BSP

ROYAL IRRIGATION DEPARTMENT
BANGKOK THAILAND

CHI BASIN
WATER USE STUDY

[redacted]

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KINGDOM OF THAILAND

MINISTRY OF AGRICULTURE AND COOPERATIVES

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PHYSICAL RESOURCES
OF
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PHYSICAL RESOURCES OF THE CHI BASIN

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PHYSICAL RESOURCES OF THE CHI BASIN

The Chi Basin occupies 49,100 square kilometers across the upper middle part of the Northeastern Region. The Changwats of Chaiyaphum, Khon Kaen, Kalasin, and portions of Maha Sarakham, Roi Et, Yasothon, Si Sa Ket, Ubon, Udon Thani, Petchabun and Loie lie within the basin. The physical setting of the area in terms of geology and landform, as well as the nature of the soils, their classification and potentials for agricultural use, are the subject of this chapter.

1 GEOLOGY

The Northeastern Region is synonymous with the geological feature known as the Korat Plateau - a large peneplain whose origins date to sedimentary materials deposited in an early Mesozoic sea.

1.1 The Korat Plateau

The Korat Plateau is at the centre of a great series of concentric folded mountains which sweep southwards from the Himalayas through Burma and the Malay Peninsula. An area of folded Palaeozoic rocks runs south along the western margin - the Phetchabun Range - and then to the Southeast into Kampuchea (Klompe, 1962). These Palaeozoic basement rocks were deformed and intruded during the orogeny at the end of the Triassic era. Subsidence during the Mesozoic era led to deposition of continental and marine sediments. The Plateau obtained its present form during the Tertiary era when the region was uplifted and tilted towards the Southeast. The uplifted western, northern and southern rims partly eroded during the latter part of the period.

Tectonic movements produced a series of three parallel broad folds which trend northwest and formed the Phu Phan Range. Smaller scale and minor folds are also present mainly in the western marginal area where the trend is generally northeast. In the Phu Phan Range fold axes trend east-northeast to the west and southeast in the area east of the Lam Pao. The change in direction of most structures takes place along a southeast directed zone which coincides with the Lam Pao reservoir, which possibly is located on a structural lineament or fault.

Minor faults occur in many places in the plateau. Doming structures may have formed in the Phu Phan anticlines, which are indicated by elongated topographic basins along the crest of anticlines. Surface features which suggest domes in the Salt Formation may have been caused by plastic deformation of the salt and overlying sediments of that formation, but no field evidence from geological or geophysical work is available to confirm or deny this.

Sediments, generally consisting of sand, silt, and clay, were deposited in a mainly continental environment during the Mesozoic era, as subsidence of the area continued following the orogeny during Triassic times. Deposition of marine sediments occurred during the Cretaceous period.

The Korat Group is subdivided into five lithostratigraphic units: Salt Formation, Khok Kruat, Phu Phan, Phra Wihan and Phu Kadung, and its total maximum thickness is 4,500 to 5,000 m or more. Table 1 shows the lithologic characteristics of these formations, their thicknesses and approximate ages and Figure 1 shows their distribution in the region. (Haworth et al. 1966 and Piancharoen 1967).

The Salt Formation and to a lesser extent the Khok Kruat Formation and quaternary sediments are of most interest in this study, as they underlie large areas of the Chi basin.

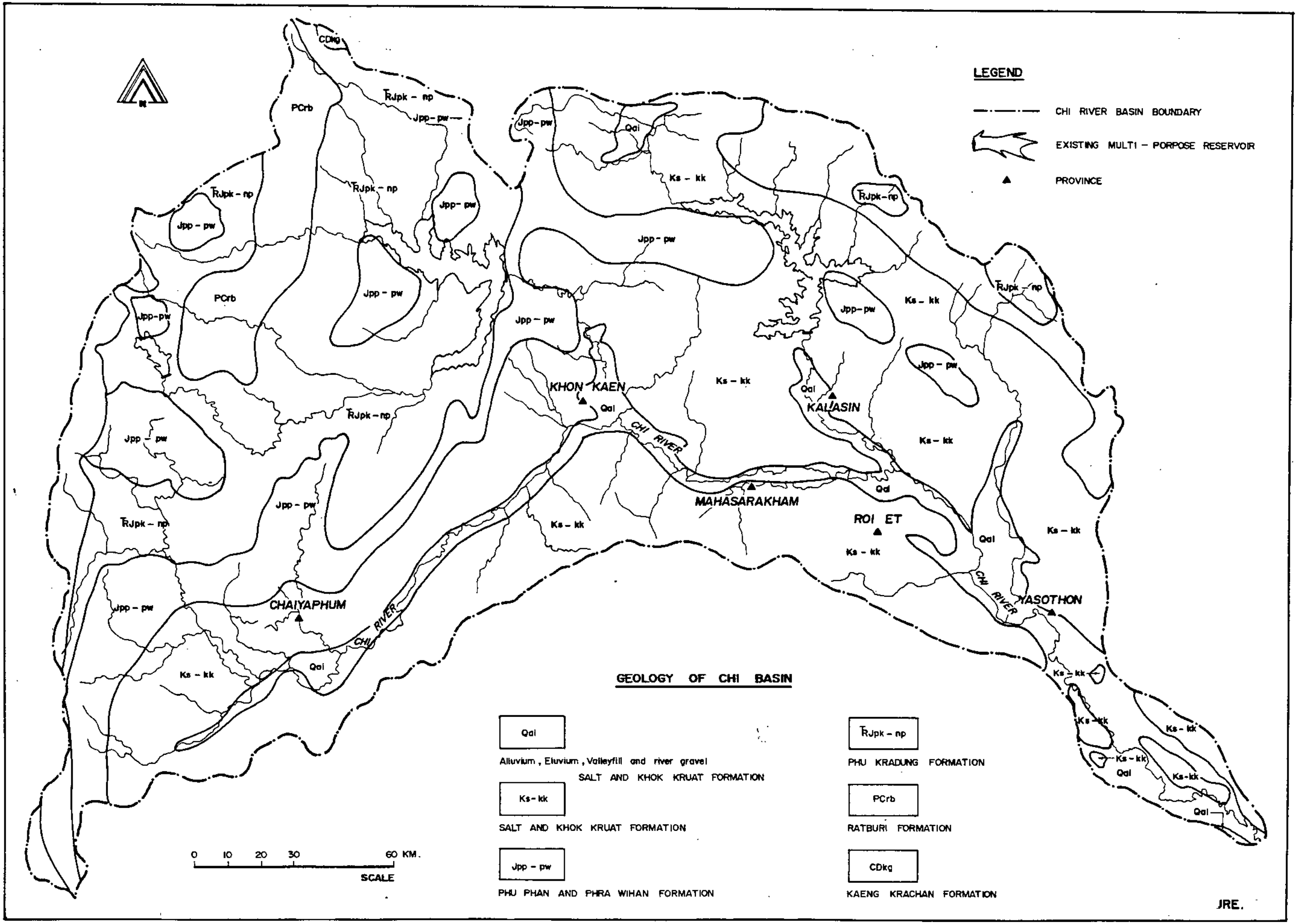
1.2 The Salt Formation

The Salt Formation derives its name from the salt-bearing beds in the uppermost sediments of the Korat Group. The formation consists predominantly of interbedded sandy shale and siltstone with few intercalations of sandstone. These sedimentary rocks contain many beds of gypsum and anhydrite up to 15 m or more in thickness, and beds of rock salt up to 200 m or more thick. Some thick beds of salt may be continuous for 100 km in the subsurface. Rock salt, gypsum and anhydrite also occur as lenses and are distributed throughout much of the area (Haworth et al. 1966; Piancharoen, 1967; Jacobson et al., 1969; Workman, 1972). The shale and siltstone are for the most part reddish-brown, but in places the shales are bright red. They are very massive, thick bedded and very friable when soaked with salty water. The beds without traces of salts are dense and hard, and are very angular when broken. The depth to salt beds or lenses is highly variable, ranging from about 60 m to more than 1,000 m (Workman 1972).

TABLE 1

LITHOSTRATIGRAPHIC UNITS IN NORTHEASTERN THAILAND
(after Haworth *et al.* 1966; Piancharoen 1967)

Age	Lithostratigraphic unit		Thickness	Lithology
Quaternary to Recent	Alluvium and terrace deposits; Valley fill (Unconsolidated rock waste) Qal		-	Alluvial sand and gravel, red fine-grained silty quartz sand; chert and older rock fragments; with logs and pieces of petified wood. Clay beds and lenses are always present, especially along the courses of the Chi and Mun River.
Upper Cretaceous?	Salt Formation Ks		610 m	Pale red to reddish brown sandstone, sandy shale and siltstone. Gypsum and anhydrite in beds up to 15 m in thickness and thick beds of rock salt (halite) of 250 m and more.
Lower Cretaceous	Khok Kruat Kkk		709 m	Grayish red to reddish brown sandstone, siltstone and shale having greenish gray mottling, streaks and spots. Gypsum occurs as thin beds, scattered crystals and as filling in joints and cracks in the upper part.
Upper Jurassic to Lower Cretaceous	Phu Phan Jpp	Jpp-pw	82-183 m	Yellowish gray to grayish pink, pale orange and pale red, massive, thick bedded and cross bedded sandstone and conglomeratic sandstone has a very thick-bedded unit of conglomeratic sandstone and conglomerate at the top. Thin beds, of grayish red to grayish-red-purple sandy shales and siltstone. Also thin beds of clacareous conglomerate.
Jurassic	Phra Wihan Jwp		460-856 m	Grayish red to olive gray to white, massive sandstone; with dark reddish brown micaceous shale and grayish red micaceous siltstone. In part crossbedded or thick-bedded with numerous joints.
Upper Triassic to Lower Jurassic	Phu Kradung Rpk		2466 m	Predominantly dark brown, grayish brown, grayish red-purple, micaceous shale, siltstone; and grayish brown to grayish red slabby to massive micaceous sandstone; and a basal conglomerate with fragments from the Kanchanaburi series and Rad Buri limestone.


GEOLOGY OF CHI BASIN
LEGEND
CHI RIVER BASIN BOUNDARY
EXISTING MULTI - PORPOSE RESERVOIR
PROVINCE
Qal
Alluvium, Eluvium, Valleyfill and river gravel
SALT AND KHOK KRUAT FORMATION
Ks-kk
SALT AND KHOK KRUAT FORMATION
Jpp - pw
PHU PHAN AND PHRA WIHAN FORMATION
TRJpk - np
PHU KRADUNG FORMATION
PCrb
RATBURI FORMATION
CDkg
KAENG KRACHAN FORMATION
0 10 20 30 60 KM.
SCALE
KHON KAEN
CHAIYAPHUM
MAHASARAKHAM
KALASIN
ROI ET
YASOTHON
CHI RIVER
JRE.

