.5	33.2	17.3	1.287	1.158	1.8	94.6	49.5	28.4
	Muang,	B1g	15-30	13.8	9.8	38.6	37.8	LiC	57.9	35.5	6.6	1.505	1.193	1.8	95.2	44.4	25.1
	Rice Ex. St.	B2g	30-50	10.3	8.9	41.8	39.0	LiC	57.0	40.1	2.9	1.483	1.181	2.1	96.0	44.9	-

No.	Location	Horizon	Depth (cm)	CoS (%)	FS (%)	Silt (%)	Clay (%)	Texture	Three phase (%) SV	LV	AV	Bulk density Field	Air-dried	Sedimentation volume (ml/g)	Dispersion ratio (%)	Max. water-holding capacity (%)	Moisture equivalent (%)
77.	Nakhon Sawan,	Apg	0-15	25.5	35.8	20.7	18.0	CL	57.1	19.8	23.1	1.514	1.233	-	85.4	43.3	27.8
	Banphot Phisai	B21g	15-30	14.1	29.1	19.0	37.7	LiC	65.7	22.2	12.1	1.740	1.278	-	86.7	41.9	24.9
		B22g	30-46	13.7	27.4	19.4	39.5	LiC	51.1	21.3	27.6	1.355	1.130	-	64.3	-	-
		BCg	46-	11.2	21.4	15.1	52.3	HC	56.9	21.9	21.2	1.507	1.233	-	57.6	-	-
131.	Saraburi,	Apg	0-15	0.3	7.6	57.9	34.2	SiC	45.6	35.7	18.7	1.185	0.956	1.4	91.9	54.2	30.5
	Nong Khae	A12g	15-32	0.4	4.3	47.4	47.9	HC	56.7	35.5	7.8	1.475	1.082	1.7	85.2	51.9	27.4
		B1g	32-55	0.4	2.8	34.7	62.1	HC	52.0	36.8	11.2	1.352	1.093	2.4	75.4	-	-
		B2g	55-75	0.5	9.0	70.1	20.4	SiCL	56.2	38.3	5.5	1.461	1.294	1.5	98.6	-	-
132.	Nakhon Nayok,	Apg	0-13	7.7	9.7	42.3	40.3	LiC	41.0	17.3	41.7	1.066	0.928	1.7	98.4	65.2	44.3
	Muang	A12g	13-20	1.0	3.5	23.8	71.7	HC	47.4	31.5	21.1	1.232	0.984	2.5	89.6	58.4	32.0
		B21g	20-60	0.9	3.4	17.3	78.4	HC	40.8	39.0	20.2	1.061	0.973	3.1	67.0	-	-
		B22g	60-	20.3	11.8	16.2	51.7	HC	41.6	33.4	25.0	1.081	1.092	2.5	99.1	-	-
133.	Prachin Buri,	Apg	0-20	1.0	21.1	32.2	45.7	HC	42.6	26.8	30.6	1.017	0.963	1.8	82.0	55.4	34.0
	Prachantakhum	ACg	20-32	2.5	21.2	21.5	54.8	HC	39.1	20.4	40.5	1.018	1.088	2.1	65.2	50.0	29.6
		Cg	32-65	2.7	33.7	30.1	33.5	LiC	53.2	18.6	28.2	1.382	1.283	1.9	87.0	-	-
134.	Prachin Buri,	Apg	0-15	9.8	43.8	32.9	13.5	L	67.4	14.8	17.8	1.753	1.381	1.2	88.8	37.6	20.7
	Watthana Nakhon	A12g	15-30	12.4	44.3	29.9	13.4	L	65.0	9.3	25.7	1.691	1.452	1.1	91.3	31.6	19.8
		Cg	30-65	27.0	26.6	22.6	23.8	CL	62.3	12.6	25.1	1.620	1.344	1.6	90.3	-	-
135.	Chachoengsao,	Apg	0-14	0.4	9.5	61.5	28.6	SiC	58.7	20.1	21.2	1.525	1.045	1.4	99.9	55.7	32.8
	Phanom Sarakham	ACg	14-29	4.1	8.8	49.3	37.8	SiC	43.3	18.8	37.9	1.125	1.135	1.9	92.9	47.2	30.7
		Cg	29-68	0.2	7.3	39.5	53.0	HC	41.7	21.4	36.9	1.085	1.160	2.1	76.8	-	-
137.	Kamphaeng Phet,	Apg	0-13	13.7	29.6	30.5	26.2	LiC	63.8	22.4	13.8	1.658	1.206	1.5	95.4	52.4	30.8
	Khranu Woralak-	A12g	13-22	8.3	11.2	29.5	51.0	HC	56.7	29.1	14.2	1.474	1.191	2.1	84.5	52.9	30.0
	Saburi	B1g	22-36	15.5	11.7	27.6	45.2	HC	63.6	18.0	18.4	1.653	1.236	2.1	92.4	-	-
		B2g	36-47	11.6	8.7	27.0	52.7	HC	59.4	26.8	13.8	1.544	1.188	2.3	83.9	-	-
		B3g	47-65	7.7	6.8	29.5	56.0	HC	52.9	27.1	16.0	1.374	1.108	2.3	86.8	-	-
138.	Kamphaeng Phet,	Apg	0-18	0.3	2.3	32.7	64.7	HC	53.7	22.6	23.7	1.395	0.992	2.1	77.8	68.5	38.6
	Khlong Khlung	A12g	18-38	1.6	3.4	37.1	67.9	HC	47.7	33.7	18.6	1.240	1.055	2.5	76.3	58.2	37.1
		Bg	38-70	2.7	5.8	16.1	75.4	HC	53.8	42.1	4.1	1.399	1.197	3.3	81.8	-	-
139.	Kamphaeng Phet,	Apg	0-10	3.5	25.2	40.2	31.1	LiC	57.0	10.7	32.3	1.481	1.224	1.3	96.2	54.3	31.8
	Phran Kratai	A12g	10-19	5.5	31.2	34.3	29.0	LiC	57.9	15.0	27.1	1.505	1.326	1.4	94.7	49.7	29.0
		Bg	19-55	6.3	23.8	17.8	52.1	HC	55.3	28.1	16.6	1.439	1.102	1.8	59.1	-	-
161.	Lop Buri,	Apg	0-14	14.7	46.3	22.8	16.2	CL	70.0	18.7	11.3	1.808	1.242	1.3	87.5	38.0	22.1
	Khok Samrong,	B1g	14-27	15.1	39.0	24.5	21.4	CL	67.1	18.2	14.7	1.745	1.364	2.3	82.7	40.1	23.4
	Rice Ex. St.	B2g	27-40	12.2	35.5	28.7	26.6	LiC	68.0	19.2	11.8	1.768	1.355	2.5	96.0	-	-
		Cg	40-68	9.7	32.2	27.2	30.9	LiC	56.6	19.9	23.5	1.471	1.288	2.2	55.5	-	-
162.	Lop Buri,	Apg	0-20	15.0	38.0	27.0	20.0	CL	66.1	17.5	11.4	1.718	-	1.3	87.8	38.1	23.8
	Khok Samrong,	B1g	20-32	15.4	35.3	26.4	22.9	CL	62.5	23.1	14.4	1.624	-	2.3	97.3	38.4	23.7
	Rice Ex. St.	B2g	32-40	13.7	36.0	27.0	23.3	CL	62.1	21.4	11.5	1.615	-	3.0	95.6	-	-
		Cg	40-70	11.0	28.1	32.5	28.4	LiC	63.8	32.0	4.2	1.660	-	4.1	93.9	-	-

Gray Podzolic Soils

No.	Location	Horizon	Depth (cm)	CoS (%)	FS (%)	Silt (%)	Clay (%)	Texture	Three phase (%) SV	LV	AV	Bulk density Field	Air-dried	Sedimentation volume (ml/g)	Dispersion ratio (%)	Max. water-holding capacity (%)	Moisture equivalent (%)
18.	Rayon, Klaeng	Apg	0-10	26.4	49.3	17.2	7.1	FSL	57.6	21.4	22.0	1.486	1.473	1.0	99.0	27.7	13.1
		Alg	10-25	27.2	52.4	18.1	3.6	FSL	64.7	22.7	12.6	1.683	1.400	1.1	95.8	31.7	11.5
		B1g	25-40	19.2	32.8	31.3	16.7	CL	65.9	20.7	13.4	1.713	1.359	1.3	62.5	29.9	-
		B2g	40-	17.7	33.3	29.6	19.4	CL	59.1	19.8	21.1	1.537	1.295	1.4	16.2	33.2	-
Non-Calcic Brown Soils																	
6.	Suphan Buri, Muang, Rice Ex. St.	Apg	0-15	0.5	29.5	26.3	43.7	LiC	43.5	12.5	44.0	1.130	1.179	2.1	83.7	56.1	36.3
		A12g	15-25	0.3	28.1	21.7	49.9	HC	46.5	21.4	32.1	1.290	1.217	2.2	78.4	52.9	35.0
		Bg	25-40	0.6	20.2	27.5	51.7	HC	54.4	32.8	12.8	1.415	1.230	2.2	77.8	50.4	-
		BIICg	40-60	0.4	24.4	29.6	45.6	HC	62.2	30.4	7.4	1.619	1.245	2.3	79.1	45.3	-
11.	Nakhon Pathom, Muang	Apg	0-15	1.0	17.0	38.2	43.8	LiC	-	-	-	-	1.194	1.9	58.6	52.8	33.1
		B1g	15-45	1.1	18.8	38.2	41.9	LiC	-	-	-	-	1.208	2.1	78.0	48.7	29.9
		B2g	45-65	1.1	3.2	26.0	69.8	HC	-	-	-	-	1.190	2.4	84.8	58.4	-
Grumusols																	
23.	Lop Buri, Muang	Ap	0-15	3.2	6.5	43.9	46.4	HC	44.2	27.9	27.9	1.150	1.127	2.6	40.1	76.6	50.2
		A12	15-30	4.4	7.2	26.3	62.1	HC	43.8	30.8	25.4	1.101	1.121	2.7	35.6	71.1	45.2
		A13	30-60	5.3	6.5	21.8	66.2	HC	45.4	34.1	20.5	1.181	1.103	2.7	48.9	72.5	-
		C	60-	5.8	6.1	24.8	63.3	HC	42.4	28.4	28.8	1.114	1.130	2.6	69.2	69.9	-
71.	Lop Buri, Muang	Ap	0-18	5.1	9.0	14.0	71.9	HC	40.5	35.3	24.2	1.054	1.038	2.5	70.0	78.1	49.5
		C1	18-42	5.5	11.6	14.6	68.3	HC	40.5	33.8	25.7	1.052	1.133	2.5	74.3	76.2	47.4
		C2	42-	9.3	12.6	14.9	63.2	HC	39.0	34.8	26.2	1.014	1.091	2.6	73.1	76.1	-
160.	Lop Buri, Muang	Apg	0-16	8.6	23.2	23.2	45.0	HC	-	-	-	-	1.218	2.4	70.0	67.8	46.6
		A12g	16-30	20.4	22.6	23.3	33.7	LiC	-	-	-	-	1.291	2.1	84.1	63.0	42.8
		Cg	30-60	13.0	21.7	30.3	35.0	LiC	-	-	-	-	1.244	2.2	86.6	-	-
163.	Lop Buri, Khok Samrong, Rice Ex. Subst.	Apg	0-12	1.6	10.4	32.9	55.1	HC	-	-	-	-	1.132	2.7	89.7	-	-
		A12g	12-40	1.6	9.9	29.0	59.5	HC	-	-	-	-	1.099	2.6	78.5	-	-
		Cg	40-70	1.1	11.2	28.7	59.0	HC	-	-	-	-	1.122	2.7	94.5	-	-

North-eastern Region

Fresh Water Alluvial Soils

No.	Location	Horizon	Depth (cm)	CoS (%)	FS (%)	Silt (%)	Clay (%)	Texture	Three phase (%) SV	LV	AV	Bulk density Field	Air-dried	Sedimentation volume (ml/g)	Dispersion ratio (%)	Max. water-holding capacity (%)	Moisture equivalent (%)
42.	Nakhon Ratchasima,	Apg	0-15	2.9	21.0	17.6	58.5	HC	40.6	23.8	35.6	1.055	1.155	1.6	60.9	61.3	37.5
	Phimai,	B1g	15-40	3.0	24.6	20.3	52.1	HC	46.8	25.2	28.0	1.216	1.215	1.7	69.8	54.3	34.3
	Rice Ex. St.	B2g	40-75	2.2	18.3	19.5	60.0	HC	42.3	30.1	27.6	1.087	1.158	1.8	44.8	63.2	-
48.	Nong Khai,	Apg	0-15	0.1	38.3	43.0	18.6	CL	40.5	21.8	37.7	1.053	1.064	1.4	79.9	65.6	33.4
	Si Chiang Mai	A12g	15-30	0.4	11.6	53.6	34.4	SiC	54.8	30.2	15.0	1.424	1.116	1.7	84.9	58.8	30.2
		Cg	30-65	3.1	8.4	58.6	29.9	SiC	63.1	24.3	12.6	1.640	1.154	1.3	95.4	44.4	-
49.	Sakon Nakhon,	ApC	0-5	4.1	58.2	23.2	14.5	L	57.7	10.4	31.9	1.501	1.383	1.1	87.7	-	-
	Muang,	Apg	5-20	3.3	50.8	30.7	15.2	CL	59.0	25.2	16.8	1.534	1.403	1.4	95.6	-	-
	Rice Ex. St.	A12g	20-35	4.8	57.9	21.0	16.3	CL	72.9	19.3	7.8	1.896	1.505	1.5	88.8	-	-
		C1g	35-43	6.9	61.5	17.3	14.3	FSL	63.7	15.6	10.7	1.657	1.534	1.5	96.3	-	-
		IIC2g	43-	5.1	42.5	25.1	27.2	LiC	63.8	27.0	9.2	1.626	1.419	1.6	88.9	-	-
95.	Nakhon Ratchasima	Apg	0-20	19.0	58.8	10.2	12.0	FSL	57.0	24.6	18.4	1.482	1.406	1.2	99.2	-	-
	Nong Sung	C1g	20-40	18.4	43.7	13.5	24.4	SCL	55.3	29.5	15.2	1.436	1.354	3.2	97.7	-	-
		C2g	40-75	15.2	35.6	24.8	24.4	CL	51.7	29.2	19.1	1.345	1.281	4.6	90.5	-	-
98.	Khon Kaen,	Apg	0-15	4.8	68.4	13.9	12.9	FSL	55.1	13.7	31.2	1.432	1.334	1.1	77.6	-	-
	Nam Phong	A12g	15-30	4.9	58.6	17.8	18.7	SCL	58.9	22.8	18.3	1.531	1.349	1.5	76.9	-	-
		C1g	30-43	3.9	51.7	19.9	24.5	SCL	51.6	24.7	23.7	1.343	1.377	1.5	81.0	-	-
		C2g	33-75	4.2	52.5	21.4	21.9	CL	45.7	23.1	31.2	1.187	1.395	1.5	73.5	-	-
102.	Nong Khai,	Apg	0-10	0.9	84.4	10.0	4.7	LFS	61.4	27.1	11.5	1.597	1.386	0.9	87.9	34.5	16.0
	Muang	A12g	10-23	1.1	85.0	8.0	5.9	LFS	64.6	20.1	15.3	1.678	1.357	0.8	87.7	33.2	14.8
		Cg	23-65	1.7	78.4	8.2	11.7	FSL	52.6	18.6	18.8	1.629	1.120	1.2	82.3	-	-

Low Humic Gley Soils

No.	Location	Horizon	Depth (cm)	CoS (%)	FS (%)	Silt (%)	Clay (%)	Texture	SV	LV	AV	Field	Air-dried	Sedimentation volume (ml/g)	Dispersion ratio (%)	Max. water-holding capacity (%)	Moisture equivalent (%)
43.	Khon Kaen,	Apg	0-15	9.7	75.2	10.8	4.3	LFS	58.7	20.5	20.8	1.525	1.485	1.0	90.1	29.2	15.4
	Muang,	BCg	15-35	11.5	64.0	10.3	14.2	FSL	65.7	25.5	8.8	1.708	1.467	1.2	93.0	36.9	12.5
	Rice Ex. St.	C1g	35-60	11.6	57.9	11.9	18.6	SCL	76.8	21.1	2.1	1.998	1.488	1.4	96.2	41.0	-
		C2g	60-75	7.5	54.8	18.8	18.9	SCL	75.2	24.2	0.6	1.957	1.474	1.6	92.2	43.3	-
45.	Khon Kaen,	Apg	0-10	3.3	53.8	22.3	20.6	CL	62.0	35.6	2.4	1.654	1.380	1.4	89.6	41.8	26.3
	Chum Phae,	A12g	10-25	2.0	32.8	22.3	42.9	LiC	51.2	30.7	18.1	1.329	1.382	1.6	81.0	43.5	22.0
	Rice Ex. St.	Bg	25-40	0.9	25.8	19.5	53.8	HC	40.9	25.8	33.3	1.076	1.374	1.8	77.8	50.1	-
		Cg	40-75	1.1	27.9	18.8	52.2	HC	57.5	25.5	17.0	1.493	1.183	1.8	88.7	55.7	-
47.	Udon Thani,	Apg	0-15	0.5	78.8	16.7	4.0	FSL	56.9	22.6	20.5	1.479	1.428	0.9	70.9	36.2	16.7
	Muang	B1g	15-30	1.3	69.7	18.3	10.7	FSL	76.2	17.6	6.2	1.977	1.434	0.9	82.8	32.5	17.8
		B21g	30-45	1.2	69.1	17.1	12.6	FSL	67.3	19.7	13.0	1.749	1.398	1.0	94.5	34.5	-
		B22g	45-75	2.8	59.5	16.6	21.1	SCL	58.2	24.7	17.1	1.541	1.454	1.4	98.6	38.8	-

No.	Location	Horizon	Depth (cm)	CoS (%)	FS (%)	Silt (%)	Clay (%)	Texture	Three phase (%) SV	Three phase (%) LV	Three phase (%) AV	Bulk density Field	Bulk density Air-dried	Sedimentation volume (ml/g)	Dispersion ratio (%)	Max. water-holding capacity (%)	Moisture equivalent (%)
52.	Maha Sarakam,	Apg	0-15	13.9	36.9	37.2	12.0	L	61.7	22.5	15.8	1.553	1.476	1.1	85.4	31.4	23.8
	Muang	Blg	15-35	25.5	46.9	18.2	9.4	FSL	77.5	18.5	4.0	2.015	1.475	1.1	32.7	31.6	19.2
		B2g	35-65	24.2	46.7	15.6	13.5	FSL	64.3	22.9	12.8	1.671	1.472	1.3	99.1	31.9	-
53.	Surin,	Apg	0-15	2.2	88.3	4.3	5.2	LFS	57.5	14.0	28.5	1.496	1.517	1.0	98.9	28.9	15.2
	Muang,	Blg	15-25	2.8	69.7	11.7	18.5	SCL	63.8	14.5	11.7	1.658	1.423	1.3	67.0	35.6	10.2
	Rice Ex. St.	B2g	25-60	2.0	62.1	13.8	22.1	SCL	60.7	16.6	12.7	1.577	1.360	2.0	53.7	38.3	-
		B3g	60-100	4.6	59.2	11.6	24.6	SCL	56.4	23.7	19.9	1.465	1.401	2.5	53.9	39.4	-
96.	Nakhon Ratchasima,	Apg	0-18	1.5	28.1	44.9	25.5	LiC	55.7	18.6	25.7	1.449	1.220	1.3	99.4	-	-
	Bua Yai	A12g	18-25	1.6	29.9	36.6	31.9	LiC	53.6	21.5	24.9	1.394	1.272	1.8	87.4	-	-
		B21g	25-35	4.3	34.8	25.3	35.6	LiC	55.0	22.7	22.3	1.429	1.312	2.0	90.2	-	-
		B22g	35-75	5.0	30.8	25.5	38.7	LiC	60.5	21.6	17.9	1.574	1.346	2.3	72.0	-	-
97.	Khon Kaen,	Apg	0-13	3.0	78.2	10.6	8.2	FSL	54.5	16.5	29.0	1.418	1.268	1.2	-	-	-
	Phon	A12g	13-19	5.9	72.9	11.1	10.1	FSL	67.7	17.0	15.3	1.759	1.356	1.3	-	-	-
		Bg	19-27	4.2	79.3	9.4	7.1	FSL	69.5	16.0	14.5	1.807	1.221	1.1	-	-	-
		IICg	27-65	3.8	70.7	8.5	17.0	SCL	64.5	24.9	10.6	1.676	1.352	3.3	-	-	-
99.	Udon Thani,	Apg	0-10	2.0	80.4	11.6	6.0	FSL	60.3	14.8	24.9	1.568	1.353	0.7	74.8	-	-
	Kumphawapi	Blg	10-21	1.5	75.9	13.1	9.5	FSL	66.0	17.6	16.4	1.717	1.421	1.1	85.9	-	-
		B2g	21-80	1.7	71.5	16.0	10.8	FSL	64.2	28.5	7.3	1.670	1.453	1.3	83.7	-	-
100.	Udon Thani,	Apg	0-13	15.1	67.4	13.2	4.3	FSL	61.6	10.0	28.4	1.600	1.386	1.0	94.7	30.1	14.9
	Kumphawapi	A12g	13-23	14.1	55.1	20.1	10.7	FSL	72.8	16.7	10.5	1.892	1.480	1.1	92.1	30.2	18.0
		Blg	23-50	14.2	53.3	15.1	17.4	SCL	74.3	25.2	0.5	1.946	1.362	1.5	97.2	-	-
		B2g	50-80	13.1	55.4	9.8	21.7	SCL	73.8	25.4	0.8	1.918	1.423	1.8	82.3	-	-
101.	Nong Khai,	Apg	0-11	0.3	34.4	49.9	15.4	SiCL	64.3	7.2	18.5	1.672	1.250	1.1	90.9	41.9	16.0
	Muang	A12g	11-18	0.5	38.9	46.3	15.3	SiCL	70.4	11.9	17.7	1.829	1.389	1.1	98.1	33.2	11.3
		B21g	18-46	0.4	33.9	46.5	19.2	SiCL	55.2	24.2	20.6	1.434	1.366	1.2	75.4	-	-
		B22g	46-80	0.6	32.3	40.1	27.0	LiC	48.9	22.5	28.6	1.272	1.299	1.6	67.5	-	-
105.	Sakon Nakhon,	Apg	0-10	0.6	91.7	5.6	2.1	FS	64.9	16.4	18.7	1.689	1.365	0.9	93.0	29.5	14.4
	Phanna Nikhom	A12g	10-30	2.1	77.7	17.5	2.7	FSL	65.7	19.0	15.3	1.708	1.269	0.9	98.9	34.9	16.6
		Blg	30-45	1.6	62.1	20.2	15.9	CL	64.0	21.4	14.6	1.665	1.357	1.3	78.2	-	-
		B2g	45-80	1.5	52.5	16.0	30.0	LiC	56.4	25.3	18.3	1.467	1.352	1.4	63.9	-	-
106.	Sakon Nakhon,	Apg	0-13	9.6	80.0	10.0	0.4	FS	53.8	18.2	28.0	1.400	1.318	0.9	83.7	27.7	15.7
	Muang	A12g	13-26	11.8	72.6	14.5	1.1	FSL	70.3	16.2	13.5	1.827	1.493	0.9	84.9	28.5	11.9
		Blg	26-48	11.8	71.2	14.6	2.4	FSL	65.9	11.7	22.4	1.713	1.414	0.7	84.2	-	-
		B2g	48-80	9.4	49.8	21.5	19.3	CL	60.9	26.0	13.1	1.583	1.398	3.7	89.0	-	-
107.	Nakhon Phanom,	Apg	0-12	0.6	45.3	43.5	10.6	L	59.4	19.1	21.5	1.284	1.110	1.2	98.5	46.4	20.7
	Muang	Blg	12-23	0.8	38.2	45.9	15.1	SiCL	63.4	18.3	18.3	1.657	1.289	1.6	88.6	41.8	19.8
		B21g	23-42	2.2	34.5	41.2	22.1	CL	65.9	25.1	9.0	1.712	1.324	2.4	98.8	-	-
		B22g	44-75	2.2	31.5	37.3	29.0	LiC	59.4	27.8	12.8	1.546	1.348	4.0	96.8	-	-
108.	Nakhon Phanom,	Apg	0-15	0.8	15.4	58.4	25.4	SiC	60.4	17.4	22.2	1.571	1.074	1.5	89.5	57.9	28.9
	Muang	Blg	15-31	1.9	15.6	46.0	36.5	SiC	56.7	27.1	16.2	1.475	1.145	1.7	84.1	51.2	24.9
		B21g	31-50	2.0	19.7	38.0	40.3	LiC	64.1	30.2	5.7	1.666	1.228	1.9	86.2	-	-
		B22g	50-80	3.4	18.0	37.6	41.0	LiC	58.5	30.0	11.5	1.521	1.240	1.9	77.3	-	-

