(2) Results of Spectral Measurement of Reflections

1 Measurment of reflection rates of surface salt covers:
To acquire data to serve as a basis for analysis of levels of surface salt covers as recognized in Landsat imagery, reflection rates were measured for salt of respective ranks by means of a spectrometer set to correspond to Landsat's range of wave lengths. Part of the results are as shown in Figure 9. As much as can be seen from the graph, it looks as if there were no correlation between the levels of salinity and those of reflections possibly due to differences in the colors and moisture levels of soils.

2 Reflection rates of straws in paddy:
There are three types of paddies in relation to straws: with straws, with straws and grass (typical of saline soil paddy), and with straw stubs (remaining after burning). Figure 10 shows reflection rates for the respective types. Due to soils seen between straws, reflections are affected more by dnesity of straws, regional differences of soils, and driness of soils rather than by types of covers. Therefore, it is difficult to differentiate the coverage by reflection.

3 Measurement of reflection rates for analysis of moisure contents of soils:
As soils become dry, their reflection rates generally

rise, whereas the higher the moisture level of soils, the darker it appears in color and the reflection rates go down. As shown in Figure 11, the reflection rate of a lake is low compared with other features with the lowest occurring in Band 7. This also applies to the reflections of turbid waters. In other words, wave lengths of Band 7 have a propensity to be absorbed by water. Therefore, as moisture contents of soils increase, reflection rates go down proportionately, in the same soil, and most markedly in Band 7.

4 Relationship between soil moisture data and reflection rates:

Figure 12 shows the relationship between moisture level of soil at a depth of 5 cm and reflection rate. As can be seen from the figure, there apparently is no rule to be deducted from the representations. This is due to the ground surface not being uniform. It will be difficult to differentiate moisture contents in many levels.

Table 5: Soil Moisture Measurements

Sample Point No.	Wet Soil & Can weight (g)	Dry Soil & Can weight (g)	Can weight (g)	Moisture (%)
1	266.41	252.3	92.8	8.65
2	257.56	245.8	93.0	7.69
3	248.08	233.4	90.1	10.24
4	261.22	242.8	90.8	12.12
5	243.30	229.6	92.8	10.01
6	202.91	195.9	91.2	6.69
7	294.06	268.0	93.7	14.95
8	273.97	251.2	93.4	14.43
9	264.14	245.3	93.8	12.44
10	268.26	255.0	93.9	8.23
11	251.14	243.3	93.6	5.24
12	245.34	236.5	94.1	6.21
13	240.31	234.7	93.2	3.96
14	236.80	234.2	94.4	1.86
15	248.47	248.0	92.5	0.30
16	240.77	240.4	93.3	0.25
17	239.49	232.3	92.0	5.12
18	293.06	268.4	94.6	14.19
19	246.40	236.3	93.4	7.07
20	243.16	238.2	94.1	3.44
21	228.78	228.4	93.0	0.28
22	245.90	242.4	92.8	2.34
23	254.27	248.8	94.3	3.55
24	250.47	245.6	93.0	3.19
25	252.90	246.9	94.0	3.92
26	237.44	233.8	94.0	2.60
27	235.35	233.6	94.3	1.26
28	251.24	248.1	93.3	2.02
29	250.51	248.2	94.4	1.50
30	251.17	230.3	93.2	15.22
31	289.25	251.2	93.3	24.10
32	268.55	233.7	94.5	25.0
33	241.74	234.9	93.0	4.8
34	265.1	252.4	92.5	7.94
35	263.4	245.1	94.0	12.11
36	245.0	236.0	94.4	6.36
37	267.5	250.9	94.6	10.62
38	277.8	263.3	94.1	8.57

$$\text{Moisture}(\%) = \frac{\text{Wet Soil \& Can weight} - \text{Dry Soil \& Can weight}}{\text{Dry Soil} - \text{Can weight}} \times 100$$