Generally, the areas underlain by the Salt Formation are plains with a rather smooth surface, only interrupted by low ridges or undulations.

1.3 The Khok Kruat Formation

The Khok Kruat Formation consists mainly of sandstone, siltstone and shale. The sandstone content tends to decrease from the base upwards. Sandstones are greyish red to reddish brown, very fine to fine grained but locally medium to coarse grained, flaggy to thick-bedded, friable, partly calcareous and micaceous and easily weathered. Siltstone and shale, which constitute about 80 percent of the formation, are similar in colour to the sandstones, but are mottled with light greenish grey and variegated in many places, Gypsum, in the form of selenite, occurs as thin wafers, scattered crystals and as fillings in cracks and joints in the upper part of the formation. Most of these are secondary deposits. Calcerous conglomerates are also well developed. The thickness of the formation is about 500 to 700 m. It occurs primarily in the Phu Phan Range in the northern and west-central parts of the Basin, unusually forming rolling to undulating terrain with low, poorly defined cuestas. In the Phu Phan Range it occurs only along and in the synclinal troughs. Outcrops are frequent but localized all ill-defined.

1.4 Alluvial Deposits

Quaternary alluvial deposits occur to a varying extent adjacent to the principal streams in the area. These beds consist of light brown, sandy limonitic clay; greyish orange to orange pink, fine to coarse sand and clayey sands; gravel and clay; gravel and pebbles, sub-angular to rounded, generally poorly sorted, composed mostly of variously coloured quartz, siltstone, sandstone and chert. Carbonized and silicified wood fragments have been encountered in wells. Most of these deposits are less than 30 m thick although they can extend to over 90 m.

1.5 Gravel Beds

At several locations there are ridges capped by gravel beds which appear to be remnants of old stream terraces. The beds are composed of rounded pebbles or cobbles of black and grey chert and white quartzs up to 5 cm in diameter. Fragments of petrified wood are scattered through the gravels which were probably derived from the conglomeratic sandstones and conglomerates of the Phu Phan Formation.

2 LANDFORMS

The study area is situated in the Korat Plateau, a slightly dishshaped undulating upland with higher elevations around the perimeter and slightly tilted to the east. Sixty three percent of the Korat Plateau lies at between 100 and 200 m (above mean see level).

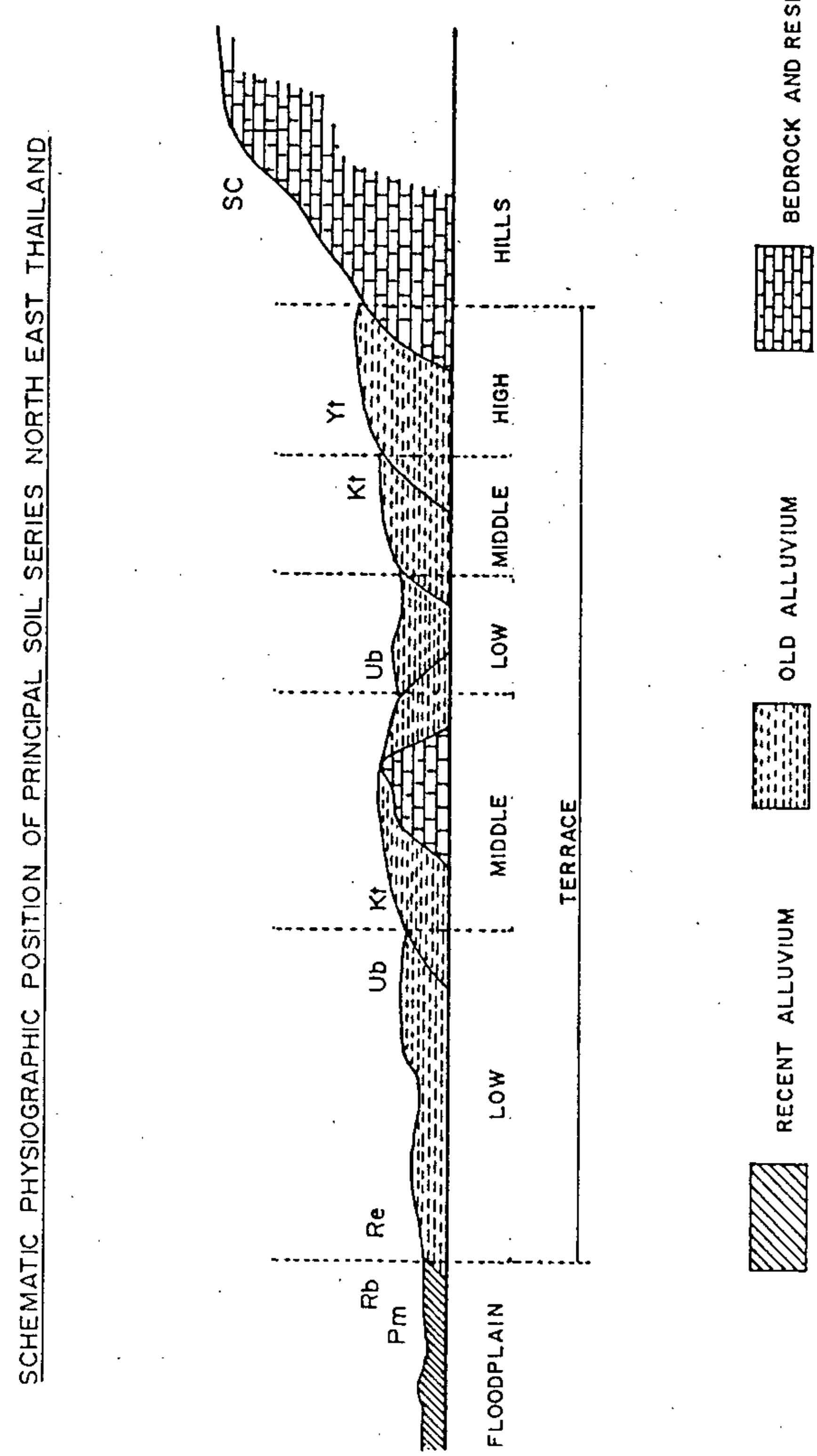
The bedrock locally influences the surface forms, topography and drainage pattern, but the geomorphological features are predominantly determined by both old and recent alluvial deposits of the Nam Chi and its tributaries (the Nam Phong, Lam Pao, Nam Yang, etc). The cycle of sedimentation and erosion and the consequent formation of different terrace levels are schematically shown in Figure 2. The principal landforms are floodplains, low terraces (older floodplains), middle to high terraces (uplands), and hills. The characteristics and distribution patterns of the Study area soils are closely related to the landforms.

The landform of the Chi Basin is predominantly alluvial terraces of differing elevations. Recent alluvial flood plains border the main drainage channels. Back from these are the slightly raised low terraces of semi recent and old alluvium. These grade into the higher alluvial terraces of older alluvium and colluvium. Along the western, northern and northeastern edges of the basin are the two main mountain ranges (the Phetchabun and Phu Phan) and isolated residual remnants.

The rivers and streams of the basin are bounded by natural levees and relative narrow ($<$5,000 m) flood plains dotted with older levee fragments which are 1-5 m higher.

2.1 Floodplains

The floodplains are nearly flat, lowlying lands which extend in parallel with the rivers and their tributaries. Most of these lands consists of the active floodplain surfaces which are frequently inundated during rainy seasons. The floodplains are the youngest surface in the area, with parent materials of deep, silty or clayey riverine deposits.



SCHEMATIC PHYSIOGRAPHIC POSITION OF PRINCIPAL SOIL SERIES NORTH EAST THAILAND

FIGURE 2

2.2 Low Terraces

The low terraces occur on the wide, slightly undulating plains between floodplains and middle terraces. Generally, these lands stand one to two meters above adjoining floodplains and undergo natural flooding only when runoff is exceptionally high during rainy seasons. The general relief and slopes of the low terraces are similar to those of the floodplains. Their parent materials consist of deep, older riverine deposits. The slightly higher parts are mainly composed of medium to coarse textured sediments, whereas in the lower parts fine deposits in the surface layers.

2.3 Middle and High Terraces and Hills

The middle to high terraces form the side slopes of the river valley. These lands have nearly level or gently sloping relief. The parent materials originated from unconsolidated old alluvial deposits and are generally coarser texture than those of floodplains and low terraces.

The dissected erosion surface and hills are found only in the uppermost portion of the area surrounding narrow river valleys. Their parent materials are resicuum or colluvium from basalt origin.

2.4 Physiography

Except in the upper reaches of the Chi and its northern tributaries, the landscape is typically composed of broad, nearly level valleys divided by gently undulating uplands with very little change in elevation. Differentiation between upland and lowland is somewhat academic because there is no clear distinction except possibly in percentage of clay and silt in the soils. Rather than be described as lowlands, most of the drainage ways are infact depressions in an upland landscape.

3 LAND USE

Over 50 percent of the Chi Basin has been classed as being used for agricultural production with some 65 percent of the agricultural area bunded for rice production (Table 2). The dominant upland crop is cassava. A further 34 percent of the land area is unclassified but believed to be used to a greater extent for agricultural endeavors. In an attempt to define the land use patterns of the Northeast, five agro-ecosystems have been described (DOA, 1979, KKU, 1982). These are mini watersheds, non-flood plains, flood plains, irrigation and hill systems.

3.1 Mini Watersheds

This is the characteristic agro-ecosystem of the gently undulating land common throughout the western half of the basin. Its main features are shown in Figure 3. The watersheds may be shallow or fairly deep, measuring from a half to several kilometres across from ridge to ridge, and the vertical distance from the lower paddy to the top of the ridge varies from 5 to 30 m.

The soils at the bottom of each watershed are usually paleaquults (i.e. Roi Et Series) which have a high enough water holding capacity or retain sufficient water in the rainy season to permit rice production. In virtually all years, enough water accumulates, both directly and by run off from the upper paddy and upland areas, to allow transplanting in July or August. Farmers often construct a small pond in the lower paddy area to retain water for hand irrigating a small area of vegetables for home consumption.

Cultivation of the upper paddy area depends critically on the rainfall pattern. Only in some years has sufficient water collected by August/September to permit rice transplanting. In the drier years, this area is usually left idle.