No.	Location	Horizon	Depth (cm)	CoS (%)	FS (%)	Silt (%)	Clay (%)	Texture	Three phase (%) SV	LV	AV	Bulk density Field	Air-dried	Sedimentation volume (ml/g)	Dispersion ratio (%)	Max. water-holding capacity (%)	Moisture equivalent (%)
109.	Nakhon Phanom,	Apg	0-13	4.2	76.4	18.3	1.1	FSL	66.7	18.4	14.9	1.474	1.367	0.9	99.5	30.2	15.1
	Raenu Nakhon	Blg	13-28	6.5	71.3	21.0	1.2	FSL	78.0	16.0	6.0	2.029	1.484	1.0	91.6	23.5	12.2
		B2g	28-42	5.4	64.7	23.8	6.1	FSL	64.7	19.0	16.3	1.683	1.423	1.3	92.9	-	-
		Cg	42-75	6.9	60.0	22.1	11.0	FSL	-	-	-	-	1.398	1.4	90.1	-	-
110.	Nakhon Phanom,	Apg	0-11	6.7	53.7	32.5	7.1	L	56.4	28.8	24.8	1.466	1.412	1.0	99.1	30.8	15.9
	That Phanom	Blg	11-25	7.3	39.4	34.6	18.7	CL	70.8	26.1	3.1	1.842	1.398	1.5	99.2	35.3	20.1
		B2g	25-75	7.7	41.6	25.2	25.5	LiC	70.7	23.3	6.0	1.839	1.423	1.9	99.7	-	-
111.	Nakhon Phanom,	Apg	0-7	2.6	69.4	25.4	2.6	FSL	60.9	17.4	21.7	1.584	1.411	0.9	93.2	30.3	15.7
	Mukdahan	Blg	7-22	3.1	59.3	31.3	6.3	L	71.8	21.6	6.6	1.866	1.477	1.0	98.0	27.2	13.2
		BCg	22-70	3.2	52.2	26.0	18.6	CL	67.3	24.2	8.5	1.750	1.427	1.4	99.5	-	-
112.	Ubon Ratchathani,	Apg	0-10	1.5	38.9	51.7	7.9	SiL	50.9	22.1	27.1	1.323	1.213	1.1	99.4	36.6	14.4
	Loeng Nok Tha	A12g	10-18	2.5	43.5	44.8	9.2	L	72.4	25.2	2.4	1.984	1.323	1.0	94.1	35.7	13.1
		B21g	18-43	3.7	32.1	42.5	21.7	CL	59.3	25.5	15.2	1.543	1.301	1.4	90.3	-	-
		B22g	43-75	3.9	28.0	35.4	32.7	LiC	57.5	29.2	13.3	1.496	1.289	1.6	78.5	-	-
113.	Ubon Ratchathani,	Apg	0-10	1.4	76.2	15.6	6.8	FSL	69.7	6.1	24.2	1.813	1.467	0.9	82.1	28.6	12.5
	Muang,	A12g	10-15	1.5	67.7	25.6	7.2	FSL	59.8	9.9	30.3	1.555	1.445	0.9	94.8	29.3	11.2
	Rice Ex. St.	Bg	15-30	4.3	43.5	30.8	21.4	CL	60.1	17.2	22.7	1.562	1.338	1.3	85.4	-	-
		BCg	30-75	6.7	25.8	30.9	36.6	LiC	48.4	20.2	31.4	1.258	1.221	1.3	80.1	-	-
115.	Ubon Ratchathani,	Apg	0-9	10.6	67.1	15.5	6.8	FSL	52.7	13.4	33.9	1.370	1.526	0.8	76.6	21.8	12.2
	Khuang Nai	Bg	9-20	11.1	57.2	20.7	11.0	FSL	60.6	11.6	27.8	1.731	1.435	1.8	94.5	26.4	13.6
		IIC1g	20-35	8.4	46.8	22.2	22.6	CL	59.9	20.6	19.5	1.558	1.429	3.4	92.1	-	-
		IIC2g	35-80	6.8	35.7	20.6	36.7	LiC	53.9	24.7	21.4	1.402	1.376	7.1	93.8	-	-
116.	Ubon Ratchathani,	Apg	0-10	15.4	68.9	10.9	4.8	FSL	70.3	17.8	11.9	1.828	1.507	0.7	78.1	21.2	11.2
	Kham Khuan Kaeo	A12g	10-24	13.2	60.5	14.5	11.8	FSL	75.2	13.5	11.3	1.954	1.275	0.7	69.2	16.8	9.8
		Blg	24-33	12.9	60.3	15.3	11.5	FSL	69.6	20.7	9.7	1.811	1.312	1.7	90.6	-	-
		B21g	33-55	15.5	63.2	19.2	2.1	FSL	67.9	20.2	11.9	1.765	1.444	1.3	84.5	-	-
		B22g	55-80	13.7	64.1	15.6	6.6	FSL	73.6	22.1	4.3	1.915	1.576	1.0	85.6	-	-
117.	Ubon Ratchathani,	Apg	0-14	3.4	84.0	8.2	4.4	LFS	55.2	15.9	28.9	1.434	1.435	0.9	70.2	29.2	14.8
	Yasothon	Blg	14-20	5.6	81.3	2.8	10.3	LFS	65.8	10.9	23.3	1.711	1.402	1.0	86.3	26.3	14.1
		BIICg	20-40	5.0	46.3	16.8	31.9	LiC	57.8	23.7	18.5	1.502	1.314	6.7	90.5	-	-
		IICg	40-75	2.2	39.0	23.3	35.5	LiC	53.3	25.2	21.5	1.387	1.304	8.8	97.6	-	-
118.	Roi Et,	Apg	0-7	4.4	29.6	53.8	12.2	SiL	62.3	18.8	18.9	1.360	1.110	1.0	96.0	35.4	16.5
	Selaphum	A12g	7-12	2.3	32.1	50.8	14.8	SiL	66.3	18.0	15.7	1.724	1.243	1.0	98.1	33.4	15.0
		Blg	12-25	2.2	24.6	51.5	21.7	SiCL	62.3	21.4	16.3	1.621	1.158	1.1	79.0	-	-
		B2g	25-75	3.9	17.1	45.8	33.2	SiC	63.7	28.0	8.3	1.657	1.213	1.6	77.9	-	-
122.	Roi Et,	Apg	0-11	4.1	85.5	8.8	1.6	FS	-	-	-	-	1.521	0.8	87.6	23.1	8.5
	Suwannaphum	Cg	11-46	7.3	84.1	7.8	0.8	FS	-	-	-	-	1.471	0.8	84.3	25.1	7.6
		IIC2g	46-57	7.0	50.9	20.8	21.3	CL	-	-	-	-	1.413	3.2	70.2	-	-
		IIC3g	57-80	4.7	50.4	17.7	27.2	SC	-	-	-	-	1.271	4.5	95.4	-	-
123.	Surin,	Apg	0-12	8.7	82.8	4.4	4.1	LFS	-	-	-	-	1.502	0.9	91.7	26.3	11.7
	Muang	Blg	12-25	11.8	75.3	8.0	4.9	LFS	-	-	-	-	1.468	2.4	68.9	25.5	9.9
		B21g	25-45	10.8	68.2	5.8	15.2	SCL	-	-	-	-	1.369	4.6	78.6	-	-
		B22g	45-70	8.0	54.8	7.9	29.3	SL	-	-	-	-	1.323	8.8	79.0	-	-

No.	Location	Horizon	Depth (cm)	CoS (%)	FS (%)	Silt (%)	Clay (%)	Texture	Three phase (%) SV	LV	AV	Bulk density Field	Air-dried	Sedimen-tation volume (ml/g)	Dis-persion ratio (%)	Max. water-holding capacity (%)	Moisture equiv-alent (%)
124.	Surin,	Apg	0-10	7.9	66.6	16.0	9.5	FSL	-	-	-	-	1.405	1.2	88.2	34.0	16.1
	Prasat	B1g	10-18	10.0	61.4	18.0	10.6	FSL	-	-	-	-	1.455	1.1	77.4	32.5	11.6
		B21g	18-43	11.3	66.2	10.5	12.0	FSL	-	-	-	-	1.387	1.2	95.3	-	-
		B22g	43-80	8.0	57.5	10.1	24.4	SCL	-	-	-	-	1.315	1.6	66.5	-	-
125.	Buri Ram,	Apg	0-9	2.3	76.7	13.1	7.9	FSL	-	-	-	-	1.372	0.9	96.1	35.1	16.9
	Prakhon Chai	A12g	9-21	3.0	72.5	11.8	12.7	FSL	-	-	-	-	1.421	1.0	80.4	36.8	17.0
		Bg	21-32	4.1	72.2	10.6	13.1	FSL	-	-	-	-	1.403	8.4	56.5	-	-
Regosols																	
50.	Ubon Ratchathani,	Apg	0-10	17.4	74.0	7.6	1.0	FS	62.3	10.8	26.9	1.627	1.597	0.9	88.0	22.4	10.7
	Muang	B1g	10-20	23.7	63.3	11.3	1.7	FS	80.7	15.3	4.0	2.153	1.689	1.0	96.8	19.9	9.6
		B2g	20-75	28.3	61.4	10.0	0.3	FS	77.6	11.9	10.5	2.017	1.732	1.2	65.8	13.0	-
51.	Maha Sarakam,	Ap	0-15	8.4	85.8	2.6	3.2	FS	58.7	21.2	20.1	1.515	1.484	0.9	60.7	24.4	9.8
	Muang,	C1	15-30	8.8	85.1	2.9	3.2	FS	61.1	23.6	15.3	1.589	1.526	1.0	65.3	23.7	5.6
	Pamong Project	C2	30-70	8.2	86.1	4.4	1.3	FS	61.8	29.1	9.1	1.604	1.569	1.2	30.8	19.8	5.3
56.	Sakon Nakhon,	Ap	0-25	22.8	68.2	7.5	1.5	FS	61.0	18.3	20.7	1.584	1.342	0.7	96.4	22.1	12.5
	Muang,	C1	25-35	19.5	72.7	7.2	0.6	FS	60.2	19.7	20.1	1.564	1.528	0.7	95.9	20.8	10.4
	Rice Ex. St.	C2	35-56	20.7	73.4	3.1	2.8	FS	60.6	14.4	25.0	1.575	1.531	0.8	95.7	21.6	-
		C3	56-70	23.5	64.5	11.2	0.8	FS	64.7	23.9	11.4	1.682	1.518	0.8	86.0	14.8	-
		C4	70-86	17.8	73.7	7.2	1.3	FS	64.0	28.2	7.8	1.665	1.564	0.9	98.1	19.3	-
		IIB	86-100	22.0	69.1	6.3	2.6	FS	59.9	33.7	6.4	1.556	1.407	1.0	66.5	26.8	-
57.	Sakon Nakhon,	Ap	0-12	25.8	64.2	1.3	8.7	LFS	57.3	13.3	29.4	1.481	1.532	0.7	75.8	25.3	13.8
	Muang,	C1	12-26	33.2	57.0	8.7	1.0	FS	60.6	14.6	24.8	1.576	1.564	0.7	95.7	18.9	12.0
	Rice Ex. St.	C2	26-44	23.6	66.2	7.9	2.3	FS	62.0	15.9	22.1	1.610	1.542	0.8	64.3	18.3	-
		C3	44-77	22.9	65.9	8.8	2.4	FS	64.0	17.8	28.2	1.664	1.562	0.8	80.9	19.5	-
		C4	77-100	22.4	63.3	6.8	7.5	LFS	61.0	21.2	17.8	1.584	1.416	0.9	80.3	20.2	-
103.	Udon Thani,	Apg	0-16	1.1	78.4	15.0	5.5	FSL	51.9	24.9	23.2	1.350	1.219	0.9	79.9	31.0	15.9
	Nong Han	A12g	16-25/31	1.4	79.1	15.8	3.7	FSL	70.4	15.6	14.0	1.830	1.342	0.9	85.9	30.6	14.7
		B1g	25/31-46	1.3	67.1	19.5	12.1	FSL	66.7	24.0	9.3	1.735	1.235	1.4	60.2	-	-
104.	Sakon Nakhon,	Apg	0-10	12.3	79.7	6.5	1.5	FS	61.0	14.2	24.8	1.585	1.501	0.8	72.4	27.8	10.9
	Sawang Daen Din	A12g	10-22	9.9	76.8	9.7	3.6	LFS	70.0	10.4	19.6	1.821	1.467	0.8	82.9	26.3	9.3
		B1g	22-35	10.6	73.5	13.8	2.1	LFS	69.4	9.7	20.9	1.805	1.482	0.7	79.6	-	-
		B2g	35-80	11.6	64.8	12.8	10.8	FSL	66.2	21.9	11.9	1.722	1.254	1.4	96.1	-	-
119.	Roi Et,	Apg	0-13	5.7	80.7	9.5	4.1	LFS	58.0	23.0	19.0	1.507	1.410	0.7	45.1	26.7	11.1
	Muang	C1g	13-40	8.1	84.4	4.6	2.9	FS	64.2	19.9	15.9	1.669	1.405	0.9	87.7	22.4	9.6
		C2g	40-80	9.2	85.6	4.3	0.9	FS	72.6	27.3	0.1	1.887	1.511	1.0	78.9	-	-
120.	Roi Et,	Apg	0-14	3.3	89.3	5.9	1.5	FS	62.3	20.6	17.1	1.619	1.436	0.8	85.7	26.0	10.2
	Chaturaphak	A12g	14-37	4.4	78.0	12.4	5.2	FSL	70.4	17.7	11.9	1.831	1.454	1.0	87.3	23.9	9.2
	Phiman	Cg	37-80	4.9	79.9	10.6	4.6	FSL	74.0	22.3	3.7	1.923	1.361	1.2	89.4	-	-
121.	Roi Et,	Ap	0-12	10.9	87.0	1.9	2.2	FS	-	-	-	-	1.520	0.7	93.2	23.4	9.5
	Kaset Wisai	C	12-75	15.3	82.4	2.2	0.1	FS	-	-	-	-	1.483	0.7	72.6	22.8	9.2

Non-Calcic Brown Soils

No.	Location	Horizon	Depth (cm)	CoS (%)	FS (%)	Silt (%)	Clay (%)	Texture	Three phase (%) SV	LV	AV	Bulk density Field	Air-dried	Sedimentation volume (ml/g)	Dispersion ratio (%)	Max. water-holding capacity (%)	Moisture equivalent (%)
114.	Ubon Ratchathani, Muang, Rice Ex. St.	Apg	0-7	1.6	17.0	39.0	42.4	LiC	45.9	14.5	39.6	1.542	1.167	1.4	93.8	45.9	28.2
		A12g	7-20	1.4	17.3	38.1	43.2	LiC	62.9	16.0	21.1	1.635	1.187	1.6	94.3	43.2	25.5
		B1g	20-33	0.3	6.1	18.8	74.8	HC	47.6	30.0	22.4	1.239	1.140	2.5	68.6	-	-
		B2g	33-80	0.4	9.9	21.7	68.0	HC	48.6	32.1	19.3	1.269	1.179	2.9	76.2	-	-
Northern Region																	
Fresh Water Alluvial Soils																	
25.	Chiang Mai, San Pa Thong, Rice Ex. St.	Apg	0-15	11.0	30.2	25.9	32.9	LiC	57.4	18.2	24.4	1.491	1.211	1.5	68.4	50.5	32.3
		A12g	15-30	20.6	34.8	19.2	25.4	SC	57.7	22.8	19.5	1.500	1.271	1.4	86.4	43.5	-
		IIC1g	30-45	28.8	32.5	15.8	22.9	SCL	55.5	22.8	21.7	1.433	1.279	1.3	94.9	45.1	-
		IIIC2g	45-55	5.4	48.8	23.5	22.3	CL	55.4	29.0	15.6	1.422	1.232	1.2	77.2	51.6	-
		IVBg	55-80	4.3	21.1	39.3	35.3	LiC	44.8	30.6	24.6	1.164	1.159	1.4	85.4	55.2	-
27.	Chiang Mai, San Kamphaeng	Apg	0-15	11.9	27.3	28.1	32.7	LiC	55.9	18.3	15.8	1.454	1.240	1.4	93.1	43.6	33.7
		B21g	15-30	7.3	22.6	30.7	39.4	LiC	54.3	19.6	26.1	1.410	1.228	1.6	93.9	45.7	28.8
		B22g	30-65	11.8	25.1	24.5	38.6	LiC	55.4	20.8	23.8	1.440	1.268	1.6	89.2	42.2	-
32.	Chiang Rai, Muang	Apg	0-12	15.5	44.8	21.4	18.3	CL	60.5	19.5	20.0	1.574	1.122	1.2	73.3	48.7	32.4
		B1g	12-25	38.6	16.6	20.5	24.3	CL	67.6	19.5	12.9	1.753	1.212	1.8	68.9	38.7	23.6
		B2g	25-60	35.9	19.8	11.7	32.6	SC	61.3	23.7	15.0	1.594	1.201	1.9	73.7	41.3	-
		Cg	60-80	30.0	21.1	10.9	38.0	LiC	-	-	-	-	1.116	2.0	24.5	51.5	-
81.	Chiang Rai, Chiang Saen	Apg	0-13	3.4	19.0	21.4	56.2	HC	43.4	33.2	23.4	1.127	0.863	1.6	72.0	60.1	39.7
		A12g	13-24	3.2	20.4	27.8	48.5	HC	45.2	29.4	25.4	1.176	0.913	1.6	74.3	50.9	37.4
		B21g	24-40	2.9	17.4	28.3	51.3	HC	42.5	28.3	29.2	1.104	0.942	1.7	63.9	-	-
		B22g	40-65	2.8	23.5	24.8	48.9	HC	33.9	26.9	39.2	0.880	0.913	1.6	56.4	-	-
83.	Chiang Rai, Mae Chan	Apg	0-12	13.4	10.9	44.1	31.6	LiC	46.7	41.3	12.0	1.213	0.977	1.5	86.9	58.2	42.1
		A12g	12-21	71.4	5.7	10.5	12.4	CoSL	54.6	38.4	7.0	1.420	1.265	1.2	86.3	33.9	15.4
		IIC1g	21-40	29.1	10.6	26.7	33.6	LiC	59.7	33.6	6.7	1.552	1.149	1.3	92.0	-	-
		IIIC2g	40-56	5.1	17.1	35.3	42.5	LiC	47.3	42.6	10.1	1.231	1.318	1.9	99.7	-	-
84.	Chiang Rai, Muang	Apg	0-12	1.2	2.5	36.5	59.8	HC	42.8	33.8	23.4	1.113	0.922	-	69.7	56.8	35.2
		C1g	12-37	2.3	5.7	31.8	60.2	HC	44.0	34.1	21.9	1.144	1.122	-	72.6	54.0	33.7
		C2g	37-65	1.2	0.7	40.0	58.1	HC	50.4	37.6	12.0	1.309	1.015	-	64.2	-	-
146.	Nan, Muang	Apg	0-10	0.4	9.0	55.1	35.5	SiC	40.6	24.1	35.3	1.056	0.921	1.7	87.9	63.2	48.2
		C1g	10-18	0.9	7.6	51.0	40.4	SiC	60.8	23.1	16.1	1.582	1.080	1.8	83.0	59.2	41.1
		C2g	18-55	1.8	8.5	47.8	41.9	SiC	58.5	34.5	7.0	1.520	1.187	2.0	92.0	-	-
152.	Chiang Rai, Mae Chan	Apg	0-10	1.5	14.9	42.0	41.6	LiC	44.8	39.1	16.1	1.166	1.216	1.9	41.0	70.9	54.1
		A12g	10-25	2.2	11.3	45.7	40.8	LiC	46.8	40.1	13.1	1.218	0.982	1.9	45.8	63.0	48.5
		B1g	25-40	3.2	12.5	39.7	44.3	LiC	43.7	43.5	12.8	1.137	1.019	2.1	60.6	-	-
		B2g	40-65	5.7	19.4	34.5	40.4	LiC	43.3	35.0	21.7	1.127	1.143	2.1	70.6	-	-