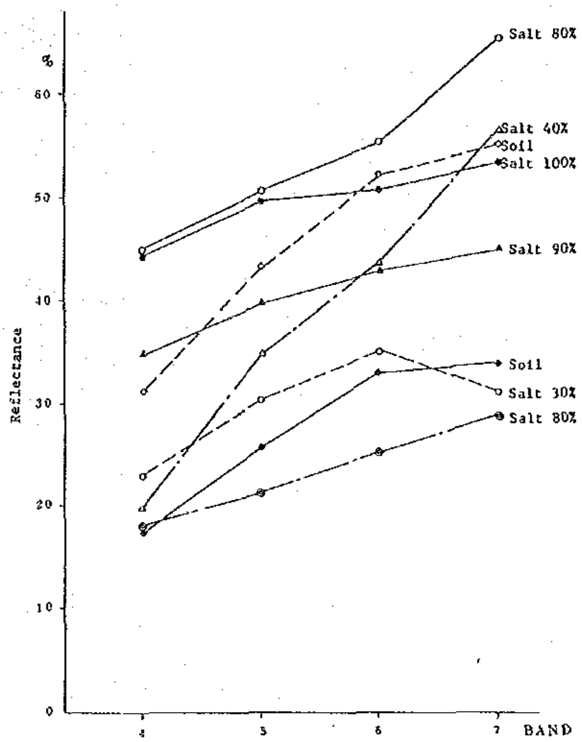


Figure 9: Salt Coverage Levels and Reflectance

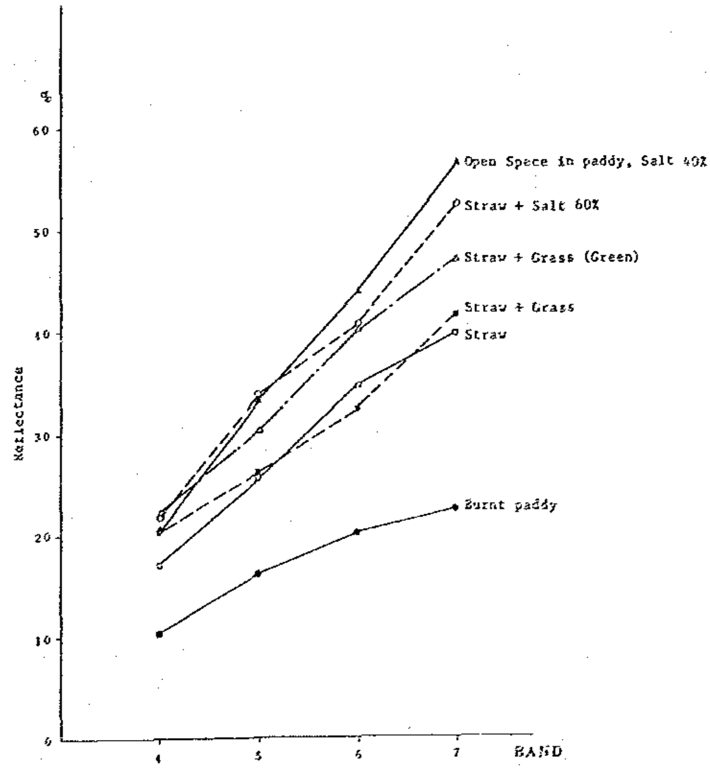


Figure 10: Reflectance of Paddy Straws

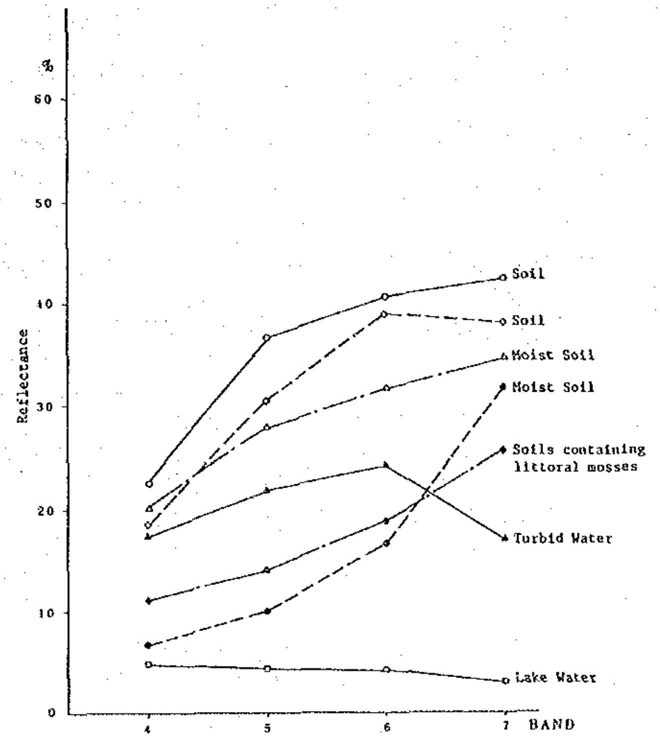


Figure 11: Reflectance for Soil Moisture Analysis

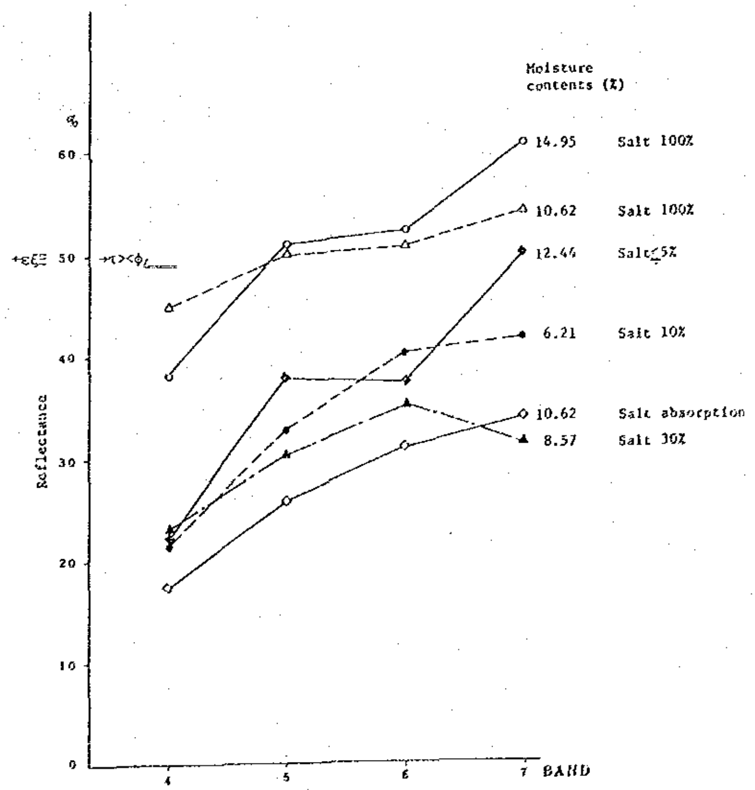
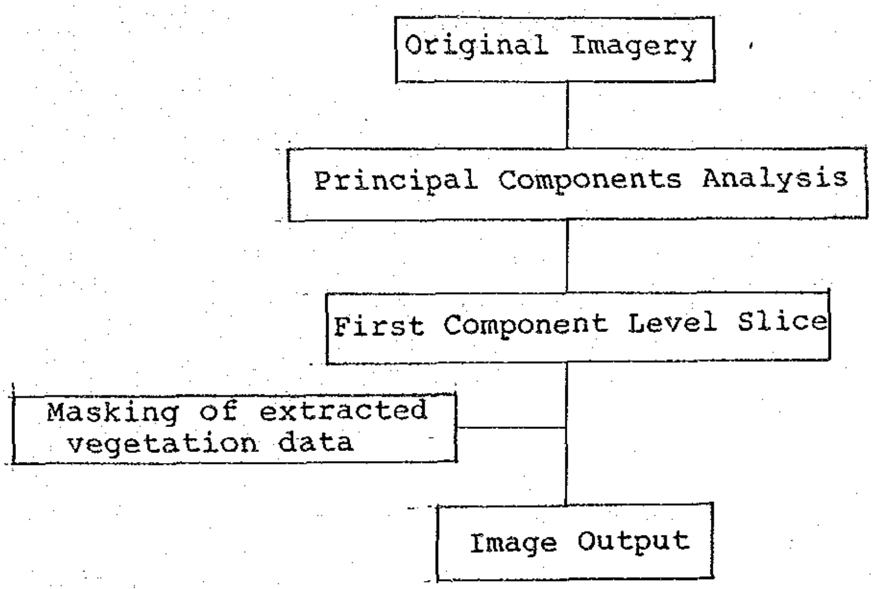


Figure 12: Soil Moisture Data and Reflectance

2. Results of Soil Moisture Level Analysis

It is knwon that moisture contents of soils reduce reflection rates and that reflection markedly weakens as it is absorbed by water in the soil in the near-infrared range of wave lengths. This can be seen also from the field survey results shown in Figure 11. Therefore, areas that look blue in false colors on Scenes 1 and 2 are considered to have high levels of water contents in soils. To take advantage of this characteristic, principal components analysis was undertaken in the procedure as shown below.



Deciding that there existed a close relationship between soil moisture contents and first principal component data based on field survey data and image interpretations, the first principal component data were stretched to 0 - 255 before level slice was performed.