The upland area is planted each year to cassava, kenaf, sugar cane, watermelons, or some other field crops. The soils, mostly paleustults (i.e. Korat Series) have very poor water holding capacity and low fertility, and thus crop yields tend to be low.

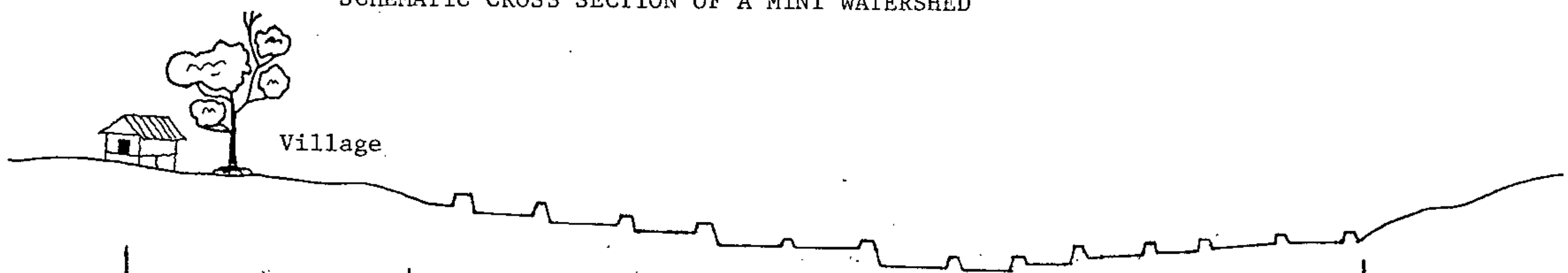
TABLE 2

LAND UTILIZATION IN CHI BASIN BY PROVINCES (1983)

Province	Farm Land					Total Farm Land (km^2)	Forest Land (km^2)	Unclassified Land (km^2)	Total Land (km^2)
	Paddy (%)	Field Crops (%)	Fruit/ Veg.[1] (%)	Housing (%)	Other (%)				
Chaiyaphum	54	32	2	2	10	4,927	2,427	5,435	12,789
Khon Kaen	68	26	1	2	3	6,474	1,163	3,249	10,886
Kalasin	69	22	1	3	5	3,440	992	2,515	6,947
Maha Sarakham	75	18	1	2	4	2,091	83	660	2,834
Roi Et	87	6	1	3	3	3,194	189	1,627	5,010
Yasothon	75	13	2	2	8	1,093	233	463	1,789
Ubon	73	9	1	1	16	484	221	318	1,020
Si Sa Ket	82	12	2	1	3	299	54	47	500
Udon Thani	67	25	1	2	5	2,454	801	1,745	5,000
Nakhon Ratchasima	60	30	2	2	6	596	148	281	1,025
Phetchaburi	43	51	2	1	3	338	203	159	700
Loei	27	68	1	2	2	159	193	248	600
Total						25,546	6,707	16,847	49,100
(Percentage of total area)	(65)	(26)	(1)	(2)	(6)	(52)	(14)	(34)	(100)
WHOLE KINGDOM	59	24	9	2	6	198,770	154,030	160,320	513,120

Note : 1 Includes all Tree Crops

SCHEMATIC CROSS SECTION OF A MINI WATERSHED



	Upland	Upper paddy	Middle paddy	Lower paddy	Middle paddy	Upper paddy	Upland
Soils	Paleustult	Paleaquult/ Paleustult	Paleaquult				
Crops	Cassava Kenaf Sugarcane Watermelon Vegetables Mulberry	Cassava Rice	Rice				
Problems	Low O.M. Drought Erosion	Insufficient water	Low soil fertility	Occasional Flooding			

SCHEMATIC CROSS SECTION OF A MINI WATERSHED

FIGURE 3

3.2 Non-Flood Plains

These occur throughout the Triangle but particularly predominate in Maha Sarakham, Roi Et and Yasothon. The main features of the non-flood plain are shown in Figure 4.

These plains are formed on the geological lower terraces which, though only slightly higher elevation than the flood plains, are rarely flooded by river overflow. The soils are usually good for paddy, and in all years there is sufficient water accumulated from rainfall to allow transplanting of rice in July/August. The soils are mainly paleaquults (i.e. Roi Et Series).

As in the mini watershed, farmers often construct small ponds and use them to hand-irrigate vegetable grown for home consumption after the rice harvest. In some limited areas, there is sufficient residual soil moisture to permit the cultivation of groundnuts after the rice crop. Some farmers particularly in Roi Et and Yasothon, also dig shallow wells to provide irrigation water, particularly for the growing of tobacco after the rice crop.

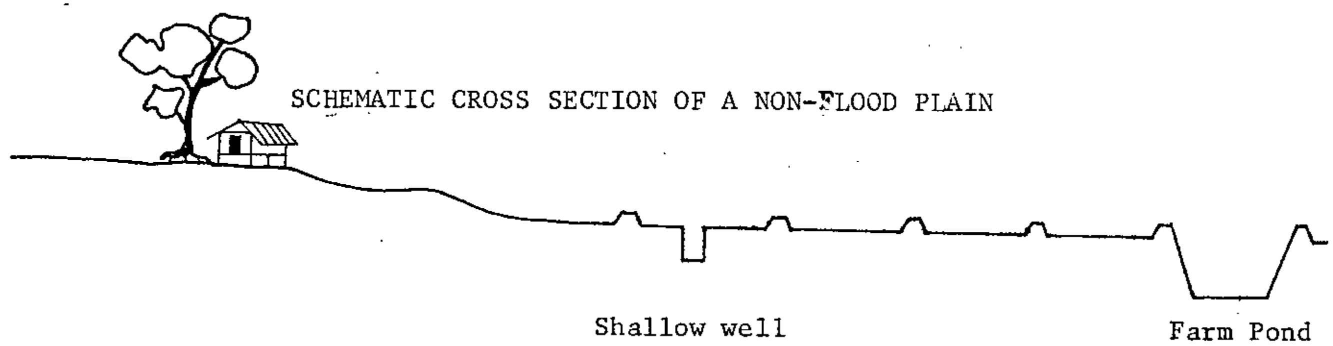
Upland areas within the non-flood plains are usually small, of low elevation, and far apart. These are mainly occupied by villages but small areas are planted to field crops such as cassava, kenaf, sugarcane, groundnuts, and watermelons.

3.3 Flood Plains

The flood plains occur along the Chi river and its major tributaries. Their main features are shown in Figure 5.

These systems are inundated each year by the annual flood caused by overflowing the river banks. The soils are mostly tropaquepts (i.e. Ratchaburi Series). The pattern of cultivation is very similar to the non-flood plains, rice being the main crop with, in limited areas, a subsequent crop of vegetables, providing the farmers are able to dig shallow wells. A number of small pump irrigation schemes have also been established along the lower reaches of the Chi. These mostly provide supplemental irrigation in the rainy season.

SCHEMATIC CROSS SECTION OF A NON-FLOOD PLAIN

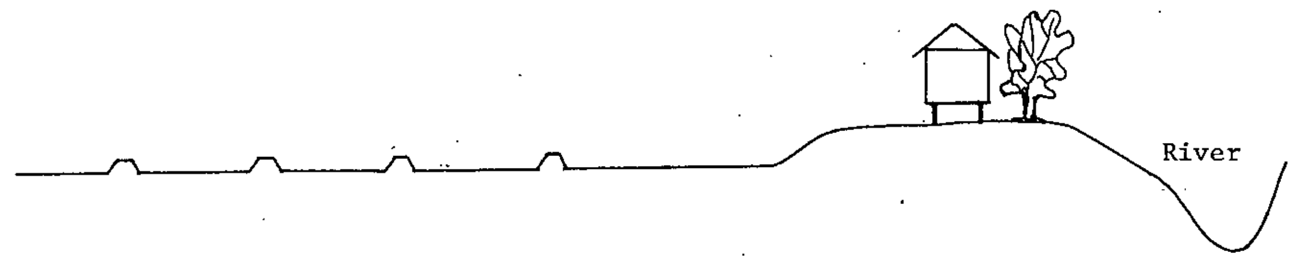


	Upland	Upper paddy	Flat paddy
Soils	Paleustult		Paleaquult or Dystropept
Crops	Cassava Kenaf Sugarcane Peanut Watermelon		Rice Rice followed by peanut or tobacco Sesame followed by rice Rice followed by vegetables
Problems	Low soil fertility	Drought	Salinity Water logging for upland crops

SCHEMATIC CROSS SECTION OF A NON-FLOOD PLAIN

FIGURE 4

SCHEMATIC CROSS SECTION OF A FLOOD PLAIN



	Flood plain	Levee
Soils	Paleaquults, Dystropepts, Tropaquepts	Ustifluvents
Crops	Rice Rice followed by vegetables	Vegetables Fruit Trees Mulberry
Problems	Flooding	Limited Area

SCHEMATIC CROSS SECTION OF A FLOOD PLAIN

FIGURE 5

Between the flood plain and the river, there is usually a narrow levee composed of ustifluvent (Chiang Mai Series) soils. On these, the farmers may grow a variety of vegetables after the floods have subsided.

3.4 Irrigation Systems

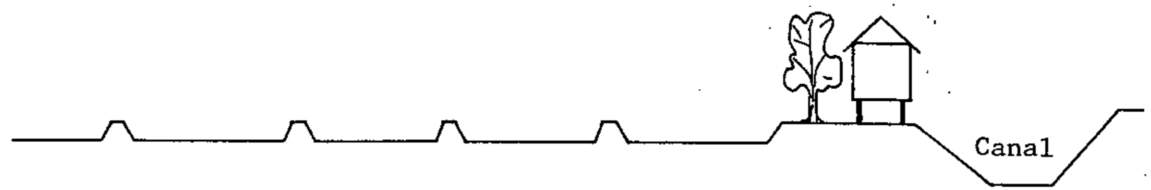
Within the study area, there are several irrigation schemes based on dams and reservoirs which are classed as either small, medium or large scale projects. The main features of any of these irrigation systems are shown in Figure 6.

The soils are of various kinds but mostly palequult (i.e. Roi Et Series). Rice is grown in the rainy season, while in the dry season there may be a second crop of rice, maize, groundnuts, watermelon, or vegetables.

3.5 Hill Systems

The hill lands are found in the more mountainous areas in the west (Upper Chi and Nam Phong catchments) and northeast (the Phu Phan Range). The hill soils (not normally differentiated) are usually of higher inherent fertility than those found in the river basins and generally planted to maize, upland rice and a variety of other crops in the rainy season. The major problems include soil erosion, shallow profile (thus low water holding capacity) and distance to markets. The major features of this system are shown in Figure 7.

