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Appendix A

Geographical and Economical Background

The Northeast of Thailand is the region of the Country covering 168,854 square kilometres which is one-third of the area of the whole country. The Northeastern region consists of 17 provinces namely Nong Khai, Nakhon Phanom, Mukdahan, Sakon Nakhon, Udon Thani, Loei, Khon Kaen, Chaiyaphum, Maha Sarakham, Kalasin, Roi Et, Yasothon, Ubon Ratchathani, Si Sa Ket, Buri Ram, and Nakhon Ratchasima, shown as Figure E.1 (1). The population in this region is about 19 million constituting over one-third of the total population. It is surounded by hills of approximately 400 metres high in the south and by mountains of 1,300 metres high in the west with the Mekong River as a border with Laos in the north and east. The Korat Basin, an area in the center of the region, is a plateau which slopes gently to the southeast and drained by the major rivers, the Chi and Mune (2).

The main problems in this region are rainfall, land form and soil.

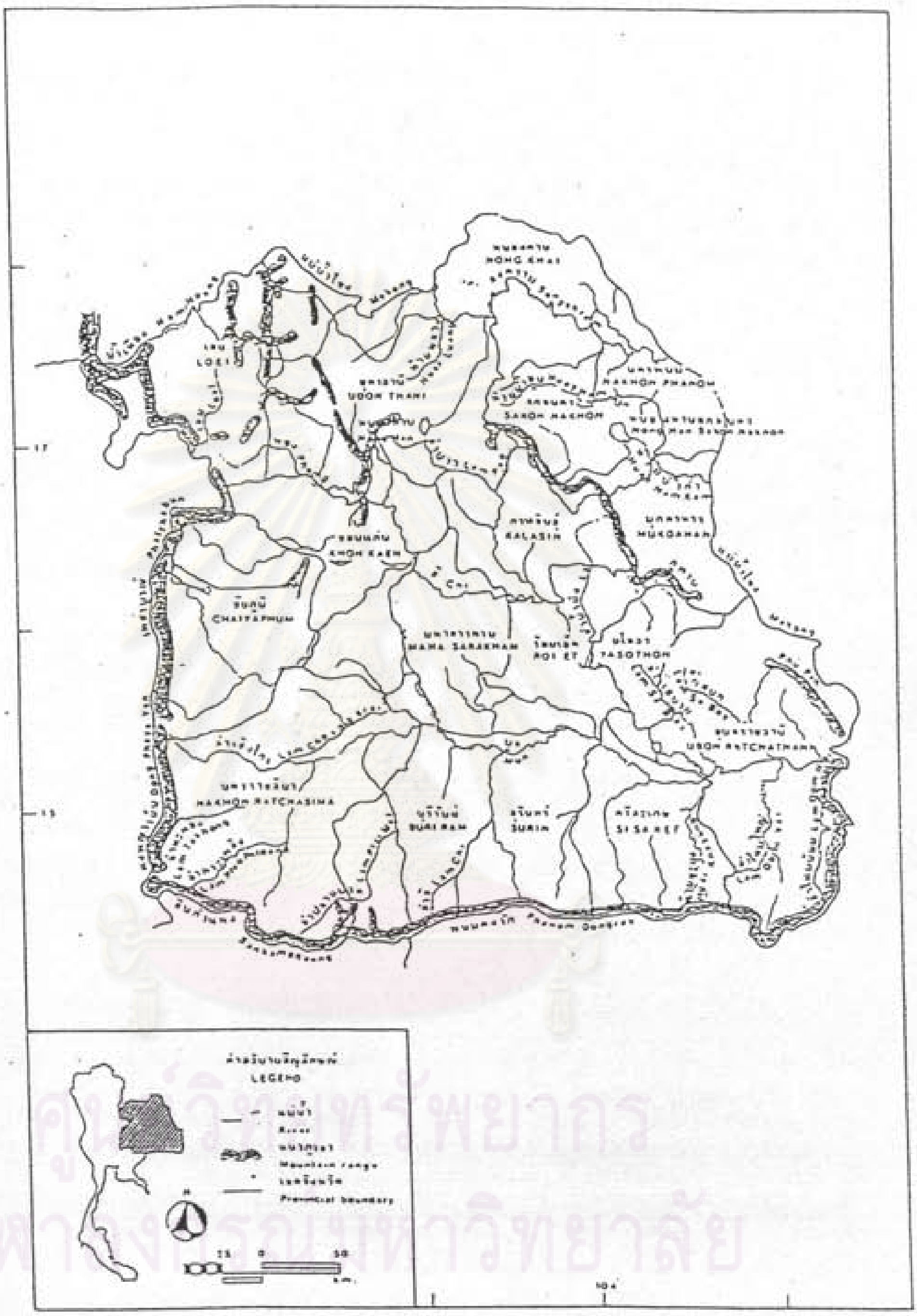

Figure A.1 Geographical Map of the Northeastern Region

a) Rainfall

The rainfall characteristics are dominated by the southwest monsoon from the Indian Ocean and tropical cyclones from the South China Sea. The rainy season normally starts from May to October with a maximum annual rainfall about 1,400 millimetres. The distribution of rainfall varies from above 1,400 millimetres to the north and east, below 1,200 millimetres to the west, and between 1,200 to 1,400 millimetres within the central area. These zones suffer from quite a large number of drought days on an average of 80-100 days. More importance of the main characteristics of rainfall in the Northeast is its high irregularity.

b) Landform

The topography in general is rolling plains bounded by mountains to the west and the south, with the whole area sloping towards the Mekong River. Geographers identify the landform of the Northeastern region as the Khorat Plateau (1).

(1) Geological Features