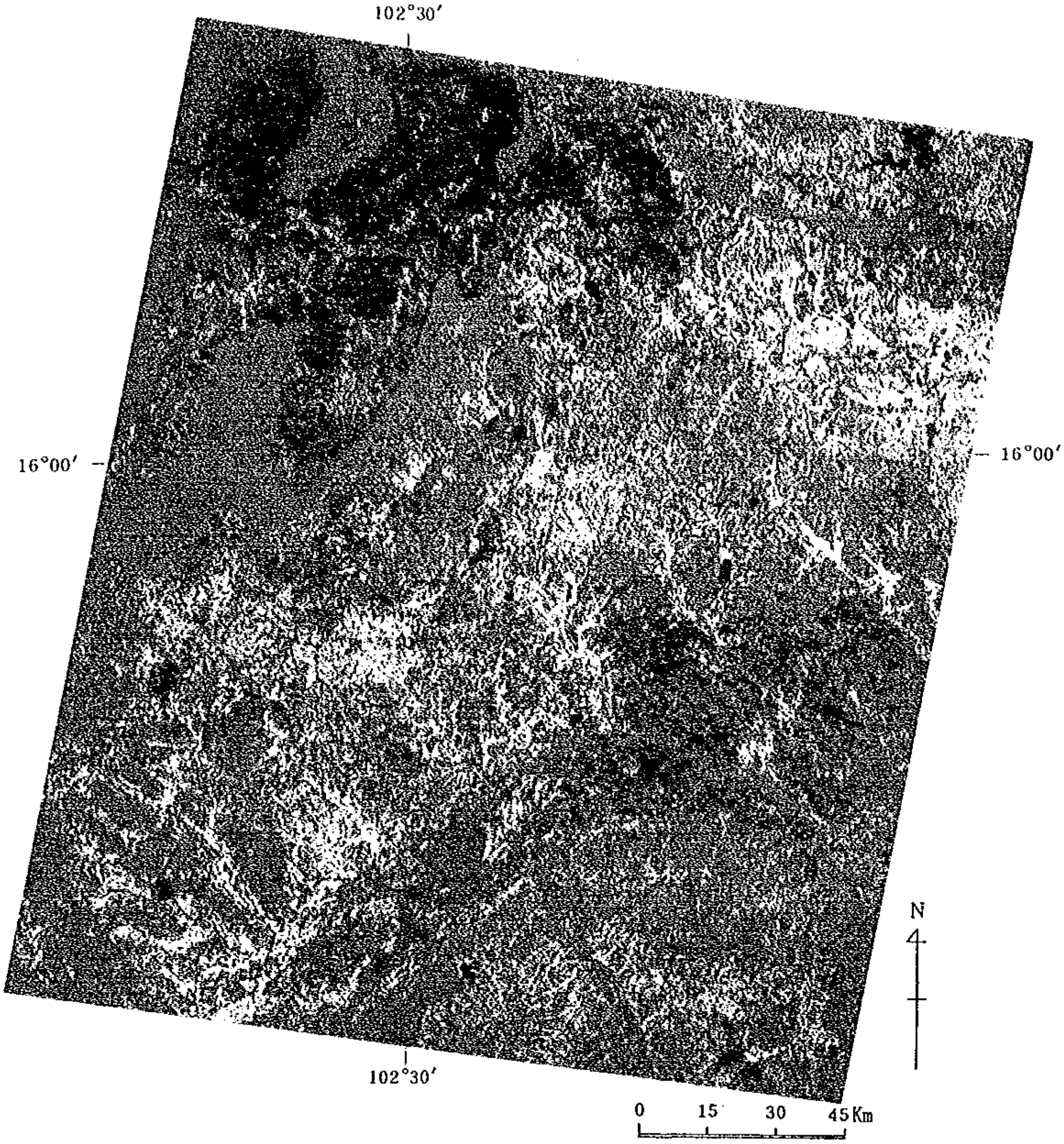
In this level setting process, water bodies, very dry areas, and areas of high moisture levels, were picked out and defined from field survey findings and false color image interpretations first, and then remaining areas classified into two additional ranks. Namely, the land was classified by soil moisture levels into five categories of (1) Water body, (2) High soil moisture level area, (3) Medium moisture level area, (4) Low mosture level area, and (5) Dry area.

Vegetation areas are considered to have enough moisture to support vegetation growth but difficult to determine where from 2 to 4 to fit, and therefore, represented as vegetation. For extraction of vegetation areas, level slice was performed on the results of the computations done by the following equation.

$$T = \frac{(\text{Band 5 data}) + 14}{(\text{Band 7 data})}$$

The results were overlaid on the analysis imagery and classified into six ranks at the final stage. Based on these results, colors were set as red for vegetation, dark blue for waters, blue for high mositure, green for medium moisture, yellow for low moisture, and white for dry soil, and images were output accordingly.

Scenes - 6 and 7.

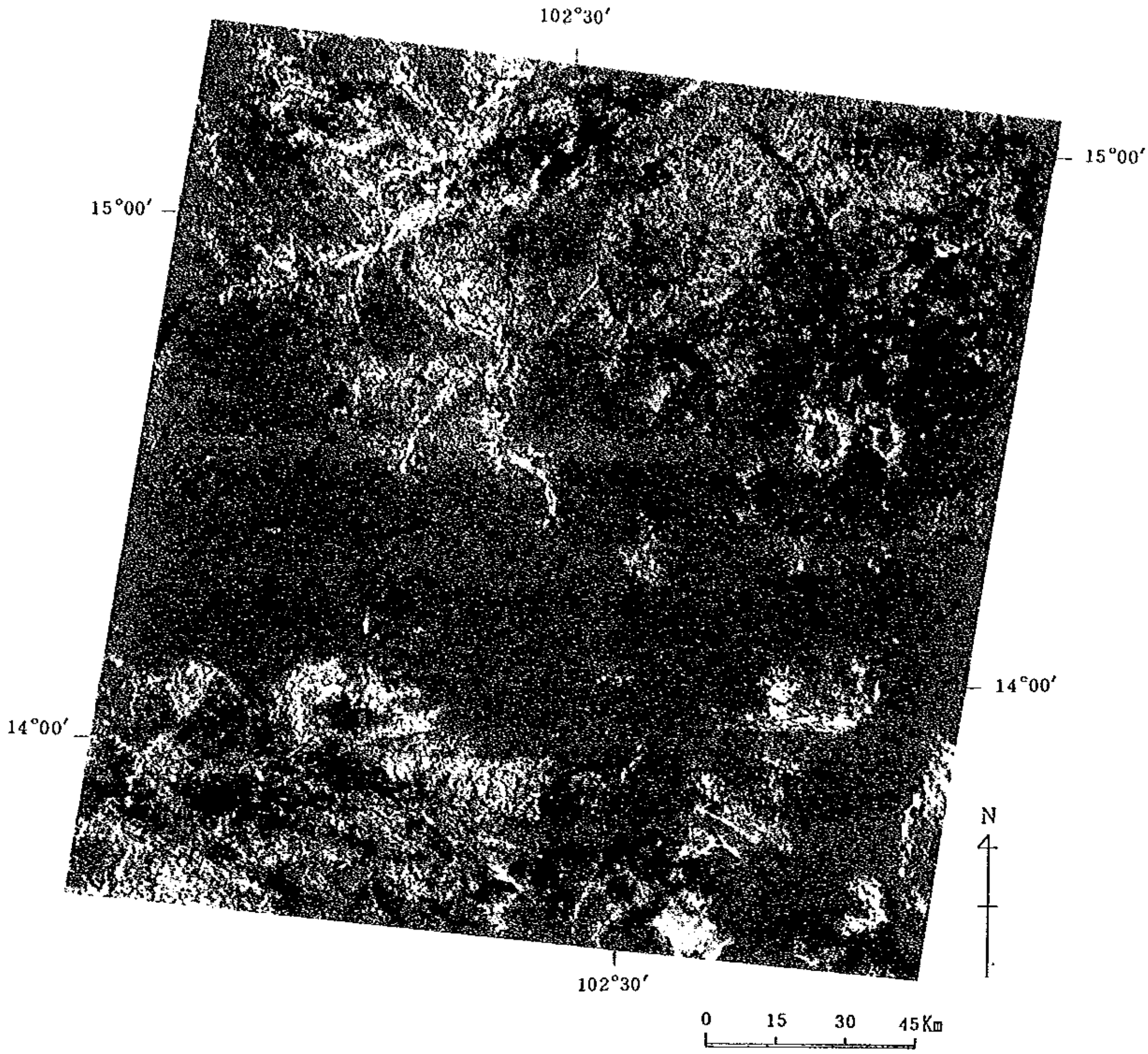


Legend

- Vegetation
- Water body
- High humidity area
- Medium humidity area
- Low humidity area
- Dry area

Date of data acquisition	:	16/Jan/84
Path-Row	:	128-49
Platform	:	Landsat 4
Sensor	:	MSS

Scene 6: Soil Moisture Analysis Image (1)



Date of data acquisition	:	16/Jan/84
Path-Row	:	128:50
Platform	:	Landsat 4
Sensor	:	MSS

Legend
- Vegetation
- Water Body
- High humidity area
- Medium humidity area
- Low humidity area
- Dry area

Scene 7: Soil Moisture Analysis Image (2)

3. Results of Saline Accumulations Analysis

As salt concentrations on the ground surface increase in volume, their reflections of sunlight intensify, to be directly reflected in the records of Landsat data pushing up the intensity values on each band. In the study area, however, besides salts, there are such other factors like dried soils and straws that contribute to raise reflection rates.