Low Humic Gley Soils

No.	Location	Horizon	Depth (cm)	CoS (%)	FS (%)	Silt (%)	Clay (%)	Texture	Three phase (%) SV	LV	AV	Bulk density Field	Air-dried	Sedimentation volume (ml/g)	Dispersion ratio (%)	Max. water-holding capacity (%)	Moisture equivalent (%)
26.	Chiang Mai, Mae Taeng	Apg	0-15	3.7	23.7	35.3	37.3	LiC	46.3	27.7	26.0	1.204	1.099	1.8	70.7	59.5	38.6
		A12g	15-25	4.5	23.2	31.8	40.5	LiC	56.5	33.3	10.2	1.466	1.220	1.9	76.8	54.4	37.1
		B21g	25-45	4.9	14.6	33.3	47.2	HC	43.3	33.0	23.7	1.127	1.094	1.9	91.9	69.9	-
		B22g	45-90	4.2	21.8	34.9	39.1	LiC	50.4	42.1	7.5	1.305	1.108	2.1	79.2	66.8	-
28.	Lampang, Hang Chat	Apg	0-15	2.5	25.5	39.9	32.1	LiC	56.0	15.2	28.8	1.457	1.087	1.4	99.0	52.4	30.4
		B1g	15-25	5.0	16.4	36.6	42.0	LiC	59.2	26.5	14.3	1.538	1.139	1.6	90.2	52.0	29.4
		B2g	25-65	5.0	15.0	36.6	43.4	LiC	60.1	29.1	10.8	1.562	1.172	1.7	85.9	51.9	-
30.	Lampang, Ngao	Apg	0-15	1.1	19.1	53.4	26.4	SiC	56.5	26.5	17.0	1.468	1.126	1.6	81.2	52.2	30.2
		B1g	15-25	1.7	10.4	55.7	32.2	SiC	63.5	26.0	10.5	1.651	1.273	1.8	80.2	42.4	26.2
		B2g	25-65	2.9	8.1	53.4	35.6	SiC	56.3	26.6	17.1	1.464	1.236	1.9	79.8	43.5	-
33.	Chiang Rai, Phan, Rice Ex. St.	Apg	0-15	2.7	11.4	31.7	54.2	HC	45.4	39.5	15.1	1.178	1.218	1.8	84.5	51.3	30.5
		A12g	15-25	1.7	8.8	28.7	60.7	HC	45.0	30.9	24.1	1.169	1.174	2.2	65.4	51.2	30.3
		B21g	25-45	1.4	6.2	23.8	68.6	HC	47.0	37.7	15.3	1.227	1.163	2.2	67.5	52.3	-
		B22g	45-65	0.5	7.1	33.7	58.7	HC	-	-	-	-	1.160	2.3	43.9	55.6	-
34.	Chiang Rai, Phayao	Apg	0-13	0.5	13.7	29.5	56.3	HC	-	-	-	-	1.114	1.8	56.0	54.2	30.1
		B21g	13-25	0.8	21.7	35.5	41.9	LiC	-	-	-	-	1.235	1.8	57.4	45.3	24.2
		B22g	25-45	2.9	19.4	28.8	49.0	HC	-	-	-	-	1.200	1.8	65.4	48.2	-
		B23g	45-75	1.0	20.4	29.9	48.7	HC	-	-	-	-	1.166	2.0	46.8	52.3	-
35.	Phrae, Muang, Rice Ex. St.	Apg	0-15	3.8	29.0	52.1	15.1	SiCL	-	-	-	-	1.184	1.1	90.0	41.0	17.4
		A12g	15-30	5.6	29.2	50.7	14.5	SiL	-	-	-	-	1.294	1.1	92.1	38.0	-
		B1g	30-50	5.8	29.2	45.4	19.6	SiCL	-	-	-	-	1.216	1.1	89.7	42.3	-
		B2g	50-75	3.9	22.7	52.0	21.4	SiCL	-	-	-	-	1.232	1.2	77.8	42.2	-
85.	Lampang, Ngao	Apg	0-12	0.9	11.3	39.0	48.8	HC	52.1	16.7	31.2	1.355	1.006	-	72.8	53.6	31.4
		B21g	12-35	1.1	4.0	44.0	50.9	HC	63.1	24.2	12.7	1.639	1.154	-	66.1	47.8	25.0
		B22g	35-65	4.0	4.8	40.7	50.5	HC	64.6	23.6	11.8	1.680	1.145	-	79.7	-	-
86.	Lampang, Muang	Apg	0-13	6.3	13.9	45.3	34.5	SiC	56.9	33.3	9.8	1.479	0.997	-	85.5	-	-
		B1g	13-24	5.2	14.5	48.7	31.6	SiC	62.7	28.9	8.4	1.631	1.240	-	91.3	-	-
		B2g	24-39	4.4	16.1	45.3	34.2	SiC	57.5	28.8	13.7	1.495	1.208	-	88.3	-	-
		BCg	39-65	6.1	21.1	42.0	30.7	SiC	-	-	-	-	-	-	94.5	-	-
87.	Lamphun, Muang	Apg	0-10	12.8	44.3	30.7	12.3	L	50.4	10.6	39.0	1.410	1.424	1.1	95.4	48.4	26.2
		A12g	10-18	17.8	42.2	30.8	9.2	L	68.3	10.2	21.5	1.776	1.451	1.1	88.0	44.1	24.9
		B21g	18-33	16.3	34.6	27.4	21.7	CL	60.8	17.4	21.8	1.582	1.212	1.2	94.6	-	-
		B22g	33-65	14.0	31.8	25.0	29.2	LiC	48.2	16.2	35.6	1.253	1.368	1.5	97.4	-	-
88.	Chiang Mai, Hang Dong	Apg	0-12	1.6	10.4	49.9	38.1	SiC	41.6	40.4	18.0	1.081	1.038	2.0	58.7	-	-
		A12g	12-18	3.1	10.5	53.7	32.6	SiC	57.8	41.3	0.9	1.503	1.134	1.9	75.9	-	-
		A12g	18-25	4.5	16.1	47.9	31.5	SiC	58.6	40.1	1.3	1.524	1.183	2.1	90.4	-	-
		ABG	25-38	6.8	14.2	41.6	37.4	LiC	53.9	44.7	1.4	1.401	1.173	2.2	93.8	-	-
		B21g	38-48	6.3	20.8	45.0	27.9	SiC	54.4	40.0	5.6	1.415	1.154	-	97.5	-	-
89.	Chiang Mai, Doi Saket	Apg	0-15	4.6	8.1	55.4	31.8	SiC	45.9	38.3	15.8	1.194	1.043	-	80.6	49.2	29.1
		B21g	15-43	6.1	3.9	40.5	49.5	HC	52.0	29.9	18.1	1.353	1.188	-	86.8	47.3	27.8
		B22g	43-55	4.7	5.1	36.9	53.4	HC	55.5	32.5	12.0	1.444	1.068	-	92.7	-	-
		IICg	55-75	5.4	8.1	28.9	57.6	HC	48.7	28.6	22.7	1.267	1.054	-	93.8	-	-

No.	Location	Horizon	Depth (cm)	CoS (%)	FS (%)	Silt (%)	Clay (%)	Texture	Three phase (%) SV	LV	AV	Bulk density Field	Air-dried	Sedimentation volume (ml/g)	Dispersion ratio (%)	Max. water-holding capacity (%)	Moisture equivalent (%)
143.	Phrae,	Apg	0-6	5.3	22.7	42.1	29.9	LiC	52.3	12.3	35.4	1.360	1.096	1.6	72.0	59.2	36.7
	Sung Men	B1g	6-22	7.0	22.5	43.8	26.7	LiC	64.1	18.1	17.8	1.660	1.224	1.4	88.5	47.9	27.5
		B2g	22-65	10.1	16.6	38.8	34.5	LiC	55.7	25.9	18.4	1.447	1.187	1.8	99.9	-	-
144.	Nan,	Apg	0-10	0.4	19.5	49.2	30.9	SiC	41.6	19.9	38.5	1.083	1.013	1.6	84.7	63.7	36.3
	Sa	A12g	10-20	0.5	23.4	47.2	28.9	SiC	62.3	23.9	13.8	1.619	1.146	1.6	86.7	54.6	32.0
		B21g	20-26	1.4	20.2	43.7	34.6	LiC	59.9	23.2	16.9	1.557	1.254	1.7	91.5	-	-
		B22g	26-65	7.0	17.8	42.6	32.5	LiC	62.7	26.6	10.7	1.630	1.239	1.7	96.4	-	-
145.	Nan,	Apg	0-10	0.5	10.6	50.5	38.4	SiC	46.1	32.0	21.9	1.199	1.006	1.5	91.7	68.7	40.4
	Muang	B1g	10-26	1.0	8.3	53.7	37.0	SiC	56.3	23.8	20.9	1.464	1.106	1.9	90.1	56.1	36.1
		B2g	26-65	1.8	12.0	46.6	39.6	SiC	62.9	27.6	9.5	1.636	1.116	2.1	95.1	-	-
147.	Phrae,	Apg	0-15	3.3	30.8	51.7	14.2	SiL	58.2	19.4	22.4	1.514	1.165	1.1	82.6	48.0	23.2
	Muang,	B1g	15-35	3.7	35.8	47.8	12.7	SiL	70.6	15.2	14.2	1.835	1.337	1.0	88.9	36.3	16.9
	Pa Daen	B2g	35-80	5.9	42.7	39.1	12.3	L	70.4	19.6	10.0	1.829	1.416	1.2	92.5	-	-
148.	Phrae,	Apg	0-13	1.3	21.7	46.0	31.0	SiC	61.1	19.1	19.8	1.587	1.105	1.4	78.8	52.2	27.6
	Song	B1g	13-23	1.7	17.5	43.3	37.5	LiC	65.4	23.7	10.9	1.701	1.247	1.5	85.9	49.8	23.9
		B2g	23-65	2.8	14.9	41.3	41.0	LiC	65.5	26.8	7.7	1.703	1.251	1.8	77.5	-	-
149.	Chiang Rai,	Apg	0-10	0.5	21.8	34.0	43.7	LiC	58.6	12.4	29.0	1.523	1.131	1.7	76.4	55.8	39.1
	Dok Kham Tai	A12g	10-18	0.6	19.2	33.0	47.2	HC	63.6	28.4	8.0	1.653	1.229	2.1	87.5	48.6	35.1
		B1g	18-40	0.9	13.8	24.2	61.1	HC	63.5	26.8	9.7	1.652	1.272	2.6	88.3	-	-
		B2g	40-65	1.2	15.9	31.4	51.5	HC	58.0	26.8	15.2	1.507	1.302	2.6	86.6	-	-
150.	Chiang Rai,	Apg	0-10	0.5	13.5	44.9	41.1	LiC	43.5	28.8	28.3	1.131	1.051	1.7	87.6	65.0	35.5
	Mae Chai	A12g	10-20	0.8	11.2	45.2	42.8	SiC	62.8	27.2	10.0	1.633	1.197	1.9	87.7	55.2	30.6
		B1g	20-45	2.5	5.6	39.9	52.0	HC	58.1	30.2	11.7	1.510	1.205	2.0	91.1	-	-
		B2g	45-70	4.5	5.9	40.3	49.3	HC	58.7	33.2	8.1	1.527	1.198	2.2	86.8	-	-
151.	Chiang Rai,	Apg	0-11	2.2	13.2	31.6	53.0	HC	53.9	35.2	10.9	1.402	1.195	2.0	87.7	53.9	32.2
	Phan,	A12g	11-20	1.8	9.8	29.9	58.5	HC	55.3	33.1	11.6	1.437	1.235	2.2	81.3	48.1	30.4
	Rice Ex. St.	B21g	20-35	0.6	8.3	30.2	60.9	HC	61.6	21.1	17.3	1.607	1.239	2.3	79.6	-	-
		B22g	35-65	0.4	7.9	31.0	60.7	HC	50.5	40.0	9.5	1.313	1.156	2.5	63.5	-	-
153.	Chiang Rai,	Apg	0-10	1.0	19.2	26.5	53.3	HC	43.0	35.5	21.5	1.118	0.987	1.8	98.2	59.2	39.1
	Chiang Saen	B1g	10-20	2.2	22.0	32.2	43.6	LiC	50.0	35.4	14.6	1.299	1.071	1.9	87.8	58.0	33.4
		B2g	20-50	1.9	25.4	38.4	34.3	LiC	50.1	34.2	15.7	1.304	1.078	1.9	86.5	-	-
154.	Lampang,	Apg	0-8	6.3	33.7	41.7	18.3	CL	52.4	17.1	30.5	1.362	1.123	1.3	98.2	54.6	28.3
	Muang	B1g	8-15	11.3	33.8	37.1	17.8	CL	57.5	13.6	28.9	1.495	1.279	1.3	87.8	46.2	26.0
		B2g	15-50	11.8	35.3	30.4	22.5	CL	63.0	22.2	14.8	1.637	1.258	1.3	86.5	-	-
155.	Chiang Mai,	Apg	0-9	4.0	22.5	45.9	27.6	SiC	50.0	19.0	31.0	1.299	1.052	1.4	85.3	50.1	28.5
	Chiang Dao	A12g	9-19	8.1	24.6	41.3	26.0	LiC	62.9	25.9	11.2	1.636	1.239	1.5	92.5	45.2	27.8
		B1g	19-30	15.3	18.8	38.6	27.3	LiC	64.2	16.3	19.5	1.669	1.255	1.7	92.4	-	-
		B2g	30-55	23.9	13.3	13.7	49.1	HC	60.1	23.9	16.0	1.564	1.230	1.8	94.5	-	-
156.	Chiang Mai,	Apg	0-13	16.5	53.9	16.5	13.1	FSL	56.8	8.9	34.3	1.476	1.285	1.6	89.9	45.9	23.1
	Fang, Mae Ai	B1g	13-23	19.6	50.1	15.0	15.3	SCL	64.8	11.6	23.6	1.685	1.375	1.3	90.1	36.3	16.7
		B2g	23-65	19.1	46.6	15.3	19.0	SCL	62.8	12.1	25.1	1.634	1.381	1.6	90.4	-	-

No.	Location	Horizon	Depth (cm)	CoS (%)	FS (%)	Silt (%)	Clay (%)	Texture	Three phase (%) SV	LV	AV	Bulk density Field	Air-dried	Sedimentation volume (ml/g)	Dispersion ratio (%)	Max. water-holding capacity (%)	Moisture equivalent (%)
157.	Chiang Mai,	Apg	0-13	0.8	14.0	27.0	58.2	HC	53.0	37.7	9.3	1.379	0.995	1.2	80.9	62.9	44.9
	Fang, Wieng	A12g	13-23	1.2	12.3	46.0	40.5	SiC	57.6	33.3	9.1	1.497	1.117	1.9	77.8	55.7	39.6
		B1g	23-45	10.8	18.4	37.8	33.0	LiC	53.6	32.3	14.1	1.394	1.024	2.1	83.9	-	-
		B2g	45-70	31.1	17.5	29.5	21.9	CL	57.6	20.8	11.6	1.758	1.045	1.6	99.7	-	-
158.	Chiang Mai,	Apg	0-7	5.8	44.3	25.3	24.6	CL	55.0	15.5	29.5	1.432	1.044	1.4	84.8	49.3	29.3
	Fang, Pong Tam	A12g	7-20	7.6	42.5	23.7	26.2	LiC	68.0	20.5	11.5	1.767	1.198	1.7	80.7	42.3	27.1
		B1g	20-30	7.0	41.8	23.1	28.1	LiC	65.0	22.7	12.3	1.689	1.196	1.9	89.5	-	-
		B2g	30-55	9.9	42.5	20.9	26.7	LiC	45.4	28.7	25.9	1.181	1.184	1.8	99.4	-	-
Humic Gley Soils																	
31.	Chiang Rai,	Apg	0-15	1.3	6.6	30.1	62.0	HC	37.1	30.9	32.0	0.966	1.018	1.8	57.5	64.6	44.0
	Mae Sai	A12g	15-25	1.2	6.1	30.9	61.8	HC	52.2	33.9	13.9	1.358	1.128	2.0	66.3	52.2	-
		B1g	25-40	1.7	6.8	27.0	64.5	HC	50.6	33.0	16.4	1.316	1.198	2.0	73.2	47.3	-
		B2g	40-60	1.6	7.5	22.2	68.7	HC	47.5	30.2	22.3	1.235	1.133	2.0	65.9	52.4	-
		Cg	60-85	0.8	3.4	21.6	74.2	HC	-	-	-	-	1.138	2.3	62.6	55.7	-
82.	Chiang Rai,	Apg	0-20	1.6	10.9	31.8	55.7	HC	42.8	31.9	25.3	1.113	0.976	1.5	50.2	64.3	40.0
	Mae Sai	B21g	20-32	4.5	6.6	29.9	59.0	HC	46.4	33.8	19.8	1.214	1.076	2.1	74.6	51.7	-
		B22g	32-48	2.5	6.2	29.3	62.0	HC	45.2	33.6	22.2	1.175	1.063	2.2	79.1	-	-
		BCg	48-65	2.2	9.5	33.0	55.3	HC	49.9	37.1	13.0′	1.296	1.134	2.2	74.0	-	-
Gray Podzolic Soils																	
24.	Chiang Mai,	Apg	0-20	36.8	42.8	9.9	10.5	SL	59.6	24.4	16.0	1.550	1.273	1.0	63.5	39.4	15.6
	Chom Thong	A12	20-35	41.0	44.7	8.4	5.9	LS	66.7	10.8	22.5	1.734	1.306	0.9	71.3	27.3	11.3
		B1	35-70	41.2	51.8	5.4	1.6	FS	68.7	21.1	10.6	1.907	1.466	0.9	94.4	26.9	-
		B2	70-85	44.0	42.9	6.9	6.4	LS	68.2	20.7	11.1	1.774	1.248	1.0	75.3	37.4	-
Southern Region																	
Marine Alluvial Soils																	
171.	Nakhon Si Tham-	Apg	0-15	0.9	4.5	39.4	55.2	HC	39.8	41.0	19.2	1.055	1.236	2.8	98.3	68.7	49.9
	marat, Muang,	A12g	15-30	0.2	5.2	35.9	58.6	HC	46.4	43.2	10.4	1.229	1.291	4.0	98.6	65.2	45.2
	Rice Ex. St.	Cg	30-50	0.2	5.0	30.6	64.1	HC	43.3	44.8	11.9	1.148	1.276	4.2	93.1	-	-
Brackish Water Alluvial Soils																	
94.	Songkhala,	Apg	0-18	4.2	25.8	37.1	32.9	LiC	40.9	27.9	31.2	1.064	1.077	1.7	86.9	-	-
	Muang	B1g	18-33	9.5	16.9	23.7	49.9	HC	42.5	30.0	37.5	1.105	1.204	2.3	75.8	-	-
		IIB2g	33-	4.3	12.7	23.3	59.7	HC	47.2	27.7	25.1	1.228	1.258	2.5	75.7	-	-

Fresh Water Alluvial Soils

No.	Location	Horizon	Depth (cm)	CoS (%)	FS (%)	Silt (%)	Clay (%)	Texture	Three phase (%) SV	LV	AV	Bulk density Field	Air-dried	Sedimentation volume (ml/g)	Dispersion ratio (%)	Max. water-holding capacity (%)	Moisture equivalent (%)
92.	Phatthalung,	Apg	0-13	2.5	30.8	53.7	13.0	SiCL	59.5	16.4	24.1	1.547	1.119	1.0	95.0	-	-
	Khuan Khanun,	A12g	13-22	2.9	25.4	57.1	14.6	SiCL	58.1	20.8	11.1	1.382	1.262	1.0	55.6	-	-
	Rice Ex. St.	IIB21g	22-33	2.7	19.3	50.3	27.7	SiC	49.4	25.8	24.8	1.284	1.190	1.2	93.2	-	-
		IIB22g	33-	0.8	12.8	46.1	40.4	SiC	55.1	20.0	24.9	1.434	1.012	1.8	14.6	-	-
174.	Phatthalung,	Apg	0-17	0.8	17.0	42.5	39.7	LiC	62.8	25.2	12.0	1.665	1.248	1.7	93.3	48.3	34.3
	Khuan Khanun,	B1g	17-30	3.8	9.7	37.7	48.8	HC	61.0	23.4	15.6	1.617	1.263	2.5	82.5	46.1	28.9
	Rice Ex. St.	B21g	30-60	1.6	5.2	33.2	60.0	HC	51.5	34.3	14.2	1.366	1.178	2.5	54.5	-	-
		B22g	60-75	1.4	6.4	24.6	67.5	HC	45.3	29.6	15.1	1.201	1.205	2.7	48.8	-	-
175.	Phatthalung,	Apg	0-14	0.8	25.5	42.3	31.3	LiC	54.1	21.3	24.6	1.435	1.254	1.8	84.7	45.7	31.4
	Khuan Khanun,	B1g	14-23	0.7	30.0	36.1	33.2	LiC	58.5	23.9	17.6	1.550	1.299	2.0	80.2	43.4	30.2
	Rice Ex. Subst.	B2g	23-70	0.4	19.8	35.6	44.2	LiC	58.5	26.6	14.9	1.552	1.216	2.1	52.1	-	-
Low Humic Gley Soils																	
91.	Phatthalung,	Apg	0-10	4.9	36.4	38.1	20.6	CL	41.3	31.4	27.3	1.073	1.158	1.3	63.2	-	-
	Muang	A12g	10-20	3.5	29.7	45.3	21.5	SiCL	47.3	35.0	17.7	1.230	1.202	1.4	93.2	-	-
		G1	20-	6.3	19.6	26.5	47.6	HC	45.1	31.8	23.1	1.172	1.175	1.9	80.6	-	-
93.	Songkhla,	Apg	0-19	7.8	61.0	12.6	18.6	SCL	50.0	26.3	33.7	1.291	1.256	1.2	55.5	-	-
	Pattaphum	B21g	19-37	4.8	47.2	19.8	28.2	LiC	60.2	31.1	8.7	1.566	1.292	1.3	88.5	-	-
		B22g	37-	3.2	39.1	22.9	34.8	LiC	43.8	32.1	24.1	1.139	1.177	1.7	95.1	-	-
164.	Prachuap Khiri	Apg	0-15	23.8	45.1	21.3	9.7	FSL	60.3	25.4	14.3	1.568	1.317	1.4	95.6	42.2	24.3
	Khan, Thap Sakae	B1g	15-32	13.9	37.0	21.2	27.9	LiC	65.8	27.2	7.0	1.745	1.421	3.5	93.6	51.0	36.1
		B2g	32-65	6.8	41.2	22.8	29.1	LiC	58.0	26.4	15.6	1.538	1.349	4.3	92.4	-	-
165.	Chumphon,	Apg	0-15	1.9	53.5	27.8	16.8	CL	65.1	28.1	6.8	1.726	1.268	1.4	98.9	49.5	29.6
	Muang	A12g	15-25	4.2	47.9	26.3	21.6	CL	65.4	30.3	4.3	1.733	1.397	1.9	93.1	40.7	25.8
		B1g	25-65	1.7	46.6	28.4	23.3	CL	62.4	26.5	11.1	1.655	1.411	1.8	92.3	-	-
		B2g	65-85	2.8	49.0	26.6	21.5	CL	67.8	28.0	4.2	1.797	1.431	2.1	90.7	-	-
167.	Pangnga,	Apg	0-15	1.5	7.0	30.0	61.5	HC	45.2	39.6	15.2	1.197	1.344	2.3	74.2	73.1	46.5
	Thai Muang	B1g	15-32	0.6	9.6	29.0	60.8	HC	45.3	40.5	14.2	1.200	1.061	2.6	88.5	68.3	42.1
		B2g	32-66	1.1	6.2	26.5	66.2	HC	46.4	47.3	6.3	1.229	1.301	2.8	98.0	-	-
170.	Krabi,	Apg	0-17	30.2	50.6	15.0	4.1	FSL	47.2	24.8	28.0	1.251	1.370	1.0	86.2	41.3	21.9
	Khlong Thom	ABg	17-30	29.7	46.9	16.6	6.7	FSL	68.5	21.3	10.2	1.815	1.580	1.1	94.3	34.4	20.1
		B1g	30-51	27.7	43.7	16.3	12.2	SL	66.0	31.7	2.3	1.749	1.536	1.4	99.3	-	-
		B2g	51-70	22.5	40.1	12.7	24.7	SCL	53.6	35.3	11.1	1.420	1.415	1.7	93.5	-	-
172.	Nakhon Si Tham-	Apg	0-13	18.0	43.0	26.4	12.6	SL	54.3	23.7	12.0	1.438	1.087	1.5	93.4	50.2	28.2
	marat,	B1g	13-23	16.0	48.4	21.7	13.9	FSL	56.7	32.2	11.1	1.503	1.276	1.7	94.6	45.8	22.1
	Thung Song	B2g	23-50	5.9	27.6	36.7	29.8	LiC	43.6	44.2	12.2	1.155	1.189	2.1	83.4	-	-

