RESEARCH ON DEVELOPMENT OF TECHNOLOGY TO PRODUCE IMAGES FOR SOIL CLASSIFICATION BY REMOTE SENSING IN CONNECTION WITH NORTHEAST THAILAND AGRICULTURAL DEVELOPMENT RESEARCH PROJECT

JULY 1986

JAPAN INTERNATIONAL COOPERATION AGENCY

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C O N T E N T S

I. Preface

Thailand is a constitutional monarchy located between North Latitudes 5° - 21° and East Longitudes 97° - 106° with land area of 514,000 square km. The study area is located in North-east Thailand where, covered by sandy loam, land is poor in productivity and irrigation facilities are yet to be built, with the result that the yield of rice production is the low-est in the country. Furthermore, in recent years, affected by increasing salinity in soils, the yield is further declining forcing some of the rice paddies out of production.

The study has been undertaken to understand saline accumulations and soil moistures during the dry season by using Landsat data in an effort to work out measures to cope with salt damages done to rice production. The methodology as well as its results is discussed in the chapters that follow.

II. Outline of Study Area

The nation's land is mostly of tropical savannah with annual rainfalls of 1,100mm - 1,500mm occurring intensively in the wet season (May - October) whereas it becomes intensely arid during the dry season. Located northeast of Bangkok, Northeast Thailand in particular is beset by chronical drought due to the Phetchabun Mountain Range rising to the west and most of the rainfall occurring on the western side of the range. As shown in Figure 1, the study area is part of Northeast Thailand as such. Rice growing is a major agricultural activity in the area, but soils being poor in productivity with high salinity typically showing in occasional outcorpping of salt, the yield of agricultural production is the lowest in the country.

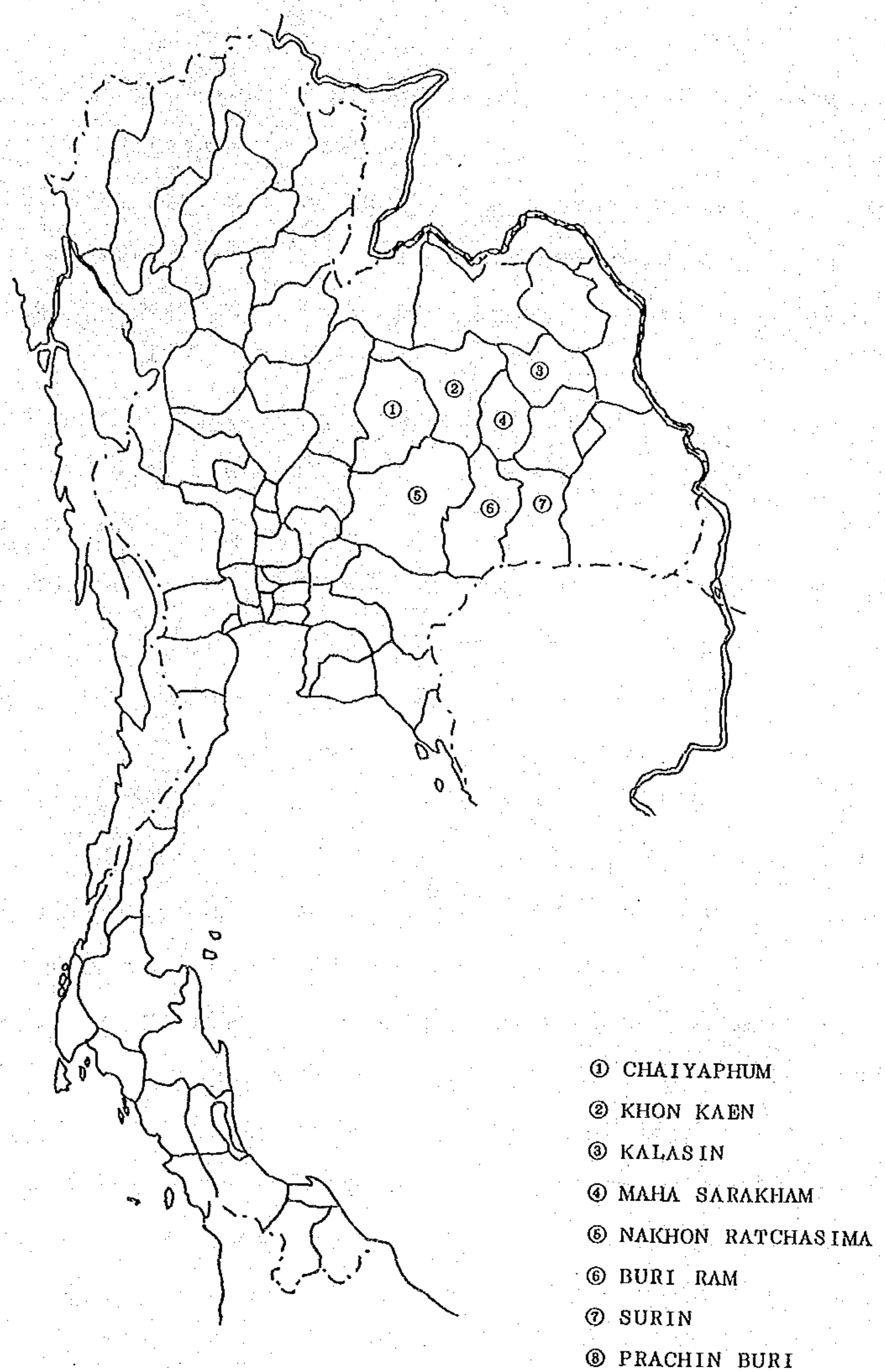


Figure 1: Study Area

1. Climate

Thailand falls in the Tropical Monsoon Zone with an annual rainfall of 1,000mm - 2,000mm. But having the dry season for a period from November to April, its climate is more like that of the savannah except for the peninsular region. In the northeastern part of the country, annual evapotranspiration exceeds rainfall locally subjecting the area to possible damages from drought except for the wet season when cultivations are possible because of the rainfall exceeds the evapotranspiration.

Since the summer monsoons (south-westerly, May - October), winter monsoons (north-easterly, November - April), typhoons (south-easterly, Many - November), Bengal cyclones (May - June), that regularly hit Thailand, have to come over such mountain ranges as Phetchabun, Phnom Damrek, Annam Cordillera, to reach Northeast Thailand, the rainfall to be brought in the area is not much compared with other parts of the country, with 1,000mm at Nakhon Ratchasima in the southwest of Northeast Thailand for example. Moreover, the rainfall pattern is extremely uneven. Specifically, at Khon Kaen, where the annual rainfall amounts to 1,275.5mm (average over 1977 - 1982), 26% of the rainfall is concentrated in one month of September whereas only 8.7% occurs during the seven-month dry season from November to April. How unevenly distributed the rainfall is at Khon Kaen can be seen better when compared with Bangkok located in the central plain, where the rainfalls are 1,485.7mm for September or 21.2%, and 13.5% for November - April (averages over 1977 - 1985).

Average annual temperatures are 27.4°C at Khon Kaen (1977 - 1982),27.6°C at Nakhon Ratcasima (1977 - 1985), which compare wtih 28.7°C at Bangkok (1977 - 1985). Relatively low temperatures can be attributed to the high latitude, the inland location and the high elevation of Northeast Thailand. Annual movements of temperatures show the minimum (23.0°C) in December gradually rising to reach the maximum of around 30°C in April - May and then start declining as the wet season sets in.
Relative humidity is low in Northeast Thailand compared with the rest of the country with the lowest of 51.8% - 66.2% occurring in January - March and the highest of 78.6% - 86.7% in August - September. It is particularly low along the Phetchabun Mountains where there is less amount of rainfall than in the rest of Northeast Thailand. During the season of winter monsoons, there is little cloud cover causing much insolation in the daytime and strong radiation at night to dry up the surface soils. And farmers burn their fields, pastures, and forests at this time of a year.

As seen above, the climate of Northeast Thailand is seasonally uneven in macro-terms. But a closer look showa that one wet season is often interupted by lengthy (lasting two weeks or longer) break periods, which actually is more of a serious problem as well as extreme aridity of the dry season. Concentration of rainfall in September makes it difficult to effectively preserve necessary water for agriculture.

Table 1: Temperature and Rainfall

Khon Kaen (16° 15'36" N、 102° 30'00" E)

1977~1982

	1	2	3	4	5	6	7	8	9	10	11	12
T(°C)	24.0	26.0	29.9	30.2	29.7	29.3	28.7	28.3	27.7	27.2	25.3	23.0
P(mm)	0.2	14.5	26.2	60.9	211.3	194.4	177.2	174.4	331.7	75.1	5.0	4.6

T: Average monthly temperature (°C) Average annual temperature 27.4°C

P: Monthly rainfall (mm) Annual rainfall 1.275.5 mm

Nakhon Ratchasima (14° 34'48" N、 102° 03'00" E)

1977~1985

	1	2	3	4	5	6	7	8	9	10	11	12
T(°C)	24.0	27.0	29.8	30.6	30.1	29.4	28.9	28.6	27.7	26.7	25.1	23.0
P(mm)	9.3	26.5	22.6	48.8	124.7	101.2	122.4	142.6	241.3	121.1	37.5	2.7

Average annual temperature 27.6°C

Annual rainfall 1,000.7 mm

Bangkok (13° 26'24" N、 100° 20'24" E)

1977~1985

	1	2	3	4	5	6	7	8	9	10	11	12
T(°C)	27.4	28.4	29.8	30.6	30.4	29.6	29.1	29.0	28.5	28.3	27.6	26.2
P(mm)	13.7	20.6	30.7	77.6	175.2	179.7	169.4	195.9	315.3	249.7	53.7	4.2

Average annual temperature 28.7°C

Annual rainfall 1,485.7 mm

2. Geomorphology and Geology

Northeast Thailand is located northeast of Bangkok bordering on Laos and Cambodia. With a land area of approximately 170,000 square km., it is the largest of the four regions of Thailand (i.e. North, Northeast, Central, and South). The Mekon River runs on the north-east fringe of the region and the Phetchabun Mountain Range rising to the west and the Sankambeng and the Phnom Damrek Ranges along the southern edge. Enclosed by these rivers and mountains is the Korat Basin forming an expanse of gently undulating terrains. As the hysometric analysis shows, 62.9% of the land area in Northeast Thailand falls in the range of 101m to 200m in elevation.

Table 2 Hypsometric analysis of North-East Thailand

Altitude(metres a.m.s.l.)	Area (Km²)	Area (%)
sca level to 100	170	0.1
101 – 200	107,072	62.9
201 – 500	48,345	23.4
501 – 1,000	11,575	6.8
above 1,000	3,064	1.8
Total	170,226	100.0

Source : Gravimetric analysis,
The Five Faces of Thiland

The three mountain ranges on the south-west fringe of North-east Thailand long served as barriers to the traffic in and out of the area setting the area apart from the rest of the regions culturally and economically. The Phetchabun Range which forms the boundary between North and Central Thailand is characterized geologically by the late Palaeozoic Ratburi Formations with lime stone as a major component mixed with shale, sandstone, conglomerate, volcanic tuff. To surround it are extensive distributions of Mesozoic Phu Kradung Formations. This formation consists of micaceous shale, siltstone, micaceous sandstone, and conglomerates, which, being vulnerable to weathering and erosion, by now forms flat terrain. Further out on the periphery of Northeast Thailand are distributed Phu Phan and Phra Wihan Formations. These formations comprise sandstone, micaceous shale, siltsone, and comglomerates, which, in contrast to Phu Kradung Formation, are resistant to weathering and erosion, from long edges of mountain ridges showing in places structural reliefs of dome and mesa.

The Phnom Damrek Range on the Thai-Cambodian border is comprised by Phu Phan and Phra Wihan Formations shwoing a structural relief of cuesta. Though steeply rising on the Cambodian side, it is a gentle range of mountains. The Phu Phan Range is geologically similar to the Phnom Damrek with its mountain ridges continuing across the Mekon River into Laos.