Geologically, the Northeastern region is largely covered with rocks of the Jurassic and Cretaceous periods. Geologists have named such rocks as the Khorat Group with is predominantly sandstone, although alternate layers of conglomerate, shale and rock salt are also present. The ages of these rocks revealed that at the end of the Mesozoic Era, the Khorat Plateau was an enormous inland basin. This inland basin intermittently subsided to become a shallow inland sea. Evaporation of sea water gave rise to beds of rock salt sandwiched among other rock layers. Through investigation, geologists have indicated that rocks of the Khorat Group in this region are more than 4,000 metres thick.

Later, in the early Cenozoic Era when the earth crust was under extreme compression and gave rise to many mountain chains in the North, the West, and the South of Thailand, the inland basin of the Northeast was also affected, as seen from large fault lines along the western and southern rims of the basin. Low mountain chains arose along the western rim, i.e., the Phetchabun and Dong Phya Yen Ranges, whereas the San Kamphaeng and Dong Rak Ranges appeared on the southern rim. Simultaneously, in the middle of the basin arose an undulating ridge with a northwest to southeast direction, dividing the basin into two parts. The folding becomes the Phuphan Range, while the two basin are called the Sakhon Nakhon Basin to the north and the Khorat basin to the south.

Besides the presence of sedimentary rocks of different periods, some igneous rocks are also found in some areas of the Northeast. For example, andesites, rhyolites, and diorites are found in Phetchabun and north of Loei, while basalt is found in some localities in Buri Ram and Si Sa Ket.

(2) Topographic Features

Topographically, the Northeastern region consists of 5 major subdivisions (1):

1. The Phetchabun and Dong Phya Yen Ranges
2. The San Kamphaeng and Dong Rak Ranges
3. The Phuphan Ranges
4. The Khorat Basin
5. The Sakon Nakhon Basin

The Phetchabun and Dong Phya Yen Ranges form the west boundary of the region from Loei to Nakhon Ratchasima.

The Phetchabun Range consists of two small parallel ranges which lie in a north-south direction and are separated by the Pa Sak river basin. The Eastern Phetchabun or Phetchabun 1 is located to the east of the Pa Sak River while the Western Phetchabun or Phetchabun 2 is to the west. The Phetchabun is also the dividing line between the Northeastern region and the Central region.

The Dong Phya Yen Range extends from Bamnet Narong in Chaiyaphum to Nakhon Nayok, with a total lenght of 129 kilimetres. It is less precipitous than the Phetchabun.