Moreover, salts are not evenly distributed and there also are ground covers like vegetation to affect the reflection, so that even in an area where salts were observed actually on site as most widely distributed, in imagery there turned out to be a difference of several levels between adjoining pixels. Therefore, as shown in Figure 13, classifications were made initially, and then finally all integrated in orverlay to be output in the images for saline accumulations analysis.

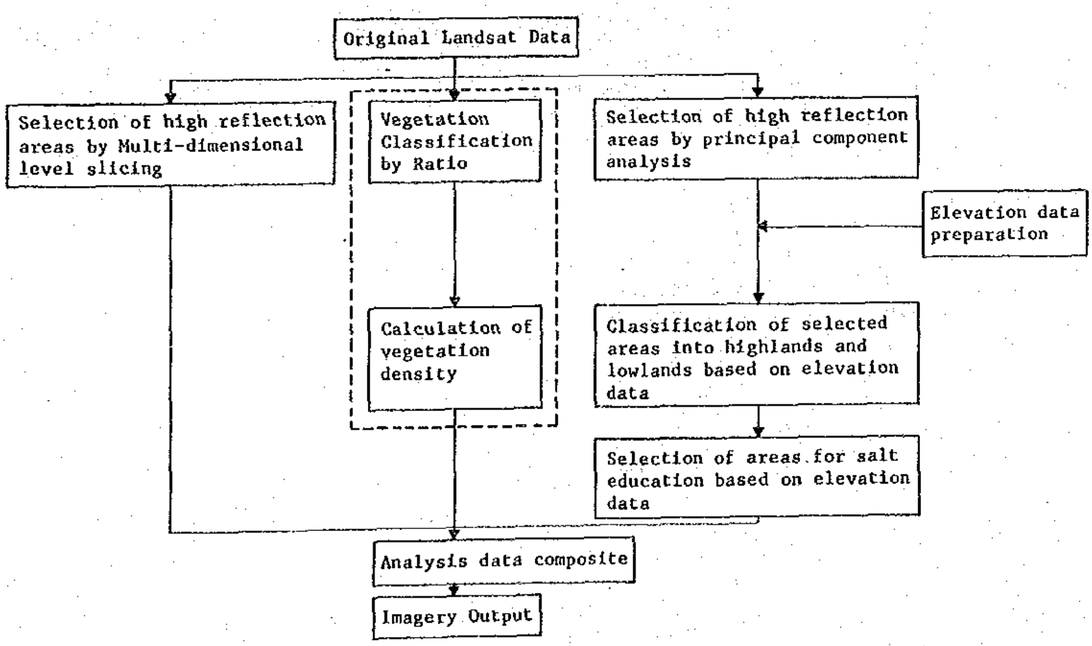


Figure 13 Saline Accumulations Analysis Flow Diagram

(1) Extraction of areas with strong reflections by multi-dimensional level slice:

Multi-dimensional level slice is a method which defines space to be formed by digital values of the respective bands each picture element has, as a feature space and considers the space in terms of three dimensional space units, each corresponding to a class, to arrive at classification by identifying picture elements contained in one space unit as belonging to the same class.

For the purpose of this study, level ranges were set for the respective bands by studying data of each band as output on CRT displays, field survey results, and the Soil Salinity Distribution Map. The levels set for this study are as follows.

Band	Level set
4	75 - 94
5	112 - 141
6	88 - 115
7	98 - 118

(2) Vegetation classification:

As mentioned in III-2-(6), by assuming vegetation density as an explanatory variable, the data were classified in three levels or ranks for application.

(3) Extraction of areas with strong reflections by principal component analysis:

By taking advantage of the first principal component representing the brightness of data, dry areas as identified by soil moisture analysis were extracted. The areas supposedly include, in addition to salt-accumulated areas, dry and strongly reflective areas like bareland and straw-covered paddies. The areas extracted in (1) were excluded.

(4) Classification of areas extracted from elevation data:

From the results of classification in (3) and elevation data, the study area was classified into upland and lowland. It assumes areas appearing white due to factors other than salt as paddy fields and therefore lowland, and upland turned into bareland due to causes like land collapse. One problem involved here is, since elevation data are taken in terms of one kilometer grid cells, the accuracy of fine details in micro reliefs is not as good.

(5) Extraction of salt-appearance areas for study from elevation data:

Using the data resulting from geological study of salt appearance study area made at the time of elevation data creation, analysis images were classified as relevant and others.

(6) Composite of analysis data:

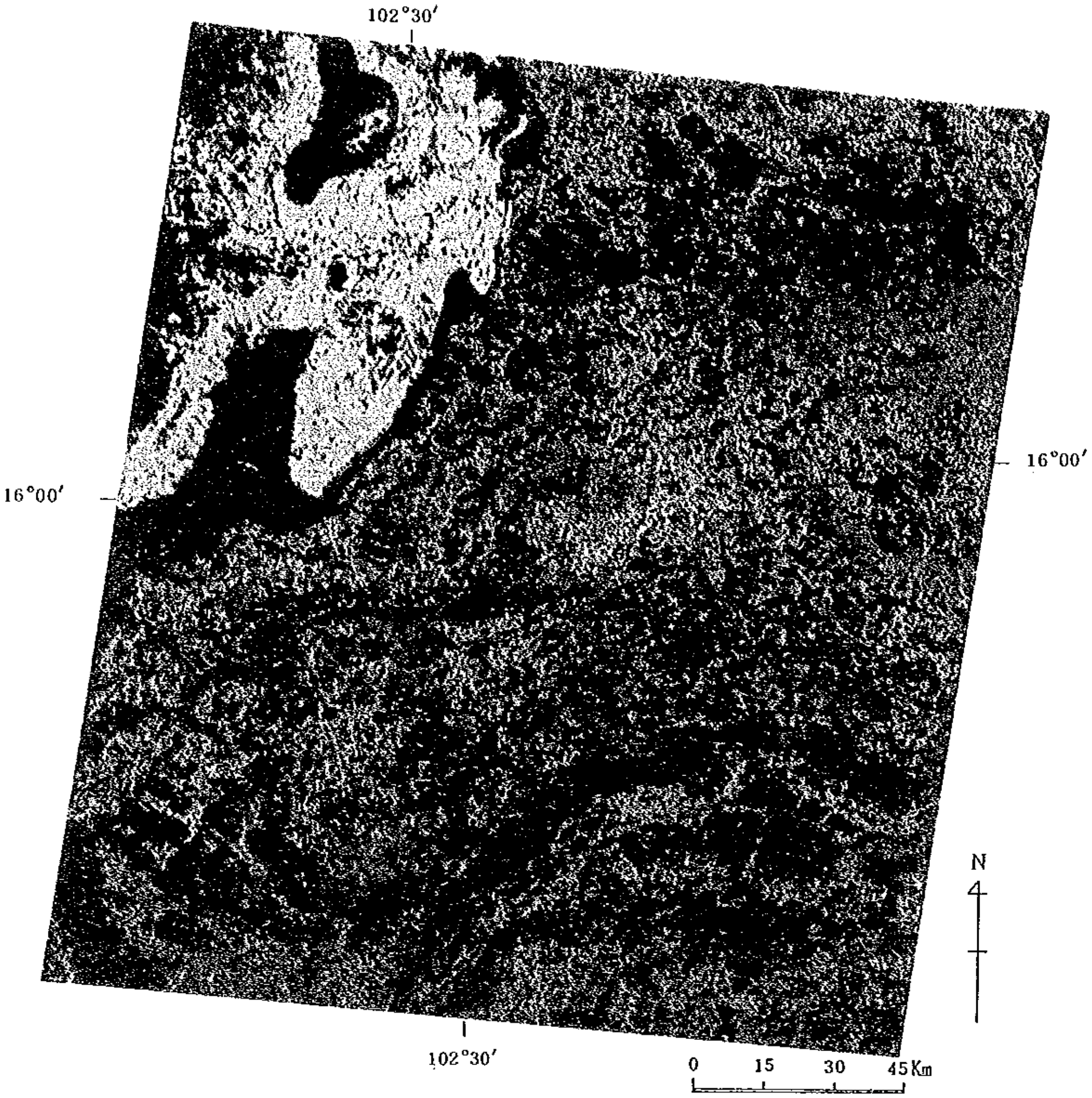
Results obtained in (1) through (5) were overlaid to create a new image file. Classifications are made as follows.