No.	Location	Horizon	Depth (cm)	CoS (%)	FS (%)	Silt (%)	Clay (%)	Texture	Three phase (%) SV	LV	AV	Bulk density Field	Air-dried	Sedimentation volume (ml/g)	Dispersion ratio (%)	Max. water-holding capacity (%)	Moisture equivalent (%)
173.	Trang, Muang	Apg	0-16	1.4	30.4	35.6	32.6	LiC	48.1	39.2	12.7	1.274	1.088	1.7	73.9	51.0	29.3
		B1g	16-45	3.4	42.0	22.6	31.9	LiC	48.7	34.1	17.2	1.290	1.260	1.8	84.1	49.3	23.0
		B2g	45-75	3.9	42.1	22.5	31.5	LiC	49.6	36.4	14.0	1.316	1.290	1.9	78.9	-	-
176.	Satun, Muang	Apg	0-10	0.9	21.7	46.5	30.9	SiC	45.9	39.5	14.6	1.216	1.128	1.5	94.1	64.2	34.8
		B1g	10-23	5.6	12.6	32.6	49.2	HC	52.4	41.6	6.0	1.388	1.163	1.9	91.2	56.5	31.7
		B2g	23-35	1.7	13.5	33.3	51.5	HC	49.8	40.2	10.0	1.321	1.107	1.8	88.9	-	-
		Cg	35-72	0.2	11.5	34.9	53.3	HC	49.3	41.9	8.8	1.307	1.158	1.7	83.5	-	-
177.	Songkhla, Muang	Apg	0-10	1.2	34.1	41.1	23.6	CL	46.8	34.6	18.6	1.240	1.090	1.5	85.5	49.4	28.5
		B1g	10-21	0.9	27.2	41.4	30.5	LiC	63.0	33.4	3.6	1.671	1.229	1.9	92.5	48.4	27.7
		B2g	21-38	1.4	29.2	43.7	25.7	LiC	60.1	32.0	7.9	1.592	1.281	1.8	98.5	-	-
		B3g	38-68	1.5	23.5	47.1	27.9	SiC	63.3	31.7	5.0	1.679	1.277	1.7	95.3	-	-
179.	Pattani, Khok Pho, Rice Ex. St.	Apg	0-12	26.3	30.1	29.0	14.6	L	63.7	26.9	9.4	1.688	1.319	2.0	80.3	38.4	17.3
		B1g	12-28	21.1	26.5	13.3	39.1	LiC	59.2	27.1	13.7	1.526	1.265	1.8	79.4	42.0	21.5
		B2g	28-70	20.0	27.7	14.7	37.6	LiC	57.4	28.3	14.3	1.521	1.280	2.0	45.9	-	-
180.	Pattani, Muang	Apg	0-12	11.9	42.8	28.2	17.1	CL	52.2	26.1	11.7	1.382	1.110	1.3	84.2	48.2	26.5
		B1g	12-26	21.5	25.5	29.9	23.1	CL	57.8	31.2	11.0	1.532	1.330	2.2	93.0	44.3	23.0
		B2g	26-65	19.7	21.3	32.5	26.5	LiC	61.0	33.0	5.7	1.618	1.320	2.5	92.2	-	-
181.	Yala, Raman	Apg	0-12	23.0	48.3	18.2	10.5	FSL	53.8	41.6	4.6	1.426	0.993	1.5	71.0	53.7	21.4
		B1g	12-22	31.1	46.8	15.7	6.4	FSL	60.7	35.0	4.3	1.562	1.478	1.4	69.5	44.5	17.6
		B2g	22-42	27.3	40.8	17.5	14.4	SL	65.0	31.6	3.4	1.722	1.425	1.6	94.1	-	-
		B3g	42-70	27.6	39.4	15.2	17.7	SCL	65.0	32.8	2.2	1.723	1.367	1.9	91.7	-	-
182.	Narathiwat, Muang	Apg	0-15	0.5	25.3	24.4	49.8	HC	43.5	44.5	12.0	1.153	1.024	2.2	75.9	74.6	37.9
		B1g	15-30	0.8	34.3	14.8	50.1	HC	44.8	45.6	9.6	1.162	1.122	2.3	48.7	63.5	34.6
		B2g	30-40	0.5	54.4	10.2	34.9	LiC	45.8	47.9	6.3	1.213	1.185	2.3	42.7	-	-
		IIC1g	40-60	2.2	72.8	9.4	15.7	SCL	54.0	43.7	2.3	1.432	1.221	1.9	90.7	-	-
		IIC2g	60-90	3.1	70.0	12.2	14.6	FSL	48.0	50.0	2.0	1.272	1.191	1.7	42.8	-	-
Regosols																	
90.	Phuket, Thalang	Apg	0-11	36.3	32.6	17.2	13.4	SL	59.8	28.7	11.5	1.555	1.164	1.2	84.7	-	-
		A12g	11-18	49.3	21.1	19.1	10.5	CoSL	44.3	31.1	24.6	1.152	1.283	1.2	86.6	-	-
166.	Ranong, Krabi	Apg	0-13	6.7	65.7	20.0	7.6	FSL	53.7	38.1	8.2	1.422	1.143	1.4	80.9	48.5	22.6
		Bg	13-40	4.9	64.2	21.9	8.1	FSL	53.7	38.1	8.2	1.422	1.362	1.4	93.4	43.9	20.4
168.	Phuket, Thalang	Apg	0-15	48.0	28.5	11.4	12.1	CoSL	54.8	31.6	14.6	1.452	1.405	1.2	95.6	44.4	24.5
		B1g	15-30	45.0	30.9	11.4	12.6	CoSL	61.4	34.0	4.6	1.628	1.395	1.6	76.3	36.8	18.4
		B2g	30-55	47.7	28.9	11.1	12.3	CoSL	57.1	33.7	9.2	1.480	1.285	1.9	96.8	-	-
		IIC	55-85	74.1	19.5	5.0	1.4	CoS	56.9	32.2	10.9	1.508	1.490	1.1	67.9	-	-

Gray Podzolic Soils

No.	Location	Horizon	Depth (cm)	CoS (%)	FS (%)	Silt (%)	Clay (%)	Texture	Three phase (%) SV	Three phase (%) LV	Three phase (%) AV	Bulk density Field	Bulk density Air-dried	Sedimentation volume (ml/g)	Dispersion ratio (%)	Max. water-holding capacity (%)	Moisture equivalent (%)
169.	Pangnga, Thap Put	Apg	0-8	9.5	56.4	19.7	14.4	FSL	67.7	27.4	4.9	1.795	1.249	1.3	90.9	43.8	22.5
		Blg	8-17	8.5	40.3	25.9	25.3	LiC	64.0	30.5	4.5	1.696	1.323	1.8	90.9	41.5	18.8
		B21g	17-35	5.9	31.4	26.9	35.8	LiC	48.8	35.6	15.6	1.295	1.269	2.0	83.3	-	-
		B22g	35-62	5.9	27.3	25.6	41.2	LiC	43.6	29.7	26.7	1.156	1.183	1.9	68.0	-	-
		B3g	62-85	9.2	23.7	24.6	42.5	LiC	46.8	34.1	19.1	1.240	1.225	1.9	22.6	-	-
178.	Songkhla, Na Thawi	Apg	0-13	1.8	58.2	26.4	13.6	L	51.1	42.4	6.5	1.353	1.093	1.2	99.3	45.1	22.0
		Blg	13-25	1.9	55.6	24.7	17.8	CL	55.9	36.4	7.7	1.481	1.355	1.8	89.0	39.1	21.0
		B2g	35-52	1.6	53.5	23.8	21.1	CL	61.9	21.7	16.4	1.640	1.361	2.1	89.1	-	-
		B3g	52-70	1.5	50.0	25.6	22.9	CL	59.5	15.2	25.3	1.577	1.179	2.5	92.8	-	-

2. Analytical Data on Chemical Properties

Central Plain

Marine Alluvial Soils

No.	Location	Horizon	Depth (cm)	pH (H_2O)	pH (KCl)	T-C %	C/N	T-N %	Av-N ppm	T-P_2O_5 mg/100g	Av-P_2O_5 ppm	Abs. coeff. P_2O_5 mg/100g	T-K_2O mg/100g	Av-K_2O ppm	C.E.C. meq/100g	Ex. Bases meq/100g Ca	Mg	Na	K	(%)*
1.	Phra Nakhon,	Apg	0-15	5.4	4.5	1.32	12.0	0.11	48.0	55.7	9.2	1442	955	532	32.75	12.16	16.96	9.23	1.13	120.5
	Bang Khen,	A12g	15-30	5.9	4.7	1.34	11.2	0.12	-	52.9	9.6	1414	1007	575	33.13	12.17	17.08	8.50	1.22	117.6
	Rice Ex. St.	AIICg	30-50	5.1	4.1	1.16	14.5	0.08	-	47.9	6.1	1534	719	518	30.33	11.76	18.45	10.14	1.10	136.7
		IIC1g	50-65	6.1	4.4	0.23	5.8	0.04	-	49.7	1.6	1498	743	466	24.84	13.26	18.05	11.25	0.99	175.3
		IIC2g	65-	6.3	4.5	0.18	6.0	0.03	-	47.7	5.7	1177	876	594	29.61	14.10	20.46	12.59	1.26	163.5
2.	Phra Nakhon,	Apg	0-15	5.2	4.3	1.41	10.8	0.13	49.5	63.7	12.1	1444	1239	603	33.05	11.44	17.07	9.72	1.28	119.5
	Bang Khen,	A12g	15-30	5.1	4.0	1.21	11.0	0.11	-	62.1	9.0	1493	1267	528	33.04	10.29	16.19	7.45	1.12	106.1
	Rice Ex. St.	AIICg	30-45	4.8	3.7	0.89	8.9	0.10	-	51.8	4.6	1581	1218	466	30.38	8.78	16.31	7.98	0.99	112.1
		IIC1g	45-65	5.3	4.0	0.42	8.4	0.05	-	55.2	2.1	1479	973	462	28.56	15.21	15.21	8.80	0.98	140.8
8.	Phetchaburi,	Apg	0-10/15	5.4	4.7	1.17	11.7	0.10	33.6	31.6	10.9	1288	860	377	25.34	5.21	6.10	2.63	0.80	58.2
	Muang	A12g	10/15-20	6.3	5.4	0.95	11.9	0.08	-	29.3	9.5	1216	989	377	26.44	5.67	6.55	3.96	0.80	64.2
		C1g	20-40	7.1	6.55	0.38	9.5	0.04	-	29.1	29.8	1365	927	480	28.09	14.10	10.28	9.82	1.02	92.5
		C2g	40-65	7.85	7.55	0.26	8.7	0.03	-	51.6	-	513	889	386	30.28	21.05	12.55	11.68	0.82	149.6
9.	Samut Songkhram	Apg	0-10/15	6.15	5.45	1.43	13.0	0.11	54.9	52.7	9.7	1428	1097	829	39.95	14.98	19.68	12.84	1.76	123.3
	Amphawa	A12g	10/15-20	6.8	6.05	0.91	15.2	0.06	-	44.0	31.8	1592	1196	867	37.92	17.37	21.43	15.47	1.84	147.8
		C1g	20-43	7.05	6.35	0.61	12.2	0.05	-	47.2	-	1457	1243	881	36.02	23.14	21.29	16.76	1.87	175.1
		C2g	43-65	7.45	6.8	0.58	14.5	0.04	-	93.9	-	1453	1162	1055	38.61	15.70	22.44	17.26	2.24	149.3
12.	Samut Prakan,	Apg	0-15	4.5	3.9	2.30	13.5	0.17	87.1	44.5	18.4	1332	2086	763	30.40	8.91	15.79	11.79	1.62	125.4
	Bang Phli	ACg	15-35	5.8	4.9	0.76	10.9	0.07	-	63.9	23.1	1141	2225	744	30.78	7.67	15.25	13.71	1.58	124.1
		C1g	35-55	6.7	5.55	0.41	10.3	0.04	-	141.4	30.2	1042	2120	768	32.02	7.80	17.37	16.16	1.63	121.7
		C2g	55-65	6.75	5.75	0.41	10.3	0.04	-	166.6	31.6	1269	2064	810	33.31	8.12	19.77	17.70	1.72	142.0
13.	Chachoengsao,	Apg-1	0-3	5.35	4.7	1.08	12.0	0.09	74.6	80.5	20.5	1017	1040	480	21.68	4.73	13.91	9.24	1.02	133.3
	Bang Pakong	Apg-2	3-15	5.1	4.4	0.80	11.4	0.07	-	80.4	16.6	1043	1161	509	21.74	4.43	12.39	9.26	1.08	124.9
		A12g	15-30	5.2	4.35	0.69	17.3	0.04	-	141.8	23.7	914	1263	589	22.01	3.85	15.21	10.42	1.25	139.6
		C1g	30-50	4.75	4.1	0.56	14.0	0.04	-	152.6	26.3	1365	1357	589	23.20	3.87	11.79	14.12	1.25	133.8
		C2g	50-	4.85	4.0	0.28	7.0	0.04	-	144.0	25.0	793	1131	608	22.85	3.80	13.89	18.97	1.29	166.1
20.	Samut Sakhon	Apg	0-15	4.4	3.9	1.57	13.1	0.12	46.8	47.4	13.9	1249	1478	339	21.01	10.09	11.58	7.78	0.72	143.6
	Krathum Baen	A12g	15-25	5.2	4.6	1.01	10.1	0.10	-	43.1	14.8	1312	1486	316	20.44	9.36	11.47	8.50	0.67	146.8
		Cg	25-65	5.4	4.75	0.43	8.6	0.05	-	44.7	14.8	1365	1368	254	17.45	8.11	8.11	6.66	0.54	251.3
58.	Thon Buri,	Apg	0-23	5.3	4.7	1.21	9.3	0.13	42.6	51.8	15.5	-	1374	495	29.75	15.91	15.31	5.75	1.05	127.8
	Nong Khaem	C1g	23-55	6.9	6.2	0.86	14.3	0.06	-	49.2	14.6	-	1498	-	-	-	-	-	-	-
		C2g	55-	8.15	7.0	0.27	6.8	0.04	-	101.0	37.6	-	1206	-	-	-	-	-	-	-
59.	Nakhon Pathom,	Apg	0-20	5.15	4.45	1.64	10.9	0.15	43.8	49.6	19.6	-	1374	306	30.82	9.97	19.85	2.03	0.65	105.5
	Nakhon Chaisi	BCg	20-50	6.1	5.5	1.12	14.0	0.08	-	42.2	14.6	-	1398	-	-	-	-	-	-	-
		C1g	50-60	7.5	6.65	0.34	8.5	0.04	-	31.5	27.2	-	1289	-	-	-	-	-	-	-

*Base saturation degree

No.	Location	Horizon	Depth (cm)	pH (H_2O)	pH (KCl)	T-C %	C/N	T-N %	Av-N ppm	$T-P_2O_5$ mg/100g	$Av-P_2O_5$ ppm	Abs. coeff. P_2O_5 mg/100g	$T-K_2O$ mg/100g	$Av-K_2O$ ppm	C.E.C. meq/100g	Ex. Bases meq/100g Ca	Mg	Na	K	(%)*
69.	Phetchaburi,	Apg	0-14	5.35	4.45	1.14	12.7	0.09	22.8	107.9	28.5	-	1823	203	25.73	6.04	16.13	2.55	0.43	97.7
	Muang	BCg	14-30	5.1	4.20	1.24	13.8	0.09	-	115.7	25.2	-	1725	-	-	-	-	-	-	-
		C1g	30-	4.55	3.95	0.30	10.0	0.03	-	104.0	28.8	-	1471	-	-	-	-	-	-	-
136.	Samut Prakan,	Apg	0-12	5.15	4.3	1.79	12.8	0.14	53.1	49.0	14.2	-	1183	-	-	-	-	-	-	-
	Bang Phli	A12g	12-30	5.25	4.6	1.42	12.9	0.11	-	51.0	16.1	-	1170	-	-	-	-	-	-	-
		C1g	30-52	5.95	5.0	0.60	12.0	0.05	-	72.6	11.3	-	833	-	-	-	-	-	-	-
		C2g	52-82	6.3	5.95	0.41	10.3	0.04	-	76.4	27.9	-	895	-	-	-	-	-	-	-
159.	Nakhon Pathom,	Apg	0-15	4.9	3.7	1.65	9.7	0.17	81.0	60.3	15.6	-	1238	570	35.76	13.66	32.33	489	1.21	145.7
	Sam Phran	A12g	15-40	6.35	5.55	1.08	12.0	0.09	-	50.9	15.3	-	1189	382	36.70	15.24	32.20	4.68	0.81	144.2
		ACg	40-55	6.55	5.8	0.20	6.7	0.03	-	44.7	16.5	-	1160	542	30.02	15.82	26.82	4.32	1.15	160.3
		Cg	55-75	6.7	5.85	0.22	7.3	0.03	-	81.9	34.0	-	1192	344	29.63	8.99	29.05	3.89	0.73	146.9
183.	Phra Nakhon,	Apg	0-15	5.3	4.3	1.44	10.3	0.13	56.9	53.1	10.2	1077	1135	517	32.8	11.7	16.8	9.1	1.1	118.0
	Bang Khen	A12g	15-32	5.2	4.2	1.23	11.2	0.11	-	52.9	-	997	1180	564	33.4	11.6	16.9	8.5	1.2	114.4
		ACg	32-50	5.4	4.3	1.04	10.4	0.10	-	49.8	-	997	1085	517	30.9	10.4	16.2	9.8	1.1	121.4
Brackish Water Alluvial Soils																				
21.	Pathum Thani,	Apg	0-15	4.0	3.4	2.35	13.1	0.18	19.8	45.6	11.7	1392	1592	302	28.01	8.34	7.46	3.38	0.64	70.8
	Thanyaburi	A12g	15-30	3.85	3.3	1.22	11.1	0.11	-	30.7	5.2	1404	1540	306	30.16	6.70	7.72	4.28	0.65	64.2
	Rangsit	BCg	30-45	3.8	3.25	0.52	10.4	0.05	-	26.8	6.4	1237	2069	264	25.32	6.10	8.80	4.80	0.56	80.0
	Rice Ex. St.	Cg	45-85	3.75	3.1	0.57	14.3	0.04	-	41.5	2.7	1167	2503	231	26.05	5.52	9.11	5.00	0.49	77.2
22.	Pathum Thani,	Apg	0-15	4.2	3.5	1.46	11.2	0.13	12.3	44.9	17.1	1120	1889	174	19.39	8.22	3.79	1.84	0.37	73.3
	Klong Luang,	A12g	15-30/50	4.05	3.35	1.01	12.5	0.08	-	35.5	15.2	920	1311	137	18.76	7.60	3.57	1.72	0.29	70.3
	Rice Ex. St.	BCg	30/50-80	3.65	3.2	0.57	9.5	0.06	-	25.2	6.4	1003	1423	99	16.65	4.07	2.51	1.32	0.21	48.6
		Cg	80-100	3.55	3.05	0.39	9.8	0.04	-	52.0	4.3	1243	2541	146	22.42	5.45	3.79	2.04	0.31	51.7
55.	Pathum Thani,	Apg	0-17	4.2	4.0	1.50	11.5	0.13	13.0	36.7	13.6	1150	1292	193	21.73	8.91	4.65	0.71	0.41	67.5
	Klong Luang,	A12g	17-35	3.9	3.4	1.11	12.3	0.09	-	35.7	9.5	1214	1585	151	22.78	7.78	5.05	0.78	0.32	61.2
	Rice Ex. St.	C1g	35-65	3.55	3.0	0.43	10.8	0.04	-	34.4	27.6	1114	2314	170	24.71	8.40	5.93	1.30	0.36	64.7
		C2g	65-100	3.5	3.2	0.40	10.0	0.04	-	44.7	18.2	1159	2023	231	24.62	7.64	6.64	1.85	0.49	67.5
74.	Nakhon Nayok	Apg	0-17	4.4	3.5	1.90	11.2	0.17	19.9	45.6	13.5	-	1236	221	25.14	4.98	6.84	0.96	0.47	52.7
	Ongkharak	A12g	17-40	4.5	3.2	1.58	10.5	0.15	-	46.5	15.7	-	1223	184	26.27	5.33	6.76	0.96	0.39	51.2
		B21g	40-58	4.35	3.5	1.56	11.1	0.14	-	45.8	26.6	-	1242	250	25.33	6.16	6.46	1.43	0.53	57.6
		B22g	58-75	4.8	4.2	1.40	10.0	0.14	-	46.3	23.4	-	1253	226	25.82	6.07	6.72	0.67	0.48	54.0
		BCg	75-90	4.0	3.6	0.85	10.6	0.08	-	46.5	11.9	-	1292	184	21.55	3.67	2.84	0.50	0.39	34.3
		Cg	90-	3.9	3.5	0.47	9.4	0.05	-	36.7	14.8	-	1687	198	24.91	3.36	3.83	0.60	0.42	32.1
80.	Ayutthaya,	Apg	0-21	4.8	4.05	1.65	11.0	0.15	18.1	62.2	18.0	-	738	141	26.10	11.70	4.32	0.54	0.30	64.5
	Wang Noi	A12g	21-35	4.4	3.85	1.57	11.2	0.14	-	42.1	29.9	-	863	-	-	-	-	-	-	-
		C1g	35-52	4.35	3.80	1.01	11.2	0.09	-	34.2	20.7	-	682	-	-	-	-	-	-	-
128.	Ayutthaya,	Apg	0-14	4.6	3.8	2.04	12.8	0.16	105.5	108.2	26.2	-	894	-	-	-	-	-	-	-
	Muang	A12g	14-32	4.7	3.25	1.30	11.8	0.11	-	52.6	14.9	-	678	-	-	-	-	-	-	-
		C1g	32-55	4.15	3.25	0.91	13.0	0.07	-	38.9	29.0	-	619	-	-	-	-	-	-	-
		C2g	55-80	4.0	3.15	0.53	10.6	0.05	-	48.2	9.9	-	667	-	-	-	-	-	-	-

*Base saturation degree

No.	Location	Horizon	Depth (cm)	pH (H_2O)	pH (KCl)	T-C %	C/N	T-N %	Av-N ppm	T-P_2O_5 mg/100g	Av-P_2O_5 ppm	Abs. coeff. P_2O_5 mg/100g	T-K_2O mg/100g	Av-K_2O ppm	C.E.C. meq/100g	Ex. Bases meq/100g Ca	Mg	Na	K	(%)*
129.	Ayutthaya, Muang, Hantra Ex. St.	Apg	0-10	4.85	4.35	1.43	13.0	0.11	52.3	94.1	38.8	1176	612	462	36.86	12.60	11.48	1.43	0.98	71.8
		ABg	10-25	5.15	4.35	1.25	13.9	0.09	-	93.7	36.6	1182	541	499	35.45	13.05	11.17	1.99	1.06	74.1
		B1g	25-57	4.55	3.75	1.03	12.9	0.08	-	67.1	16.7	1184	636	424	35.72	16.87	8.35	1.58	0.90	77.5
		B2g	57-90	4.05	3.3	1.00	14.3	0.07	-	55.6	11.3	1056	622	350	35.09	13.24	6.18	1.34	0.76	61.3
130.	Ayutthaya, Wang Noi	Apg	0-16	4.45	3.4	2.29	13.5	0.17	56.5	72.2	12.0	-	840	-	-	-	-	-	-	-
		A12g	16-35	4.5	3.5	2.77	13.9	0.20	-	91.3	18.7	-	507	-	-	-	-	-	-	-
		ACg	35-63	4.2	3.25	1.34	10.3	0.13	-	46.6	15.9	-	489	-	-	-	-	-	-	-
		Cg	63-	3.9	3.35	0.40	13.3	0.03	-	39.0	8.9	-	634	-	-	-	-	-	-	-
Fresh Water Alluvial Soils																				
4.	Nakhon Sawan, Phayuhakiri	Apg	0-15	5.5	3.6	1.24	13.8	0.09	24.3	19.2	5.5	1274	356	104	21.38	4.19	1.72	1.95	0.22	37.8
		B1g	15-25	5.9	3.7	0.65	10.8	0.06	-	21.3	3.4	1198	324	57	20.67	7.97	3.27	1.37	0.12	61.6
		B2g	25-50	6.1	3.8	0.58	9.7	0.06	-	19.0	2.5	1231	304	61	21.76	10.37	3.85	4.35	0.13	85.9
10.	Ratchaburi, Muang	Apg	0-10/15	6.6	6.0	1.51	13.7	0.11	32.8	129.7	21.9	1088	1168	118	25.11	22.73	2.71	0.78	0.25	105.4
		A12g	10/15-30	7.9	7.0	0.93	11.6	0.08	-	107.9	22.9	1119	1110	75	25.02	26.94	2.64	0.75	0.16	121.9
		C1g	30-50	8.15	7.4	0.77	11.0	0.07	-	113.6	20.1	1155	1096	75	23.80	35.18	2.23	0.78	0.16	161.2
		C2g	50-65	8.15	7.6	0.62	10.3	0.06	-	100.8	19.7	1290	1220	61	18.54	59.67	1.86	0.88	0.13	337.3
36.	Uttaradit, Muang	Apg	0-12	5.3	4.65	1.38	10.6	0.13	20.7	55.0	6.2	715	1080	42	9.97	4.90	2.99	0.35	0.09	83.6
		B1g	12-23	7.25	5.8	0.94	9.4	0.10	-	55.2	8.0	788	1180	38	10.86	4.93	3.60	0.39	0.08	82.9
		B21g	23-36	7.15	5.3	0.65	7.2	0.09	-	55.7	7.6	753	1128	24	10.49	4.91	3.32	0.55	0.05	84.2
		B22g	36-60	6.9	4.85	0.74	8.2	0.09	-	44.9	3.5	775	926	9	10.19	3.73	3.64	0.82	0.02	80.6
37.	Phitsanulok Muang, Rice Ex. St.	Apg	0-14	4.95	4.05	1.07	11.9	0.09	24.3	66.9	18.0	738	657	104	12.75	3.85	2.25	0.11	0.22	50.4
		B1g	14-25	5.2	4.0	0.74	12.3	0.06	-	39.0	9.2	717	814	38	14.95	4.35	1.84	0.14	0.08	42.7
		B21g	25-50	5.5	4.05	0.43	8.6	0.05	-	22.2	9.5	738	786	5	12.59	2.57	1.58	0.13	0.01	34.1
		B22g	50-70	5.5	4.05	0.34	8.5	0.04	-	17.9	5.5	642	604	5	8.53	1.76	1.64	0.29	0.01	43.4
61.	Suphan Buri, U Thong	Apg	0-15	5.15	4.0	1.44	11.1	0.13	32.0	171.2	22.7	-	1703	245	14.64	4.91	4.26	0.88	0.52	72.2
		B21g	15-30	6.35	5.5	0.57	11.4	0.05	-	108.0	12.5	-	2556	-	-	-	-	-	-	-
		B22g	30-	5.8	4.55	0.50	10.0	0.05	-	127.4	14.6	-	2473	-	-	-	-	-	-	-
63.	Suphan Buri, Muang	Apg	0-11	8.15	6.9	-	-	-	-	26.7	15.9	-	312	42	5.32	1.93	1.71	0.16	0.09	73.1
		Bg	11-25	9.0	7.35	-	-	-	-	27.3	24.3	-	438	-	-	-	-	-	-	-
		BCg	25-	-	-	-	-	-	-	21.4	21.4	-	712	-	-	-	-	-	-	-
68.	Ratchaburi, Pak Tho	Apg	0-20	5.2	4.25	1.45	10.4	0.14	43.9	19.0	14.6	-	228	38	3.38	1.21	2.04	0.71	0.08	119.1
		Bg	20-45	6.15	4.45	1.13	11.3	0.10	-	14.1	21.4	-	424	-	-	-	-	-	-	-
		IICg	45-	6.4	4.65	0.67	11.2	0.06	-	-	-	-	-	-	-	-	-	-	-	-
70.	Phetchaburi, Tha Yang	Apg	0-15	5.15	4.5	1.08	9.0	0.12	40.5	100.6	43.9	-	-	132	10.10	5.57	2.64	1.22	0.28	96.1
		Bg	15-55	6.8	5.35	1.02	9.3	0.11	-	103.8	40.5	-	-	-	-	-	-	-	-	-
		Cg	55-	7.9	6.25	0.59	11.4	0.05	-	148.5	35.1	-	-	-	-	-	-	-	-	-