The most distinctive landforms of the Phetchabun and Dong Phya Yen Ranges are the flat-topped cuesta formations which are well exemplified by the Phu Rua and Phu Kradung Mountains in Loei.

The San Kamphaeng Range begins near the southern end of the Dong Phya Yen at Kaeng Khoi in Saraburi and extends east to Chong Tago Pass at Ta Phraya in Prachin Buri, comprising a total length of 185 kilometres. At the portion of the range near Dong Phya Yen, is located the Khoa Yai National Park which is famous for its scenic beauty.

The Dong Rak Range starts near Chong Tago Pass at Ta Phraya in Prachin Buri and extends east to the mounth of the Mun River at Khong Chaim in Ubon Ratchathani, comprising a total lenght of 544 kilometres. It forms an escarpment with rather steep slopes on the south side and gentle slopes to the north. Some basaltic hills are found along the northern side of the escarpment in Buri Ram, Si Sa Ket and Ubon Ratchathani.

The Phu Phan Range separates the Sakon Nakhon basin to the north from the Khorat basin to the south. The range begins at Na Klang in Udon Thani, passing through Sakon Nakhon, Kalasin, Mudahan and terminates near the Mekong River at Khong Chiam in Ubon Ratchathani. the range has an average height of only 300-500 metres, with many parts of the range having small hills rising out of the plain.

The Khorat Basin lies to the south of the Phu Phan Range and is drained by the Mun-Chi system. It is the largest river basin in the country, with an average elevation of 120-170 metres above sea level.

The Mune-Chi system covers an extensive area including the basins of numerous tributaries. The Chi is 764 kilometres long and the Mune 750 kilometres. Both rivers converge at Nong Bo in Ubon Ratchathani, then empty into the Mekong River at Khong Chaim.

The Sakon Nakhon Basin lies between the north of the Phu Phan Range and the Mekong River. Its elevation is about 140-180 metres above sea level. Numerous small streams drain into the basin, the largest one being the Songkhram River. All rivers in the basin flow into the Mekong River.

Landforms in the Khorat and Sakon Nakhon Basins consist of two main features: undulating plains and floodplains

Undulating plains are abound on higher grounds away from river banks. They are characterised by small depressions interspersed with many low hills. Such landscapes are caused not only by the weathering process of the rocks and the erosive power of the rivers, but also by the action of ground water which dissolved the rock salt beneath the ground. Geological surveys indicate that there are three thick layers of rock salt underneath the Khorat and Sakon Nakhon Basins. In some places the salt layers are 700-800 metres deep, but in other areas they may be found at only 30-40 metres. Where the rock salt layers are at shallow depths, ground water can dissolve the salt easily, causing the ground to subside. Hence, depression are formed on the surface where subsidence took place. It is not surprising, therefore, to note that there are numerous ponds and lakes of various sizes scattered all over Northeast Thailand.

Whereas undulating plains cover quite extensive areas in the Khorat Plateau, Flood plains are more limited in extent. They are found mainly in the lower parts of the river basin, especially along the Chi-Mune in Nakhon Ratchasima, Khon Kaen, Maha Sarakham, Roi-et and Ubon Ratchathani. Where the rivers meander intensively, numerous oxbow lakes can be found, such as at Maha Sarakham and Roi-et. In some places, the rivers may overflow their banks during the rainy season and cause flooding over wide areas. The flood-plains of Thung Kula Ronghai, covering 3,372 kilometre square in Maha Sarakham, Roi-et, Surin, Yasothon and Si Sa Ket, are quite well-known for its annual floods. During the rainy season, the land is flooded by water from the Mune and the Chi which are located nearby. On the other hand, water is usually scarce during the dry season.

c) Soils

The main land forms of the Northeastern comprise predominantly high alluvium terraces, including fans of old alluvium and colluvium, forming the feature of the plateau proper (3). This landscape is surrounded by the bordering mountains in the west and the south with dissected erosion surfaces and structural plateaux ocurring over various rocks, forming the foothills, and being overtopped by hills and mountains proper. Such mountains rise immediately from the high alluvium terraces in the northeastern of the region, forming the Phu Phan Range. The activities of the rivers have further dissected the plateau and formed low-lying river plains. Primarily the watershed of the Mune river, but also that of the Chi and of smaller rivers in the north shows extended low alluvial terraces of semi-recent and old alluvium, whereas the flood plains proper of Mune and Chi, and to a small extent also the Mekong, consist of recent river alluvium.