SCHEMATIC CROSS SECTION OF AN IRRIGATION SYSTEM

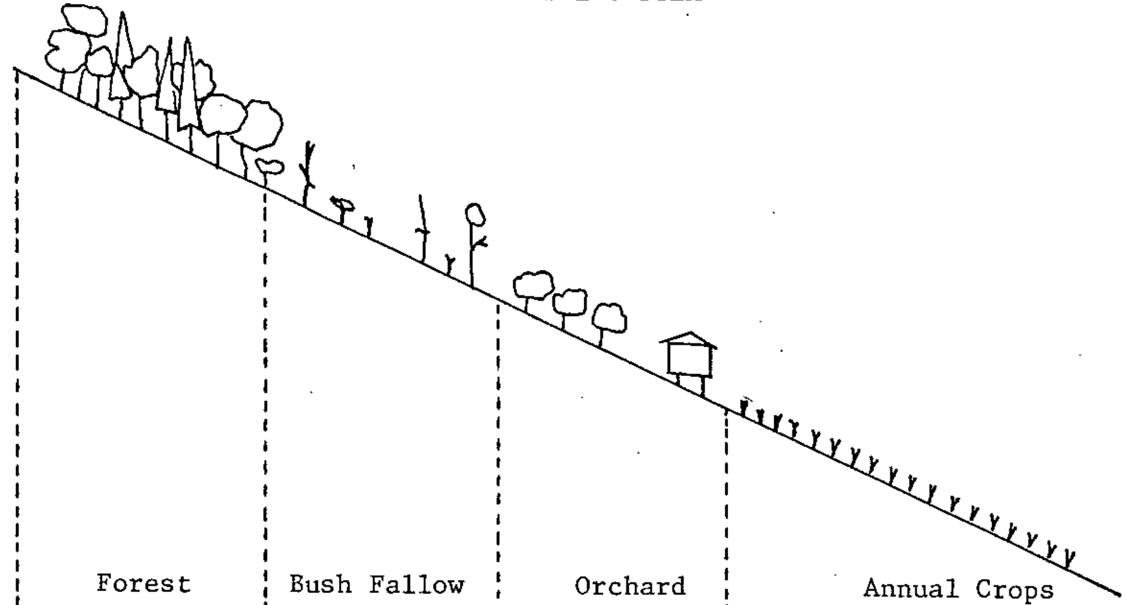


	Irrigated paddy	
Soil	Paleaquult	
Crops	Rice Rice-rice Rice- peanut - corn - watermelon - vegetables	
Problems	Irregular water supplies, salinity	

SCHEMATIC CROSS SECTION OF AN IRRIGATION SYSTEM

FIGURE 6

SCHEMATIC CROSS SECTION OF A HILL SYSTEM



SOILS	Paleustults (loamy, fine-clayey), Haplustalfs			
CROPS	Gathering firewood Hunting	Upland rice Cassava Maize	Mango Jack-fruit Custard apple	Maize, Cassava Mungbean Sorghum
PROBLEMS	Diminishing area	Shorter fallows Weeds Erosion	Marketing Price	Drought, Weeds Soil erosion Price

SCHEMATIC CROSS SECTION OF A HILL SYSTEM

FIGURE 7

4 SOILS

4.1 Soils of the Chi Basin

The soils in the Chi basin have been formed under the various influences of micro-climate, relief, drainage conditions, and nature of parent materials. The general characteristics and distribution patterns of the soils are closely correlated with the landforms that they occupy (Figure 2).

The majority of the soils (68%) of the Chi basin belong to the Ultisol Order, the highest percentage being Paleustults (gray Podzols). These represent the uplands, and are mostly of a loamy (sandy loam - loamy sand) texture. The broad flood plains of the Chi and its major tributaries are predominantly Inceptisols. These account for about 12 percent of the soils of the basin and generally are Tropoquepts with a somewhat finer texture (sandy clay loam to clay loam). Loamy Dystropepts are predominant either side of the Chi in Changwat Roi Et. Salt affected soils normally belong to this order. Sandy Quartzipsamments account for about 5% of the basin soils and undifferentiated slope complex soils about 10%. The major characterists of the Chi basin soil series are summarized in Appendix A.

All soils have very similar physical and chemical characteristics. They generally have a coarse textures (LS-SL) surface horizon with a slightly finer (SL-SCL) subsoil, very low levels of organic matter (generally 0.5%), little or no structure, a slightly to strongly acid reaction (pH 4.5 to 6.0), low cation exchange capacity and thus a low nutrient status, and a low water holding capacity (4 to 10%). Plinthite modules are common.

The majority of soil profile are dominated by the fine sand fraction (50 to 90%). Cation exchange capacities are generally less than 5.0 but base saturation percentages usually exceed 30. Calcium : magnesium ratios of the surface horizon are generally greater than 5.0 while magnesium : potassium ratios are rarely less than one. Sodium : Potassium ration also tend to be high but exchangeable sodium percentages are low in all profiles, though some soils do have a sodic horizon. Available phosphorous levels tend to be low (rarely exceeding 10 ppm - Bray No. 2) while available potassium levels vary considerably (between 9 and 224 ppm ammonium acetate).

4.2 Soil Improvement

There is a need for general soil improvement through various methods of conservation, organic matter build up and chemical fertilization. However, the coarse texture, low cation exchange capacity and low organic matter content of all soils mean that improvement of overall soil fertility is not easy to accomplish. For the most part soil erosion will not be a serious problem as much of the area is divided into bunded paddy fields. Methods need to be established for reducing erosion on the uplands which are compatible with farmer resources. Very little work has been (or seems to have been) done on soil water conservation. Much work could be done. Good responses have been recorded to chemical fertilizers containing the macro - nutrients (N, P, K, S and Mg) and to compost organic matter incorporation. Establishment of perennial crops and careful crops rotations as well as the use of organic mulches in theory, will assist in building up soil organic matter levels and reduce evaporation thus allowing more efficient crop water use. Increasing organic matter levels in the soil (even by 0.5% to 1.0%) should significantly improve soil structure and increase both water-holding and nutrient-holding capacity, allowing more efficient use of fertilizers. Improved soil structure, mulches and vegetative cover would also assist infiltration, allowing early and late rains to be more effective.

However, the evidence is that it is virtually impossible to obtain any lasting residual effect from organic matter incorporation - partly because of the difficulty of obtaining sufficient quantities of organic materials, and partly due to the rapid rate at which organic compounds are broken down.

A more complete discussion of research on soil amelioration is contained in Appendix B.

4.3 Land Suitability

The suitability of the soils and land within the Chi Basin, for various crops will be evaluated in the basis of criteria set out in Tables 3 and 4. The classification is, with slight modifications, according to principles presented in the Soil Survey Interpretation Handbook for Northeast Thailand. The criteria are based on USBR Land Classification Specifications for the Nam Chi Project (1971). Table 5 summarizes the general suitability of the main soil series for both rice and upland crop production.

TABLE 3

LAND/SOIL SUITABILITY FOR UPLAND CROPS AND FOR PADDY (WETLAND) RICE

The suitability of the soils of the Chi Basin for various crops will be evaluated as outlined below. Classification will be (with slight modifications) according to the principles presented in the Soil Survey Interpretation Handbook for Northeast Thailand, part II, Soil Survey Report No. 60 (1976) by D.L. Gallup, Srilak Kashemsanta and Avudh Pimpand. The Paddy suitability classification is different from that for upland crops because the soil and water requirements are different. A prefix 'U' is used to distinguish upland from paddy ('P') soils.

Upland Crops

Classes U-1 through U-IV are suitable for cultivated upland crops, with increasing degrees of limitation. Soils placed in U-V through U-VIII are generally not suited for cultivated crops, but can be used for grassland, woodland or tree crops, though U-VIII will not produce economic returns under any use.

U - I - Soils very well suited: for growing a wide range of upland crops - no significant limitations to restrict their use.

U - II - Soils well suited for upland crops: slight limitations restrict their use.

U - III - Soils moderately suited for upland crops: moderate limitations reduce the choice of crops and/or require special management.

U - IV - Soils poorly suited for upland crops: severe limitation restrict the choice of crops and/or require very careful management.

U - V - Soils unsuited for upland crops: little or no erosion hazard, but having other limitations that are impractical to remove.

U - VI - Soils having severe limitations: unsuited for cultivation; suitable for pasture, woodland, wildlife habitat and water supply.

U - VII - Soils having very severe limitations: unsuited for cultivated crops; use restricted to woodland, wildlife habitat, water supply and recreation.

U - VIII - Soils and land types having limitations that preclude their use for commercial plant production and restrict their use to recreation, wildlife habitat and water supply.

TABLE 3

(Continued)

Paddy (Wetland) Rice

Groups P-I through P-IV are suitable for rice, with increasing limitations from P-I to P-IV. Soils and land types placed in P-V are not suited for paddy rice.

P - I - Soils very well suited for paddy production: no significant limitations; sufficient water from rainfall and/or irrigation for at least one high yielding crop of rice in most years.

P - II - Soils well suited for paddy: slight limitations to use for rice production.

P - III - Soils moderately suited for paddy: moderate limitations restrict use for rice production and/or require special management.

P - IV - Soils poorly suited for paddy: severe limitations restrict use for rice production and/or require very special management.

P - V - Soils not suited for paddy: very severe limitations preclude rice production with ordinary methods.

Types of limitations

Eight limitations are recognized for both upland and wetland crops.

Erosion (e): soils with an erosion hazard or past erosion damage.

Soil limitation (s): soils with problem such as shallow profile, unfavourable texture, stoniness, low fertility levels.

Soil moisture (m): soils on which plant growth is severe reduced by low water holding capacity.

Topography (t): soils whose relative position or relief (macro or micro) limits use for crops and paddy in particular.

Flooding (f): soils susceptible to flash floods prolonged deep flooding, or both, which damage the crops or limit choice of crops.

Drainage (d): soils whose use for upland crops is limited by excess water due to high water table, slow permeability or slow surface drainage.

Salinity or alkalinity (x): soils that have salinity or alkalinity levels which restrict crop growth.

Soil acidity (a): soils for which extreme acidity (difficult to correct) is the major limitation for crop production.