The flat land and hilly uplands comprise late Mesozoic Korat Formation. This formation has distributions of sand stone, shale, and siltstone as well as thick layers of rock. There also are other formations that contain slat. Soem such salts affect the surface soils causing salinization problems in Northeast Thailand. The sedimentary rocks that contain these salts are called Maha Sarakham Formation, which, as a recent study estimates, dates back to early Tertiary.

3. Soils

Northeast Thailand stands on the plateau of around 180 meters in elevation called Korat Basin. With arrpoximately 90% (as of 1970) of its workforce engaged in agriculture, the region is a predominatly agricultural zone. During the wet season, paddy rice is planted, and other crops like cassava, sugar canes, corn, are also raised. In Northeast Thailand, paddy fields account for 72.4% (1977 - 1978) of its agricultural land use and as much as 46% of all paddy fields in the country showing a high concentration of paddy fields in this region. But in terms of production volumes, the region accounts for 33.3% (as of 1978 - 1979) of the nationwide total with the yield (t/ha) being 1.18 (1978 - 79) which compares with 2.03 for the rest of the country. Considering the yield was 1.84 in 1969, the productivity has been declining over years in the region. The same tendency is observed for other crops than rice. The yields are below the nationwide averages for all crops except mung beans and cotton.

Table 3: Average Hields of Crops by Region (t/ha)

	North	North-east	Central Plain	South	Nation-wide
Rice	2.19	1.18	1.92	1.70	1.63
Corn	2.01	1.78	1.98	1.83	1.94
Cassava	15.31	12.79	14.01	14.31	13.40
Sugar Cane	44.35	34.16	48.61	-	47.07
Mung Beans	0.72	0.74	0.68	0.63	0.70
Soy Beans	0.89	0.83	0.85	0.71	0.87
Peanuts	1.23	1.10	1.16	1.26	1.18
Castor Beans	-	-	-	-	0.97
Sesame	-	-	-	-	0.78
Coconut	-	-	-	-	3.28
Cotton	0.95	1.13	1.09	-	1.04
Kenaf	0.89	1.01	1.00	-	1.04
Regional yield Ratios*	1.04	0.93	1.03	0.97	
% of fertilizer cost in total production cost	4.50	12.50	9.60	6.80	9.00

* Averages of regional crop ratios against nation-wide averages

The soil distribution pattern of Northeast Thailand can be described as follows.

In valley bottoms and natural levees are distributed alluvial soils and low humic gley soils, and similarly in alluvial low lands and low terraces in general, but in some higher portions there appear gray podzolic soils. In low terraces, no alluvial soils are observed. In high terraces, soils are mainly gray podzolic with sporadic distributions of red yellow podzolic soils, recosols, red yellow latosols. In hilly uplands and mountains, soils are similar to those in high terraces generally but as it gets higher in elevation, there appear more of lateritic soils.

Other types of soils include such saline soils as solonchaks and solonetz which are dist ributed in alluvial lowlands. One characteristic shared by these soil types as observed in Northeast Thailand is that they are rich in coarse materials but extremely poor in fertility. In terms of land use, paddy fields relate to low humic gley soils and other farm fields to gray podzolic soils.

The geology of Northeast Thailand, namely, mother materials of soils, consists mainly of Mesozoic sedimentary rocks, (sandstone, shale, siltstone, conglomerate, etc.) and Tertiary basalt. Soils based on these materials have kaolinite as a major component of clay mineral structure. The kaolinized soils are low in cation exchange capacity and also low in PH, compared with other soils of clay minerals (illite, montmollironite). In terms of primary minerals, soils in Northeast Thailand have a higher proportion of quartz than those of other regions and, therefore, hold little promise in the potential fertility of soils. Low humic gley soils and gray podzolic soils, both widely distributed in Northeast Thailand, are based on either kaolinite or halloysite, and inert by nature, being strongly acid (PH 5 more or less).

With the total carbon contents averaging less than 0.8% and the total nitrogen contents 0.07%, these soils contain extremly little amount of organic substances. With respect to total phosphates, exchangeable potassium, calcium, and magnesium, they are small in volume across the board except in some cases of clayish low humic gley soils where these contents can rise slightly.

Gray podzolic soils most commonly observed in the high terraces and over to the hilly uplands of Northeast Thailand, have a high permeability of 10^{-3} - 10^{-4}cm/S possibly due to loamy sands and sandy clay loam being coarse-grained and highly porous. Also having a physical property of high dispersion, the soils are prone to sheet erosion and rille erosion.

In view of the low capacity of soils to retain water, efforts are being made to build a number of reservoirs to ensure agricultural water supply. As of 1978, there were reservoirs built at 354 locations including those under construction with the total volume of water reserves amounting to 30 billion cubic meters. As many as 85% of these reservoirs are located in Northeast Thailand accounting for 10% of the total water reserves. The reason for the unproportionately low percentage of water reserves is due to its flat topography which constrains the height of reservoir banks. The area to benefit from a reservoir in irrigation is limited to two to three times the area immersed under water for the reservoir.

The great soil groups typical of Northeast Thailand are described below in terms of their distributions and characteristics.

(1) Alluvial Soils - Mostly Tropaquept, partly Ustifluvents

Distributed along rivers in lowlands, this type of soils do not drain well. High in contents of calcium, magnesium, and potassium, but low in phosphates and nitrogen, and organic substances, it is mildly acid. The land of this soil type is used for paddy fields whereas alluvial land with better drainage is made into farms for cotton, tobacco, sugar canes, mung beans, soy beans, etc. It ranges in soil property from loam to clay and in color from dark brown to brown.

(2) Low Humic Gley Soils - Paleaquult

Distributed in low terraces near rivers of old allvial lands, it does not drain well and is used for paddies. Those of higher elevations are turned into farms for sugar canes, soy beans, mung beans, peanuts, etc. While low in humus contents, due to the considerable change of ground water level, the soils are relatively rich in calcium and magnesium contents. Top soils are dim yellowish brown or dim yellowish orange in color, and medium to strong in acidity.

(3) Gray Padzoic Soils - Paleuslults

Formed on top of coarse to mid-size grained, acid, old deposits, this type of soils are widely distributed in lower parts of mid-level terraces. Particularly common in Northeast Thailand. All of the layers are sandy in general but lower layers show a slight accumulation of clay. Its color dim brown. Sometimes it contains lateritic pans. Since its clay materials are mainly kaoline type, its saline exchange capacity is small and the soils are lean. Primary minerals are mostly quartz. Major crops raised in Northeast Thailand are kenaf, mulberry, and cassava.

(4) Red Yellow Podzolic Soils - Paleustults

Distributed mainly in upper parts of mid-level terraces, this type is formed over the residual soils or old alluvial deposits. Top soils have colors of dark brown to dim yellowish brown, and the lower ones reddish brown to yellowish brown. PH values are generally low. Clay minerals are of kaoline type having accumulations in B horizon. Often it has concrete lateritic layers which once exposed on the ground surface, become erosion resistant and makes it difficult for vegetation to grow. They are mostly left in their original forests.

(5) Red Yellow Latosols - Paleustult

Sporadically distributed in high terraces. Top soils are chocolate colored. Lower layers are generally coarse grained, and dark reddish brown to bright brown in color. Clay minerals are mainly kaolin. Small saline exchange capacity. Lean in nutrients but good in physical properties. Cassava, kenaf, and corn are grown in this type of soils. (Reference: Tropical Agriculture Research Center Publication No. 50, 1985)

III. Study Method

The study has been conducted in the procedure as shown in the following flow diagram.

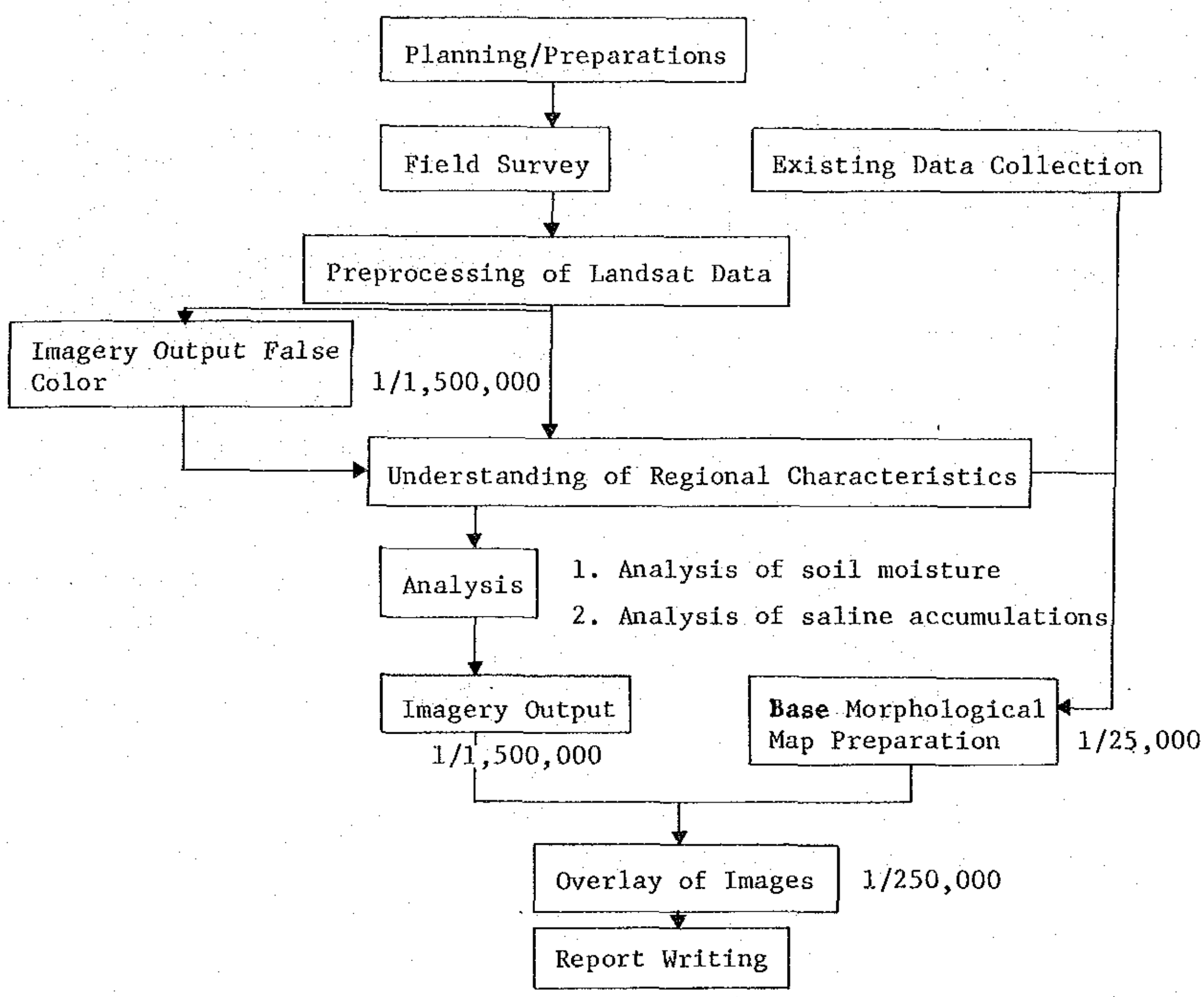


Figure 2: Work Flow Chart

1. Field Survey

(1) Period:

April 7 - May 9, 1986

(2) Survey Items:

By studying Landsat imagery and consulting D.L.D. (Department of Landuse Development) staff members, suvery sites were selected for measurement of spectral reflections, determination of moisture contents by soil sampling, and photographing for circumstantial evidence. Salt surface coverage rates were decided to be determined by visual observation.