<u>Type of area</u>

1 Salt concentrated on surface ground
2 White surface, high elevation (195m or higher)
3 White surface, low elevation (less than 195m)
4 Vegetation, sparse
5 Vegetation, medium
6 Vegetation, dense
7 Lakes, ponds, water bodies
8 Unclassfied inside study area
9 Outside of study area

(7) Image output:

By setting colors for the respective classifications as above, images were output. (Scenes 8 and () With respect to 1 in the above classifications, i.e., Area with salt concentration on surface ground, there is an area south of Khon Kaen that falls in that type but it is so small in size it does not show up clearly enough in the image affected by the surrounding colors, and looks as if it did not exist at all. Therefore, this category of classification has been dropped from the 1/250,000 analysis imagery.

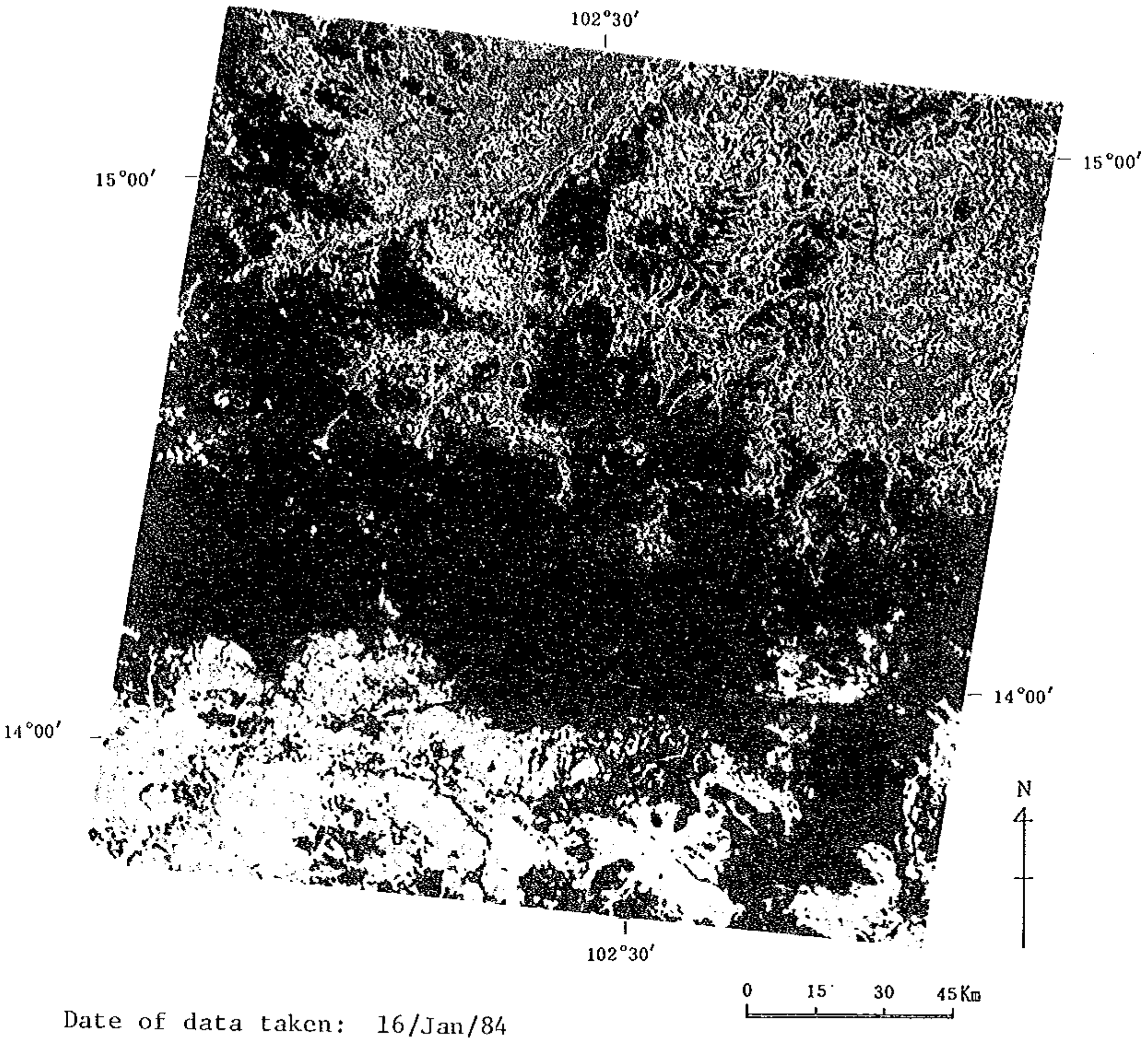


Date of data taken	:	16/Jan/84
Path-Row	:	128-49
Platform	:	Landsat 4
Sensor	:	MSS

Legend

- Water body
- Area with Salt concentration in ground surface
- White surface; 195 m of higher in elevation
- White surface; 195 m of in elevation
- Vegetation: Sparse
- Vegetation: Medium
- Vegetation: Dense
- Others
- Not of study area

Scene 8: Saline Accumulations Analysis Image (1)



Date of data taken: 16/Jan/84

Path-Row : 128-50

Platform : Landsat 4

Sensor : MSS

Legend

- Water body
- Area with Salt concentration in ground surface
- White surface; 195 m of higher in elevation
- White surface; 195 m, of less in elevation
- Vegetation: Sparse
- Vegetation: Medium
- Vegetation: Dense
- Others
- Not of study area

Scene 9: Saline Accumulations Analysis Image (2)

4. Landsat Image Interpretation for Geomorphology

Landsat MSS imagery (composite of Band 4 for blue, Band 5 for green, Band 7 for red) at 1/250,000 scale was interpreted visually for landform classification. Criteria used for the interpretation are given in Table 6.

Table 6: Criteria for Landform Interpretation

Terrain Type	Colors	Forms and other remarks
1. Valley bottoms & Natural levees	Dark red, partly dark blue	Branching out in narrow strips, meandering follwing dranage patterns.
2. Marshlands	Dark green, brown	Irregular in form. Generally observed in vicinity of rivers.
3. Alluvial lowlands	Dark green - bright green brown, gray brown, blue green, partly white or blue	Widely distributed surrounding rivers. Branching out but narrower and shorter than 1.
4. Low terraces	Dark green brown but lighter than 2,reddish brown, sporadically in spots.	Distributed partly inside or in vicinity of alluvial lowlands. With or without vegetation. Sometimes traces of old streams can be observed.