ABLE

BUREAU OF RECLAMATION
LAND CLASSIFICATION SPECIFICATIONS
NAM CHI PROJECT - THAILAND

	For diversified crop production		For wetland rice production	
	Class 1 - arable	Class 2 - arable	Class 1R-Arable	Class2R-arable
Soils				
Texture				
Surface (0-30 cm)	Fine sandy loam to clay loam	Loamy fine sand to permeable clay	Fine sandy loam to clay	Land sand to clay
Subsurface	Sandy loam to permeable clay	Loamy fine sand to permeable clay	Loamy sand to clay	Sand to clay
Depth (after land development)				
To clean sand or gravel	> 90 cm	>60 cm	> 60 cm	< 30 cm
To pisolitec in permeable matrix	> 90 cm	>60 cm	> 60 cm	< 30 cm
To permeable bedrock	>150 cm	>90 cm	> 60 cm	< 45 cm
To relatively impermeable zone water table	>210 cm	>210 cm	< 210 cm	< 210 cm
Available water capacity	15 cm or more in 120 cm depth with 2.5 cm in 0-30 cm	8 cm or more in 120 cm depth with 2.5 cm in 30cm	Not applicable	Not applicable
Reaction				
pH in 0.01 M $CaCl_2$	>5.0 <7.7	>4.0 <8.0		
pH in H_2O (1:1)	>5.5 <8.2	>4.5 <8.5		
pH (anaerobic)			>5.5	>5.0 (may be less provided aluminum and active iron are satisfactory)
Acidity*				
Neutral salt exchange acidity	None	May be moderate		
Buffered salt exchange acidity	May be moderate	May be moderate		
Anion exchange acidity	May be moderate	May be moderate		
Inorganic (acid sulthate soil)	None	None	None	None
Sodium (at equilibrium)**				
Exchangeable sodium percentage	< 20	< 20		
Sodium-adsorption-ration (soil solution)			< 20	<35
Cation-exchange capacity (at soil pH) of surface soils (0-30 cm)	> 10 meq/100 g	> 5 meq/100 g	>10 meq/100 g	> 3 meq/100 g
Base status				
Calcium	> 6 meq/100 g	> 2.0 meq/100 g		
Magnesium	1 to 2 or 4 of Ca 1 to 10 of Ca	> 1.0 meq/100 g > 0.4 meq/100 g		
Potassium	1 to 4 of Mg			
Sodium	> 0.2 meq/100 g	> 0.2 meq/100 g		
Reduction products				
Dithionate-EDTA ext.			Low	May be moderate
Soil solution (after prolonged flooding)			< 200 ppm	< 500 ppm
Salinity (at equilibrium under irrigation)				
Electrical conductivity				
Saturation extract	< 4.0 mmhos/cm	< 10.0 mmhos/cm		
Soil solution			< 4.0mmhos/cm	< 8.0 mmhos/cm
Topography				
Slope	< 2% > 0.25%	< 5% > 0.25%	< 2%	< 5%
Drainage				
Flooding	None	None		
Internal ***	Good	Good	Very slow	Slow

CLASS 5-TENTATIVELY NONARABLE : Includes lands which will require additional economic and engineering studies to determine their irrigability. The designation (5) is particularly suited to areas above proposed canal lines pending determination of feasibility of service. Also applies to suspected high or isolated lands within the known service area and lands subject to seasonal inundations requiring project flood protection works.

CLASS 6-NONARABLE : Includes lands which do not meet the minimum requirements for the other land classes, and are not suitable for irrigation. They include lands with soils that are very shallow over armor sandstone, or other formation impervious to roots or water; lands with salt affected soils that are reclaimable with difficulty because of texture, position, substratum conditions, etc.; lands with extremely coarse-texture surface soils, soils having low available water capacity; rough hummocky and severely channel dissected lands; high areas such as hillocks and river levees; overflow and run-off channels; permanent waste and sump areas; lands having excessively steep or complex topography; and all other obviously nonarable areas.

* Appraisal is dependent on charge characteristics and ion populations as related to cropping pattern.

** Appraisal for diversified crop production is dependent on type of clay and cropping pattern.

*** In arability studies drain spacing and economic correlation will determine whether the land should be utilized for diversified crop or wetland rice production.

TABLE 5

SUITABILITY OF SOILS OF THE CHI BASIN

Geomorphology	Soil Series	Suitability for Rice	Suitability for Upland Crops
Flood Plains	Alluvial Complex	P-IIIf and P-Vt	U-IIf and U-Vf
	Ratchaburi	P-IIIf	U-IVf
	Phimai	P-IIIf	U-IVf
	Chiang Mai	P-Vt	U-IIf
Low Terrace	Roi-Et	P-IIIs, P-IIIf and P-Wt	U-IIId, U-IVf and U-IVs
	Ubon	P-IVs	U-IVs
Middle Terrace	Korat	P-Vt	U-IIIs
	Phon Phisai	P-Vt	U-VIe
	Nam Phong	P-Vt	U-IVe
	Warin	P-Vt	U-IVe
High Terrace	Yasothon	P-Vt	U-IVe
	Satuk	P-Vt	U-IVe
Hills and Residual High Lands	SC	P-Vt	U-VIIe
	Borabu	P-Vt	U-VIIe
	Chatturat	P-Vt	U-VIIe

Rice - Flood Plains and Low Terrace generally moderately well suited.

Upland - Flood plains, Low and Middle Terrace generally moderately well suited.

The land suitability classification system in Thailand are based on the relative productivity of soils cultivated under assumed climatic and management conditions. The soils of the Northeast Region are relatively poorer in inherent qualities than elsewhere in Thailand and thus tree and pasture crops tend to be the most suitable. In preparing the criteria and assessing the suitability of each series, the land classification staff made a number of assumptions which, though based on available information, appear to be somewhat optimistic. Thus the suitability ratings may be seen by some to be better than expected. One of the assumptions was that farmers would use some soil amelioration techniques, such as application of recommended amount of fertilizers and compost, along with chemical weed, pest and crop disease control. Very little of these inputs appear to be used. Perhaps the classes should be seen as potential rather than present suitability.

4.4 Soil Salinity

Soil salinity is an inherent problem in the Northeast. Some Amphoes have an estimated 40 percent of total area affected by salinity. The general opinion is that salinity levels are increasing in the lowland areas as a result of groundwater flow and soil erosion from the uplands to the lowlands.

Investigations to date conclude that the primary source of salts in the soil of the basin is the geologic "salt formation" or other salt bearing strata, but soil salinity in the region is ultimately related to the quality and seasonal movement of shallow groundwater. The reduction of primary forest contributes significantly to the local and regional groundwater flow, since less rainfall is intercepted and used by the forest. Downward percolating rainwater in the upper parts of landscape (the ridge crests and upper slopes) dissolves and transports salts to the lower slopes, where the groundwater table surfaces or comes within capillary range of the surface. In the latter situation the physical characteristics of the soil profile is very important. Here the water evaporates leaving the dissolved solids at the soil surface. Over the years the concentration increases.

The Soil Survey Division of the Land Development Department has produced a map showing the distribution of saline soils in the study area. This map is summarized in Figure 8.

SALINE SOIL DISTRIBUTION MAP OF CHI BASIN

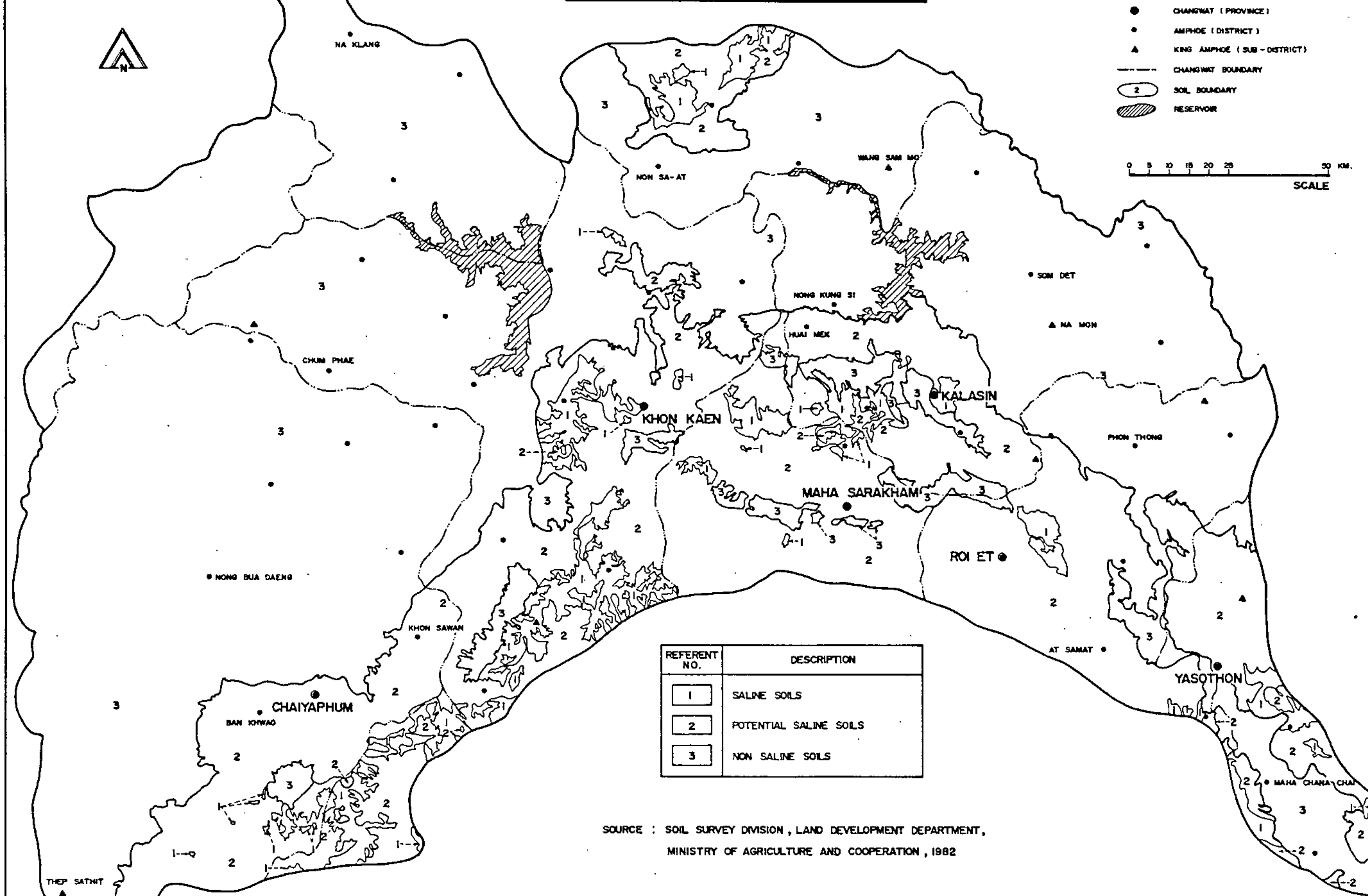


FIGURE 8

Although the movement of deep groundwater (> 20 m) may be the cause of soil salinity in localized areas, shallow groundwater is clearly far more important. Studies of groundwater together with the physical characteristics of the various soils are therefore of great significance with respect to salinity hazards in the region. No known studies have been carried out on the hydrodynamics of shallow groundwater or on the mechanism of salt transport, and proper understanding of these processes is essential for devising measures to prevent salinization and reclaim salt-affected areas.