(3) Equipement used:

1 Landsat (EARTS) Ground Truth Radiometer Model 100-4

2 R.P.M.I. (Radiant Power Measuring Instrument)

3 Portable Photometer

The instruments 1 , 2 and 3 above provided, mainly this survey was made by the instrument 1 .

(4) Existing Data Collection:

Following are the data collected for the purposes of Landsat imagery analysis and field survey.

1. Soil Salinity Distribution Map 1/250,000

a. Ubon Ratchthani

b. Kalasin

c. Srisaket

d. Surin

e. Maha Sarakham

f. Sakhon Nakhon

g. Yasathorn

h. Udon Tharie

i. Chaiyaphum

j. Khon Kaen

k. Nakhon Ratchasima

l. Roi Et

m. Nakhon Phanom

n. Nong kai

o. Buri Rum

2. Detailed Reconnaissance Soil Map 1/100,000

a. Surin Province Series: No.19 Bangkon, 1974

b. Chaiyaphum Same : No.17 Bangkok, 1973

c. Buri Rum Same : No.16 Bangkok, 1975

d. Khon Kaen, Province Series: No. 14 Bangkok, 1973

e. Kalasin, Same : No. 9 Bangkok, 1972

f. Maha Sarakham, Same : No. 13 Bangkok, 1972

g. Nakon Ratchasima, Same : No. 21 Bangkok, 1972

3. Land Use Planning Map 1/250,000.

a. Chaiyaphum

b. Kalasin

c. Prachin Buri

d. Roi Et (copy)

e. Maha Sarakham (copy)

4. Soil Moisture and Electric Conductivity Data

Data on soil moisture levels and electric conductivity as taken by D.L.D. in January 1986 at Maha Sarakham are given in Table 4. Data are computed from sampling data taken at depths of 0 - 5 cm and 5 - 15 cm for moisture contents and 5 - 15 cm for electric conductivity. Sampling sites are as shown in Firgure 3.

Table 4: Soil Moisture and Electric Conductivitv

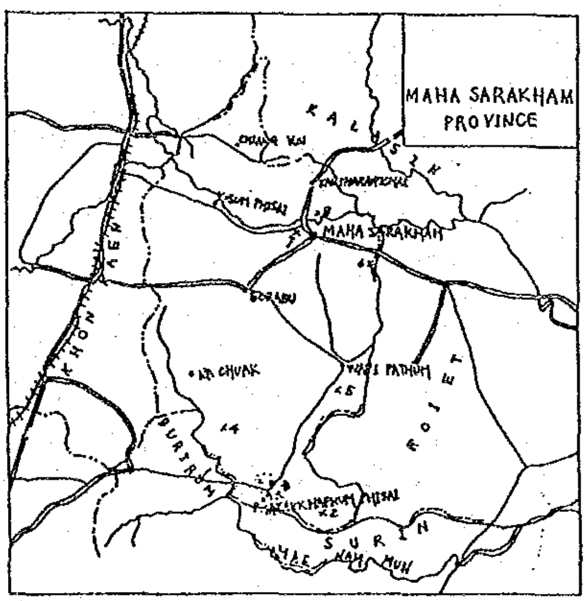
(1)

Site No	Sample No	Moisture (%)	ECe · 10 ^{3} (μs／cm)
1	1／1 0～5 cm 1／2 5～15 cm	0.84 9.53	0.1
	2／1 2／2	0.25 5.99	—
	3／1 3／2	19.55 7.50	0.26
	4／1 4／2	0.1 3.9	—
2	5／1 5／2	0.55 1.86	4.0
	6／1 6／2	2.99 1.01	0.93
	7／1 7／2	2.17 2.15	0.215
	8／1 8／2	0.71 0.91	—
	9／1 9／2	0.91 —	0.72
	10／1 10／2	1.63 4.66	—

Site No.	Sample No.	Moisture (%)	ECe・10 3 (μs／cm)
3	11／1 11／2	0.62 0.76	1.9
	12／1 12／2	0.54 2.18	0.47
	13／1 13／2	1.86 6.07	0.55
	14／1 14／2	0.25 2.15	0.46
	15／1 15／2	0.3 1.32	0.7
	16／1 16／2	1.62 4.44	12.0
	17／1 17／2	0.3 1.52	0.855
	18／1 18／2	0.81 6.23	0.6
	19／1 19／2	0.32 2.88	1.3
	20／1 20／2	1.06 7.06	—
	21／1 21／2	0.25 5.75	1.55
4	22／1 22／2	1.23 3.79	0.41
	23／1 23／2	0.5 7.53	—
	24／1 24／2	0.53 4.82	0.125
	25／1 25／2	0.25 0.86	0.08
	26／1 26／2	0.0 0.01	4.35
	27／1 27／2	0.05 7.70	1.3
	28／1 28／2	0.20 5.4	0.17
	29／1 29／2	0.5 4.66	7.0
	30／1 30／2	0.55 6.61	8.35

Site No.	Sample No.	Moisture (%)	ECe・10^3 (μs/cm)
5	31/1 31/2	0.15 2.15	2.7
	32/1 32/2	0.10 0.05	0.29
	33/1 33/2	0.55 5.0	9.6
	34/1 34/2	6.33 10.50	0.38
	35/1 35/2	7.49 28.45	4.45
	36/1 36/2	1.42 7.4	0.21
	37/1 37/2	6.9 20.2	2.35
	38/1 38/2	4.55 12.74	1.4
	39/1 39/2	3.69 11.4	0.13
	40/1 40/2	1.27 6.49	0.625
	41/1 41/2	0.375 3.47	0.145
6	42/1 42/2	16.39 11.89	0.012
	43/1 43/2	3.56 10.64	0.21
	44/1 44/2	0.78 5.5	0.515
	45/1 45/2	19.32 19.54	0.08
	46/1 46/2	0.19 1.06	–
7	47/1 47/2	10.87 13.81	–
	48/1 48/2	12.31 26.51	0.195
	49/1 49/2	1.35 13.15	0.0935
	50/1 50/2	2.45 8.25	2.2

Site No.	Sample No.	Moisture (%)	ECe・10³ (μs/cm)
	51/1 51/2	2.24 11.73	0.13
	52/1 52/2	1.24 13.25	0.16
	53/1 53/2	2.72 11.73	0.19
	54/1 54/2	1.40 8.75	0.13
	55/1 55/2	1.03 10.56	—
	56/1 56/2	1.62 14.99	0.32
	57/1 57/2	1.84 15.67	0.185
	58/1 58/2	3.21 16.14	0.13
	59/1 59/2	2.07 16.85	0.34
	60/1 60/2	2.04 12.80	0.135



×：Site No.

Figure 3 Check Sites (Jane 1986)

2. Landsat Image Processing

(1) Data Used

Past dry season Landsat data were gone through for two scenes covering the study area, which were cloud-free and of identical dates. The data for selected scenes were purchased from the Remote Sensing Technical Center of Thailand in the form of magnetic tapes of the following specifications.

Date of data acquisition:

January 16, 1984

Path-Row:

128 - 49

128 - 50

Data Format:

CCRS BIL Format, with no correction made.

Landsat 4 MSS specifications for the present study are as follows.

Altitude: 705 km.

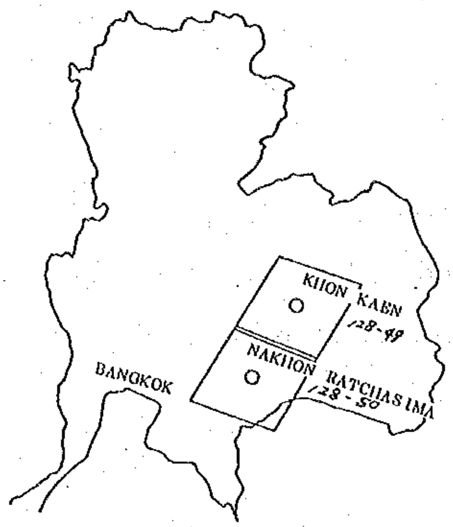
Orbit: Sun-synchronous polar orbit

Repeat Cycle: 16 days

Wave lengths: (continued to next page)

Band 4	0.5 - 0.6 μm
Band 5	0.6 - 0.7 μm
Band 6	0.7 - 0.8 μm
Band 7	0.8 - 1.1 μm

Resolution at ground level: 80 m.



(2) Preprocessing

Format conversion, and radiometric and geometric corrections were made before image outputting and analysis.

1 Format conversion:
The original format of the two scenes of MSS data as they were obtained from the Remote Sensing Technical Center of Thailand was CCRS BIL Format, which was converted into a format for imagery analysis.

2 Radiometric correction:
Radiometric correction refers to relative correction of variances between the six sensors in each band to enhance the quality of images as well as the accuracy of image analysis. Specifically, discrepancies in response due to the difference of individual sensors are to be corrected by using the accumulative frequency curves. Figures 5 and

6 show the cumulative frequnecy curves for Band 5 and the same curves as corrected, respectively.

3 Geometric correction:

Geometric corrections are performed by selecting several locations where ground coordinates are known and then converting image coordinates UV to ground coordinates XY by means of coordinate conversion equations, which are established based on the known points in both coordinate systems, i.e., the UV coordinate system of the imagery with geometric distortions and the XY coordinate system of geometrically corrected maps.

In the Landsat data used for this study, there were data missing in two places in each scene due to bad synchronization at the time of receiving. Therefore, defective lines were removed first before the following corrections were made. The correction formula used is based on linear affine transformation. The coordinates of 13 points in 128 - 49 scene were used whereas there were only a few known points in 128 - 50 scene, for which, therefore, the same mathematical formula was applied as for the other scene. The mathematical formula used is as follows.

$$U = AX + BY + C$$

$$V = DX + EY + F$$

where: $A=0.1308 \times 10$ $D=-0.1293$

$B=0.1881$ $E=0.8820$

$C=0.4627 \times 10^3$ $F=-0.1320 \times 10^3$

Taken from the 1/250,000 topographic maps (paper sheets), the ground coordinates had errors in reading. (In Japan 1/50,000 maps are usually used for this purpose.) A pixel size of 75 m square was chosen considering the size of imagery to be output among other factors.