*Base saturation degree

No.	Location	Horizon	Depth (cm)	pH (H$_2$O)	pH (KCl)	T-C %	C/N	T-N %	Av-N ppm	T-P$_2$O$_5$ mg/100g	Av-P$_2$O$_5$ ppm	Abs. coeff. P$_2$O$_5$ mg/100g	T-K$_2$O mg/100g	Av-K$_2$O ppm	C.E.C. meq/100g	Ex. Bases meq/100g Ca	Mg	Na	K	(%)*
72.	Phetchabun,	Apg	0-12	6.65	5.4	1.71	11.4	0.15	68.0	134.0	65.3	1111	946	151	32.96	28.42	5.33	0.62	0.32	105.2
	Muang	B21g	12-37	7.0	5.7	1.29	11.7	0.11	-	140.7	69.9	1245	1105	146	37.44	31.92	8.20	1.03	0.31	110.7
		B22g	37-57	7.2	5.9	0.92	13.1	0.07	-	107.9	67.0	1565	1344	146	38.76	32.61	8.30	1.36	0.31	109.9
		BCg	57-	7.55	6.5	0.80	13.3	0.06	-	105.6	51.0	1599	1167	151	43.40	37.19	9.77	2.34	0.32	114.3
73.	Phetchabun,	Apg	0-17	7.5	5.7	1.81	12.1	0.15	55.4	208.3	46.1	1359	1101	155	38.76	31.53	9.15	0.93	0.33	108.2
	Lom Sak	B21g	17-38	8.2	6.1	0.92	13.1	0.07	-	105.9	42.6	1422	1130	132	40.31	32.42	9.67	1.37	0.28	102.5
		B22g	38-52	7.9	5.9	0.85	14.2	0.06	-	104.5	42.1	1244	1097	132	35.91	27.29	8.35	1.08	0.28	103.3
		B23g	52-	7.6	5.5	0.55	13.8	0.04	-	45.1	39.6	1181	1155	132	36.38	25.66	9.46	1.82	0.28	102.3
76.	Nakhon Sawan,	Apg	0-17	5.4	3.9	1.38	12.5	0.11	53.8	86.3	39.4	-	790	123	30.47	13.31	8.16	1.44	0.26	76.1
	Phayuha Khiri	B1g	17-36	6.2	4.45	0.68	9.7	0.07	-	91.3	29.9	-	791	-	-	-	-	-	-	-
		B2g	36-60	6.6	4.7	0.37	9.3	0.04	-	54.8	32.2	-	450	-	-	-	-	-	-	-
		BCg	60-	6.7	4.6	0.34	8.5	0.04	-	35.6	18.5	-	438	-	-	-	-	-	-	-
78.	Sing Buri,	Apg	0-19	5.7	4.6	0.86	10.8	0.08	16.7	112.0	28.5	-	903	57	12.82	9.06	3.10	0.21	0.12	97.5
	In Buri,	A21g	19-38	6.5	5.1	0.73	12.2	0.06	-	96.0	45.5	-	1141	-	-	-	-	-	-	-
	Ponang Dum	B22g	38-64	6.5	4.8	0.82	11.7	0.07	-	121.1	38.4	-	1197	-	-	-	-	-	-	-
79.	Ayutthaya,	Apg	0-18	5.8	4.85	1.27	12.7	0.10	17.5	177.4	17.2	-	1268	123	20.87	14.26	3.79	1.14	0.26	87.8
	Maha Rat	Bg	18-33	6.25	5.25	0.89	12.7	0.07	-	120.0	30.0	-	1120	-	-	-	-	-	-	-
		Cg	33-	5.75	4.8	0.71	10.1	0.07	-	117.8	43.7	-	1512	-	-	-	-	-	-	-
126.	Ang Thong,	Apg	0-10	4.9	4.15	1.59	9.9	0.16	42.9	84.3	13.2	-	828	339	22.37	11.44	6.67	1.22	0.72	89.6
	Muang	B1g	10-37	5.55	4.8	0.73	14.6	0.05	-	71.8	14.9	-	378	297	19.40	9.59	6.94	1.23	0.63	92.5
		IIB21g	37-47	5.75	4.75	1.08	13.5	0.08	-	44.3	7.4	-	781	283	23.81	11.16	7.79	3.27	0.60	95.8
		IIB22g	47-62	5.95	4.95	0.83	11.9	0.07	-	50.7	5.5	-	679	311	23.07	11.36	5.51	2.11	0.66	85.1
		IIICg	62-90	6.95	5.05	0.56	28.0	0.02	-	54.3	4.5	-	278	269	7.69	3.06	2.98	1.19	0.57	101.4
127.	Sing Buri,	Apg	0-13	4.9	3.9	1.67	12.8	0.13	29.4	126.2	31.6	808	1034	344	31.11	12.11	4.69	0.89	0.73	59.2
	Muang	B1g	13-33	5.25	4.45	1.14	12.7	0.09	-	84.3	7.1	874	1027	330	25.03	16.04	6.45	1.23	0.70	97.6
		B2g	33-68	5.35	4.45	1.05	15.0	0.07	-	76.7	4.6	742	626	316	24.92	14.62	6.53	2.27	0.67	96.7
		B3g	68-90	5.55	4.6	0.81	13.5	0.06	-	82.6	9.4	739	563	325	23.85	15.95	6.67	1.99	0.69	106.2
140.	Sukhothai,	Apg	0-10	5.45	4.75	1.58	9.3	0.17	46.6	152.9	19.2	749	1348	372	20.81	5.69	6.16	1.33	0.79	67.2
	Si Samrong	A12g	10-24	5.55	4.95	1.26	9.0	0.14	-	152.1	16.9	756	1261	349	20.77	5.61	6.30	1.06	0.74	66.0
		Cg	24-60	5.95	5.25	0.89	11.1	0.08	-	123.8	12.9	690	960	330	22.70	5.52	6.48	2.76	0.70	68.1
141.	Sukhothai,	Apg	0-10	5.85	4.6	1.43	9.5	0.15	43.6	105.1	12.7	-	509	174	20.10	5.19	5.89	2.17	0.37	67.8
	Si Satchanalai	A12g	10-25	5.9	4.75	0.85	9.4	0.09	-	88.3	7.6	-	955	245	20.28	5.59	5.94	2.08	0.52	69.7
		Cg	25-50	6.15	5.0	0.68	9.7	0.07	-	70.8	9.2	-	675	165	23.37	7.65	5.25	1.74	0.35	64.1
142.	Uttaradit,	Apg	0-15/19	5.4	4.15	1.26	9.7	0.13	36.7	142.4	8.9	-	377	146	17.61	5.50	9.43	2.69	0.31	101.8
	Laplae	Cg	15/19-52	6.0	4.8	0.52	10.4	0.05	-	150.4	9.8	-	541	132	15.98	7.19	11.94	1.88	0.28	133.3
Low Humic Gley Soils																				
3.	Saraburi,	Apg	0-12	5.2	4.1	0.89	12.8	0.07	25.5	8.2	9.3	754	186	113	9.77	1.72	1.07	1.97	0.24	51.2
	Muang	B1g	12-25	5.7	4.1	0.58	14.5	0.04	-	4.6	4.6	673	190	47	9.10	2.67	1.03	1.12	0.10	54.1
		B2g	25-55	5.7	3.8	0.38	12.7	0.03	-	4.6	2.8	924	300	75	14.24	3.24	1.31	1.25	0.16	41.9
5.	Chai Nat,	Apg	0-15	5.25	3.75	1.40	12.7	0.11	43.8	25.2	3.6	1220	840	193	24.79	12.38	3.82	1.06	0.41	71.3
	Muang,	B21g	15-30	6.3	3.9	0.73	12.2	0.06	-	18.8	4.7	1379	927	113	25.35	18.65	3.49	1.22	0.24	93.1
	Rice Ex. St.	B22g	30-60	6.4	5.15	0.65	13.0	0.05	-	18.3	3.9	1400	521	113	25.91	20.16	3.58	1.25	0.24	97.4
7.	Ratchaburi,	Apg	0-15	7.0	6.5	1.75	13.5	0.13	41.7	118.2	35.7	1193	1150	344	16.65	7.09	2.74	1.45	0.73	72.1
	Muang,	B1g	15-30	6.5	6.0	1.16	11.6	0.10	-	84.1	29.7	877	1235	321	13.09	4.61	2.02	1.46	0.68	67.0
	Rixe Ex. St.	B2g	30-50	5.75	5.2	0.85	10.6	0.08	-	61.6	8.8	689	839	316	11.70	2.97	2.14	1.17	0.67	59.4

*Base saturation degree

No.	Location	Horizon	Depth (cm)	pH (H$_2$O)	pH (KCl)	T-C %	C/N	T-N %	Av-N ppm	T-P$_2$O$_5$ mg/100g	Av-P$_2$O$_5$ ppm	Abs. coeff. P$_2$O$_5$ mg/100g	T-K$_2$O mg/100g	Av-K$_2$O ppm	C.E.C. meq/100g	Ex. Bases meq/100g Ca	Mg	Na	K	(%)*
77.	Nakhon Sawan,	Apg	0-15	6.0	4.5	0.82	11.7	0.07	20.9	26.6	19.3	-	240	80	6.09	2.21	0.93	1.22	0.17	74.4
	Banphot Phisai	B21g	15-30	6.5	4.8	0.56	11.2	0.05	-	34.1	23.2	-	554	-	-	-	-	-	-	-
		B22g	30-46	6.2	4.2	0.32	8.0	0.04	-	33.6	23.6	-	727	-	-	-	-	-	-	-
		BCg	46-	6.1	4.1	0.32	8.0	0.04	-	20.9	33.0	-	891	-	-	-	-	-	-	-
131.	Saraburi,	Apg	0-15	4.55	3.5	1.75	12.5	0.14	35.7	35.6	14.1	516	328	316	10.52	2.72	1.23	0.89	0.67	52.4
	Nong Khae	A12g	15-32	4.65	3.45	1.22	10.2	0.12	-	37.8	20.2	517	644	259	12.83	4.27	0.94	0.80	0.55	51.1
		B1g	32-55	4.55	3.3	1.14	11.4	0.10	-	38.2	20.8	450	1152	302	19.37	4.14	0.69	0.85	0.64	32.6
		B2g	55-75	5.05	3.25	0.49	12.3	0.04	-	24.8	10.0	405	476	269	8.64	5.77	1.02	1.02	0.57	97.0
132.	Nakhon Nayok,	Apg	0-13	4.55	3.3	2.40	12.6	0.19	31.5	50.2	22.1	-	661	302	19.82	1.55	0.52	0.77	0.64	17.6
	Muang	A12g	13-20	4.5	3.45	1.26	12.6	0.10	-	43.0	15.1	-	1330	292	20.67	1.94	0.53	0.74	0.62	18.5
		B21g	20-60	4.15	3.2	0.83	10.4	0.08	-	39.4	9.6	-	1159	297	31.92	1.61	0.36	0.70	0.63	10.3
		B22g	60-	4.5	3.15	0.61	10.2	0.06	-	38.0	8.4	-	669	320	19.92	1.06	0.35	0.64	0.68	13.9
133.	Prachin Buri,	Apg	0-20	5.1	3.5	1.63	13.6	0.12	15.5	50.4	6.8	619	635	325	16.60	2.94	1.82	1.31	0.69	40.7
	Prachantakhum	ACg	20-32	4.95	3.45	0.85	14.1	0.06	-	45.5	12.0	679	829	283	19.38	2.29	1.50	1.38	0.60	29.8
		Cg	32-65	5.6	3.7	0.45	11.3	0.04	-	32.9	11.8	440	636	278	16.53	1.21	0.95	1.26	0.59	24.3
134.	Prachin Buri,	Apg	0-15	5.5	4.1	0.77	19.3	0.04	13.5	22.8	5.2	-	273	255	10.42	1.58	1.52	0.92	0.54	43.8
	Watthana Nakhon	A12g	15-30	5.5	3.85	0.22	11.0	0.02	-	19.4	6.8	-	134	123	6.44	1.14	0.76	0.44	0.26	47.8
		Cg	30-65	5.7	3.7	0.24	12.0	0.02	-	24.8	6.1	-	543	160	8.39	1.29	1.29	0.38	0.34	39.5
135.	Chachoengsao,	Apg	0-14	5.05	3.6	1.06	8.8	0.12	46.0	51.0	6.8	-	451	-	-	-	-	-	-	-
	Phanon Sarakham	ACg	14-29	5.05	3.5	0.65	6.5	0.10	-	50.8	5.7	-	531	-	-	-	-	-	-	-
		Cg	29-68	4.8	3.4	0.57	7.1	0.08	-	42.4	16.5	-	612	-	-	-	-	-	-	-
137.	Kamphaeng Phet,	Apg	0-13	5.45	3.9	1.14	10.4	0.11	32.2	58.1	21.2	451	546	184	5.80	1.52	1.01	1.72	0.39	80.1
	Khranu Woralak-	A12g	13-22	5.65	3.95	0.96	9.6	0.10	-	50.2	13.3	413	590	226	9.47	2.91	2.34	1.61	0.48	88.0
	Saburi	B1g	22-36	5.6	3.9	0.81	11.6	0.07	-	57.1	11.4	466	509	203	9.77	2.55	2.75	0.76	0.43	66.4
		B2g	36-47	5.6	3.8	0.53	17.0	0.03	-	47.8	10.0	414	661	349	12.61	2.20	3.96	0.34	0.74	57.4
		B3g	47-65	5.65	3.7	0.53	17.0	0.03	-	49.7	12.9	416	520	353	14.58	4.15	4.76	0.92	0.75	70.6
138.	Kamphaeng Phet,	Apg	0-18	5.3	4.25	2.28	14.2	0.16	57.8	123.2	22.9	-	951	471	33.26	14.38	5.09	2.38	1.00	68.7
	Khlong Khlung	A12g	18-38	5.1	4.25	1.71	13.2	0.13	-	144.3	20.1	-	1050	316	34.15	12.32	6.53	0.95	0.67	59.9
		Bg	38-70	5.15	4.25	0.77	12.8	0.06	-	88.3	12.1	-	1080	377	32.99	9.49	16.58	2.01	0.80	87.5
139.	Kamphaeng Phet,	Apg	0-10	5.4	3.9	0.97	13.8	0.07	18.4	45.3	13.6	-	690	264	9.61	2.38	0.77	2.60	0.56	65.7
	Phran Kratai	A12g	10-19	5.35	4.05	0.81	10.1	0.08	-	42.3	15.3	-	542	344	9.04	3.61	1.15	2.88	0.73	72.6
		Bg	19-55	5.4	4.35	0.69	13.8	0.05	-	71.2	13.3	-	759	316	13.72	4.20	1.23	1.43	0.67	50.1
161.	Lop Buri,	Apg	0-14	5.45	4.0	0.43	14.3	0.03	14.0	31.6	21.1	334	327	316	12.47	4.16	3.91	1.79	0.67	84.4
	Khok Samrong,	B1g	14-27	6.6	5.1	0.26	13.0	0.02	-	25.0	5.7	432	568	264	11.33	4.65	2.88	1.98	0.56	88.9
	Rice Ex. St.	B2g	27-40	7.0	5.2	0.22	11.0	0.02	-	17.7	4.2	433	525	287	13.76	5.72	4.76	1.94	0.61	82.7
		Cg	40-68	8.45	6.75	0.19	9.5	0.02	-	15.6	5.6	692	733	302	19.12	8.82	5.20	3.92	0.64	97.1
162.	Lop Buri,	Apg	0-20	5.65	3.6	0.43	10.8	0.04	12.5	27.2	13.2	-	298	283	10.04	4.12	3.07	1.69	0.60	94.4
	Khok Samrong,	B1g	20-32	6.55	4.7	0.34	11.3	0.03	-	24.4	9.5	-	291	99	11.66	4.34	4.38	1.75	0.21	91.5
	Rice Ex. St.	B2g	32-40	7.2	5.55	0.27	9.0	0.03	-	18.1	6.5	-	238	99	13.32	6.11	4.12	1.79	0.21	91.8
		Cg	40-70	8.0	6.0	0.19	9.5	0.02	-	16.7	5.8	-	295	99	19.21	9.35	5.45	3.62	0.21	97.5

*Base saturation degree

Gray Podzolic Soils

No.	Location	Horizon	Depth (cm)	pH (H_2O)	pH (KCl)	T-C %	C/N	T-N %	Av-N ppm	$T\text{-}P_2O_5$ mg/100g	$Av\text{-}P_2O_5$ ppm	Abs. coeff. P_2O_5 mg/100g	$T\text{-}K_2O$ mg/100g	$Av\text{-}K_2O$ ppm	C.E.C. meq/100g	Ex. Bases meq/100g Ca	Mg	Na	K	(%)*
18.	Rayon,	Apg	0-10	4.25	4.05	0.56	11.2	0.05	12.0	6.9	13.8	423	149	38	1.71	0.50	0.28	0.50	0.08	79.5
	Klaeng	Alg	10-25	4.75	4.15	0.45	11.3	0.04	-	17.9	25.1	425	191	19	2.92	1.05	0.34	0.39	0.04	62.3
		B1g	25-40	4.25	3.75	0.26	8.7	0.03	-	6.9	4.9	452	255	19	2.43	0.79	0.10	0.39	0.04	54.3
		B2g	40-	4.5	3.75	0.10	10.0	0.01	-	2.3	3.3	412	211	9	2.88	1.06	1.25	0.45	0.02	96.5
Non-Calcic Brown Soils																				
6.	Suphan Buri,	Apg	0-15	5.3	4.2	1.16	11.6	0.10	41.1	25.4	7.0	1044	940	160	19.16	12.49	2.87	1.10	0.34	87.7
	Muang,	A12g	15-25	5.65	4.45	0.94	13.4	0.07	-	28.2	9.4	1293	925	85	20.06	14.12	2.29	1.24	0.18	88.9
	Rice Ex. St.	Bg	25-40	5.15	3.8	0.50	12.5	0.04	-	19.2	6.8	1202	572	71	20.18	14.21	1.86	1.35	0.15	87.1
		BIICg	40-60	5.35	3.95	0.23	7.7	0.03	-	15.1	10.5	1126	1328	66	18.17	13.10	1.68	1.36	0.14	90.0
11.	Nakhon Pathom	Apg	0-15	6.0	5.65	1.51	15.1	0.10	36.9	63.7	12.1	929	698	80	19.02	16.11	2.51	1.70	0.17	107.7
	Muang	B1g	15-45	6.65	5.9	1.02	17.0	0.06	-	60.7	8.3	1164	2387	61	21.87	19.38	3.63	4.02	0.13	124.2
		B2g	45-65	7.3	6.55	0.69	13.8	0.05	-	44.9	12.1	1295	2619	66	26.04	19.49	8.77	5.79	0.14	131.3
Grumusols																				
23.	Lop Buri,	Ap	0-15	7.3	6.15	1.70	17.0	0.10	19.2	79.7	47.6	2498	216	170	53.12	61.59	5.05	2.41	0.36	130.7
	Muang	A12	15-30	7.2	6.3	1.38	16.0	0.08	-	75.2	58.0	2251	228	118	58.73	59.88	3.68	2.81	0.25	113.4
		A13	30-60	7.15	6.2	1.07	15.3	0.07	-	44.9	27.5	2325	218	94	57.16	59.85	3.27	3.68	0.20	117.2
		C	60-	7.25	6.9	0.61	20.3	0.03	-	36.2	33.5	2352	196	165	53.36	88.32	3.26	5.13	0.35	181.9
71.	Lop Buri,	Ap	0-18	7.4	6.1	1.79	16.3	0.11	14.9	53.8	27.4	-	265	245	58.96	69.54	5.54	0.89	0.52	129.7
	Muang	C1	18-42	8.0	6.0	0.69	17.2	0.04	-	33.9	37.8	-	143	240	56.49	60.00	4.93	1.59	0.51	118.7
		C2	42-	8.15	6.4	0.56	18.7	0.03	-	17.9	20.1	-	118	236	52.90	77.87	4.79	1.62	0.50	160.3
160.	Lop Buri,	Apg	0-16	6.30	5.85	1.52	19.0	0.08	37.2	55.8	21.1	-	557	193	34.59	49.24	5.64	1.35	0.41	163.7
	Muang	A12g	16-30	6.85	5.95	0.98	16.3	0.06	-	25.9	15.7	-	326	118	27.90	25.20	3.52	1.33	0.25	108.6
		Cg	30-60	7.05	6.2	0.34	17.0	0.02	-	19.9	8.2	-	292	127	31.51	29.30	2.41	2.66	0.27	109.9
163.	Lop Buri,	Apg	0-12	5.60	4.5	1.44	16.0	0.09	38.8	63.0	22.4	-	167	325	35.04	23.71	13.10	1.84	0.69	112.3
	Khok Samrong	A12g	12-40	5.55	4.6	0.82	16.4	0.05	-	49.6	16.5	-	142	250	36.85	24.31	13.20	2.28	0.53	109.5
	Rice Ex. Subst.	Cg	40-70	5.25	4.45	0.41	13.6	0.03	-	36.1	8.3	-	124	184	36.55	26.71	12.42	1.95	0.39	113.5