(To be continued)

(continued: Table 6)

Terrain Type	Colors	Forms and other remarks
5. High terraces	Gray brown, gray reddish brown, scatteredly in places.	Scattered distribution of listed (on left) colors. Widely distributed in vicinity of rivers and alluvial lowlands. Ruggedly fringed for some alluvial lowlands.
6. Hilly uplands & Mountain footslopes	Dark reddish brown, misty; gray reddish brown with white dots densely set inside, south of Khon Kaen.	Mostly adjoining or inside high terraces, distributed in isolation. Distributed also in vicinity of mountains in belts, many with yellowish white bareland patterns.
7. Plateaus	Red, green brown dots.	Distributed over sizeable area.
8. Mountains	Bright red, red, dark red	Fine wrinkles, extending in radials or linear. Distributed over sizeable area, way upstream of rivers.

Results of the interpretation performed on the basis of the above criteria are given in Figure 14.

Geomorphology of the study area can be characterized mainly by alluvial lowlands and high terraces. There are the Chi River running in the north and the Mune River in the south, and alluvial lowlands are distributed to surround these rivers. Running through the extensive terrains with little change in elevation the rivers flow slowly meandering gently. Drainange pattern of the Mune River is more clearly defined by vegetation than that of the Chi River. Alluvial lowlands also appear darker in color in the Mune River basin to possibly show that they are wet and damp compared with the Chi River basin. Marshlands are concentrated along the Mune River.

Alluvial lowlands further cut into high terraces vermiculatingly. In this type of terrain, where drainage patterns are not clearly recognizable during the dry season, when it comes time for the rainy season, the area becomes highly wet and likely to be flooded.

Low terraces also are relatively wet land. They are in many cases distributed a little further away from a river stream. There are vegetations grown in lines as seen in the imagery, presumably vegetations grown on old natural levees. This is considered to indicate that what was once alluvial lowland has turned into low terraces due to shifting or subsiding of a river stream. Landuse for the above mentioned types of lowlands is predominantly paddy fields. But in some higher locations, there are vegetables grown.

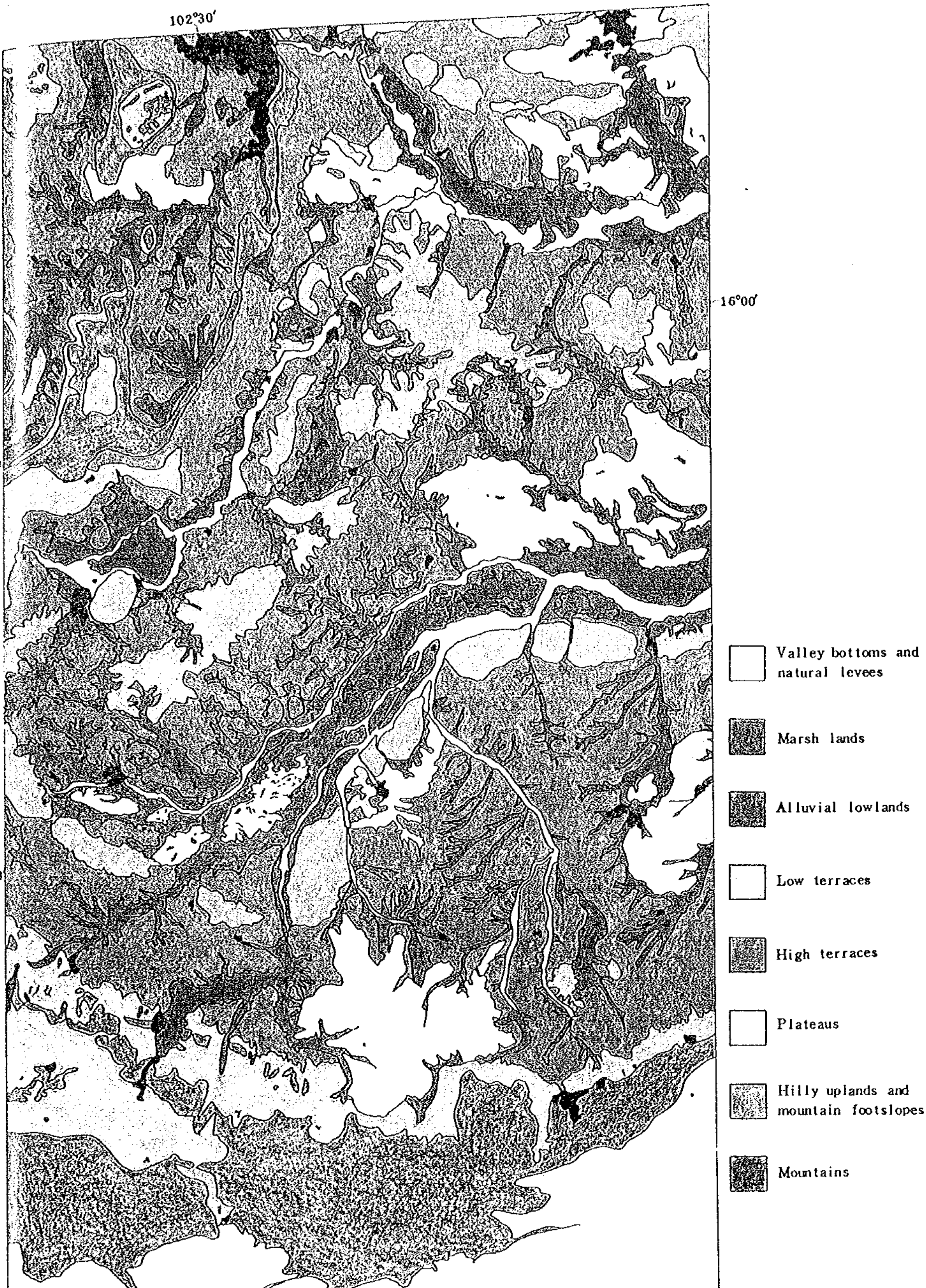
High terraces are most widely distributed in the study area. They are more finely segmented than alluvial lowlands. According to the soil map (1/100,000 scale) prepared by D.L.D., the high terraces in the study area correspond to the old alluvial facies and they were formed as a result of the river beds of the Chi River and the Mune River subsiding and elevating, in relative terms, the areas where are terraces now.

The high terraces between the two rivers, as well as hilly uplands, form the watersheds but as the alluvial lowlands have extended to merge the flood plains of both rivers making it difficult to differentiate the two plains.

Hilly uplands and mountain footslopes can be looked upon as falling between forests and vegetable fields as the former is turned into the latter land use. Extensive soil erosion was observed. The erosion has resulted from relatively recent introduction of cultivation, sharp slopes, and sandy soils, among other factors. Erosion is advanced particularly in the hills lying south of Khon Kaen to southwest, where bright gray brown land with no vegetation cover is distriubted.

There is plateau, as classified here, at one location in the study area. It is Tertiary basalt lava plateau located on the northern side of the Phnom Damrek Mountain Range. Hills of geologically similar types are distributed sporadically east and west of the area. With poor growth of vegetation and reddish soils partly exposed, the land is not cultivated to any significant degree. The soils here can be classified as oxisol which is observed in the old geomorphological facies of the tropical zone and defined as Haplustox of Soil Taxonomy in D.L.D. Soil Map (1/500,000).

Mountains surrounding this area as they extend south and west, as mentioned earlier, feature Mesozoic formations consisting of sandstone, shale, and conglomerates, presenting typical structural reliefs. Edged mountain ridges of Chaiyaphum resulted from sloped anticlinal ridges cut off by erosion. The Phnom Damrek Range has steep cliffs extending in the east-west direction and cuesta reliefs gently sloping north, and is divided into pieces by streams that cross these reliefs.