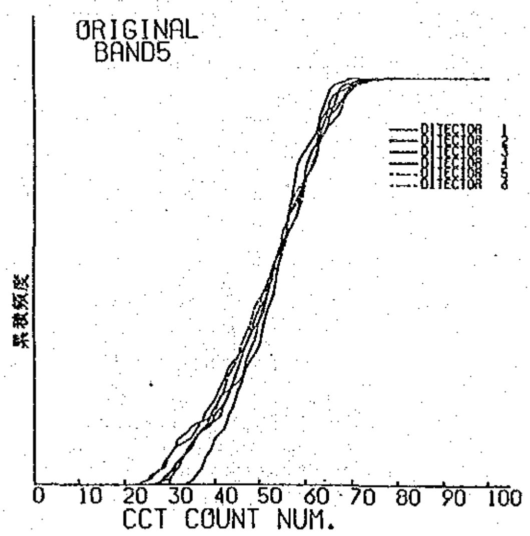


Figure 5

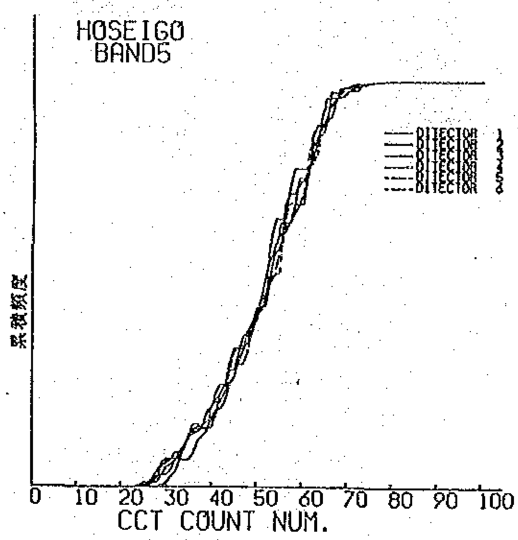
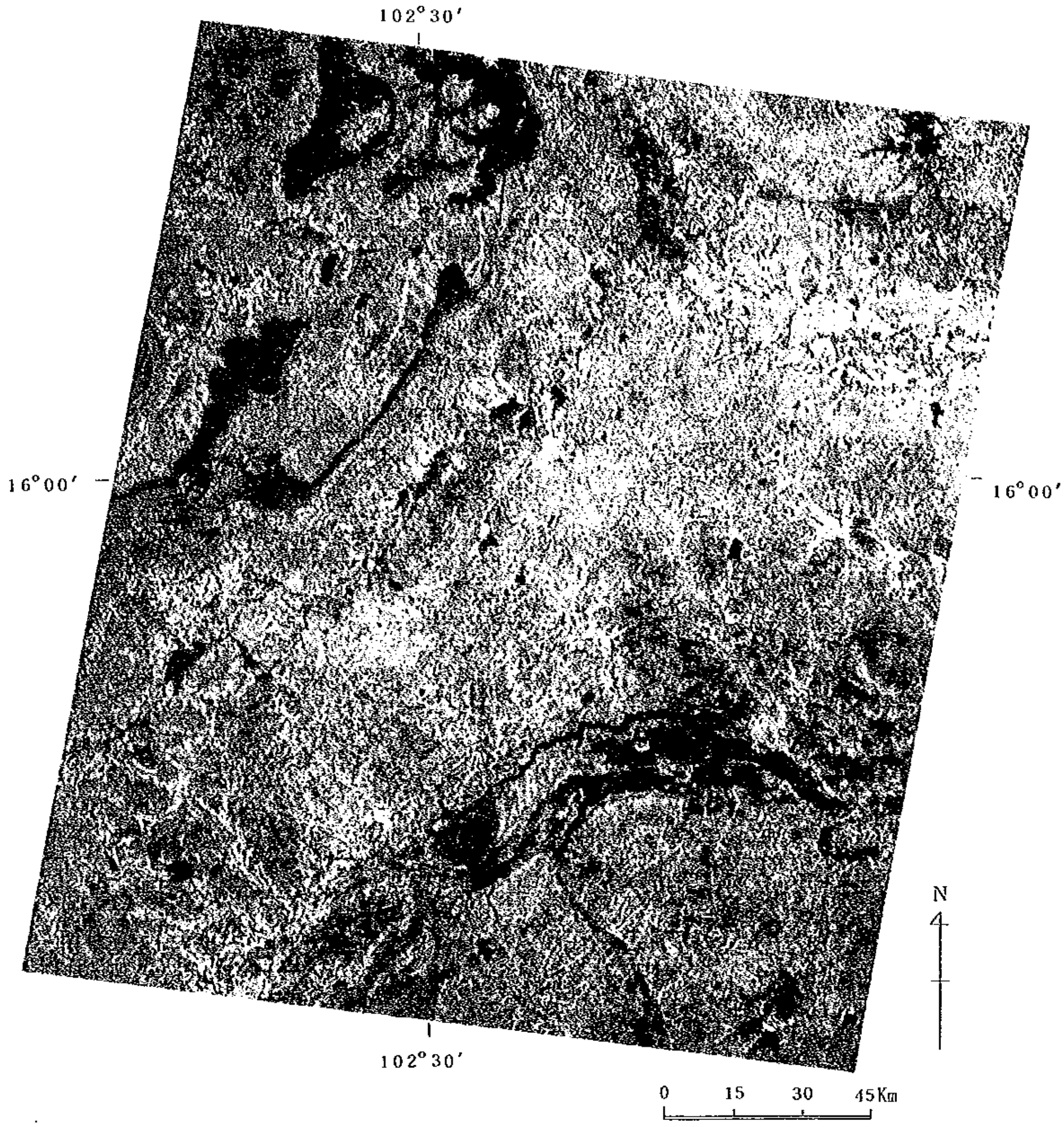


Figure 6

(3) False Color (Original) Composite Image

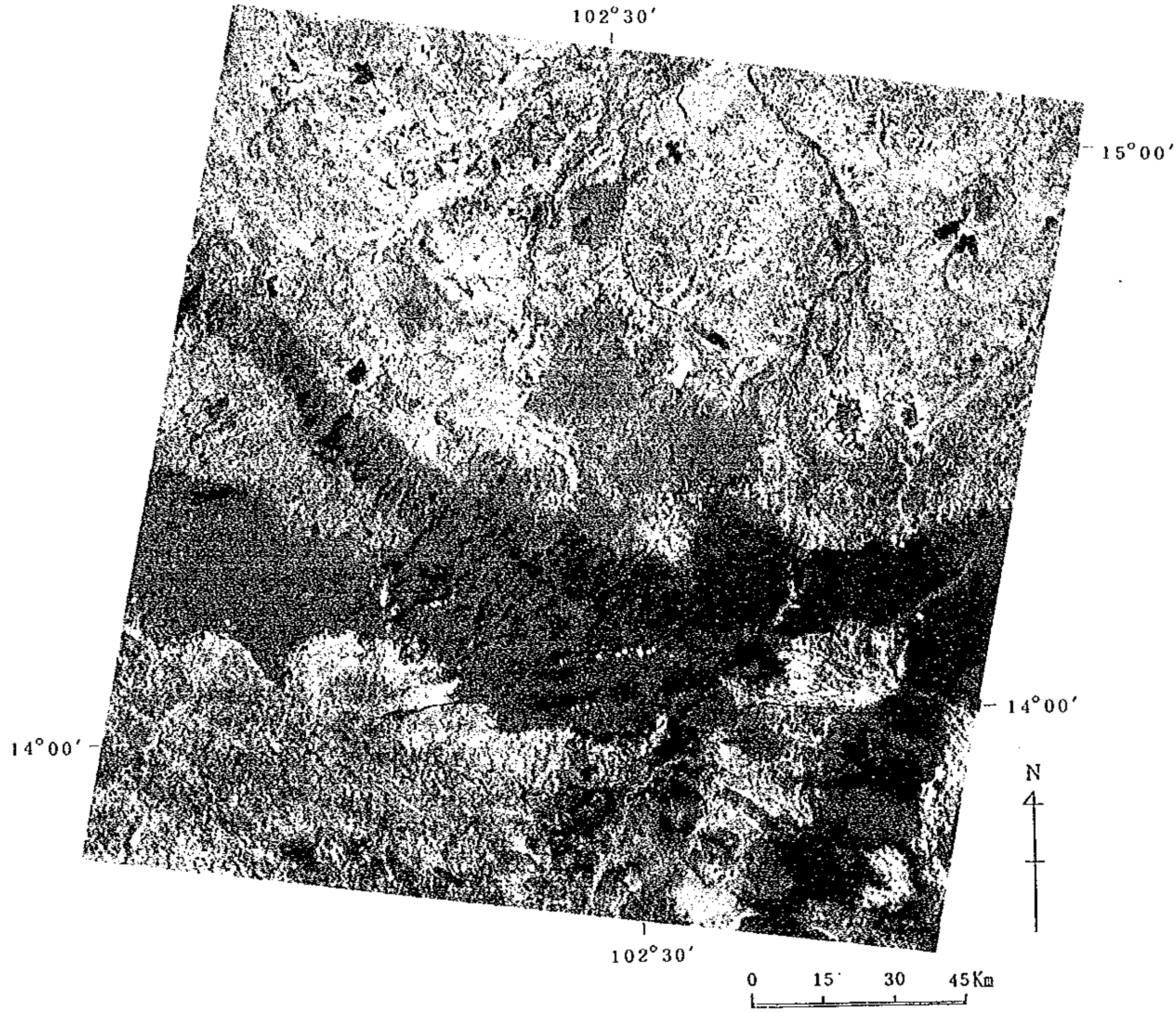
To have an udernstanding of the study area, the false color images was created on 8 X 10 inch positive film (50 m pixel; 1/1,500,000 scale) by comositing Band 4 (blue), Band 5 (green), and Band 7 (red), for preprocessed data. The image then was reversely developed on the inter negative film and contact prints made. Scenes 1 and 2 are contact print images.



Date of data acquisition: 16/Jan/84

Path-Row	: 128-49	Band 4:	Blue
Platform	: Landsat 4	Band 5:	Green
Sensor	: MSS	Band 7:	Red

Scene 1: Landsat MSS Image (1)



Date of data acquisition:	16/Jan/84		
Path-Row :	128-50	Band 4:	Blue
Platform :	Landsat 4	Band 5:	Green
Sensor :	MSS	Band 7:	Red

Scene 2: Landsat MSS Image (2)

(4) Principal Components Analysis Data

Principal components analysis was undertaken to maximize the characteristics of the original image data to help interpretation and classification. Principal components analysis is a mathematical manipulation which, based on the correlation matrix of a number of variables to arrive at elements shared by these variables. In Landsat data, where spectral radiance is normally distributed in the multi-dimensional space, it relates to the process of creating a new set of axes relative to the main axis of an ellipse centered on the average of such normal distribution.

The reason why principal components analysis was undertaken was that since there were significant discrepancies in prevailing conditions between the dates of field survey and Landsat data taken, and salt appearances could change substantially even after one rain shower, it was decided as difficult to perform maximum likelihood analysis based on field survey points.

Correlation coefficients between the four spectral bands obtained are as follows.

Correlation coefficient	Band 4	Band 5	Band 6	Band 7
Band 4	1.00	0.848	0.620	0.473
Band 5	0.848	1.00	0.678	0.493
Band 6	0.620	0.678	1.00	0.853
Band 7	0.473	0.493	0.853	1.00

It can be seen from the above table that there are closer correlations between Band 4 and Band 5, and between Band 6 and Band 7.

Eigen values and accumulated contributions for respective principal components are given in the following table.

	Eigen Value	Cumulative Accumulated Contributions (%)
First Principal Component	2.988	74.7
Second Principal Component	0.742	93.2
Third Principal Component	0.163	97.3
Fourth Principal Component	0.107	100.0