Salt affected soils commonly occur along the lower slopes, elongated ridges and old river levees, where salt accumulates on the surface during the dry season. Some salt affected soils also occur on near level older flood plains. Throughout the basin the presence of high concentrations is distinctive and easy to observe-either as white evaporates in the dry season or as patches of no or poor growth during the rainy season. It is possible that there are some soils which have sufficient concentrations of soluble salts to restrict yields, but not show visible signs of being affected.

The implication is significant to crop improvement in the study area since large areas of agricultural land already have salinity levels greater than 8 dS/m.

A number of reclamation techniques have been tried and research is continuing, but so far the suggested remedies do not appear to be practical options for the farmers.

All crops are sensitive to salinity in the seedling stage and become less sensitive with maturity. Most salts are not actually toxic to plants, but because they are hygroscopic compete with the plant for available moisture. At the seedling stage, few plants have a sufficient root system to withstand drought conditions, which is essentially what the plant experiences in a saline soil. Thus good soil moisture conditions are essential at planting and transplanting time. The water does not necessarily have to be non-saline, but this is preferable.

Crops react differently to saline conditions in the root zone, some being more tolerant (i.e. less affected by salinity) than others (see Table 6). Soils with electrical conductivity levels of less than 2 dS/m (1:2:5 soil water solution) in the effective root zone are considered to be non saline and not restricting, though there are a few very sensitive crops which show effects at salinity levels greater than 1 dS/m. Soils with salinity levels between 2 and 8 dS/m are classed as saline and sensitive crops will be affected. Salinity levels of 8 to 16 and greater than 16 dS/m are considered to be moderately and strongly saline and crops that can grow in these conditions are rated as semi-tolerant and saline-tolerant.

A number of crops grown in the study area have some degree of tolerance. Rice and maize are only moderately sensitive and some varieties have higher levels of tolerance. Some tree species such as Eucalyptus, Acacia, Leucaena, Cashew and Tamarind, also show a degree of tolerance.

In irrigated areas, salinity concentrations are likely to be maintained at somewhat lower levels than in rainfed areas due to the leaching of excess salts, during the cropping season, below the root zone. Such leachates could, however, appear elsewhere lower down the groundwater gradient.

4.5 Soil Conservation

Soil conservation is not a major problem in the study area as the slopes are generally gently undulating and the greater part of each amphoe is already terraced and bunded for rice. However some further conservation works will be necessary particularly in catchment areas for farmponds and small reservoirs, and in the steeper lands at the western and northern margins of the Chi Basin.

TABLE 6

CROP TOLERANCE TABLE
Yield Potentials expected when
Common Surface Irrigation Methods are Used

FIELD CROPS

CROP	100%		90%		75%		50%		No Yield
	ECe[1/]	ECw[2/]	ECe	ECw	ECe	ECw	ECe	ECw	ECe
Cotton (Gossypium hirsutum)	7.7	5.1	9.6	6.4	13	8.4	17	12	27
Soybean (Glycine max)	5.0	3.3	5.5	3.7	6.2	4.2	7.5	5.0	10
Sorghum (Sorghum bicolor)	4.0	2.7	5.1	3.4	7.2	4.8	11	7.2	18
Groundnut (Arachis hypogaea)	3.2	2.1	3.5	2.4	4.1	2.7	4.9	3.3	6.5
Rice (paddy) (Oryza sativa)	3.0	2.0	3.8	2.6	5.1	3.4	7.2	4.8	11.5
Sesbania (Sesbania exaltata)	2.3	1.5	3.7	2.5	5.9	3.9	9.4	6.3	16.5
Corn (Zea mays)	1.7	1.1	2.5	1.7	3.8	2.5	5.9	3.9	10
Cowpea (Vigna unguiculata)	1.3	0.9	2.0	1.3	3.1	2.1	4.9	3.2	8.5
FRUIT CROPS									
Lemon (Citrus limon)	1.7	1.1	2.3	1.6	3.3	2.2	4.8	3.2	8
Grape (Vitis spp.)	1.5	1.0	2.5	1.7	4.1	2.7	6.7	4.5	12
VEGETABLE CROPS									
Tomato (Lycopersicon esculentum)	2.5	1.7	3.5	2.3	5.0	3.4	7.6	5.0	12.5
Cucumber (Cucumis sativus)	2.5	1.7	3.3	2.2	4.4	2.9	6.3	4.2	10
Pepper (Capsicum annuum	1.5	1.0	2.2	1.5	3.3	2.2	5.1	3.4	8.5
Onion (Allium cepa)	1.2	0.8	1.8	1.2	2.8	1.8	4.3	2.9	7.5
Beans (Phaseolus Vulgaris)	1.0	0.7	1.5	1.0	2.3	1.5	3.6	2.4	6.5
FORAGE CROPS									
Bermuda grass 6/ (Cynodon dactylon)	6.9	4.6	8.5	5.7	10.8	7.2	14.7	9.8	22.5
Orchard grass (Dactylis glomerata)	1.5	1.0	3.1	2.1	5.5	3.7	9.6	6.4	17.5

Notes:

1/ ECe means electrical conductivity of the saturation extract of the soil reported in mmhos/cm at 25°C.

2/ ECw means electrical conductivity of the irrigation water in mmhos/cm at 25°C.

APPENDICES

APPENDIX A

SOIL CLASSIFICATION

The soils in the Chi Basin have been formed under the various influences of micro-climate, relief, drainage conditions, and nature of parent materials. The general characteristics and distribution patterns of the soils are closely correlated with the land forms they occupy.

A.1 SOILS OF FLOOD PLAINS

The soils of flood plains are Hydromorphic Alluvial soils (Ustifluvents and Tropaquepts) derived from parent materials originating from the recent or semi-recent alluvium deposited by the annual floods. These soils are commonly deep, fine textured (silty clay loam, silty clay or clay and poorly drained. A particular feature of these soils is a grayish color and distinct mottling. The surface layer is usually very plastic and sticky when wet, and very hard when dry. Small, soft manganese concretions are common in the subsoils. These soils have relatively high natural fertility. Topography is level to nearly level with slopes usually less than one percent except on the levees where slopes can reach two percent.

Transplanted rice is cultivated on most lands during the rainy season and give satisfactory yield when flooding is not destructive, and where some supplemental irrigation can be provided by the farmer.

These soils cover the considerable area along the Chi River and its major tributaries. The soil series included are Chiang Mai on the levees, and Ratchaburi and Phimai on the flood plain - the latter occupying the lowest positions. These soils and their associates are frequently mapped as Alluvial Complex soils. Collectively, the flood plain soils occupy about 10 percent of the Chi Basin land area.

A.1.1 Chiang Mai Series

This series is the most common of the levee soils (Typic Ustifluvents) found adjacent to the Chi and its major tributaries. They are deep well drained, dark brown loams or sandy loams over sandy loam to clay subsoils. The profile's highly stratified and frequently contain soft many area nodules and prominent dark brown mottles. These soils are strongly acid and have a moderately low to medium fertility status. Topography and permeability are the major limitations to using Chiang Mai soils for rice cultivation but they are well suited to upland crops, limited primarily by the risk of flooding in the late wet season.

A.1.2 Ratchaburi Series

This series has also formed on recent alluvial deposits and occupies the transition zone between the river levees and the lower parts flood plain. They are deep, somewhat poorly drained, dark brown to greyish brown clays or silty clays and are classed as Aeric Tropaquepts. These soils are strongly acid, have a moderately low to medium fertility status. A typical profile commonly has pronounced mottling and few fine iron-manganese contretions. Ratchaburi soils are well suited to rice cultivation but poorly suited to upland crops, limited by high risk of flooding in the wet season. Upland crops or vegetables can be grown in the dry season of these is an adequate water supply.

A.1.3 Phimai Series

Very deep, poorly drained dark greyish brown to gray clays occupying the lower parts of the flood plain. They are commonly flooded during the rainy season and thus are used only for rice cultivation, for which they are well suited. Phimai soils are characterized by neutral to slightly acid pH's, medium fertility status, strong mottling in the profile and slow internal drainage. The water table is nearly always within one metre of the surface.

A.2 SOIL OF LOW TERRACES

The soils of low terraces are low Humic Gley Soils (Paleaquults) which have developed on older alluvial deposits under poorly drained condition. The well developed A-horizon is usually sandy loam, loam, or silty clay loam while the B-horizon ranges from sandy clay loam to clay. These soils are commonly grayish brown in color and have prominent reddish or brownish mottlings throughout the profiles. Surface layers are usually slightly or moderately sticky and plastic when wet, and slightly hard when dry. Practically, all of the soils found on low terraces are used for transplanted paddy rice cultivation.

The principal soil series is Roi Et series and its variants. Ubon series becomes prominent in Roi Et and Yasothon Changwats. These soils cover approximately 28 percent of the Study area.

A.2.1 Roi Et Series

These soils belong to the fine-loamy, kaolinitic, acid family of Low Humic Gley Soils (Aeric Paleaquults). They are deep, poorly drained, and characterized by a grayish brown or light gray or whitish clay loam or clay C-horizon. Mottles occur throughout the profile, with common to many. Strong brown or yellowish brown mottling at the surface and strong brown and/or yellowish brown of dark brown and some red mottling in the subsoil. Reaction is medium acid over strongly to very strongly acid. Natural fertility is low. A loamy and a clayey variants have been identified.

The soils are subject to flooding to about 30 cm depth by impounded rain water for 3 to 4 months. The groundwater table descends below 3 m during mid-dry seasons. These soils are moderate to well suited for rice and thus they are commonly only used for transplanted rice in the rainy seasons. Roi-Et soils are poorly suited for upland crops due to water-logging.

A.2.2 Ubon Series

The Ubon series consists of very deep, nearly level to level, moderately well drained soils that formed on sandy alluvium on the higher parts of the low terrace. Under present land-use, they are normally flooded up to 20 cm depth by impounded rain water for two to three months during the rainy season. In the dry season, when the ground water level drops to 4 m below the surface, these soils dry out completely.