*Base saturation degree

North-eastern Region

Fresh Water Alluvial

No.	Location	Horizon	Depth (cm)	pH (H_2O)	pH (KCl)	T-C %	C/N	T-N %	Av-N ppm	T-P_2O_5 mg/100g	Av-P_2O_5 ppm	Abs. coeff. P_2O_5 mg/100g	T-K_2O mg/100g	Av-K_2O ppm	C.E.C. meq/100g	Ex. Bases meq/100g Ca	Mg	Na	K	(%)*
42.	Nakhon Ratchasima,	Apg	0-15	4.7	3.9	1.044	9.8	0.107	40.6	29.1	12.2	892	764	165	21.85	13.02	2.99	1.50	0.35	81.7
	Phimai,	B1g	15-40	5.1	4.2	0.732	9.3	0.079	-	25.2	7.7	831	300	90	17.27	11.30	3.25	1.01	0.19	91.2
	Rice Ex. St.	B2g	40-75	4.9	3.9	0.493	8.5	0.058	-	24.7	6.1	919	424	80	20.45	12.75	2.92	1.20	0.17	83.3
48.	Nong Khai,	Apg	0-15	8.05	7.6	0.882	8.6	0.093	50.4	101.3	7.6	539	1030	80	9.58	55.85	6.46	0.16	0.17	653.9
	Si Chiang Mai	A12g	15-40	7.9	7.25	0.698	10.0	0.070	-	94.6	11.2	540	822	57	11.89	23.65	3.54	0.21	0.12	231.5
		Cg	30-60	8.05	6.5	0.440	8.6	0.051	-	52.0	12.3	537	995	47	8.71	8.15	1.92	0.24	0.10	119.5
49.	Sakon Nakhon,	ApC	0-5	4.5	3.85	0.319	8.0	0.040	12.1	19.9	13.4	169	71	57	4.29	1.92	0.38	0.45	0.12	66.9
	Rice Ex. St.	Apg	5-20	4.75	3.8	0.460	9.2	0.050	-	25.0	13.4	209	118	24	4.87	1.99	0.32	0.24	0.05	53.4
		A12g	20-35	5.5	4.15	0.092	7.8	0.012	-	11.5	4.0	116	79	9	4.04	2.02	0.43	0.21	0.02	66.3
		C1g	35-45	5.65	4.4	0.104	8.2	0.020	-	10.8	4.0	116	51	5	3.18	1.78	0.12	0.21	0.01	66.7
		IIC2g	43-	5.45	4.35	0.116	7.7	0.015	-	14.9	5.3	303	16	24	6.41	4.19	0.10	0.35	0.05	73.2
95.	Nakhon Ratchasima,	Apg	0-20	5.45	4.55	0.452	10.3	0.044	8.4	7.2	-	279	87	71	5.57	2.79	1.58	1.61	0.15	109.9
	Nong Sung	C1g	20-40	6.6	6.3	0.252	10.5	0.024	-	9.5	-	422	181	28	11.16	7.29	3.62	1.91	0.06	115.5
		C2g	40-75	7.0	6.4	0.244	13.6	0.018	-	6.1	-	569	158	127	16.55	10.98	5.94	3.24	0.27	123.5
98.	Khon Kaen,	Apg	0-15	5.75	4.1	0.244	9.4	0.026	16.3	10.6	4.4	-	436	-	-	-	-	-	-	-
	Nam Phong	A12g	15-30	6.2	3.95	0.209	11.6	0.018	-	10.9	-	-	744	-	-	-	-	-	-	-
		C1g	30-43	5.05	4.0	0.278	11.0	0.025	-	12.4	-	-	55	-	-	-	-	-	-	-
		C2g	43-75	4.9	3.85	0.109	10.9	0.010	-	10.7	-	-	358	-	-	-	-	-	-	-
102.	Nong Khai,	Apg	0-10	4.3	4.1	0.255	9.8	0.026	14.5	19.7	7.3	-	328	-	-	-	-	-	-	-
	Muang	A12g	10-23	4.8	4.25	0.264	8.8	0.030	-	9.6	-	-	190	-	-	-	-	-	-	-
		Cg	23-65	5.15	4.15	0.91	10.1	0.019	-	9.5	-	-	568	-	-	-	-	-	-	-

Low Humic Gley Soils

No.	Location	Horizon	Depth (cm)	pH (H_2O)	pH (KCl)	T-C %	C/N	T-N %	Av-N ppm	T-P_2O_5 mg/100g	Av-P_2O_5 ppm	Abs. coeff. P_2O_5 mg/100g	T-K_2O mg/100g	Av-K_2O ppm	C.E.C. meq/100g	Ca	Mg	Na	K	(%)*
43.	Khon Kaen	Apg	0-15	5.3	4.75	0.316	12.2	0.026	6.0	3.4	3.9	115	26	24	3.54	1.53	0.64	0.88	0.05	87.6
	Muang,	BCg	15-35	6.3	5.6	0.221	12.3	0.018	-	4.4	3.8	211	49	29	5.57	3.11	0.69	1.78	0.06	101.3
	Rice Ex. St.	C1g	35-60	7.35	6.25	0.216	14.4	0.015	-	3.7	2.4	212	49	24	8.22	5.27	0.97	2.80	0.05	110.6
		C2g	60-75	7.95	6.45	0.117	9.8	0.012	-	0.5	1.9	188	48	29	8.79	5.40	1.06	2.80	0.06	106.0
45.	Khon Kaen,	Apg	0-10	5.85	5.5	0.604	9.2	0.066	30.4	32.3	13.5	477	467	90	10.31	5.94	2.19	0.38	0.19	84.4
	Chum Phae,	A12g	10-25	6.25	4.95	0.508	8.7	0.066	-	23.6	5.9	569	715	99	16.34	9.04	2.70	1.00	0.21	79.3
	Rice Ex. St.	Bg	25-40	6.15	4.05	0.500	9.4	0.053	-	25.6	2.4	660	817	132	21.98	11.19	3.48	1.98	0.28	77.0
		Cg	40-75	6.55	4.2	0.450	9.0	0.050	-	18.6	14.2	733	145	104	20.62	11.68	3.52	2.29	0.22	85.9
47.	Udon Thani,	Apg	0-15	4.65	4.0	0.355	9.9	0.036	12.0	9.2	2.4	167	116	14	1.84	0.84	0.16	0.10	0.03	61.4
	Muang	B1g	15-30	6.0	4.4	0.189	9.0	0.021	-	4.7	2.5	139	140	14	3.21	1.09	0.76	0.14	0.03	62.9
		B21g	30-45	6.25	4.2	0.182	10.1	0.018	-	5.7	2.3	139	298	14	4.22	2.70	0.52	0.37	0.03	85.8
		B22g	45-75	6.15	3.95	0.181	10.7	0.016	-	10.5	3.6	170	291	28	8.62	4.49	1.14	1.01	0.06	77.7

*Base saturation degree

No.	Location	Horizon	Depth (cm)	pH (H_2O)	pH (KCl)	T-C %	C/N	T-N %	Av-N ppm	T-P_2O_5 mg/100g	Av-P_2O_5 ppm	Abs. coeff. P_2O_5 mg/100g	T-K_2O mg/100g	Av-K_2O ppm	C.E.C. meq/100g	Ex. Bases meq/100g Ca	Mg	Na	K	(%)*
52.	Maha Sarakam, Muang	Apg	0-15	4.35	3.95	0.380	9.5	0.040	22.8	6.8	4.6	139	37	19	3.50	1.40	0.61	0.80	0.04	81.4
		B1g	15-35	5.4	4.8	0.167	9.3	0.018	-	9.4	1.4	92	29	28	3.21	1.83	0.20	0.20	0.06	71.3
		B2g	35-65	6.0	4.35	0.153	9.6	0.016	-	4.6	1.3	170	40	14	4.09	2.37	0.61	0.38	0.03	82.9
53.	Surin, Muang, Rice Ex. St.	Apg	0-15	4.7	3.3	0.102	6.4	0.016	5.1	2.3	1.1	-	37	42	2.20	0.92	0.29	0.09	0.09	63.2
		B1g	15-25	5.0	4.3	0.138	6.6	0.021	-	2.3	0.8	-	32	19	4.06	2.92	0.38	0.09	0.04	83.7
		B2g	25-60	5.2	4.2	0.081	5.4	0.015	-	2.3	2.5	-	61	14	6.56	3.98	1.36	0.15	0.03	84.1
		B3g	60-100	5.4	4.4	0.069	4.9	0.014	-	1.6	2.5	-	83	24	7.18	4.05	1.17	0.44	0.05	78.4
96.	Nakhon Ratchasima, Bua Yai	Apg	0-18	5.5	4.1	0.644	11.1	0.058	15.5	9.5	2.3	479	180	104	7.92	4.44	2.01	1.20	0.22	99.4
		A12g	18-25	6.3	5.35	0.418	10.7	0.039	-	9.8	-	422	188	80	10.25	5.38	2.39	1.28	0.17	90.0
		B21g	25-35	5.85	4.3	0.331	13.2	0.025	-	9.8	-	445	200	90	10.62	6.13	2.89	1.49	0.19	100.8
		B22g	35-75	5.75	4.05	0.220	8.5	0.026	-	9.7	-	445	168	94	11.39	6.02	2.91	1.31	0.20	91.5
97.	Khon Kaen, Phon	Apg	0-13	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
		A12g	13-19	7.0	4.05	0.307	11.4	0.027	-	6.3	2.2	-	213	-	-	-	-	-	-	-
		Bg	19-27	7.55	4.8	0.174	11.6	0.015	-	3.2	-	-	30	-	-	-	-	-	-	-
		IICg	27-65	6.6	4.0	0.122	11.1	0.011	-	4.6	-	-	60	-	-	-	-	-	-	-
99.	Udon Thani, Kumphawapi	Apg	0-10	4.95	4.9	0.325	14.8	0.022	7.1	7.2	3.2	-	83	47	2.81	1.32	0.59	1.22	0.10	113.9
		B1g	10-21	5.25	4.55	0.261	14.5	0.018	-	7.2	-	-	113	38	3.31	1.63	0.84	1.15	0.08	111.8
		B2g	21-80	4.95	4.3	0.191	9.6	0.020	-	5.3	-	-	42	38	3.83	1.69	1.07	0.47	0.08	87.0
100.	Udon Thani, Kumphawapi	Apg	0-13	4.75	4.8	0.365	10.7	0.034	9.2	-	3.5	69	-	9	2.10	0.75	0.27	0.30	0.02	64.0
		A12g	13-23	5.3	4.25	0.348	10.9	0.032	-	9.7	-	160	74	28	3.03	1.02	0.55	0.53	0.06	71.3
		B1g	23-50	5.45	4.35	0.161	8.9	0.018	-	12.3	-	229	101	38	4.94	2.70	0.63	0.75	0.08	84.1
		B2g	50-80	4.85	3.95	-	-	-	-	108.3	-	278	210	47	6.57	3.09	0.40	0.88	0.10	67.8
101.	Nong Khai, Muang	Apg	0-11	4.55	4.05	0.673	12.1	0.055	25.0	15.0	3.7	-	158	47	5.64	1.31	0.40	0.76	0.10	45.4
		A12g	11-18	5.9	4.4	0.487	11.1	0.044	-	9.9	-	-	130	28	5.23	2.03	0.59	1.54	0.06	80.7
		B21g	18-46	5.65	4.35	0.299	9.6	0.031	-	9.6	-	-	170	47	5.67	2.27	0.51	0.73	0.10	81.3
		B22g	46-80	5.15	4.15	0.278	9.6	0.029	-	14.4	-	-	180	52	7.40	3.67	0.55	0.72	0.11	68.2
105.	Sakon Nakhon, Phanna Nikhom	Apg	0-10	4.2	4.1	0.319	13.9	0.023	7.2	6.2	3.2	-	105	-	-	-	-	-	-	-
		A12g	10-30	4.7	4.25	0.302	13.1	0.023	-	7.4	-	-	43	-	-	-	-	-	-	-
		B1g	30-45	4.55	4.2	0.209	11.0	0.019	-	8.0	-	-	54	-	-	-	-	-	-	-
		B2g	45-80	4.2	3.85	0.205	11.3	0.018	-	6.1	-	-	178	-	-	-	-	-	-	-
106.	Sakon Nakhon, Muang	Apg	0-13	4.35	4.2	0.348	11.2	0.031	10.6	5.3	3.2	-	-	-	-	-	-	-	-	-
		A12g	13-26	4.95	4.25	0.336	10.5	0.032	-	5.3	-	-	-	-	-	-	-	-	-	-
		B1g	26-48	5.55	4.8	0.174	10.3	0.016	-	2.3	-	-	-	-	-	-	-	-	-	-
		B2g	48-80	5.65	4.0	0.104	8.0	0.013	-	4.3	-	-	-	-	-	-	-	-	-	-
107.	Nakhon Phanom, Muang	Apg	0-12	5.05	4.1	0.755	9.9	0.076	30.6	18.7	7.1	-	132	66	4.94	0.76	0.40	0.74	0.14	41.3
		B1g	12-23	6.25	5.35	0.338	8.9	0.038	-	73.8	-	-	234	28	4.68	1.01	2.44	1.03	0.06	97.1
		B21g	23-42	7.45	6.25	0.210	6.8	0.031	-	33.5	-	-	283	47	6.84	1.83	3.34	1.94	0.10	105.4
		B22g	42-75	8.2	6.75	0.254	8.5	0.030	-	23.2	-	-	502	108	7.83	2.66	3.67	2.47	0.23	115.3
108.	Nakhon Phanom, Muang	Apg	0-15	4.85	4.1	0.448	9.3	0.048	39.8	54.6	6.5	418	707	94	7.71	2.54	1.86	0.39	0.20	64.6
		B1g	15-31	6.15	5.3	0.429	8.9	0.048	-	44.1	-	420	600	94	7.54	3.07	2.76	0.38	0.20	85.0
		B21g	31-50	6.05	4.95	0.278	9.0	0.031	-	31.3	-	420	753	127	8.09	3.18	3.35	0.69	0.27	92.6
		B22g	50-80	6.05	4.55	0.191	8.0	0.024	-	30.3	-	420	548	127	7.95	3.49	3.35	0.63	0.27	97.5

*Base saturation degree

No.	Location	Horizon	Depth (cm)	pH (H$_2$O)	pH (KCl)	T-C %	C/N	T-N %	Av-N ppm	T-P$_2$O$_5$ mg/100g	Av-P$_2$O$_5$ ppm	Abs. coeff. P$_2$O$_5$ mg/100g	T-K$_2$O mg/100g	Av-K$_2$O ppm	C.E.C. meq/100g	Ex. Bases meq/100g Ca	Mg	Na	K	(%)*
109.	Nakhon Phanom, Raenu Nakhon	Apg	0-13	4.45	4.1	0.354	8.6	0.041	31.4	5.2	4.2	-	40	14	2.80	0.25	0.17	0.66	0.03	39.6
		B1g	13-28	4.75	4.0	0.128	7.5	0.017	-	5.9	-	-	68	14	2.16	0.55	0.21	0.60	0.03	64.3
		B2g	28-42	5.45	4.8	0.160	10.7	0.015	-	6.5	-	-	120	38	2.50	0.62	0.40	0.62	0.08	68.8
		Cg	42-75	5.65	4.25	0.107	10.7	0.010	-	9.7	-	-	79	5	2.46	0.63	0.46	0.52	0.01	71.2
110.	Nakhon Phanom, That Phanom	Apg	0-11	4.75	4.0	0.447	14.9	0.030	27.3	14.4	3.8	-	129	28	4.04	0.75	0.23	0.30	0.06	33.2
		B1g	11-25	5.85	4.75	0.336	14.0	0.028	-	14.2	-	-	266	52	6.66	0.88	0.88	0.74	0.11	39.0
		B2g	25-75	5.6	4.65	0.347	14.6	0.024	-	18.1	-	-	317	33	7.44	2.80	0.82	0.63	0.07	58.1
111.	Nakhon Phanom, Mukdahan	Apg	0-7	4.5	4.1	0.348	14.5	0.024	28.2	8.3	4.5	92	80	-	-	-	-	-	-	-
		Bg	7-22	4.65	3.9	0.255	11.9	0.013	-	8.4	-	92	120	-	-	-	-	-	-	-
		BCg	22-70	5.15	4.05	0.180	12.9	0.014	-	8.3	-	160	339	-	-	-	-	-	-	-
112.	Ubon Ratchathani, Loeng Nok Tha	Apg	0-10	5.1	4.0	0.423	8.0	0.053	37.5	15.3	5.8	-	180	47	5.55	1.28	0.44	0.72	0.10	45.7
		A12g	10-18	5.55	4.0	0.323	11.1	0.029	-	14.3	-	-	198	28	6.12	1.78	0.70	0.50	0.06	49.4
		B21g	18-43	5.65	4.1	0.326	9.8	0.033	-	15.0	-	-	507	80	9.54	3.82	1.55	0.40	0.17	62.8
		B22g	43-75	5.15	4.05	0.226	11.8	0.019	-	15.0	-	-	387	94	13.32	4.82	1.93	0.39	0.20	55.1
113.	Ubon Ratchathani, Muang Rice Ex. St.	Apg	0-10	4.5	4.0	0.336	15.3	0.022	10.1	14.6	33.5	-	30	28	3.10	0.30	0.10	0.80	0.06	40.7
		A12g	10-15	4.55	4.05	0.394	14.6	0.027	-	14.5	-	-	40	38	3.96	0.38	0.23	0.54	0.08	31.1
		Bg	15-30	4.95	4.0	0.318	14.5	0.022	-	11.4	-	-	80	47	6.74	1.14	0.32	0.36	0.10	28.4
		BCg	30-75	5.0	4.0	0.209	11.0	0.019	-	7.1	-	-	10	47	8.62	1.21	0.42	0.53	0.10	26.2
115.	Ubon Ratchathani, Khuang Nai	Apg	0-9	5.5	4.4	0.269	9.3	0.029	9.9	7.3	4.8	-	30	-	-	-	-	-	-	-
		Bg	9-20	6.4	4.45	0.166	8.7	0.019	-	7.3	-	-	53	-	-	-	-	-	-	-
		IIC1g	20-35	7.1	5.8	0.174	8.7	0.020	-	8.3	-	-	118	-	-	-	-	-	-	-
		IIC2g	35-80	7.0	6.35	0.151	9.4	0.016	-	10.5	-	-	319	-	-	-	-	-	-	-
116.	Ubon Ratchathani, Kham Khuan Kaeo	Apg	0-10	5.0	4.45	0.287	10.3	0.028	8.4	7.9	3.7	-	37	-	-	-	-	-	-	-
		A12g	10-24	6.0	5.05	0.108	9.0	0.012	-	5.1	-	-	38	-	-	-	-	-	-	-
		B1g	24-33	6.05	4.6	0.119	8.5	0.014	-	5.1	-	-	28	-	-	-	-	-	-	-
		B21g	33-55	5.9	4.6	0.105	8.1	0.013	-	5.6	-	-	21	-	-	-	-	-	-	-
		B22g	55-80	5.25	4.55	0.128	7.1	0.018	-	5.6	-	-	28	-	-	-	-	-	-	-
117.	Ubon Ratchathani, Yasothon	Apg	0-14	5.45	4.4	0.331	7.4	0.045	17.3	11.5	4.3	-	44	28	3.00	0.50	0.17	0.34	0.06	35.4
		B1g	14-20	6.5	4.85	0.239	9.2	0.026	-	10.5	-	-	56	24	4.60	0.55	0.27	0.51	0.05	30.0
		BIICg	20-40	7.0	5.7	0.293	9.2	0.032	-	11.7	-	-	304	99	12.88	3.86	1.44	3.73	0.21	71.7
		IICg	40-75	7.5	6.2	0.263	8.8	0.030	-	11.4	-	-	289	108	15.73	4.83	1.85	3.67	0.23	69.7
118.	Roi Et, Selaphum	Apg	0-7	5.0	4.2	0.511	8.0	0.064	23.8	12.0	6.8	-	67	151	3.87	0.54	0.13	0.36	0.32	34.9
		A12g	7-12	5.3	4.2	0.398	9.5	0.042	-	11.7	-	-	65	156	3.78	1.36	0.17	0.59	0.33	64.8
		B1g	12-25	5.45	4.35	0.383	9.3	0.041	-	11.7	-	-	139	146	4.25	0.95	0.13	0.83	0.31	52.2
		B2g	25-75	6.0	4.15	0.270	7.0	0.034	-	11.8	-	-	198	146	11.48	1.16	0.17	0.50	0.31	18.6
122.	Roi Et, Suwannaphum	Apg	0-11	5.5	4.5	0.537	8.8	0.061	4.2	7.9	4.4	-	37	38	1.90	0.50	0.27	0.65	0.08	78.9
		Cg	11-46	6.95	5.15	0.221	7.9	0.028	-	7.9	-	-	37	38	1.20	0.33	0.30	0.35	0.08	88.3
		IIC2g	46-57	8.05	6.4	0.200	9.5	0.021	-	7.9	-	-	43	99	7.29	4.31	0.30	0.81	0.21	77.2
		IIC3g	57-80	8.1	6.6	0.152	9.5	0.016	-	9.5	-	-	118	123	13.74	7.26	0.34	1.49	0.26	68.0
123.	Surin, Muang	Apg	0-12	5.9	4.7	0.522	9.7	0.054	28.5	11.5	4.2	92	122	57	2.68	0.58	0.21	0.63	0.12	57.5
		B1g	12-25	6.4	5.2	0.417	8.9	0.047	-	10.5	-	92	160	71	3.28	0.67	0.35	1.22	0.15	72.9
		B21g	25-45	5.9	4.2	0.310	8.9	0.035	-	9.1	-	164	234	156	9.36	2.64	0.30	2.07	0.33	57.1
		B22g	45-70	6.1	5.2	0.274	8.8	0.031	-	7.8	-	288	440	160	15.65	3.66	0.33	2.11	0.34	41.2