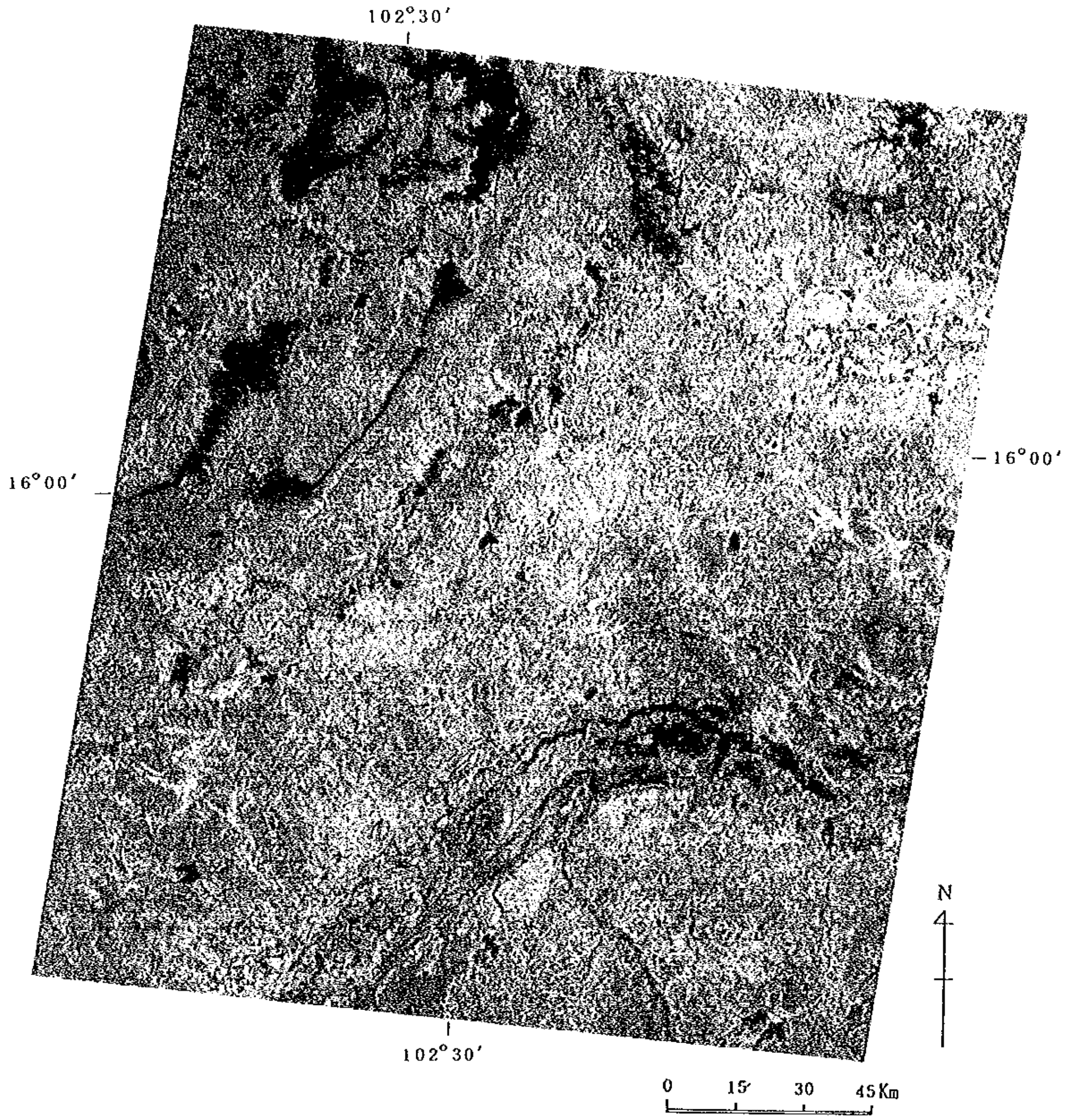
Eigen vectors for respective principal components are as follows.

	Eigen Vector Values			
	Band 4	Band 5	Band 6	Band 7
1st Principal Component	0.493	0.507	0.528	0.470
2nd Principal Component	-0.515	-0.458	0.360	0.629
3rd Principal Component	-0.667	0.587	0.336	-0.311
4th Principal Component	0.216	-0.434	0.691	-0.536

Therefore, first principal component data (P1) are obtained as follows.

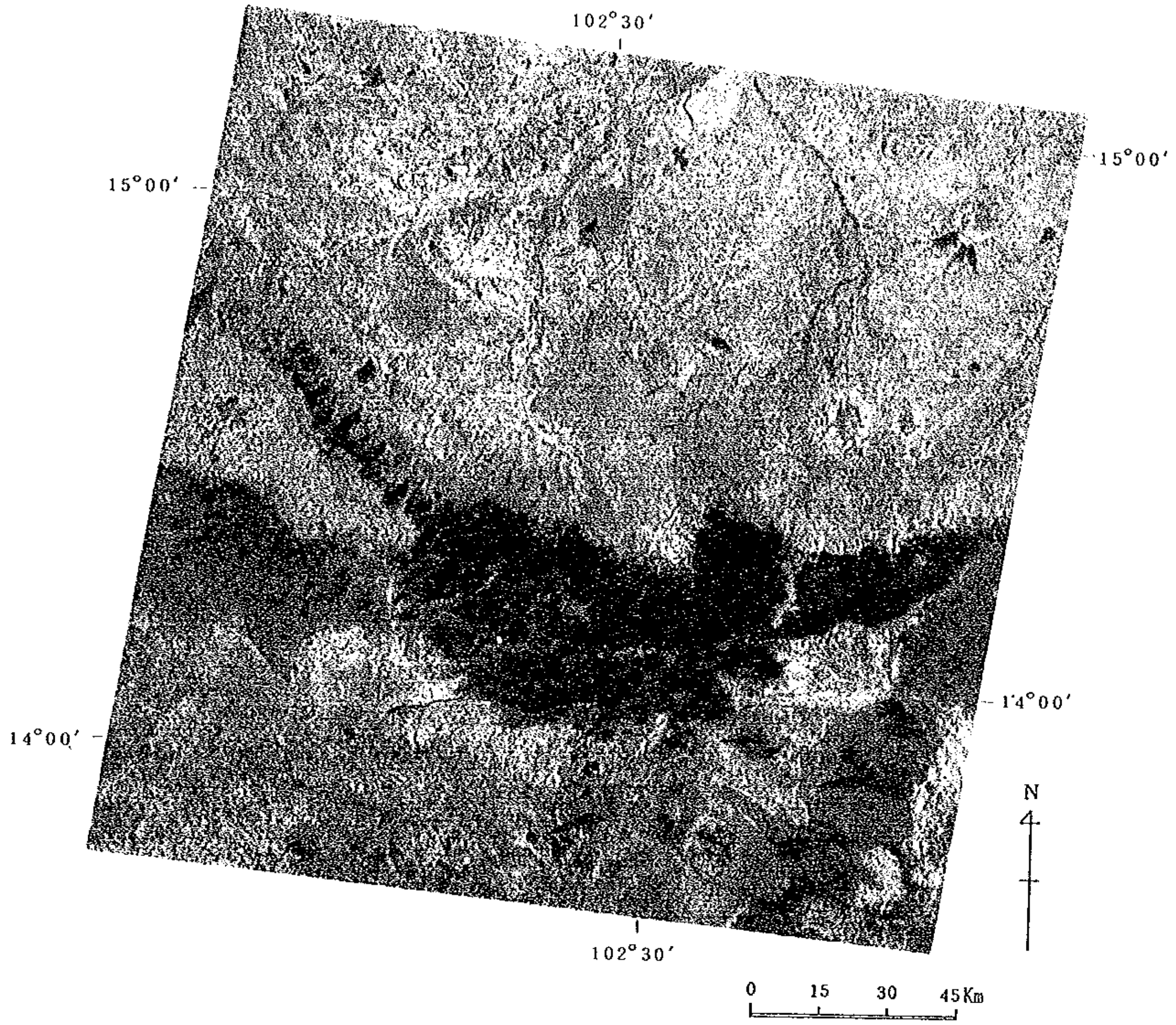
$$P1 = 0.493 \times (\text{Band 4 data}) + 0.507 \times (\text{Band 5 data}) + 0.528 \times (\text{Band 6 data}) + 0.470 \times (\text{Band 7 data})$$

And its contribution is 74.7% of total data. P2 and P3 were obtained similarly, and images were output with P1 for green, P2 blue and P3 red as shown in Scnes 3 and 4.



Date of data acquisition:	16/Jan/84		
Path-Row :	128-49	First Principal Component:	Green
Platform :	Landsat 4	Second Principal Component:	Blue
Sensor :	MSS	Third Principal Component:	Red

Scene 3: Principal Component Analysis Image (1)

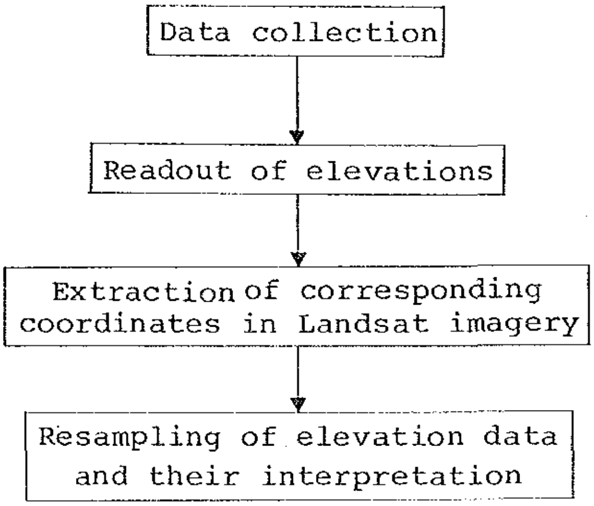


Date of data acquisition:	16/Jan/84		
Path-Row :	128-49	First Principal Component:	Green
Platform :	Landsat 4	Second Principal Component:	Blue
Sensor :	MSS	Third Principal Component:	Red

Scene 4: Principal Component Analysis Image (2)

(5) Creation of Elevation Data

Checking of field survey results and Landsat data found that available data were not enough to make classifications in accordance with the ranking applied in the Soil Salinity Distribution Map. Elevation data were picked out from the existing data to supplement image analysis. The procedure for elevation data preparation was as follows.



1 Data collection:

Since 1/50,000 scale topographic maps were not permitted to be taken out of the country, 1/100,000 soil maps were used as a substitute.

2 Readout of elevations:

The 1/100,000 soil map was originally made from the topographic map of 1/50,000 scale so that contour lines were difficult to recognize. Therefore, contours were restored and then elevations were read for every one kilometer along the contours. With contours given at an interval of 10 meters, the readouts were made visually in the unit of meter. The readout was confined to areas with salt appearances on the Landsat imagery. Readout data were fed into magnetic tapes and made into a file.

3 Extraction of corresponding coordinates in Landsat imagery: To match elevation readouts to corresponding locations in the Landsat imagery, known locations in the imagery were pinpointed at intersections of 1-kilometer grids overlaid on the data and read out by line and column.

4 Resampling of elevation data and their interpretation: To relate elevation data taken every one kilometer to one pixel (75 m X 75 m) of Landsat imagery, the data were interpolated by direct approximation and traslated into 75 m grid cells. After that, the data were resampled by means of linear affine transformation using the data mentioned previously in 3 . The resulting data were output in the form of B/W images. Original data were taken of elevations of 100 m and upwards while the study area is less than 300 m in height. The output image is based on 8 bit data (256 steps) with 100 m as 0 and over 355 m as 255. See Scene 5.

Scene 5: Elevation Data Image

(6) Creation of Vegetation Distribution Data

The study area has relatively a reduced amount of vegetation coverage. But seen on the Landsat imagery, vegetation occupies significant portions of area. Vegetation covers hamper the study of salt appearances by Landsat data. For the purpose of this study, vegetation was classified by making assumptions. Namely, by assuming that the presence of vegetation represents no or least effect from salt, vegetation covers were classified in three ranks as surrogates of salinization. (1) Sparse growth: It assumes some effect, of salt or other artificial nature, but not much. (2) Growth of medium density: Area with more than 50% vegetation coverage assuming there is no salinization. (3) Dense growth: No salinization. No adverse effects on vegetation to be expected except from artificial origin. Based on these assumptions, classification was undertaken in the following procedure.

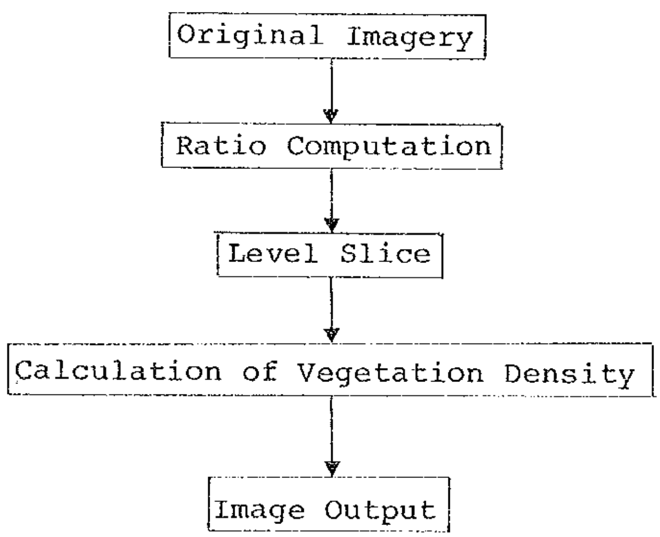


Figure 7

1 Original imagery:

The field survey confirmed that reflection rates of vegetation are low in Band 5 and high in Band 7. Therefore, data from these two bnads were applied. Figure 8.