102°30′
16°00′
Valley bottoms and natural levees
Marsh lands
Alluvial lowlands
Low terraces
High terraces
Plateaus
Hilly uplands and mountain footslopes
Mountains
102°30′

Table 7

ITEM	Geology	Soil Type	Soil Moistur Level	Vegetation Density Level	Land Use (including Plans)
Valley Bottoms & Natural Levves	o Alluvium, eluvium, Valley-fill and river gravel (Quarternary to Recent)	Allvial Soils, Hydromorphic Alluvial Soils, Low Humic Gley Soils	Wet	High	o Paddy fields o Woods o Areas for field crop
Marsh Lands	o Alluvium, eluvium, valley fill and river gravel	Low Humic Gley Soils, Solonchak	Wet (marshy)	Low	o Paddy fields o Swamps
Alluvial Low Lands	o Alluvium, eluvium, valley fill and river gravel Calory the Chi & the Mune) o Salt and Khaok Kruat Formation (cretaceous)	Hydromorphic Alluvial Soils, Low Humic Gley Soils, Gray Podzolic Soils, Red Yellow Podzdic Soils, Noncalcic Brown Soils, Solonchak, Solonetz, Solanchoc Soils	Along the Mune Wet - Medium Along the Chi Medium - dry (except irrigated area)	Low	o Paddy fields (irrigated Agr.) o Areas for field crop (Soil tex. is sandy)
Low Terraces	o Alluvium, eluvium, valley fill and river gravel o Salt and Khok Kruat Formation	Hydromorphic Alluvial Soils, Low Humic Gley Soils, Gray Podzolic Soils	Along the Mune Wet (partially Marshy) Along the Chi Medium - dry	Low - Middle	o Paddy fields (rainfed Agr.)
High Terraces	o Salt and Khaok Kruat Formation o Phu Kradung Formation (Jurassic and Triassic) West of Khon Kare Chaiyaphum	Gray Podzolic Soils, Red Yellow Podozlic Soils, Red Brown Earth, Regosolic Soils, Red Yellow Latosols,	Wet - Medium	Middle	o Paddy fields o Areas for field crop (Soil tex. is sandy) o Pastures o Partially, not suitable gor Agr.
Hilly Uplands & Mountainfoot Slopes	o Salt and Khok Kruat Formation o Phu Phan and Phra Wihan Formation (Jurassic) upper site	Gray Podzolic Soils, Red Yellow Podzodic Soils, Red Brown Earth Rezosolic Soils, Red Yellow Latosols, (top of hills) Reddish Brown Lateritic Soils	Wet - Medium (eroded areas are dry)	Middle - High (eroded areas are low)	o Areas for field crop o Shifting cultivation o Pastures o Forest o Not suitable for Agr. (=eroded area)
Plateaus	o Basalt and its equivalent (Tertiary)	Reddish Brown Lateritic Soils	Medium	High	o Forest
Mountains	o Phu Phan and Phra Wihan Formation	Slope Compley Soils, Gray Podzolic Soils, Red Yellow Podzolic Soils, Regosols	(indistinguishable by vegetation)	High	o Forest

V. Areas with Salt Concentrations and Environmental Factors

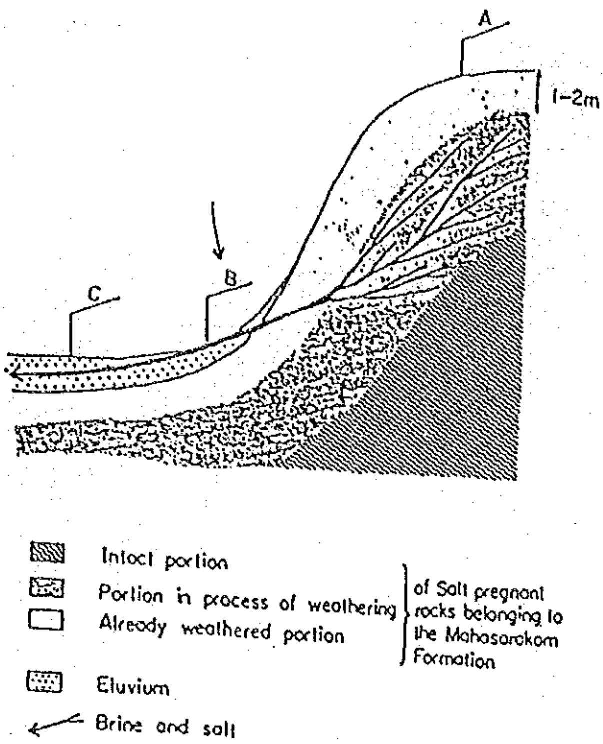
Salt concentrations in Northeast Thailand and their environmental factors have been studied by searching the leterature, field survey, and consulting experts.

1. Geomorphology

The morphological map, Landsat imagery, and the Soil Salinity Distribution Map, show that salt can be found on alluvial lowlands and low terraces, particularly in the vicinity of an area with slightly elevated topography. It appears much in the vicinity of terraces and hills between the Chi and the Mune Rivers, particularly in the alluvial lowland surrounded by the high terraces on the side of the Mune River towards the Phenchabun Mountains.

According to Takaya (1974), this area is summarized as follow.

a. Highly salt-affected lowland:
   Salt encrustations are common as observed in the valleys in the vicinity of highland along the western fringe of the Korat Plain.



b. Moderately sal-affected lowland:

Salt encrustations are not so common. This includes many of shallow valleys.

c. Slightly salt-affected lowland:

Rarely recognizable visually. Salt is contained in ground water. Observed in new alluvial valleys.

d. Elevated ground composed of saline rocks:

Covered by vegetation, surface layers one meter thick are composed of leached material.

e. In micro terms, concentrations appear in slight topographical depressions (where water tends to collect in pools).

2. Geology

Geological factors supposedly include the salt rock layers and the salt-containing sedimentary rock layers of the Maha Sarakham Formation. The presence of salk rocks was confirmed by boring in the 1950's. Existing deep underground at a depth of several scores of meters, there is little likelihood for them to rise all the way to the ground surface. Rather, since the Maha Sarakham Formation, which contains sandstone, shale, salts, belonging to the upper Tertiary Korat Group, is topographically elevated in position, the salts contained in the upper parts of the formation are suspected to have seeped into ground water as those upper parts were weathered, showing up in areas around highland where ground water comes up closer to the ground surface.

Distributions of the Mahasarakam Formation nearly correspond to terraces and hills, according to Takaya (1974), and salts appear around them. A field report shows that when a dam for irrigation was constructed in this area, salt appeared in places where no salt had been observed earlier due to the rise in the level of downstream ground water caused by the dam construction. This points to the big impact the ground water has on salt appearance.

3. Soils

Soils are generally sandy in Northeast Thailand. Its structural characteristic as observed in alluvial lowland and low terraces is schematically described in Figure 14.

The sandy layer as shwon in the figure has good permeability and let salt-contained groundwater pass through easily. Therefore, during the dry season, salt accumulates due to evapo-transpiration at the ground surface, whereas in the wet season, it is washed away or going further underground to disperse.

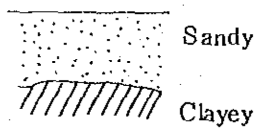


Figure 14

It can be considered that in topographically elevated places like high terraces, even where soils are sandy, groundwater level is low enough for salt water to rise because capillary tubes of soil water are cut off in the path to prevent the passage of salt water.