*Base saturation degree

No.	Location	Horizon	Depth (cm)	pH (H_2O)	pH (KCl)	T-C %	C/N	T-N %	Av-N ppm	T-P_2O_5 mg/100g	Av-P_2O_5 ppm	Abs. coeff. P_2O_5 mg/100g	T-K_2O mg/100g	Av-K_2O ppm	C.E.C. meq/100g	Ex. Bases meq/100g Ca	Mg	Na	K	(%)*
124.	Surin,	Apg	0-10	6.1	5.2	0.882	9.8	0.090	37.8	11.7	5.5	-	123	127	4.74	1.09	0.23	0.42	0.27	42.4
	Prasat	B1g	10-18	5.4	4.9	0.556	8.8	0.064	-	9.8	-	-	126	123	5.32	1.25	0.21	0.44	0.26	40.6
		B21g	18-43	5.8	4.6	0.395	9.2	0.043	-	7.9	-	-	148	127	7.68	2.40	0.21	0.44	0.27	43.2
		B22g	43-80	6.0	4.3	0.355	8.3	0.043	-	7.9	-	-	141	127	12.17	4.42	0.17	0.38	0.27	43.1
125.	Buri Ram,	Apg	0-9	5.9	4.6	0.807	9.5	0.085	27.5	11.6	3.9	-	139	141	8.14	2.03	0.68	0.88	0.30	47.8
	Prakhon Chai	A12g	9-21	5.8	4.55	0.390	9.8	0.040	-	11.6	-	-	131	123	8.62	2.54	0.64	0.42	0.26	44.8
		Bg	21-32	6.0	4.45	0.269	8.4	0.032	-	11.6	-	-	130	156	7.79	2.37	0.30	0.33	0.33	42.7
Regosols																				
50.	Ubon Ratchathani,	Apg	0-10	4.5	4.5	0.213	9.3	0.023	5.9	5.7	1.0	69	20	19	0.35	0.48	0.02	5.27	0.04	1660.0
	Muang	B1g	10-20	5.6	5.6	0.090	9.0	0.010	-	4.6	4.7	69	18	14	0.28	0.44	0.02	2.16	0.03	946.4
		B2g	20-75	6.2	6.3	0.080	9.0	0.009	-	4.4	3.5	92	18	5	0.29	0.40	0.01	2.14	0.01	882.8
51.	Maha Sarakam,	Ap	0-15	5.85	5.1	0.112	6.6	0.017	2.6	4.6	6.6	35	20	5	0.65	0.62	0.02	0.27	0.01	141.5
	Muang, Pamong	C1	15-30	7.0	5.9	0.061	6.1	0.010	-	4.6	2.9	35	18	5	0.85	0.78	0.02	0.07	0.01	103.5
	Project.	C2	30-70	7.35	6.3	0.054	6.8	0.008	-	2.3	2.7	127	17	9	0.37	0.46	0.02	0.02	0.02	178.4
56.	Sakon Nakhon,	Ap	0-25	4.25	4.2	0.350	10.0	0.035	10.9	9.2	14.2	-	15	18	0.98	0.68	0.22	8.14	0.08	1012.2
	Muang,	C1	25-35	6.0	4.6	0.392	10.6	0.037	-	5.7	13.0	-	13	-	1.10	-	-	-	-	-
	Rice Ex. St.	C2	35-56	5.85	4.7	0.298	9.9	0.030	-	4.7	8.5	-	13	-	0.63	-	-	-	-	-
		C3	56-70	5.7	4.7	0.070	8.8	0.008	-	2.3	3.6	-	10	-	0.30	-	-	-	-	-
		C4	70-86	5.1	4.85	0.231	13.6	0.017	-	2.1	3.4	-	12	14	0.70	0.49	0.19	0.09	0.03	114.3
		IIB	86-100	4.8	4.7	0.374	14.4	0.026	-	22.9	25.2	-	27	14	2.06	0.42	0.22	0.71	0.03	67.0
57.	Sakon Nakhon,	Ap	0-12	4.7	4.3	0.283	13.5	0.021	7.8	6.9	15.5	-	19	19	0.95	0.11	0.16	0.46	0.04	81.1
	Muang,	C1	12-26	4.8	4.5	0.182	12.1	0.015	-	2.1	6.0	-	19	-	0.82	-	-	-	-	-
	Rice Ex. St.	C2	26-44	5.0	4.55	0.182	12.1	0.015	-	2.1	6.5	-	12	-	0.95	-	-	-	-	-
		C3	44-77	4.9	4.5	0.118	9.8	0.012	-	1.1	0.4	-	12	-	0.65	-	-	-	-	-
		C4	77-100	5.05	4.5	0.246	11.1	0.022	-	3.0	2.3	-	29	-	1.85	-	-	-	-	-
103.	Udon Thani,	Apg	0-16	4.25	4.15	0.218	10.9	0.020	9.0	7.1	3.7	-	30	-	-	-	-	-	-	-
	Nong Han	A12g	16-25/31	5.75	5.45	0.191	9.6	0.020	-	1.5	-	-	56	-	-	-	-	-	-	-
		B1g	25/31-46	5.15	4.25	0.061	7.6	0.008	-	6.0	-	-	36	-	-	-	-	-	-	-
104.	Sakon Nakhon,	Apg	0-10	4.1	4.05	0.267	11.1	0.024	10.4	6.2	5.0	90	87	28	1.74	0.94	0.36	0.62	0.06	113.8
	Sawang Daen Din	A12g	10-22	4.95	4.2	0.174	10.9	0.016	-	3.2	-	160	29	-	2.10	1.18	0.21	0.49	0.08	93.3
		B1g	22-35	5.3	4.45	0.139	9.3	0.015	-	1.7	-	69	35	-	1.80	1.55	0.22	0.45	0.08	127.7
		B2g	35-80	5.25	4.25	0.128	9.8	0.013	-	7.2	-	60	34	-	3.91	1.26	0.40	0.97	0.10	69.8
119.	Roi Et,	Apg	0-13	4.6	4.4	0.380	10.6	0.036	12.6	9.1	4.3	69	17	-	-	-	-	-	-	-
	Muang	C1g	13-40	5.55	4.7	0.105	8.8	0.012	-	5.0	-	92	17	-	-	-	-	-	-	-
		C2g	40-80	6.1	5.0	0.087	9.7	0.009	-	6.5	-	69	13	-	-	-	-	-	-	-
120.	Roi Et,	Apg	0-14	4.6	4.45	0.182	7.0	0.026	7.6	5.0	2.0	92	10	-	-	-	-	-	-	-
	Chaturaphak	A12g	14-37	5.5	4.8	0.190	6.7	0.028	-	5.6	-	92	12	-	-	-	-	-	-	-
	Phiman	Cg	37-80	5.6	4.55	0.132	6.9	0.019	-	5.0	-	60	20	-	-	-	-	-	-	-
121.	Roi Et,	Ap	0-12	6.25	4.9	0.187	5.8	0.032	3.6	7.3	2.5	-	14	-	-	-	-	-	-	-
	Kaset Wisai	C	12-75	6.95	5.6	0.187	5.7	0.033	-	7.3	-	-	13	-	-	-	-	-	-	-

*Base saturation degree

Non-Calcic Brown Soils

No.	Location	Horizon	Depth (cm)	pH (H₂O)	pH (KCl)	T-C %	C/N	T-N %	Av-N ppm	T-P_2O_5 mg/100g	Av-P_2O_5 ppm	Abs. coeff. P_2O_5 mg/100g	T-K_2O mg/100g	Av-K_2O ppm	C.E.C. meq/100g	Ex. Bases meq/100g Ca	Mg	Na	K	(%)*
114.	Ubon Ratchathani,	Apg	0-7	4.25	3.75	0.862	9.7	0.089	38.5	20.5	7.4	491	120	71	9.69	2.49	1.38	1.02	0.15	52.0
	Muang,	A12g	7-20	4.65	3.7	0.417	8.9	0.065	-	14.4	-	425	89	80	11.49	2.63	1.76	1.05	0.17	48.8
	Rice Ex. St.	B1g	20-33	4.7	3.75	0.310	8.9	0.051	-	14.5	-	717	130	80	20.01	5.96	2.59	1.40	0.17	50.6
		B2g	33-80	4.95	3.65	0.274	8.8	0.044	-	14.5	-	642	120	71	20.84	6.48	2.38	1.39	0.15	49.9

Northern Region

Fresh Water Alluvial Soils

No.	Location	Horizon	Depth (cm)	pH (H₂O)	pH (KCl)	T-C %	C/N	T-N %	Av-N ppm	T-P_2O_5 mg/100g	Av-P_2O_5 ppm	Abs. coeff. P_2O_5 mg/100g	T-K_2O mg/100g	Av-K_2O ppm	C.E.C. meq/100g	Ex. Bases meq/100g Ca	Mg	Na	K	(%)*
25.	Chiang Mai	Apg	0-15	6.95	5.8	1.201	10.6	0.113	16.6	72.6	28.4	1049	1135	66	16.17	15.75	1.56	0.45	0.14	110.7
	San Pa Thong,	A12g	15-30	7.95	6.9	0.632	11.3	0.056	-	78.1	29.2	884	1058	90	11.39	10.58	1.45	0.61	0.19	112.6
	Rice Ex. St.	IIC1g	30-45	7.95	6.6	0.354	12.2	0.029	-	65.3	28.1	825	1020	47	9.51	9.79	1.13	0.39	0.10	120.0
		IIIC2g	45-55	7.85	6.4	0.368	12.3	0.030	-	77.7	29.3	809	992	66	10.37	10.58	1.19	0.50	0.14	119.7
		IVBg	55-80	7.75	6.2	0.581	12.1	0.048	-	113.0	30.4	1150	1515	71	16.01	15.62	2.33	0.68	0.15	117.3
27.	Chiang Mai,	Apg	0-15	5.95	4.8	0.710	11.5	0.062	32.4	52.2	12.3	540	867	94	8.00	4.73	2.59	0.34	0.20	98.3
	San Kamphaeng	B21g	15-30	6.85	5.35	0.358	9.0	0.040	-	51.8	11.8	763	844	61	11.66	7.79	3.93	0.42	0.13	105.3
		B22g	30-65	7.60	5.80	0.391	8.9	0.044	-	42.2	14.5	638	935	75	9.72	6.78	2.63	0.31	0.16	101.6
32.	Chiang Rai,	Apg	0-12	5.15	4.15	1.312	10.1	0.130	27.4	50.6	22.3	495	295	57	5.40	2.17	1.94	0.32	0.12	84.3
	Muang	B1g	12-25	5.75	4.95	0.650	12.5	0.052	-	33.2	10.2	471	263	19	4.48	2.21	1.15	0.13	0.04	78.8
		B2g	25-60	6.05	5.10	0.377	11.1	0.034	-	27.3	13.7	515	477	19	5.39	2.75	1.28	0.10	0.04	77.4
		Cg	60-80	6.05	5.50	0.372	11.3	0.033	-	91.4	13.9	729	511	38	5.88	3.04	1.89	0.08	0.08	86.6
81.	Chiang Rai,	Apg	0-13	6.0	4.45	1.818	8.5	0.215	24.5	145.8	18.5	1547	935	57	14.89	5.78	2.94	0.13	0.12	60.2
	Chiang Saen	A12g	13-24	6.2	4.6	1.298	8.7	0.149	-	101.7	11.7	1226	935	47	12.82	4.94	3.00	0.09	0.10	63.4
		B21g	24-40	5.4	4.5	0.826	8.2	0.101	-	91.9	18.5	1031	888	47	12.16	4.86	1.89	0.09	0.10	57.1
		B22g	40-65	5.0	4.25	0.775	8.2	0.095	-	103.3	14.6	984	843	108	11.74	4.13	1.96	0.64	0.23	59.3
83.	Chiang Rai,	Apg	0-12	5.55	4.05	1.670	10.4	0.160	-	135.8	20.1	905	781	80	14.15	5.56	2.98	0.40	0.17	64.4
	Mae Chan	A12g	12-21	6.2	4.45	0.842	11.2	0.075	-	82.9	41.8	394	877	24	5.35	1.86	1.37	0.07	0.05	62.6
		IIC1g	21-40	6.45	4.95	1.130	11.1	0.102	-	140.7	47.8	843	901	42	10.45	5.91	3.22	0.48	0.09	92.8
		IIIC2g	40-56	6.45	4.6	0.769	8.8	0.087	-	83.2	19.3	934	1073	47	14.50	6.36	5.36	0.65	0.10	86.0
84.	Chiang Rai,	Apg	0-12	5.3	4.2	2.571	11.6	0.221	149.9	151.2	26.0	-	1208	141	21.58	9.32	3.98	0.78	0.30	66.6
	Muang	C1g	12-37	6.8	5.05	1.069	10.1	0.106	-	80.3	21.4	-	1409	-	-	-	-	-	-	-
		C2g	37-65	6.25	4.55	1.216	9.8	0.124	-	82.3	25.6	-	1363	-	-	-	-	-	-	-
146.	Nan,	Apg	0-10	5.3	3.2	1.629	9.8	0.166	77.3	41.2	3.1	600	607	118	12.19	5.21	3.48	0.93	0.25	81.0
	Muang	C1g	10-18	6.2	4.95	1.136	9.1	0.125	-	36.2	-	634	423	113	12.33	7.33	5.08	1.46	0.24	114.4
		C2g	18-55	7.15	6.45	0.609	9.5	0.064	-	34.9	-	649	486	99	13.93	9.33	6.55	1.09	0.19	122.8
152.	Chiang Rai,	Apg	0-10	5.1	4.0	2.279	12.2	0.187	165.8	105.4	29.8	845	506	250	16.61	8.23	6.83	2.51	0.53	109.0
	Mae Chan	A12g	10-25	5.8	4.5	1.548	9.9	0.129	-	111.5	-	1010	537	104	16.90	8.71	6.39	1.37	0.22	98.8
		B1g	25-40	5.85	4.5	1.015	9.9	0.103	-	155.6	-	755	269	113	16.76	8.80	6.84	1.18	0.24	101.8
		B2g	40-65	6.0	4.7	0.649	11.2	0.058	-	81.6	-	656	225	113	16.38	8.71	6.43	1.30	0.24	101.8

*Base saturation degree

Low Humic Gley Soils

No.	Location	Horizon	Depth (cm)	pH (H₂O)	pH (KCl)	T-C %	C/N	T-N %	Av-N ppm	T-P₂O₅ mg/100g	Av-P₂O₅ ppm	Abs. coeff. P₂O₅ mg/100g	T-K₂O mg/100g	Av-K₂O ppm	C.E.C. meq/100g	Ex. Bases meq/100g Ca	Mg	Na	K	(%)*
26.	Chiang Mai, Mae Taeng	Apg	0-15	5.35	4.55	1.572	10.5	0.150	97.5	84.1	21.8	749	1512	108	14.81	10.62	1.98	0.29	0.23	88.6
		A12g	15-25	7.15	6.15	0.750	11.9	0.063	-	130.6	19.8	941	1804	90	16.33	15.25	2.63	0.35	0.19	112.8
		B21g	25-45	7.15	5.65	0.901	12.2	0.074	-	202.6	17.2	1041	1651	113	19.38	16.28	3.18	0.41	0.24	103.8
		B22g	45-90	6.95	5.5	0.693	9.8	0.071	-	197.7	20.2	1025	1791	179	17.31	14.35	2.45	0.29	0.38	100.9
28.	Lampang, Hang Chat	Apg	0-15	4.9	4.05	0.910	10.2	0.089	23.1	50.4	16.6	564	806	151	8.60	4.40	2.19	0.94	0.32	91.3
		B1g	15-25	6.0	4.25	0.596	9.3	0.064	-	53.4	18.8	784	1210	113	13.87	5.37	3.61	0.42	0.24	69.5
		B2g	25-65	5.85	3.85	0.494	8.8	0.056	-	51.8	15.4	816	1159	90	13.97	4.79	3.75	0.42	0.19	65.5
30.	Lampang, Ngao	Apg	0-15	5.65	5.2	1.252	10.4	0.120	46.9	51.6	20.1	684	678	66	9.66	7.66	1.80	0.23	0.14	101.8
		B1g	15-25	7.25	6.8	0.453	9.4	0.048	-	22.7	11.8	646	579	42	9.28	11.19	0.45	0.30	0.09	129.6
		B2g	25-65	7.25	6.5	0.470	10.7	0.044	-	27.1	10.5	705	699	38	9.85	10.42	0.45	0.24	0.08	113.6
33.	Chiang Rai, Phan, Rice Ex. St.	Apg	0-15	5.65	4.9	1.461	11.2	0.131	72.2	45.1	14.8	669	1268	264	15.26	10.91	2.07	0.43	0.56	89.8
		A12g	15-25	6.9	6.1	0.808	8.7	0.093	-	41.9	16.6	493	1270	108	14.32	12.02	2.92	0.39	0.23	108.7
		B21g	25-45	7.55	6.6	0.711	10.5	0.068	-	41.0	13.1	458	1182	75	14.77	12.68	2.05	0.46	0.16	103.9
		B22g	45-65	8.0	7.15	0.439	8.1	0.054	-	36.4	13.6	624	900	66	14.90	13.43	1.99	0.41	0.14	107.2
34.	Chiang Rai, Phayao	Apg	0-13	4.75	4.0	1.553	10.7	0.145	25.3	73.6	12.0	661	876	137	16.84	6.82	3.12	0.14	0.29	61.6
		B21g	13-25	4.75	4.1	0.737	10.0	0.074	-	45.4	9.4	584	1030	47	11.76	3.81	2.98	0.11	0.10	59.6
		B22g	25-45	5.1	4.0	0.654	9.1	0.072	-	55.2	9.6	657	711	80	13.24	2.97	3.05	0.22	0.17	48.4
		B23g	45-75	4.55	3.95	0.494	8.4	0.059	-	45.6	9.7	613	1126	14	13.43	2.30	2.21	0.09	0.03	34.5
35.	Phrae, Muang, Rice Ex. St.	Apg	0-15	5.3	4.65	0.625	11.4	0.055	23.1	17.9	7.8	421	273	42	3.84	2.62	0.99	0.02	0.09	96.9
		A12g	15-30	5.75	4.7	0.525	12.2	0.043	-	13.3	8.7	413	280	24	3.77	3.39	0.97	0.05	0.05	90.6
		B1g	30-50	5.05	4.15	0.356	11.9	0.030	-	11.9	4.8	398	360	5	4.07	1.47	1.25	0.11	0.01	69.7
		B2g	50-75	4.45	3.95	0.268	10.3	0.026	-	6.6	3.5	461	398	5	3.98	1.11	1.17	0.01	0.01	58.8
85.	Lampang Ngao	Apg	0-12	5.75	5.0	1.516	9.6	0.158	62.3	67.8	28.5	582	1823	132	15.61	12.68	2.57	0.83	0.28	104.8
		B21g	12-35	7.85	6.65	0.730	9.7	0.075	-	54.7	26.5	568	1866	-	-	-	-	-	-	-
		B22g	35-65	7.75	6.5	0.462	9.6	0.048	-	39.5	14.3	604	1437	-	-	-	-	-	-	-
86.	Lampang Muang	Apg	0-13	5.35	4.35	1.410	12.8	0.110	62.4	48.0	22.7	-	650	80	12.85	5.46	2.06	0.73	0.17	65.5
		B1g	13-24	7.65	6.25	0.637	11.4	0.056	-	38.4	26.9	-	583	-	-	-	-	-	-	-
		B2g	24-39	7.9	6.15	0.427	9.5	0.045	-	45.1	28.5	-	723	-	-	-	-	-	-	-
		BCg	39-65	7.2	5.55	0.428	9.1	0.047	-	55.5	33.3	-	722	-	-	-	-	-	-	-
87.	Lamphun, Muang	Apg	0-10	5.35	4.2	0.382	12.3	0.031	30.8	22.2	25.9	299	185	52	3.14	1.76	0.24	0.09	0.11	70.1
		A12g	10-18	5.80	4.85	0.286	11.4	0.025	-	23.9	42.6	288	188	118	2.92	1.61	0.32	0.04	0.25	76.0
		B21g	18-33	6.15	4.25	0.267	12.1	0.022	-	25.7	31.7	399	555	28	5.63	1.92	0.41	0.17	0.06	45.5
		B22g	33-65	6.15	3.7	0.182	14.0	0.013	-	29.1	33.4	420	735	28	7.03	1.10	0.53	0.66	0.06	33.4
88.	Chiang Mai, Hang Dong	Apg	0-12	6.55	5.15	1.904	10.6	0.179	-	92.3	12.9	963	753	71	18.28	15.28	2.72	1.50	0.15	107.5
		A12g	12-18	8.4	6.4	1.200	10.9	0.110	-	94.8	14.6	887	993	52	20.00	19.61	0.42	1.74	0.11	109.4
		A12g	18-25	8.7	6.4	0.774	9.7	0.080	-	100.6	8.5	921	1005	47	18.67	19.52	0.58	1.91	0.10	118.4
		ABG	25-38	8.5	6.25	0.811	11.1	0.073	-	108.3	29.2	989	970	80	17.96	18.85	0.39	1.77	0.17	117.9
		B21g	38-48	8.3	6.05	0.593	11.4	0.052	-	122.2	16.7	1359	717	33	19.39	16.97	1.30	1.31	0.07	101.3
89.	Chiang Mai, Doi Saket	Apg	0-15	5.3	3.8	1.257	11.1	0.113	105.6	109.2	23.2	-	885	80	12.64	5.68	1.98	0.11	0.17	62.8
		B21g	15-43	7.8	5.65	0.625	12.0	0.052	-	88.9	23.2	-	1120	-	-	-	-	-	-	-
		B22g	43-55	7.5	5.0	0.590	11.1	0.053	-	98.4	15.1	-	1220	-	-	-	-	-	-	-
		IICg	55-75	7.2	4.65	0.570	11.4	0.050	-	170.7	25.6	-	1553	-	-	-	-	-	-	-

*Base saturation degree

No.	Location	Horizon	Depth (cm)	pH (H$_2$O)	pH (KCl)	T-C %	C/N	T-N %	Av-N ppm	T-P$_2$O$_5$ mg/100g	Av-P$_2$O$_5$ ppm	Abs. coeff. P$_2$O$_5$ mg/100g	T-K$_2$O mg/100g	Av-K$_2$O ppm	C.E.C. meq/100g	Ex. Bases meq/100g Ca	Mg	Na	K	(%)*
143.	Phrae,	Apg	0-6	6.1	5.25	1.508	13.3	0.113	32.5	35.1	2.5	-	557	118	12.10	8.18	5.12	0.85	0.25	119.0
	Sung Men	B1g	6-22	7.2	5.85	0.893	11.6	0.077	-	30.1	-	-	533	123	14.93	10.70	6.44	0.94	0.26	122.4
		B2g	22-65	7.45	5.95	0.609	10.3	0.059	-	26.3	-	-	638	141	16.80	11.27	7.81	1.20	0.30	122.5
144.	Nan,	Apg	0-10	5.3	3.95	1.548	10.7	0.145	83.9	38.7	6.1	-	815	165	10.20	5.34	2.78	1.54	0.35	98.0
	Sa	A12g	10-20	6.2	4.95	1.136	11.8	0.096	-	38.9	-	-	780	123	10.15	7.07	3.86	1.16	0.26	121.7
		B21g	20-26	7.25	6.2	0.609	12.4	0.049	-	36.4	-	-	863	113	10.46	7.57	4.62	1.65	0.24	134.6
		B22g	26-65	7.0	5.5	0.527	12.5	0.042	-	74.4	-	-	951	113	10.05	8.90	5.41	2.09	0.24	165.6
145.	Nan,	Apg	0-10	5.1	3.55	1.386	10.0	0.138	71.5	45.7	5.4	349	894	127	12.93	4.74	5.54	1.39	0.27	92.3
	Muang	B1g	10-26	5.95	4.8	0.868	9.9	0.088	-	39.3	-	302	937	99	12.68	4.29	5.46	1.13	0.24	87.6
		B2g	26-65	6.6	5.5	0.649	9.9	0.065	-	42.1	-	328	918	123	10.41	5.56	5.80	0.97	0.19	100.9
147.	Phrae,	Apg	0-15	7.9	7.2	0.974	12.8	0.076	24.9	28.6	52.7	-	281	160	5.72	4.53	1.96	1.15	0.34	139.5
	Muang,	B1g	15-35	7.6	6.65	0.203	9.2	0.022	-	9.1	-	-	172	99	4.26	3.68	1.18	0.49	0.21	130.3
	Pa Dean	B2g	35-80	7.4	6.15	0.120	9.2	0.013	-	11.3	-	-	148	123	4.84	4.04	1.01	0.41	0.26	118.2
148.	Phrae,	Apg	0-13	5.9	4.9	1.386	10.7	0.130	41.7	49.7	5.6	551	483	141	9.91	5.43	2.99	0.98	0.30	97.9
	Song	B1g	13-23	7.65	6.4	0.852	10.1	0.084	-	39.4	-	434	1022	123	9.62	7.48	3.67	0.80	0.26	126.9
		B2g	23-65	7.75	6.55	0.527	9.5	0.055	-	39.4	-	579	1102	160	13.42	11.25	4.30	1.17	0.34	127.1
149.	Chiang Rai,	Apg	0-10	4.7	3.8	1.670	13.4	0.125	62.4	32.1	2.3	-	1035	226	14.83	7.53	2.60	0.81	0.48	77.0
	Dok Kham Tai	A12g	10-18	5.6	4.5	1.299	12.9	0.101	-	35.0	-	-	1150	174	14.94	9.11	3.99	0.77	0.37	95.3
		B1g	18-40	6.2	5.6	0.812	12.5	0.066	-	31.7	-	-	1855	179	19.46	13.53	5.96	0.50	0.38	104.6
		B2g	40-65	5.8	5.05	0.446	9.3	0.048	-	24.6	-	-	726	113	18.25	10.03	5.03	1.22	0.24	90.5
150.	Chiang Rai,	Apg	0-10	5.75	4.5	1.589	11.1	0.143	58.1	36.7	14.8	835	1127	123	9.11	4.55	2.40	0.72	0.26	87.1
	Mae Chai	A12g	10-20	7.4	6.3	0.690	9.5	0.072	-	28.8	-	714	1202	99	9.56	6.57	2.77	0.59	0.19	105.9
		B1g	20-45	7.6	6.65	0.609	10.0	0.061	-	34.9	-	714	1482	113	10.84	8.45	2.83	1.12	0.24	116.6
		B2g	45-70	6.95	5.95	0.446	7.6	0.059	-	50.2	-	581	1480	160	10.14	8.78	2.14	1.67	0.34	128.4
151.	Chiang Rai,	Apg	0-11	5.85	4.7	1.096	9.1	0.120	72.7	55.7	17.6	-	1247	217	15.21	10.64	2.41	1.44	0.46	98.3
	Phan,	A12g	11-20	7.0	6.0	0.852	9.5	0.090	-	46.5	-	-	1385	174	14.61	12.31	2.13	0.95	0.37	107.9
	Rice Ex. St.	B21g	20-35	7.2	6.3	0.690	9.4	0.073	-	40.1	-	-	1404	207	14.43	13.11	1.99	1.61	0.44	118.9
		B22g	35-65	7.65	7.15	0.365	8.5	0.043	-	37.8	-	-	791	113	14.14	12.58	2.15	1.35	0.24	115.4
153.	Chiang Rai,	Apg	0-10	5.25	4.0	1.786	9.1	0.196	82.5	116.4	8.7	-	685	-	-	-	-	-	-	-
	Chiang Saen	B1g	10-20	6.15	4.7	0.893	10.9	0.082	-	71.2	-	-	732	-	-	-	-	-	-	-
		B2g	20-50	6.3	5.0	0.487	12.5	0.039	-	65.9	-	-	746	-	-	-	-	-	-	-
154.	Lampang,	Apg	0-8	5.4	4.25	1.299	12.7	0.102	60.8	36.3	19.2	-	331	-	-	-	-	-	-	-
	Muang	B1g	8-15	6.7	5.55	0.690	11.9	0.058	-	28.2	-	-	318	-	-	-	-	-	-	-
		B2g	15-50	6.65	5.55	0.368	11.9	0.031	-	28.0	-	-	381	-	-	-	-	-	-	-
155.	Chiang Mai,	Apg	0-9	5.2	3.75	1.670	13.5	0.124	61.0	56.7	23.3	-	542	189	5.33	2.24	1.06	1.50	0.40	97.6
	Chiang Dao	A12g	9-19	5.65	4.2	0.649	12.0	0.054	-	49.7	-	-	507	108	5.08	2.54	1.04	1.28	0.23	100.2
		B1g	19-30	5.75	4.5	0.446	9.4	0.048	-	63.3	-	-	581	108	5.50	2.71	1.96	1.01	0.23	107.5
		B2g	30-55	5.7	4.25	0.493	10.0	0.050	-	71.9	-	-	675	170	7.26	2.84	2.49	1.45	0.36	98.4
156.	Chiang Mai,	Apg	0-13	5.2	4.0	0.893	10.4	0.086	44.9	39.4	13.1	-	55	66	3.20	1.30	0.75	0.83	0.14	94.4
	Fang, Mae Ai	B1g	13-23	5.5	4.35	0.406	8.1	0.050	-	32.7	-	-	94	47	4.20	1.80	0.82	0.83	0.10	84.5
		B2g	23-65	5.6	4.25	0.265	12.0	0.022	-	26.0	-	-	82	57	4.40	1.50	1.25	0.85	0.12	84.6