2 Ratio computation:

Ratio computations were made of Bands 5 and 7 data, to create a new file.

$$VI = \frac{(\text{Band 5 data}) + a}{(\text{Band 7 data}) + b}$$

where: a=14, b=0

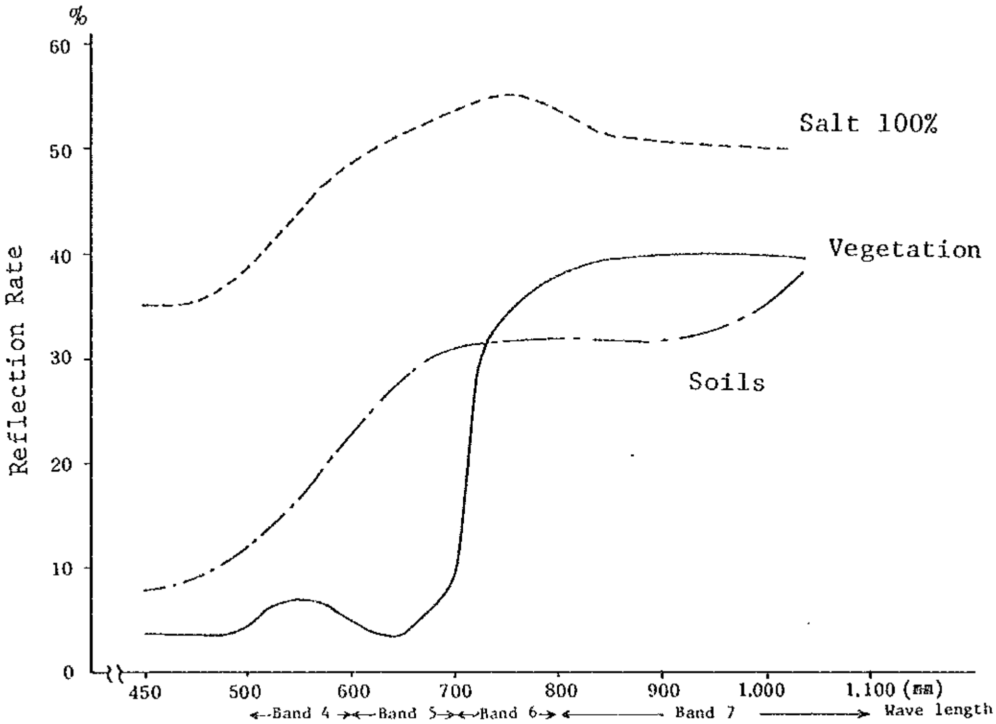
3 Level Slice:

In order to extract vegetation portions of data, the results from 2 above were represented in a histogram to set up levels. After confirming the data on CRT, computations were performed and a new data file was created, in which vegetation data are identified as 1 against the rest of data as 0.

4 Calculation of vegetation density:

Vegetation density was classified in the following five ranks on the basis of the numbers of vegetation pixels in each 9 x 9 (81 pixels) space.

Density	Numbers of vegetation cells out of 81 pixels
None	0 - 25
Sparse	26 - 50
Medium	51 - 75
Dense	76 - 100


%
60
50
40
30
20
10
0
Reflection Rate
Salt 100%
Vegetation
Soils
450
500
600
700
800
900
1,000
1,100 (nm)
Band 4
Band 5
Band 6
Band 7
Wave length

IV. Survey Analysis Results

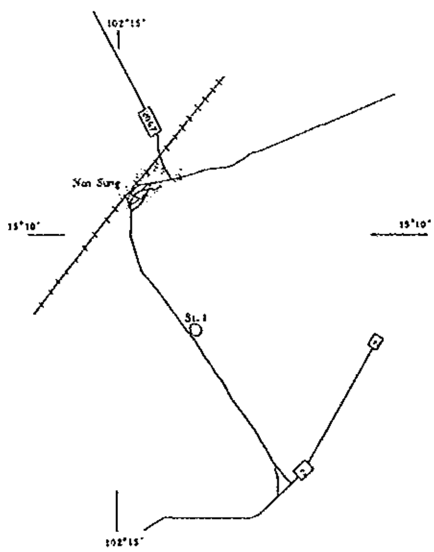
1. Field Survey Results

(1) Site Conditions

Survey sites are each described below.

St. (Site) 1:

Located 4 km south of Non Sung. High salinity was recognized in bareland. Marked appearance of grass compared with other sites. Much salt also identified among scattered grass in the boundary zone between bareland and grass land. Ranked 2 (moderately saline soil) in the Soil Salinity Distribution Map (reffered to as S.S.D.M. for short hereafter) prepared by Thai Government.



St. 2:

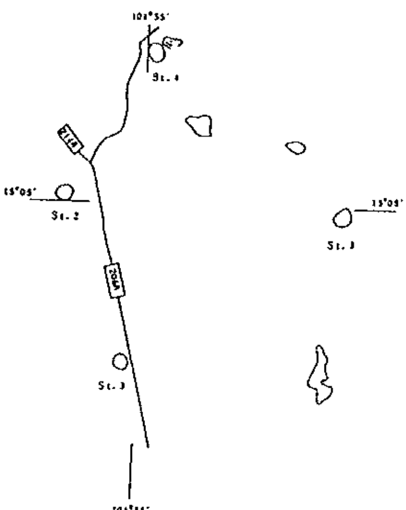
Bareland in this area is ranked 1 in S.S.D.M. But the impression gained on site was less than 50%. On the periphery of bareland were recognized the presence of Nam Prom and Nam Daeng which grow in saline soils. There is a small lake to the north and around the lake there are good growths of vegetaion. (Photo 2)

St. 3:

Five kilometers further south from Site 2. Fixed point observations including ground water observation were conducted at this site. Many grasslands and paddies. More than 50% of salinity observed in bareland. Rank 5 by S.S.D.M. classification. (Photo 3)

St. 4:

One kilometer north of Ban Mong Tho. Appearances of salt in the lower (by 50 cm - 1 m) bareland was observed but it disappeared overnight after a rain shower. It was said that there certainly had been much salt observed the previous night. There were traces of salt collection made during the dry season. Rank 2 by S.S.D.M. classification. (Photo 4)

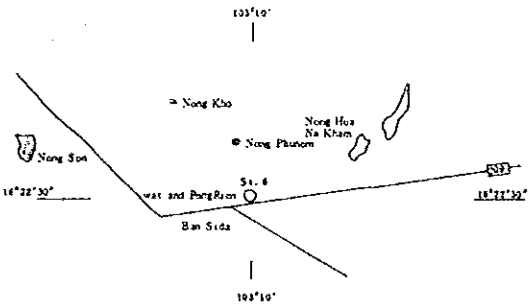


St. 5:

Close to Ban Nong Kok, paddies in this area contain saline soils. Growth of Kae Garg, grass characteristic of saline paddies, was observed. S.S.D.M. Rank 5. The lower bareland appeared white from accumulated salt. But hills were covered by grass and trees with no appearance of salt. Paddies in the lower parts around the hills were affected strongly by salt and some of them were deserted. S.S.D.M. Rank 1. (Photo 5)

St. 6:

Three kilometers east of Ban Hua Na Kham. Paddies are widely distributed near the boundary of Kalasin and Maha Sarakham. Ranked 2 by S.S.D.M., the area is strongly saline and a lot of salt was observed in the paddies. Straws, salt and dried white colored cakes of soils, combine to cause strong reflection, which appears white on Landsat imagery. (Photo 6.)

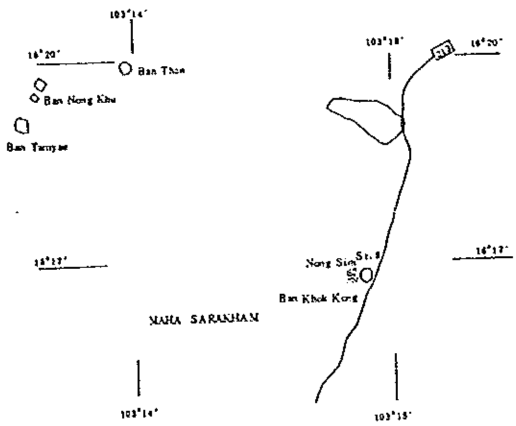


St. 7:

Paddy field 6 km west of Amphoe Kanthawichai. Some of the paddies had growth of Kae Garg grass, usually associated with saline soil paddy, and there were others which did not. There was no salt in either paddies observed at least visually. S.S.D.M. Rank 3. (Photo 7)

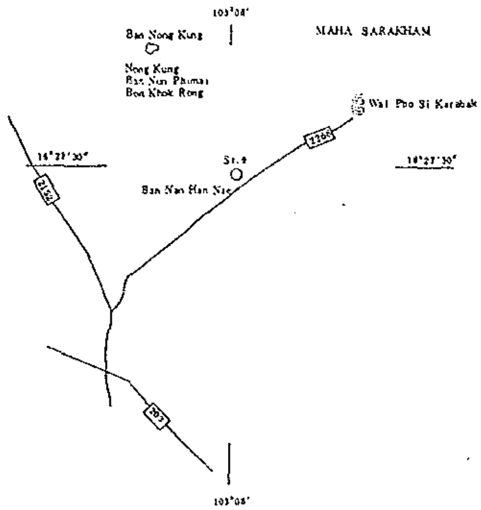
St. 8:

Four Kilometers south of Amphoe Kanthawichai. Elevated from the surrounding area. Some of the paddy soils in this area contained a good measure of iron showing in reflection in red color at straw roots. S.S.D.M. Rank 5. No salt observed. (Photo 8)



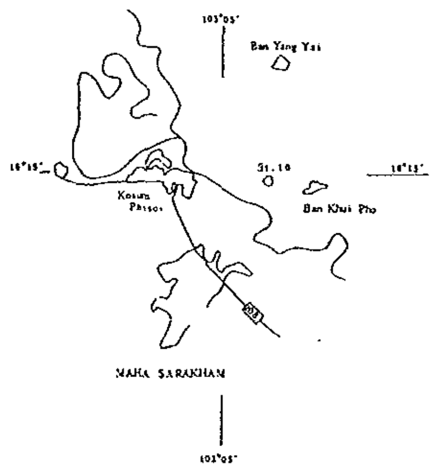
St. 9:

Hilly land near Ban Krebak. No salt present in paddies. Trees and grass, vegetable fields, were observed on the highest parts of land. S.S.D.M. Rank 5/4. (Photo 9)



St. 10:

Paddy zone 2 km east of Amphoe Kosum Phisai. Soils were dried up, forming many cracks in the paddies. No salt observed. S.S.D.M. Rank 4. (Photo 10)

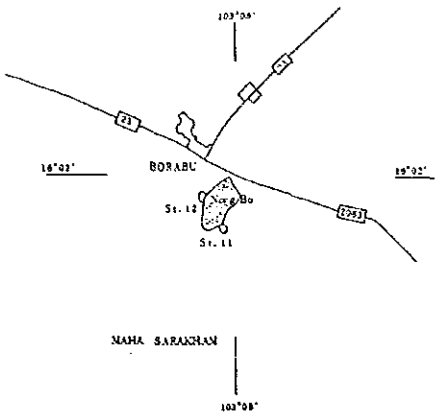


St. 11:

Located on the southeastern side of a lake south of Amphoe Burabu. Large scale salt fields once existed. Much salt and sites of old salt fields were observed. S.S.D.M. Rank 1. (Photo 11)

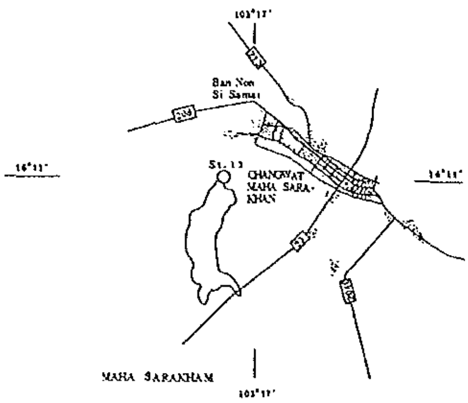
St. 12:

Located on the other side of the same lake as mentioned for Site 11. Presence of salt observed on lake shores but in less density than at Site 11. S.S.D.M. Rank 1. (Photo 12)



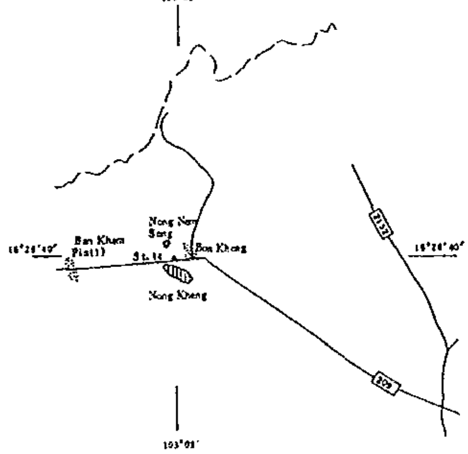
St. 13:

Three kilometers west of Changwat Naha Sarakham. A paddy zone near the dam site to the north of the lake. A channel constructed to take water for irrigation from the lake. No salt observed on exposed river bed, nor in the paddy. S.S.D.M. Rank 4. (Photo 13)



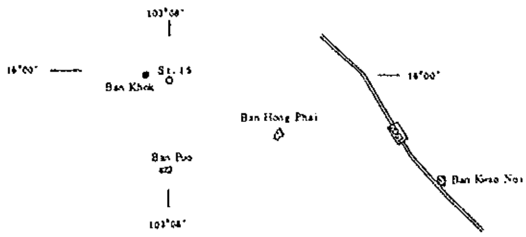
St. 14:

Along the road running south of Nong Nam Song. Cassava were being dried on concrete grounds. Similar sights were observed at several other locations within the area. They appear white in Landsat imagery. (Photo 14)



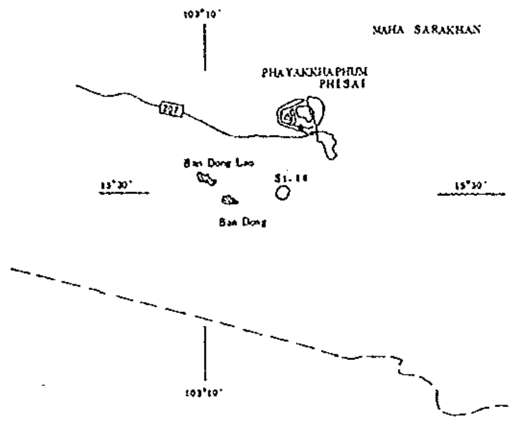
St. 15:

To the east of Bank Khok. Channel for irrigation. Along the channel were growths of vegetation and paddies. Pools of water and dried up portions with salt concentrations in the river bed. Outcrops of sandstone also observed. S.S.D.M. Rank 4.



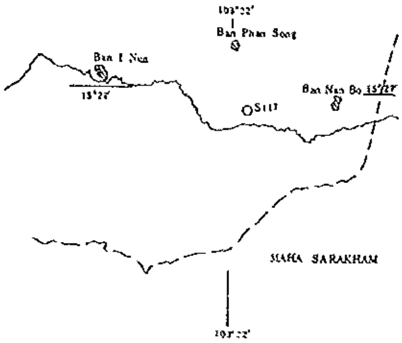
St. 16:

Beside the road north of Ban Mnang Laeng. Mostly paddies. Appearance of grass typical of saline paddy soils in some paddies. There were many paddies burned after harvesting observed. No salt observed at least visually. S.S.D.M. Rank 2.



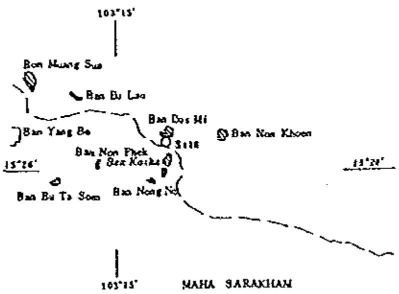
St. 17:

Paddy field near Ban Non Bo. Virtually no presence of salt. Appearance of grass typical of saline soils in a few paddies but not in most paddies. S.S.D.M. Rank 4.



St. 18:

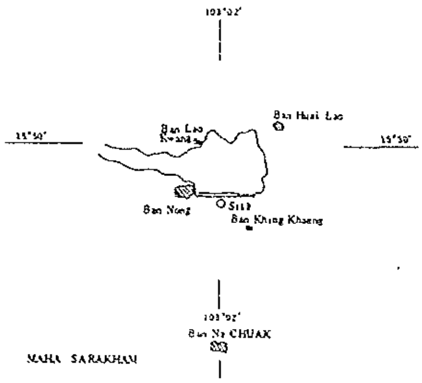
Paddy field 2 km north of Ban Nong No. High moisture contents in soils. No salt observed. S.S.D.M. Rank 4.



St. 19:

A channel located downstream of the dam built 3 km north of Ban Na Chuak. Appearance of salt in places in the river bed. Salt also observed on elevated areas surrounding the channel. Presumably the construction of the dam causing the ground water level to rise downstream and salt to appear.

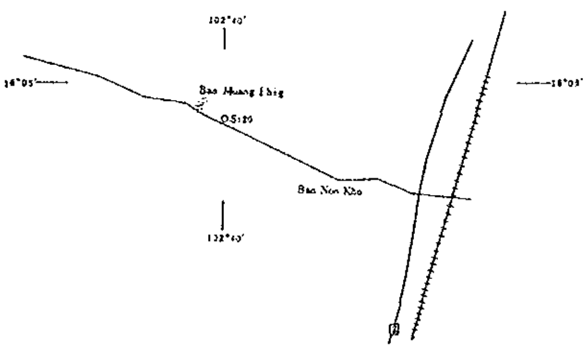
S.S.D.M. Rank 3.



St. 20:

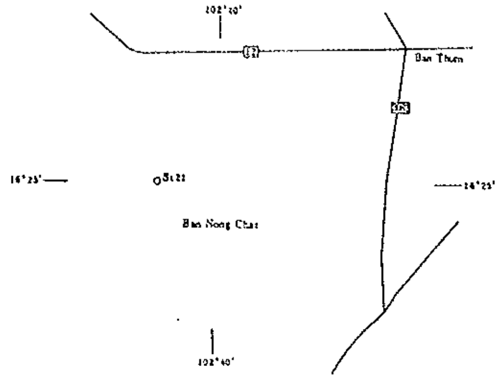
Five kilometers west of Amphoe Ban Phai. Submerged under water in the wet season. Salt appearing in patches.

S.S.D.M. Rank 1



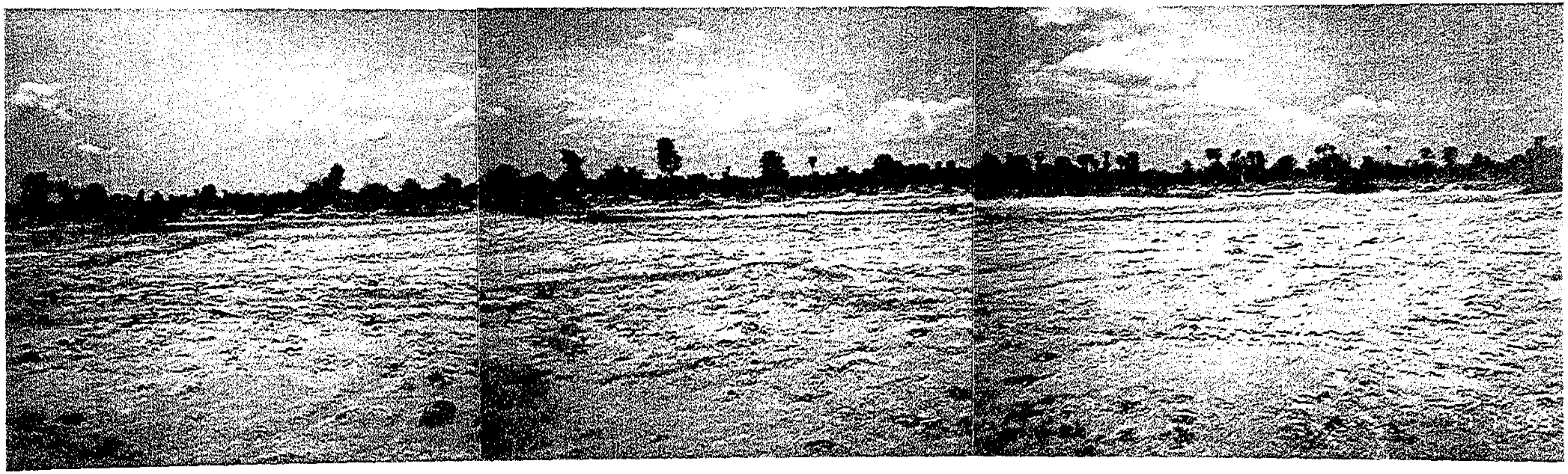
<u>St. 21:</u>

Near Ban Nong Chat. There are accumulated salts. S.S.D.M. Rank 1.