It has been repeatedly stressed that the soils of the Northeastern are poor and not very suitable for growing crops successfully compared with other parts of Thailand.

The soils of the region are mostly sandy although a sandy clay layer or lens is often present at some depth. Lateritic nodules are common in many soils and layers of compact but not indurate laterite are found in a number of soil series. The more common soil, however, is a fine sandy loam on the surface with some increase in clay content with depth. Chemically, these soils consist largely of silica. Organic matter present in the soil seldom runs much over 1 percent. Surface soil is often only slightly acid but layers with appreciable clay are usually much more acid. These soils are quite infertile in comparison to the silt loam soils of temperate regions. In addition to the low level of nutrients, there is a relatively high ratio of magnesium to calcium and of sodium to potassium. As would be expected, the soils have low water-holding capacity. Available soil water in the surface soils usually ranges from 4-10 percent. The water table is often close to the surface and in many case will not drop below 2 metres even during the dry season.

The region as it appears today is a result of the underlying bedrock and of its weathering and long-lasting erosion. Although most of the Korat Plateau is underlain by old sedimentary rocks, most of its soils are formed from alluvium and colluvium deposited during several cycles of erosion. The latter can be recognized in the landscape as distinct surfaces or terraces: the present dry alluvial plain, the low terrace, the middle terrace, and the high terrace.

(1) The Present Dry Alluvial Plains (or Flood Plains)

This soil which borders all the rivers and streams represents the young cycle. They are most extensive along the Mune river and its southern tributaries, the Chi river and its north-western tributaries, but very rare along the Mekong river. In this area, pronounced levee-basin features occur with swamps and permanent or intermittent lakes in the lowest parts of the basins. Textures of the alluvium plains are loamy on the levee and clayey in the basins.

The material, doposited in the wider alluvial valleys is usually fine-textured. Clays and heavy clays dominate and even the river levees are mainly composed of clay loam or clay. Only in spots, lighter material usually loam or sandy loam, can be observed in the river levees. The material in the narrow valleys which is derived directed from the adjacent areas is, on the average much lighter, with medium texture (loam, sandy loam) dominating. Where the adjacent material is very sandy, the alluvial deposits of the creeks usually are also sandy (4).

(2) The low terrace

The low terrace occurs just above the alluvial plains and is most extensive in the south-central and south-eastern parts of the region; especially in the lower basins of the Mune and Chi rivers. The topography is flat to slightly undulating with only minor stream incision. There are heavy textured sediments in the lower sub-level and medium to light textured sediments in a higher sub-level.

(3) The middle terrace

The middle terrace is fairly widespread throughout the Northeastern, but is most extensive in the Northern part of Northeastern Thailand. Reconnaissance surveys indicate the predominance of middle terrace formation, roughly north of a line Khon Kaen-Kalasin-Amnat Charoen. The topography is undulating to rolling. The sediments of the middle terrace show a distinct lithological break with a sandy upper part and a clayey lower part, often with laterite gravels. In place, the upper sandy parts have been partly or wholly eroded away, leaving the lower clayey sediments at or near the surface.

(4) The high terrace

The oldest or high terrace exists now only as small remnants or islands scattered throughout the region. The sediments of this terrace are generally sandy clay loam in texture and show a typical red colour. Gravels usually occur at great depth. These island-terraces have been found in several provinces. Typical spots can be observed along a line starting north of Khon Kaen and going east to a point north of Kalasin. Other spots were observed south-east of Khon Kaen, along the road from Ban Phai to Maha Sarakham and near Yasothon, Ubon province. South of Korat, larger surfaces of this high terrace are present and it is not excluded that other areas will be found elsewhere in the Northeastern.