*Base saturation degree

No.	Location	Horizon	Depth (cm)	pH (H_2O)	pH (KCl)	T-C %	C/N	T-N %	Av-N ppm	T-P_2O_5 mg/100g	Av-P_2O_5 ppm	Abs. coeff. P_2O_5 mg/100g	T-K_2O mg/100g	Av-K_2O ppm	C.E.C. meq/100g	Ex. Bases meq/100g Ca	Mg	Na	K	(%)*
157.	Chiang Mai, Fang, Wieng	Apg	0-13	5.35	4.0	1.596	10.0	0.159	113.2	55.8	13.5	479	950	203	8.00	3.70	2.07	1.46	0.43	95.8
		A12g	13-23	6.15	5.0	0.933	9.7	0.096	-	55.8	-	419	923	141	6.49	3.86	2.73	1.59	0.30	130.7
		B1g	23-45	6.55	5.7	0.568	8.6	0.066	-	50.6	-	383	1031	66	5.19	3.35	2.98	0.88	0.14	142.4
		B2g	45-70	6.35	5.0	0.346	8.9	0.039	-	76.8	-	359	627	85	4.74	3.85	2.80	0.79	0.18	160.8
158.	Chiang Mai, Fang, Pong Tam	Apg	0-7	5.35	4.1	1.458	10.0	0.146	57.3	30.8	10.9	283	485	217	5.94	3.72	1.78	1.51	0.46	125.8
		A12g	7-20	6.75	5.95	0.609	10.7	0.057	-	25.1	-	499	673	85	7.82	6.09	1.79	1.19	0.18	118.3
		B1g	20-30	7.65	6.55	0.243	10.1	0.024	-	28.5	-	464	655	99	10.98	7.92	2.12	1.10	0.21	103.4
		B2g	30-55	7.4	6.1	0.306	8.3	0.037	-	34.8	-	430	686	108	10.31	7.25	2.47	1.49	0.23	111.0
Humic Gley Soils																				
31.	Chiang Rai, Mae Sai	Apg	0-15	7.65	7.3	3.192	12.8	0.250	86.8	129.1	32.6	1143	841	123	21.53	50.46	0.59	0.53	0.26	240.8
		A12g	15-25	7.85	6.8	1.648	12.9	0.128	-	87.5	36.1	1137	821	71	20.71	20.56	0.92	0.48	0.15	106.8
		B1g	25-40	7.9	6.65	0.911	13.4	0.068	-	72.4	17.0	1066	1235	71	22.31	20.52	1.83	0.45	0.15	102.9
		B2g	40-60	7.8	6.5	1.092	13.8	0.079	-	97.3	17.6	1079	976	75	24.72	25.88	2.87	0.51	0.16	119.0
		Cg	60-85	8.15	6.75	0.712	13.4	0.053	-	88.9	17.8	1130	907	66	25.11	24.32	2.44	0.43	0.14	108.8
82.	Chiang Rai, Mae Sai	Apg	0-20	7.85	7.0	2.776	12.2	0.227	72.6	129.4	31.7	-	820	123	19.78	42.08	2.20	0.57	0.26	228.0
		B21g	20-32	8.25	6.75	1.052	11.8	0.089	-	101.1	20.7	-	876	-	-	-	-	-	-	-
		B22g	32-48	8.1	6.35	0.947	13.3	0.071	-	80.0	23.2	-	1029	-	-	-	-	-	-	-
		BCg	48-65	8.15	6.45	0.714	11.0	0.065	-	90.2	26.0	-	969	-	-	-	-	-	-	-
Gray Podzolic Soils																				
24.	Chiang Mai, Chom Thong	Apg	0-20	7.2	6.65	0.660	11.8	0.056	3.8	23.1	19.8	312	213	66	6.73	7.20	0.36	0.22	0.14	117.8
		A12g	20-35	7.95	6.9	0.145	12.1	0.012	-	13.1	13.0	343	162	28	3.86	4.10	0.44	0.33	0.06	127.7
		B1	35-70	8.65	7.3	0.052	7.4	0.007	-	9.2	8.0	293	76	19	1.24	1.55	0.22	0.22	0.04	164.0
		B2	70-85	8.7	7.6	0.039	7.8	0.005	-	8.0	9.6	209	132	52	2.85	2.69	0.52	1.81	0.11	180.6
Southern Region																				
Marine Alluvial Soils																				
171.	Nakhon Si Tham-marat, Muang, Rice Ex. St.	Apg	0-15	6.1	5.05	2.142	13.9	0.154	58.2	53.4	15.5	1072	1089	589	27.80	16.64	20.78	5.70	1.25	159.6
		A12g	15-30	8.25	6.55	2.242	13.8	0.162	-	76.4	-	1045	1309	631	25.46	16.63	19.34	5.69	1.34	168.9
		Cg	30-50	8.35	6.75	1.330	13.9	0.092	-	54.1	-	990	1856	815	25.81	14.00	19.10	5.75	1.73	156.8
Brackish Water Alluvial Soils																				
94.	Songkhla, Muang	Apg	0-18	3.95	3.4	3.156	15.9	0.198	41.1	62.6	19.5	-	1011	189	19.51	3.01	2.14	1.12	0.40	34.2
		B1g	18-33	3.9	3.3	0.844	11.3	0.075	-	32.4	-	-	1196	13	14.35	2.65	1.34	0.26	0.24	31.3
		IIB2g	33-	4.25	3.85	0.403	10.6	0.038	-	25.1	-	-	1769	90	14.34	1.44	1.27	0.75	0.19	25.5

*Base saturation degree

Fresh Water Alluvial Soils

No.	Location	Horizon	Depth (cm)	pH (H₂O)	pH (KCl)	T-C %	C/N	T-N %	Av-N ppm	T-P_2O_5 mg/100g	Av-P_2O_5 ppm	Abs. coeff. P_2O_5 mg/100g	T-K_2O mg/100g	Av-K_2O ppm	C.E.C. meq/100g	Ex. Bases meq/100g Ca	Mg	Na	K	(%)*
92.	Phatthalung,	Apg	0-13	5.2	4.05	1.065	12.5	0.085	34.7	24.0	18.4	-	344	66	6.91	1.79	1.49	0.17	0.14	52.0
	Khuan Khanun,	A12g	13-22	5.1	4.65	0.720	11.4	0.063	-	16.3	-	-	344	18	6.35	3.40	1.28	0.10	0.04	75.9
	Rice Ex. St.	IIB21g	22-33	5.4	4.8	0.534	11.4	0.047	-	38.7	-	-	641	18	7.50	2.08	0.92	0.05	0.04	41.2
		IIB22g	33-	5.45	4.95	0.479	14.1	0.034	-	20.4	-	-	591	42	9.55	3.20	0.92	0.34	0.09	47.6
174.	Phatthalung,	Apg	0-17	5.4	4.3	1.019	11.2	0.091	44.2	33.7	13.0	517	473	75	9.12	6.29	0.70	0.17	0.16	80.3
	Khun Khanun,	B1g	17-30	5.65	4.5	0.745	10.8	0.069	-	28.1	-	427	620	66	9.23	6.89	0.56	0.33	0.14	85.8
	Rice Ex. St.	B21g	30-60	5.65	4.4	0.471	10.7	0.044	-	11.3	-	512	681	52	11.02	8.29	0.30	0.68	0.11	85.1
		B22g	60-75	5.45	4.35	0.374	9.6	0.039	-	28.3	-	539	893	61	15.99	8.29	0.34	0.19	0.13	56.0
175.	Phatthalung,	Apg	0-14	5.1	4.0	1.339	12.4	0.108	43.7	38.7	20.3	522	319	57	10.08	4.10	0.75	0.31	0.12	52.4
	Khuan Khanun,	B1g	14-23	5.45	4.1	0.625	11.8	0.053	-	28.1	-	317	385	33	9.24	4.39	0.53	0.40	0.07	58.3
	Rice Ex. Subst.	B2g	23-70	5.1	4.95	0.225	9.8	0.023	-	11.2	-	472	501	43	12.38	5.01	1.34	1.15	0.09	61.3

Low Humic Gley Soils

No.	Location	Horizon	Depth (cm)	pH (H₂O)	pH (KCl)	T-C %	C/N	T-N %	Av-N ppm	T-P_2O_5 mg/100g	Av-P_2O_5 ppm	Abs. coeff. P_2O_5 mg/100g	T-K_2O mg/100g	Av-K_2O ppm	C.E.C. meq/100g	Ex. Bases meq/100g Ca	Mg	Na	K	(%)*
91.	Phatthalung,	Apg	0-10	4.6	3.9	1.194	12.3	0.097	62.5	20.4	16.2	-	298	57	5.32	1.41	1.02	0.39	0.12	55.3
	Muang	A12g	10-20	5.5	4.85	0.589	13.1	0.045	-	26.2	-	-	826	57	5.95	1.15	1.48	0.26	0.12	50.6
		G1	20-	5.4	4.85	0.386	10.2	0.038	-	27.0	-	-	955	71	7.75	1.04	1.91	0.15	0.15	41.8
93.	Songkhla,	Apg	0-9	4.8	3.95	0.696	11.2	0.062	42.2	30.1	11.0	-	370	57	3.88	1.20	0.78	0.29	0.12	61.6
	Pattaphum	B21g	19-37	5.4	5.25	0.441	10.3	0.043	-	32.9	-	-	597	66	6.56	1.40	0.47	0.19	0.14	33.5
		B22g	37-	5.4	4.85	0.386	12.9	0.030	-	25.0	-	-	805	38	5.92	1.46	0.58	0.65	0.08	46.8
164.	Prachuap Khiri	Apg	0-15	6.35	5.5	0.690	8.6	0.086	18.4	73.2	21.7	-	503	71	5.66	2.54	1.64	0.96	0.15	93.5
	Khan, Thap Sakae	B1g	15-32	7.5	6.0	0.402	8.3	0.048	-	73.6	-	-	774	113	9.74	5.00	2.61	3.64	0.24	117.9
		B2g	32-65	8.8	6.85	0.361	8.6	0.042	-	62.4	-	-	894	99	11.25	6.55	2.19	4.76	0.21	121.9
165.	Chumphon,	Apg	0-15	4.9	3.95	1.325	10.9	0.122	51.8	33.7	26.4	397	650	58	7.30	3.17	1.60	0.19	0.08	69.0
	Muang	A12g	15-25	6.8	5.35	1.013	12.2	0.083	-	33.5	-	502	733	33	7.27	4.33	1.30	0.19	0.07	81.0
		B1g	25-65	5.8	4.8	0.596	14.2	0.042	-	28.4	-	302	894	28	7.64	4.19	1.83	0.22	0.06	82.5
		B2g	65-85	6.8	5.5	0.668	13.1	0.051	-	27.8	-	303	760	38	7.93	3.69	0.70	0.44	0.08	61.9
167.	Pangnga,	Apg	0-15	4.6	3.95	2.100	9.5	0.221	93.4	82.1	34.0	-	1994	127	9.11	1.81	1.64	0.15	0.27	42.4
	Thai Muang	B1g	15-32	5.1	4.0	0.806	10.2	0.079	-	60.6	-	-	2029	75	7.59	2.69	1.97	0.43	0.16	69.0
		B2g	32-66	5.2	4.0	0.805	10.9	0.074	-	53.4	-	-	2217	42	7.77	2.90	2.23	0.32	0.09	71.3
170.	Krabi,	Apg	0-17	5.05	4.3	0.932	14.8	0.063	12.3	30.6	15.1	-	64	42	2.65	0.62	0.64	0.43	0.09	68.7
	Khlong Thom	ABg	17-30	5.0	4.3	0.480	15.0	0.032	-	11.3	-	-	70	19	2.80	0.63	0.67	0.31	0.02	58.2
		B1g	30-51	4.95	4.3	0.294	14.0	0.021	-	7.8	-	-	70	14	3.08	1.50	0.29	0.24	0.03	66.9
		B2g	51-70	4.75	4.1	0.131	11.9	0.011	-	13.6	-	-	88	52	6.33	2.68	0.43	0.42	0.11	57.5
172.	Nakhon Si	Apg	0-13	5.25	4.4	1.114	8.4	0.132	47.1	39.2	18.6	-	972	66	5.08	3.17	0.80	0.19	0.14	84.8
	Thammarat,	B1g	13-23	5.7	4.7	0.714	8.1	0.088	-	28.4	-	-	717	52	4.25	2.78	0.72	0.57	0.11	98.4
	Thung Song	B2g	23-50	6.05	4.85	0.323	8.1	0.040	-	75.8	-	-	118	57	6.16	4.27	1.10	0.24	0.12	93.0

*Base saturation degree

No.	Location	Horizon	Depth (cm)	pH (H₂O)	pH (KCl)	T-C %	C/N	T-N %	Av-N ppm	$T\text{-}P_2O_5$ mg/100g	$Av\text{-}P_2O_5$ ppm	Abs. coeff. P_2O_5 mg/100g	$T\text{-}K_2O$ mg/100g	$Av\text{-}K_2O$ ppm	C.E.C. meq/100g	Ex. Bases meq/100g Ca	Mg	Na	K	(%)*
173.	Trang,	Apg	0-16	5.0	4.15	1.088	8.5	0.128	82.0	73.6	8.5	-	1280	85	13.65	8.97	1.79	0.32	0.18	89.8
	Muang	B1g	16-45	7.65	7.15	0.385	7.4	0.052	-	70.7	-	-	1069	85	13.38	12.26	3.65	0.35	0.18	115.4
		B2g	45-75	8.25	7.3	0.340	7.9	0.043	-	71.0	-	-	955	90	14.93	15.54	4.09	0.23	0.19	114.2
176.	Satun,	Apg	0-10	5.15	4.2	1.141	9.2	0.124	62.9	40.0	9.6	581	1679	52	6.79	2.30	0.72	0.17	0.11	48.6
	Muang	B1g	10-23	6.45	5.15	0.571	10.0	0.057	-	53.3	-	430	1475	42	8.92	5.19	1.64	0.43	0.09	82.4
		B2g	23-35	6.4	5.1	0.392	9.8	0.040	-	52.4	-	368	2031	61	9.05	5.43	1.68	0.35	0.13	83.9
		Cg	35-72	6.25	5.0	0.373	9.1	0.041	-	28.4	-	344	2301	113	11.52	5.85	1.77	1.87	0.24	84.5
177.	Songkhla,	Apg	0-10	4.55	4.0	1.132	10.2	0.111	51.7	28.5	19.7	528	449	66	4.83	1.60	0.63	0.46	0.14	58.6
	Muang	B1g	10-21	4.8	4.0	0.606	10.1	0.060	-	19.4	-	643	1838	28	6.76	1.99	0.59	0.48	0.06	46.2
		B2g	21-38	4.9	3.9	0.409	9.5	0.043	-	7.9	-	511	802	14	5.23	1.51	0.51	0.86	0.03	55.6
		B3g	38-68	4.95	3.85	0.313	9.2	0.034	-	33.6	-	-	942	38	6.16	1.15	1.50	1.33	0.08	65.9
179.	Pattani,	Apg	0-12	4.95	4.1	0.862	11.2	0.077	21.7	39.9	21.4	469	269	57	3.91	1.30	0.43	0.62	0.12	63.2
	Khok Pho,	B1g	12-28	4.55	4.0	0.408	10.2	0.040	-	39.2	-	702	359	33	4.82	1.84	0.41	0.84	0.07	65.6
	Rice Ex. St.	B2g	28-70	4.9	4.1	0.279	9.0	0.031	-	33.6	-	705	410	24	4.13	2.33	0.56	0.20	0.05	76.0
180.	Pattani,	Apg	0-12	4.35	3.9	1.098	12.2	0.090	40.3	39.8	13.0	-	928	61	5.20	1.04	1.50	1.05	0.13	71.5
	Muang	B1g	12-26	5.95	4.35	0.616	13.1	0.047	-	33.4	-	-	1229	38	6.82	2.04	2.46	1.08	0.08	83.0
		B2g	26-65	6.15	4.7	0.421	10.8	0.039	-	39.7		-	1043	42	7.03	1.61	2.76	1.67	0.09	87.2
181.	Yala,	Apg	0-12	5.0	4.15	3.256	13.4	0.243	47.0	54.1	18.5	-	299	71	5.24	1.33	0.26	0.18	0.15	36.6
	Raman	B1g	12-22	5.25	4.2	0.714	12.1	0.059	-	33.6	-	-	294	19	3.96	1.65	0.33	0.19	0.04	55.8
		B2g	22-42	5.3	4.05	0.203	10.7	0.019	-	20.0	-	-	360	24	4.04	1.40	0.54	0.22	0.05	54.7
		B3g	42-70	5.4	4.2	0.210	10.5	0.020	-	28.4	-	-	239	61	5.07	2.12	0.84	0.61	0.13	73.0
182.	Narathiwat,	Apg	0-15	4.5	3.95	2.081	10.3	0.202	50.3	71.7	20.1	646	898	127	11.51	2.30	2.21	0.43	0.27	45.3
	Muang	B1g	15-30	4.6	4.1	0.637	9.8	0.065	-	39.9	-	583	869	42	7.15	3.34	1.88	0.56	0.09	82.1
		B2g	30-40	4.7	4.1	0.313	9.2	0.034	-	39.4	-	476	651	33	5.33	2.56	1.41	0.49	0.07	84.9
		IIC1g	40-60	4.8	4.2	0.156	7.8	0.020	-	28.4	-	216	449	24	3.40	2.54	1.43	0.35	0.05	128.5
		IIC2g	60-90	4.8	4.05	0.108	7.2	0.015	-	34.0	-	217	417	24	3.77	2.44	1.27	0.27	0.05	107.0
Regosols																				
90.	Phuket,	Apg	0-11	4.95	4.0	1.084	12.2	0.089	36.5	30.2	23.4	-	342	47	2.58	0.79	0.57	0.25	0.10	66.4
	Thalang	A12g	11-18	5.9	4.85	0.864	10.8	0.080	-	32.0	-	-	405	38	4.96	1.01	0.76	0.16	0.08	40.6
166.	Ranong,	Agp	0-13	4.8	4.25	1.290	12.8	0.101	37.3	39.7	33.7	-	596	56	4.36	0.63	0.34	0.46	0.12	35.7
	Kra Buri	Bg	13-40	5.3	4.4	0.191	8.3	0.023		39.5	-	-	593	61	4.94	0.75	0.38	0.19	0.13	29.4
168.	Phuket,	Apg	0-15	4.75	4.3	0.583	11.9	0.049	20.1	80.4	39.6	-	437	108	4.80	1.39	0.30	0.07	0.23	41.4
	Thalang	B1g	15-30	5.0	4.2	0.425	10.1	0.042	-	75.9	-	-	384	28	4.53	0.89	0.51	0.29	0.06	38.4
		B2g	30-55	4.5	4.2	0.244	9.8	0.025	-	72.8	-	-	707	56	2.88	1.02	0.82	0.04	0.12	69.4
		IIC	55-85	5.65	4.55	0.164	10.9	0.015	-	34.1	-	-	299	38	1.50	0.68	0.58	0.22	0.08	104.0

*Base saturation degree

Gray Podzolic Soils

No.	Location	Horizon	Depth (cm)	pH (H_2O)	pH (KCl)	T-C %	C/N	T-N %	Av-N ppm	T-P_2O_5 mg/100g	Av-P_2O_5 ppm	Abs. coeff. P_2O_5 mg/100g	T-K_2O mg/100g	Av-K_2O ppm	C.E.C. meq/100g	Ex. Bases meq/100g Ca	Mg	Na	K	(%)*
169.	Pangnga, Thap Put	Apg	0-8	4.75	4.1	1.031	11.2	0.092	29.2	34.2	11.9	244	719	57	5.93	2.41	0.97	0.03	0.12	59.7
		Blg	8-17	5.95	5.0	0.406	9.0	0.045	-	28.0	-	380	1061	33	6.60	2.82	1.82	0.60	0.07	80.5
		B21g	17-35	5.05	4.05	0.284	10.9	0.026	-	33.7	-	468	1478	52	8.21	3.83	1.45	0.58	0.11	72.6
		B22g	35-62	5.3	4.1	0.181	9.5	0.019	-	39.6	-	474	1250	71	9.79	2.07	1.16	0.47	0.15	39.3
		B3g	62-85	5.15	4.0	0.184	10.2	0.018	-	33.9	-	473	1602	75	9.72	1.16	1.03	0.30	0.16	27.3
178.	Songkhla, Na Thawi	Apg	0-13	5.2	4.4	1.356	12.0	0.113	39.3	33.8	26.0	-	504	170	5.08	0.59	0.73	0.31	0.36	39.7
		Blg	13-35	5.6	4.0	0.769	11.4	0.067	-	11.4	-	-	509	33	4.98	2.03	0.59	0.77	0.07	69.5
		B2g	35-52	5.8	3.95	0.332	10.9	0.031	-	19.9	-	-	688	38	6.63	2.55	0.76	1.29	0.08	70.6
		B3g	52-70	5.85	3.75	0.273	10.1	0.027	-	19.7	-	-	538	38	7.36	1.36	1.62	1.65	0.08	63.8

*Base saturation degree