The Ubon soils have a brown to dark brown sand or loamy sand surface overlying a light brown or light reddish brown loamy sand subsoil. This in turn is underlain by a light gray or gray sandy clay which usually occurs below 80 cm depth. Mottles of strong brown or reddish yellow and/or yellowish brown colour are common throughout the soil profile.

These soils are very low in fertility status due to very low clay and organic matter contents. Soil reaction is very strongly acid in the surface and medium acid in the subsoil. They have rapid permeability and low available water holding capacity. Ubon soils, are poorly suited for both upland crops and for wet-land rice. The main limitations are unfavorable soil characteristics and, low fertility status that is difficult to ameliorate.

A.3 SOILS OF MIDDLE TERRACES

On the middle terraces, the soils are predominantly Gray and Red-yellow Podzolics (Oxic Paleustults) which have developed from old riverine alluvium in imperfectly drained positions. The natural vegetation on these soils is mainly brush or low open forest. Upland crops such as cassava, maize, kenaf, and upland rice are grown on better drained soils. have loamy surface layer and clay loam or clay subsoil, and grayish brown or brown color with prominent reddish or brownish mottling.

The principal soil on the middle terrace is Korat Series, which with to associate Satuk, Warin, Phon Phisai series occupy approximately 35 percent of basin.

A.3.1 Korat Series

Korat soils are deep and moderately well drained soils with moderate to rapid permeability, and the normally rapid surface runoff. They are characterized by a grayish brown to very dark grayish brown sandy loam or loam sand A-horizon overlying a brown or light brown or pale brown sandy clay loam B-horizon. Few to common fine faint strong brown and/or reddish yellow mottles occurs in the deeper B-horizon. Reaction is medium acid to strongly acid to very stronly acid. They have moderate to rapid permeability and because of poor structure cap easily resulting erosion of the soils surface.

The lands occupied by these soils are originally dry dipterocarp forest and mixed deciduous forest but the forest in most cases has now been cleared for upland crops such as cassava, maize and kenaf. Relief is normally undulating with the slopes ranging from 2 to 6%. Korat series is moderately suited to upland crops but unsuitable for paddy. The main limitations are low nutrient status and droughtiness.

A.3.2 Satuk Series

Satuk series is found on the upper middle terrace, on undulating to gently rolling relief; slopes ranging from 2 to 8%. They are deep, well drained soils, characterized by a very dark grayish brown to dark brown sandy loam overlying a yellowish brown to reddish yellow sandy clay loam or clay loam. Reaction is slightly acid to medium over strongly acid to very strongly acid. The groundwater table falls below 1.5 m from the surface in most of the years. Fertility status is low to moderate.

The lands covered by these soils were originally covered by dipterocarp and mixed deciduous forest which has now been partly cleared for upland cropping. Satuk soils are moderately suited for growing upland crops but unsuited for rice cultivation.

A.3.3 Warin Series

Characteristics of this series are very similar to those of Satuk.

A.3.4 Phon Phisai Series

The Phon Phisai series consists of shallow, gently sloping, moderately well drained, very dark grayish brown to dark brown sandy loams to loam overlying a very gravelly clay loam to clay upper subsoils. The lower subsoils consist of gray clay with prominent, coarse red mottles. Gravel, composed of loose - or semi-consolidated ironstone concretions, form a continuous layer within 50 cm from the soil surface.

The Phon Phisai soils are very strongly acid to strongly acid in reaction and have moderately low fertility status. They are moderately permeability in the upper part of the soil profile, but slowly permeable in deeper subsoil. The ground water table commonly falls below 3 m during peak of the **dry** season.

These soils are generally poorly suited for cultivation of upland crops with ordinary methods. The most serious limitations include shallow profile, erosion, hazard and low nutrient status. Their best use is as road building material and for forestry.

A.4 SOILS OF HIGH TERRACES

In the relatively higher positions of upland area the soils are Red-Yellow Latisols (Haplustox) which have originated from unconsolidated old alluvial deposits under relatively well drained conditions. Having undergone severe weathering and leaching after the deposition of the coarse-texture sediments, these soils are of relatively low fertility. These soils used for forest or Upland crops, mainly cassava and maize. The soils have a coarse-textured surface layer(loamy sand, sandy loam, or loam) which becomes slightly finer with depth. The surface layers are usually non-sticky and non-plastic when wet, and slightly hard or loose when dry. Associated with these is a Ustoxic Quartzipsamment (Nam Phong Series) formal on coarse textured alluvium. Relief is undulating with slopes ranging from 2 to 8 percent.

These soils occupy approximately 6 percent of the Chi Basin. The principal soil series on the high terraces are Yasothon and Nam Phong.

A.4.1 Yasothon Series

This is the typical series of the High Terrace and is a very deep, well drained dark reddish brown loamy sand to sandy loam over red sandy loam to sand clay loam. They have rapid permeability and relatively low water holding capacity. Soil reaction is medium acid in the surface and very strongly acid. The subsurface horizons. These is a gravelly variant is similar to that of the Nam Phong series.

Yasothon series soils are moderately suited upland cropping not at all suited for rice cultivation, the major limitation being topography. The gravelly variant is unsuitable for both upland and rice cultivation.

A.4.2 Nam Phong Series

The Nam Phong series consists of very deep, gently sloping, somewhat excessively drained soils that developed from sandy alluvium on middle terrace. These are the only quartzipsamments in the basin.

This soil is characterized by a dark grayish brown to light brown sand or loamy sand surface overlying a pinkish light yellowish brown loamy sand subsoils. The underlying material consists of a pale colored sandy clay loam or sandy clay which commonly occur at some depth below 80 cm. Few to common strong brown and/or reddish brown mottles occur in the deeper subsoil.

The Nam Phong soils generally have a strongly acid soils reaction. They have rapid permeabilitly low available moisture capacity. This is a concretionary variant which contains hard iron concretions or loose laterites at the depth below 80 cm but within 1 m from the soil surface. The ground water table is commonly below 3 m from the soil surface during the dry season.

Nam Phong soils are very poorly suited for upland crops due to low fertility, unfavorable texture in the surface soils, moisture deficiencies and erosion susceptibility. They are not suitable for wet-land rice. They can be used for pasture cultivation.

A.5 SOILS OF DISSECTED EROSION SURFACE AND HILLS

The soils on the dissected erosion surface are distributed in higher elevation lands, that is, the fringe of the area. These soils have been formed from residuum of sedimentary rock, and contain a considerable quantity of gravels and laterite concretions also. They are relatively insignificant in their extent within the study area. The secondary dipterocarp forests cover these soils predominantly, and parts of these forests have been cleared for upland crops such as cassava and maize.

These soils occupy some 21 percent of the study area primarily on the western and northeastern margins of the basin. The soil series found on the dissected erosion surface and hills for the most part have not been differentiated and are known only as Slope Complex soils. These soils have severe restrictions to general agricultural use but have potential for forestry, recreation and to some extent tree crops.

Soils of the hilly, less steeply dissected footslopes and smoother ridges have been differentiated. In the Chi Basin these are typified by Chaturat and Borabu series and associates.

A.5.1 Chaturat Series

The Chaturat series consists of moderately deep, gently sloping, well drained soils that formed in situ from calcareous shale or calcareous silstone. They commonly occur on slightly dissected erosional surface. The native vegetations are mixed deciduous forest. At present many places have been used for cultivation of upland crops such as kenaf, maize, and cotton. Other areas have been abandoned and colonized by a low secondary forest.

Chaturat soils are characterized by a dark reddish brown silty clay or clay overlying a reddish brown to red silty clay - clay subsoil. They are neutral to mildly alkaline in reaction and generally have moderate to high in nutrient status. The underlying parent material, consisting of weathered calcareous shale or siltstone, occurs between 50 and 100 cm of the soil surface. Permeability and surface runoff are generally slow. Ground water level often falls below 2 m throughout the year.

These soils are moderately suited for upland crops especially for plant having a short root system. Due to their moderate effective soil depth, they are poorly suited for fruit trees. The main limitations are shallow profile and liability to drought.

A.5.2 Borabu Series

The Borabu series consists of shallow to moderately deep, well drained soils that have formed from old alluvium overlying sandstone bedrock. They are commonly found on the gently to moderately steep sloping middle terrace along the southern margin of the basin.

These soils are characterized by a very dark grayish brown sandy loam or loamy sand overlying a strong brown to reddish yellow sandy clay loam subsoil. The underlying material, which commonly occur at some depth between 40 cm to 80 cm from the soil surface, consists of weathered sandstone fragments as well as laterite concretions. In some areas, sandstone rock outcrops are scattering on the soil surface.

The Borabu soils are low in nutrient status and are very strongly acid. However, the pH value of the soil surface is slightly higher than that of subsoil. These soils have severe limitations which generally leave them unsuited to agricultural use. Principal suitabilitly is forest and recreation.

APPENDIX B

SOIL AMELIORATION

B.1 INTRODUCTION

There are six major soil series in the Chi Basin-Korat, Roi Et, Satuk, Yasothon, Ratchaburi and Phi Mai - accounting for over 50 percent of the area. Six more series make up a further 20 percent. These are Chiang Mai (Ta Tum), Phon Phisai, Nam Phong, Warin, Ubon and Phan. In addition, the undifferentiated Slope Complex - a grouping of lithosolic and residual soils which occupy the hilly and mountainous areas-covers an estimated 10 percent. These soils primarily occur in Changwat's Chaiyaphum, Khon Kaen and Kalasin - accounting for 34, 7 and 11 percent of these Changwat's respectively. A summary of the main chemical and physical characteristics of these soils is shown in Table B.1

Soils research undertaken in the past decade or so has concentrated on paddy soils, primarily because some 70 percent of the study area is bunded for paddy production.

B.2 SOIL CHEMICAL CHARACTERISTICS

Chemical analysis data of the soils of the Chi Basin indicate that nutrient status and fertility are generally low and that there is considerable variability within the same soil series. Trials with low-land rice provide results indicating that (a) most if not all of the soil are deficient in N (b) some soils are deficient in either P or K or both, (c) some soils are likely to be deficient in Mg, (d) a few soils are deficient Zn and tended to be deficient in Mn and Cu, and (e) Si is beneficial to rice grown on some soils. However, detailed investigations, especially in respect to rate of application, on Mg. Zn, Mn, Cu B and Mo need be undertaken to verify these results.