Apart from these terraces, colluvial fans are also an important feature of the north-eastern landscape. These fans occur skirting the hilly areas and the escarpments on the different terraces.

A few remarks may be made on some of the major great soils groups, their geographical occurence, their characteristics and their economic use.

Alluvial soils occur on the immediate river plains of the rivers Mune and Chi as well as in the lower reaches of their tributaries. Along the Mekong, they prevail in the changewats of Nong Khai and Nakhon Pranom. They are characterized by generally poor drainage in the lowest levels and have a moderate fertility for rice production with high contents of calcium, magnesium, and potassium, but low contents of phosphorus, organic matter and nitrogen. Acidity ranges from moderate to slight, but is somewhat higher in swampy areas.

Low humic gleys, often with laterite concentrations and sheet laterite, dominate in the lower strata, between the river valleys, and form extensive areas of the Korat Plateau. They often show poor drainage, low content of organic matter, nitrogen and phosphorus, but medium or high content of calcium and magnesium. Acidity is moderate to strong. Groundwater laterite occurs in some of these soils but is usually deep enough so as not to interfere with the growth of crops.

Similarly, saline soils may be associated with some low humic gley soils, as a result of large rock salt deposites underneath the plateau. It seems, however, that until now the salt does not interfere much with rice production as each rainy season helps dilute and wash away the salt. It may, however, become a problem in soils of finer texture. Where conditions do not permit the cultivation of rice, upland crops such as kenaf and millet prevail.

Grey podzolic soils, typical for the foothills in the south and toward the west as well as in the Phu Phan Range, are poor in weatherable minerals, have a high content of quartz and more organic matter than other soils. But the tendency of the ingredients of these soils to separate often results in a washing out of the clay, leaving large areas of coarse sand-surfaced soils. Some profiles have a laterite pan fairly deep in the solum.

Red-yellow podzolic soils are predominant in the plain of the Sakon Nakhon Basin, between the Phu Phan Range and the Mekong, but they form also mountains in the Phu Phan Range and in the western and southern border mountains of the region. They contain laterite concretions and rarely cultivated since they are very susceptible to erosion which leaves the concretionary layer exposed. Once this has taken place, further cultivation is difficult. In addition, these soils have usually moderate acidity in the surface and they are strongly acid in the subsoil. Except for virgin soils, the organic matter content is low and there is a lack of calcium and phosphorus.

Finally, there are the red-yellow lathosols which are often used for upland crops such as kenaf and occasionally cotton. They are scattered geographically and do not form large areas. They are low in calcium, magnesium, potassium, phosphorus, and organic matter which, together with water deficiency, results in low yield.

In general, soils in the Northeast are not fertile partly due to their parent materials being sandstone which has low inherent fertility.

The water holding capacity of soils in the Northeast is generally low because the organic matter and clay contents are very low. Erratic rainfall together with low water holding capacity of soils often creates water stress affecting the stability of rice production as well as other crops.

d) Farming in the Northeast

Farming in the Northeast are crops based on rice as the subsistence and field crops as cash crops. Soil have profound effects on the productivity or crop yield, and stability of the Northeast farming systems. The generally low fertility of the soils results in low crop productivity while the erratic rainfall leads to the instability of rice fields.

Rice production is the center of the Northeast farming systems around which other activities, such as field-crops and animal production and various social activities, revole. The four most important crops are cassava (10%), corn (6%), kenaf (3%), and sugarcane (1%). Rice is grown mostly on the so-called "low land" which are flood plains and low terrace because water accumulation in paddy field is required for rice growth. Field crops generally occupy the upland areas to paddy fields, the so-called "upper paddy field", apparently because of increasing population pressure.