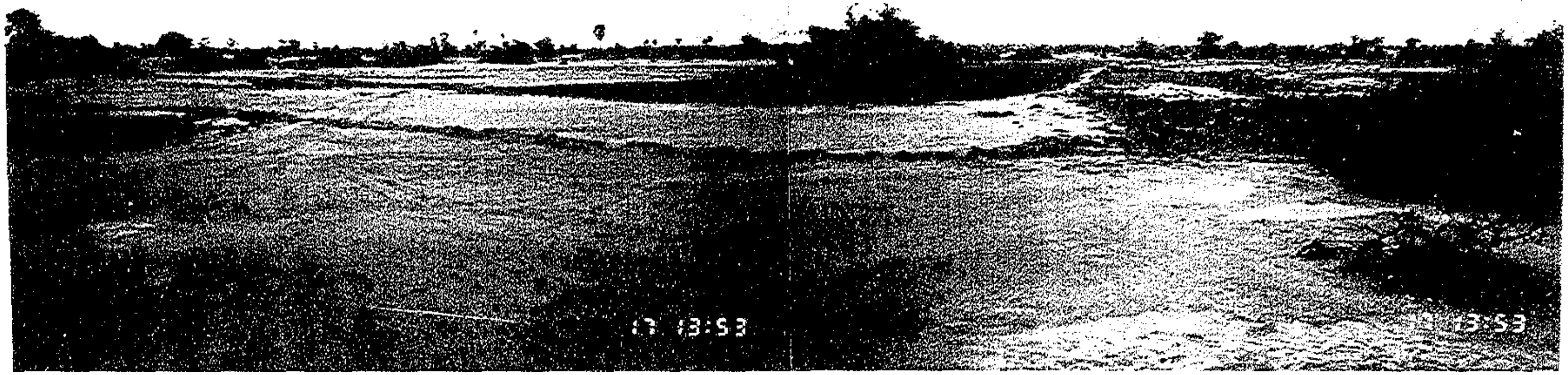
St.1

St.2



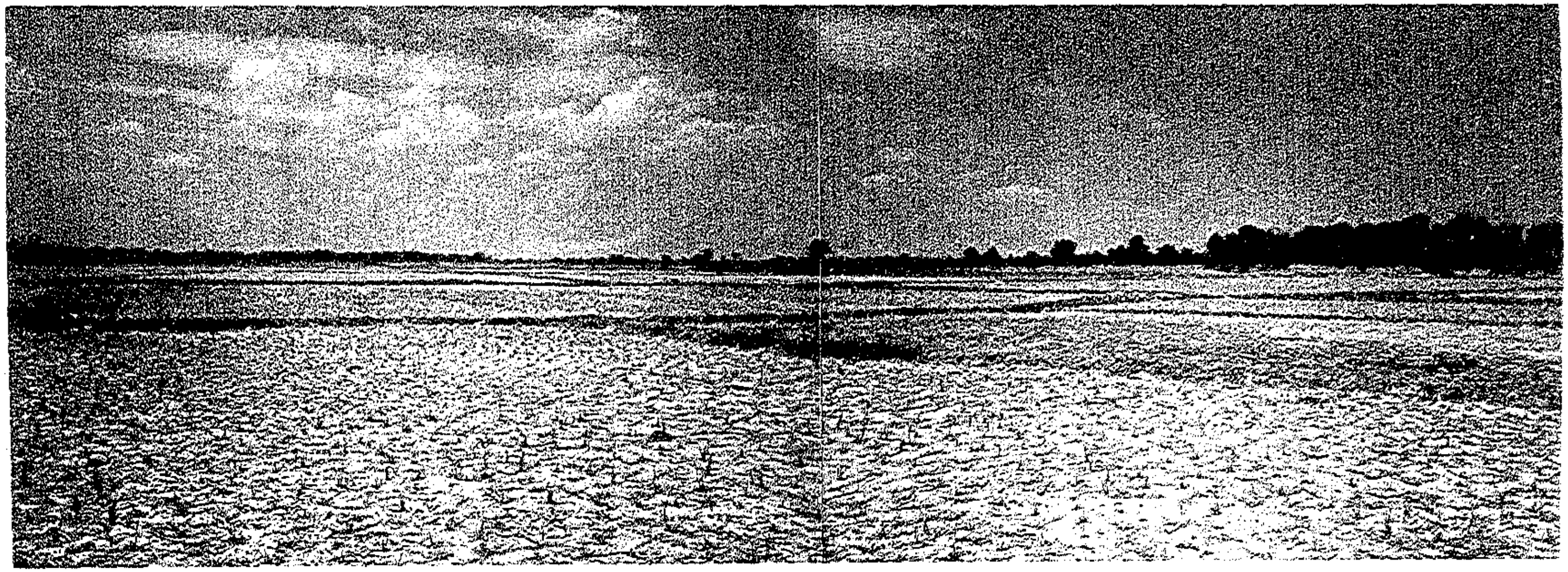
St.3

St.4



St.5

St.6

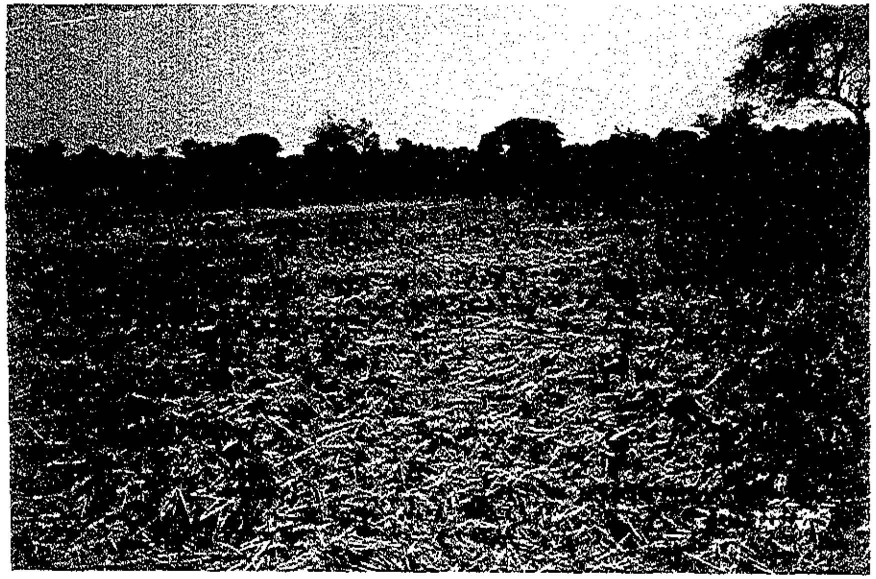


St.7

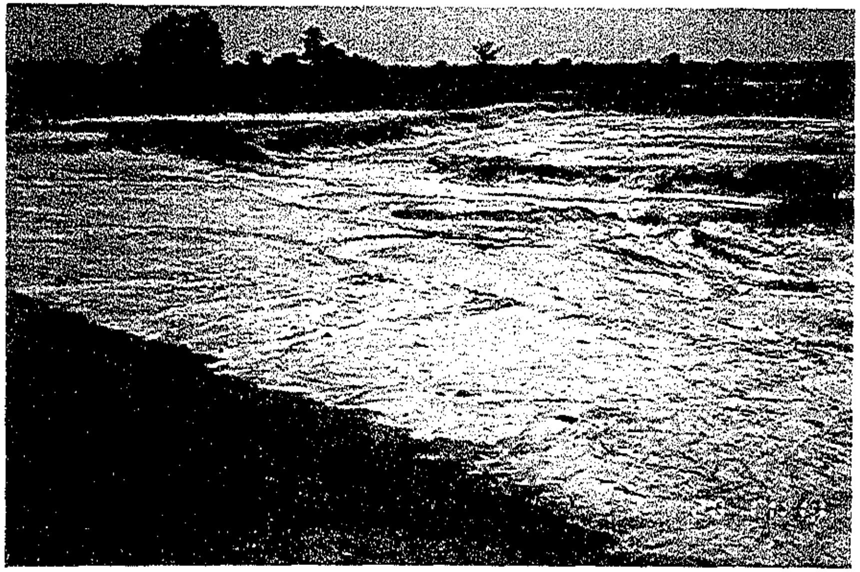
St.8

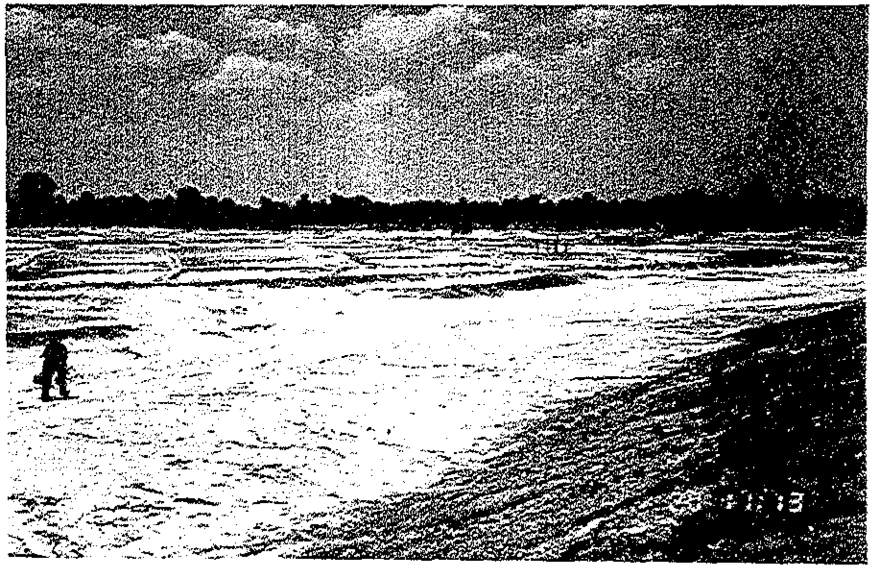
St.9

St.10

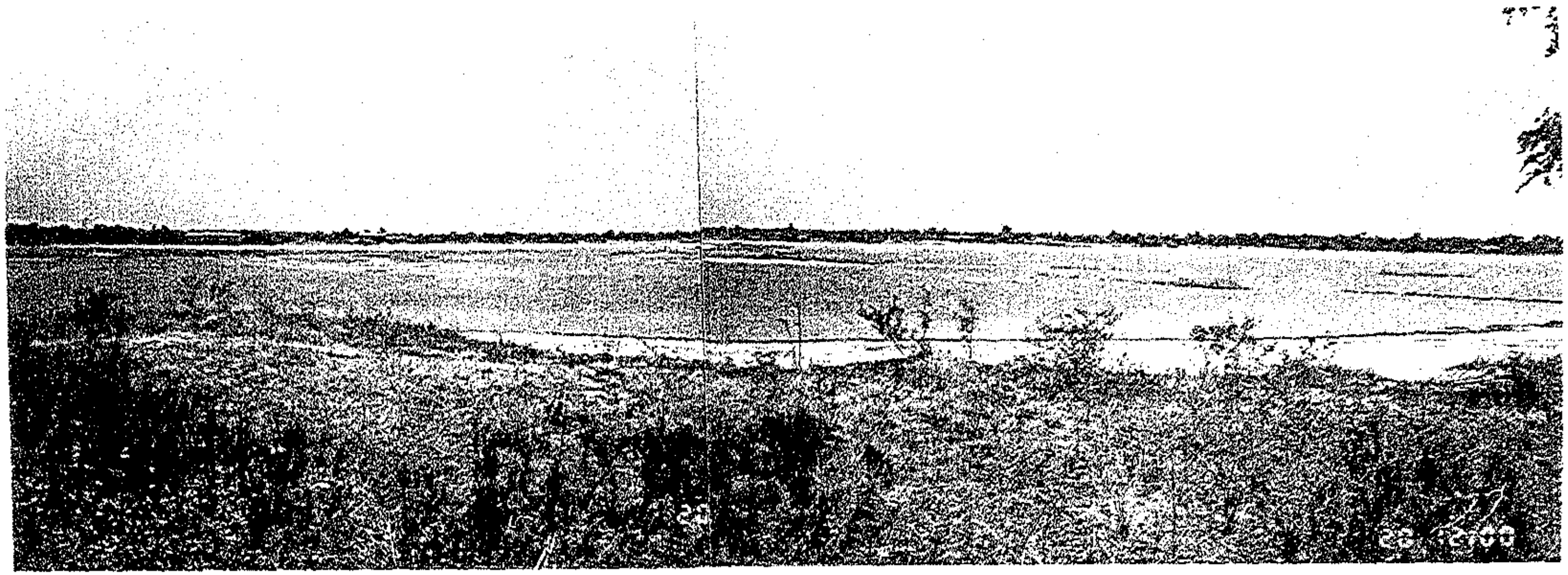


St.11



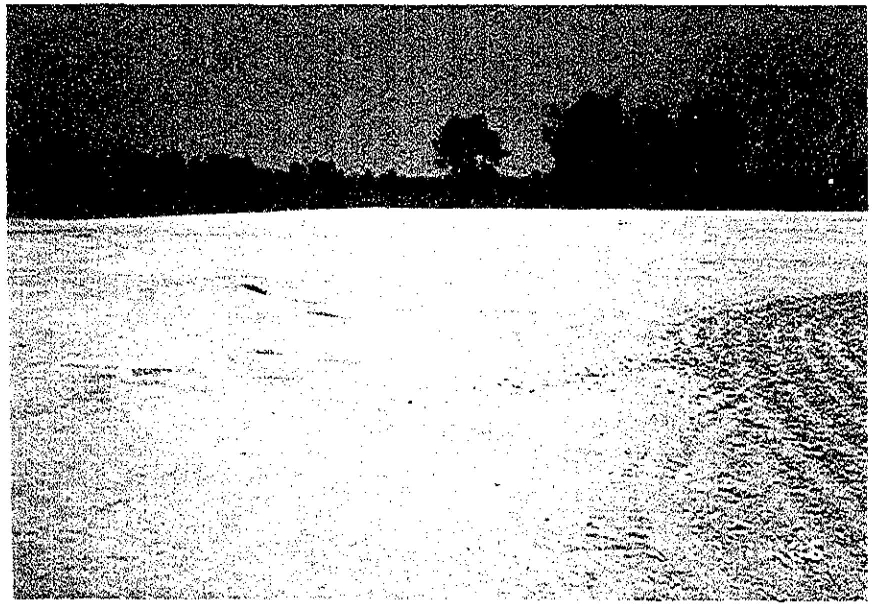


St.12



St.13

St.14



St.15

St.16

St.17

St.19

St.20

St.21