For upland crops, some soils are deficient in N for most crops, while the others are not. Phosphorus and potassium have been less frequently found deficient. Evidences from trials with kenaf in early

TABLE B-1

CHEMICAL PROPERTIES OF SOME SOIL SERIES IN THE CHI BASIN

A. Great groups and Soil series for Paddy field (0-30 cm depth) (Aquic Moisture Regime)

Great groups	Soil series	Organic matter content (%)	Base saturation (%)	Cation exchange capacity (me/100g soil)	Available phosphorus	Available potassium	Soil reaction (water:soil 1:1)	Soil fertility evaluation
1. sandy Tropaquents	Chai Nat (Ch)	low	low to medium	low	low	low	5.5-7.0	low
2. clayey Tropaquepts	Phimai (Pm), Ratchaburi (Rb), Saraburi (Sb), Si Songkhram (Ss)	medium	medium	medium to high	low to medium	medium to high	5.0-6.5	medium
3. loamy Tropaquepts	Si Thon (St)	low	medium	medium	low	low	4.0-4.5	low
4. clayey Tropaqualfs	Nakhon Pathom (Np)	medium	medium to high	low to medium	low	medium	5.5-7.0	medium
5. loamy Natraqualfs	Kula Ronghai (Ki)	low	medium	medium	low	low	6.5-8.0	low
6. loamy Tropaqualfs	Wichian Buri (Wb)	low	medium	low	low	low	5.0-7.0	low
7. clayey Paleaquults	Nakhon Phanom (Nn) Roi-Et (Re), Renu (Rn)	low to medium	low	low	low	low	5.0-6.5	low
8. skeletal Plinthaquults	On(On), Phen (Ph), Sathon (Stn)	low	low	low	low	low	4.5-5.5	low

B. Great groups and Soil series for Upland crops (a. soil surface, b. subsurface) (Ustic Moisture Regime)

Great groups	Soil series	Organic matter content (%)	Base saturation (%)	Cation exchange capacity (me/100g soil)	Available phosphorus	Available potassium	Soil reaction (water:soil 1:1)	Soil fertility evaluation
9. Quartzipsamments	Nam Phong (Np)	low	a. medium b. medium	a. low b. very low	a. low v. very low	a. low b. very low	a. 5.5-6.0 b. 5.5-6.0	a. low b. low
10. loamy Dystropepts	San Pa Thong (Sp)	medium	a. low b. low	a. low b. low	a. medium b. low	a. low b. low	a. 5.5-6.0 b. 5.0-5.5	a. low b. low
11. clayey pellusterts	Lob Buri (Lb)	high	a. high b. high	a. very high b. high	a. medium b. high	a. very high b. very high	a. 7.0-8.0 b. 7.0-8.0	a. high b. high
12. clayey calciustolls	Ta Kli (Tk)	very high	a. high b. medium	a. very high b. very high	a. moderately high b. very high	a. very high b. high	a. 6.0-6.5 b. 5.5-6.0	a. high b. high
13. skeletal Plinthustults	Phon Phisai (Pp)	low to medium	a. low b. low	a. medium b. high	a. low b. low	a. low b. low	a. 4.0-4.5 b. 4.0-4.5	a. low b. low
14. skeletal Paleustults	Mae Rim (Mr)	medium	a. medium b. medium	a. low b. medium	a. low b. very low	a. medium b. low	a. 5.5-6.0 b. 5.5-6.0	a. medium b. medium
15. clayey Paleustults	Pak Chong (Pc)	medium	a. high b. medium	a. high b. medium	a. medium b. low	a. medium b. medium	a. 6.0-6.5 b. 5.0-5.5	a. high b. medium
16. loamy Palestults	Korat (Kt)	medium	a. medium b. medium	a. low b. low	a. low b. low	a. medium b. low	a. 5.5-6.0 b. 5.0-5.5	a. medium b. low

seventies and early eighties clearly show increasing frequency of response to N, P and K fertilizers, and thus indicate a decrease in N, P and K status of soils with time.

Calcium and magnesium seem not to be a problem though liming has been shown to be beneficial in some strongly acid soils for soybean and mungbean. Most of the major soils are deficient in S for production of pasture legumes, and some of the soils for maize production. Result obtained during the past 10 years indicate no deficiency in trace elements in most of the major soils, though boron deficiency has been noted in soils at a few sites for pasture legumes and peanut, and a positive response was obtained in yields of peanut grown on Korat series soils.

B.3 SOIL PHYSICAL CHARACTERISTICS

Partial size analysis indicate that soils of the Chi Basin are primarily loamy texture with predominantly sandy loams. Most, if not all, of the major soils are either weakly structured or structureless (massive). These textural and structural characteristics encourage slaking at the soil surface when wetted either by rain or irrigation water. This results in the formation of a thin crust on the soil surface, which affects seed germination and crop growth though physical obstruction, poor soil aeration and reduced infiltration. This condition affects upland crops much more than if affects transplanted lowland rice. Cultivation of such soils does not appreciably improve infiltration or soil aeration because the next water application repeats the crusting process. Remedial measures include incorporation of organic matter (i.e. ridges of suitable height) seems to be an effective practice for temporary improvement of physical conditions for upland crop production, but this needs further studies, especially in respect to cost/benefit.

For relatively permanent improvement of soil physical condition, soil treatments which are likely to help improving soil structure include (a) minimum tillage and/or hoeing in the case of no or low rate of organic application (b) application of calcium and (c) ploughing in high rates of organic matter (green manure) and calcium. Further research work are needed to examine feasibility of these practices especially in long-term socio-economical viewpoints.

B.4 ORGANIC MATTER

Physical, chemical and microbial properties of any soil are strongly influenced by the quantity and quality of organic compounds within the profile. Addition of organic residues (compost, farm manure, green manure, etc.) normally results in improved physical and chemical characteristics and micro biological activity. Soils with an optimum level of organic matter generally have good structural characteristics, which allow easy infiltration of rainfall or irrigation, uniform wetting of the soil profile, adequate aeration, good water holding capacity, reduced susceptibility to surface crusting and erosion. Cation exchange capacity and general level of plant nutrients are also increased. The activities of some heterothrophic micro organisms will be stimulated. Further, when chemical fertilizers are added in combination with organic material, the efficiency of the fertilizer is usually increased. The overall result is an increase in soil productivity.

Levels of soil organic matter in Chi Basin soils is generally very low-due to continuous cultivation of these soils, their physical characteristics, the climatic environment, etc.- all of which encourages rapid decomposition of organic compounds. Studies on rates of decomposition are limited, but the decrease in organic matter levels of something like 10% undar the original forest conditions to less than 1% in most soils has been accomplished, in most cases, in less than 40 years.

The improvement of soil productivity and water conservation in the Chi Basin requires greater use of organic materials. These can be obtained from a wide range of sources but most practically will have to be produced on the farm.

B.4.1 Crop Residues

Beneficial effects of compost prepared from crop residues on growth and yields of crops have been reported by many research workers. However, all of the composts under study were prepared continuously at experimental stations where facilities and labour were available. It is doubted that farmers will be able to prepare sufficient compost from crop residues since preparation usually requires considerable time (at least 30 days), labour, and other inputs. More practical may be use of residual material already in the field on the growing of specific crops for this purpose.

B.4.2 Organic Wastes

Organic wastes are considered to be a most important ammendment for sandy soils that are low in organic matter. In the past research on the use of organic wastes to improve soil properties and crop yields in the Northeast seemed to emphasize the use of manures, city compost, and rice hulk but not wastes from industries. Almost all of the research objectives were to compare the effectiveness of organic materials, in supporting growth and yields of the crops commonly cultivated with the chemical fertilizers. However, definite conclusions can not easily be drawn from results since soil series were not always indicated, the physico-chemical properties of soils used for experiments were not completely analysed or reported, and there was no economic assessment of the benefit, in cash terms to the farmer.

B.4.3 Legumes

Most of the research projects on green manure emphasize the use of legumes mainly Crotararia, but also Clitoria, Vigna and other legumes. According to the findings, some of the green manure legumes are will suited to this rainfed cultivation system, but there are still several constraints to the practical use of this soil improvement methodology. Examples of these constraints are the uncertainty of the beginning of the reliable rainy season (causing difficulties of setting planting-dates), drought conditions which occasionally occur after 1st or 2nd rainfall at the beginning of rainy season (causing damage of seedlings and reducing survival rate for inoculants when inoculated seeds are planted), lack of information on the value off lime and fertilizers (expecially phosphorus and potassium fertilizers) to support optimal growth of legumes.

In many cases, the use of legumes as inter-crops in the rainfed multiple cropping systems have been shown to be more advantageous than those of the green manure practices, since there is less risk from the uncertainty of the rainy season. It could be that most of research projects on the green manure legumes did not use inoculants to improve legume growth. This could mean that seed inoculation was considered to be ineffective in the soil series used.

It should also be noted that the use of inoculants to improve legume growth and yields is difficult in tropical environment, especially under non-irrigated conditions, due to high temperatures and dry conditions which reduce survival rate of Rhizobium during storage, and seed germination periods.

In case of Azolla, much work has been concentrated on the effects of local varieties on the rice yield. Research on variety selection, including local and introduced varieties has recently been initiated. Since most of the Northeast soils are low in phosphorus and potassium levels, studies designed to evaluate fertilizer rates suitable for growth and yield of both Azolla and rice on each major soil groups should be of considerable importance.

B.4.4 Additional Research

Although much research works have been done to evaluate the use of soil improving crops some important information is still lacking and insufficient to develop technologies appropriate for these cultivation areas.

The following additional research directions are recommended.

- Selection of more suitable legumes drought tolerant and, fast growing under low fertility conditions.

- Selection of effective Rhizobium strains for nodulation and nitrogen fixation with particular legume cultivers.

- More extensive selection of Azolla varieties and its associate Anabaena azallae.

B.5 SUMMARY

There is no doubt that the majority of soils in the Northeast, and the crops grown on them, could significantly benefit from any of a wide range of soil improving practices. The problem is to identify and introduce practices that are both practical and economic from the farmers point of view. Application of Nitrogen at critical stages in the rice growth cycle has give good, if not economic returns and some farmers have adopted this practice. Even so yields have still been low. Availability and use of slow release fertilizers may prove beneficial. Incorporation of sufficient amounts of organic matter presents a double problem. The first is how (and where) to generate the quanlities needed and the second is how to plow it in given present methods of cultivation. Growing of green manure crops seem most logical but these are difficult to plow in and decompose rapidly. Rice straw mineralizes more slowly but is even more difficult to incorporate.

In general it is difficult to see what the average farmer can do to significantly improve his soils and by this means increase their production potential, and thus future development options should be based on the assumption that little can be done to improve the soil resource.