In an attempt to adapt to unfavorable growing conditions of upper paddy land, farmers grow short-duration varieties of rice in order to fully utilize the short period of water accumulation in the upper paddy fields. Some farmers try to improve their rice-based cropping system by incoporating field crops into system before and after rice plantation.

e) Crop Yield and Improvement

The average rice yield in Northeast is less than 2 tons a hectare, which is the lowest in the Country. Farmers use very little chemical fertilizers because of the expensive price relative to the income from their crops. Animal manure, and other organic residues such as rice straw, ash from rice husks, and corn stover are normally applied to soil so as to maintain and increase the soil fertility. Wherever crops are grown in rotation, fertilizer are applied to the high-value cash crops such as water melon and tobacco.

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Appendix B.1

Effect of the Concentration of Acrylic Acid on the Gel Permeation Chromatrographic Peaks

	starch (g) / Acrylic acid (M)									
	30 : 1.47		30 : 2.21		30 : 2.95		30 : 3.68		30 : 4.42	
	Peak 1	Peak 2	Peak 1	Peak 2	Peak 1	Peak 2	Peak 1	Peak 2	Peak 1	Peak 2
Peak start (min.)	95.51	106.30	96.15	106.20	95.36	106.40	95.56	106.50	95.18	107.00
Peak max. (min.)	103.50	108.00	103.50	107.90	103.60	108.00	103.60	108.00	103.60	108.30
Peak end (min.)	106.30	109.70	106.20	109.80	106.40	109.70	106.50	109.70	107.00	109.60
Peak height (microvolt)	45,655	442,833	651,185	533,839	650,345	445,006	644,342	427,314	670,300	266,999
Peak area (microvolt-sec)	$1.74x10^8$	$6.13x10^7$	$1.75x10^8$	$7.85x10^7$	$1.78x10^8$	$6.27x10^7$	$1.75x10^8$	$5.75x10^7$	$1.97x10^8$	$2.87x10^7$

Appendix B.2

Effect of the Hydrogen Peroxide Concentration on the Gel Permeation Chromatrographic Peaks

	Hydrogen peroxide concentration (M)											
	0.0553		0.1107		0.1661		0.2217		0.2768		0.3322	
	Peak 1	Peak 2	Peak 1	Peak 2	Peak 1	Peak 2	Peak 1	Peak 2	Peak 1	Peak 2	Peak 1	Peak 2
Peak start (min.)	95.50	106.20	94.63	106.10	95.66	106.30	95.36	106.40	95.61	106.30	95.54	106.30
Peak max. (min.)	103.60	107.90	103.00	107.50	103.70	108.00	103.60	108.00	103.70	108.00	103.60	107.90
Peak end (min.)	106.20	109.60	106.10	109.00	106.30	109.70	106.40	109.70	106.30	109.70	106.30	109.80
Peak height (microvolt)	619,401	441,557	662,404	346,091	626,837	472,849	650,345	445,006	620,780	457,872	626,007	461,867
Peak area (microvolt-sec)	$1.67x10^8$	$6.23x10^7$	$1.91x10^8$	$4.06x10^7$	$1.68x10^8$	$6.69x10^7$	$1.78x10^8$	$6.27x10^7$	$1.67x10^8$	$6.40x10^7$	$1.69x10^8$	$6.57x10^7$

Appendix B.3

Effect of the Reaction Temperature on the Gel Permeation Chromatrographic Peaks

	Reaction temperature (°C)							
	35		45		55		65	
	Peak 1	Peak 2	Peak 1	Peak 2	Peak 1	Peak 2	Peak 1	Peak 2
Peak start (min.)	95.36	106.40	95.43	106.30	95.17	106.30	95.23	105.90
Peak max. (min.)	103.60	108.00	103.70	108.00	103.60	107.90	102.80	107.30
Peak end (min.)	106.40	109.70	106.30	109.70	106.30	109.70	105.90	108.80
Peak height (microvolt)	650,345	445,006	626,921	460,525	625,653	456,146	658,330	350,818
Peak area (microvolt-sec)	$1.78x10^{8}$	$6.27x10^{7}$	$1.69x10^{8}$	$6.48x10^{7}$	$1.7x10^{8}$	$6.48x10^{7}$	$1.87x10^{8}$	$4.2x10^{7}$

VITA

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