4. Vegetation

Salt appears mostly in paddy areas. Growth of vegetation is poor in such areas. Such environment is difficult for plants in general but there are saline plants like Nam Daeng and Nam Prom which are distributed in shrubs in the area. Vegetation is also poor in the surrounding areas. Micro-reliefs and hilly uplands running from the hills north and south of Khon Kaen to the Korat Plain are turning into bareland due to soil erosion in progress. The vicinity of a salt accumulated area upstream of the Mune River has vegetation cover but it is exceptional.

5. Climate

As previously mentioned under II. 1. Climate, rainfalls are unevenly distributed through a year. In the wet season, salt flows out while during the dry season salt appears and accumulates as groundwater rises due to evapotranspiration.

6. Drainage System

Drainage systems were extracted from the 1/250,000 topographical maps and, further, areas of Ranks 1 and 2 in the Soil Salinity Distribution Map were transcribed to create a new map. (Figure 15)

From the figure, it can be seen that the areas are concentrated along the Mune River particularly on the left bank of the river. This is possibly because, compared with the Chi River which runs alongside with hills in between, the area here is low in elevation and therefore salt containing groundwater tends to collect on the sie of the Mune River. Judging from the concentration of salt on the left bank side, salt is considered to have originated in the terraces between the two rivers.

In relation to drainage systems, salt areas are characterized as follows.

1 Salt is highly dense in areas where water drains in a fan. (ex. upstream of the Mune River.)

2 Salt tends to accumulate in areas slightly upstream of a confluence of rivers.

Areas with salt concentrations as observed in the imagery are located in relatively dry areas (ex. upstream of the Chi and the Mune Rivers).

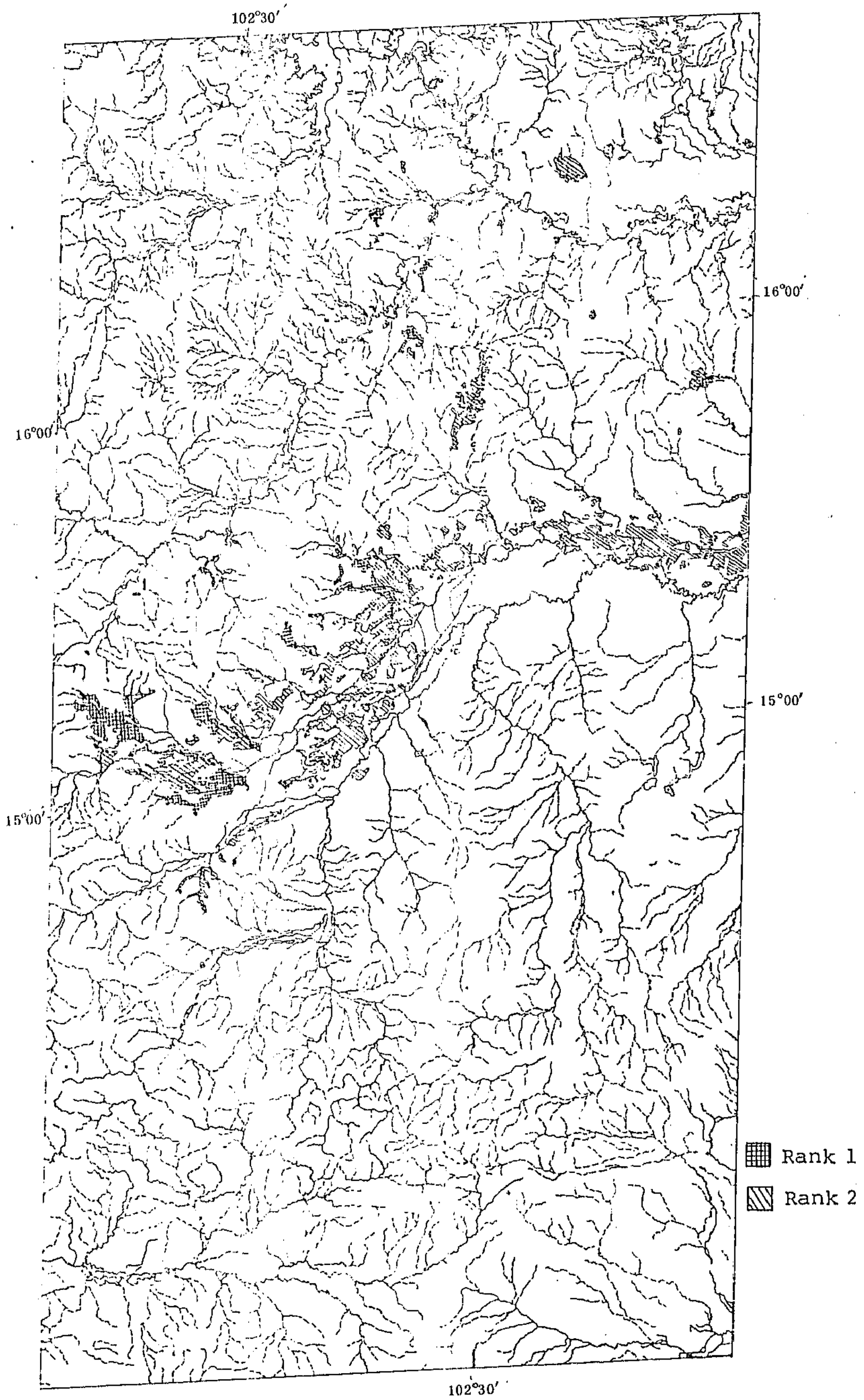


Figure 16 Drainage System and Salt Concentration Area

VI. Evaluation of Landsat Data Application

Landsat data allow us to study a wide geographical area instantly in two dimensions. It has an advantage over aerial photography in that data are made available at lower costs. By making the best of their characteritics, Landsat data should serve the purpose of this study most effectively. First, problems pertaining to the application of Landsat data for this study are discussed below.

There are problems as follows.

1 Reflections are too similar in salt-accumulated areas, straw-covered paddies, and sandy land turning into bareland due to cultivation or soil erosion, to differentiate these areas.
2 Classifications can be made as detailed as in the Soil Salinity Distribution Map, because of the presence of vegetation in low ranking areas whose reflection is not excluded.
3 It partly relates to 2 above. Areas without any salt appearance can not be distinguished by Landsat data alone.
4 Straws get in the way and make it impossible to differentiate salt-containing paddies from those free of salt.
5 Considering the land use of Thailand which is as highly segmented as that of Japan, Landsat MSS resolution (80 m

square) is too rough . One pixel contains data on reflections of bareland, vegetation, and salt all mixed.

If these problems are resolved, effectiveness of the imagery for monitoring salinization of soils will be greatly enhanced. Therefore, suggestions are offered as follows in an attempt to overcome these problems.

First. Salt, rice plants, bareland, should be studied in terms of their characteristics relevant to the problems. For example. Salt: Appearances change easily due to a rain shower. Rice: They change seasonally as they grow. Bareland: No change.

Thefore, it should be possible to differentiate salt from rice by studying the data taken in late September before rice harvesting starts. Similarly, for salt and bareland, dry season data of around March, can be studied in overlay.

Problems 2 and 3 can possibly be resolved by overlaying existing data (geology, soils, elevation, etc.) on landsat data for analysis on a set of criteria. In rank setting with respect to areas with salt coverage of less than 50%, since vegetation should involve explanatory variables, representation will be different from Soil Salinity Distribution Map ranking.

As for Problem 4, it will be very difficult to differentiate salt appearance and grass typical of saline soil paddy because these are usually covered by straws. Problem 5 is expected to be resolved in the near future as Thematic Mapper (TM) of higher resolution (30 meter square) will come into use.

From the above, it might be concluded that Landsat data are effective at least as a means to identify new appearance of salt or areas fast turning into bareland.

VII. Comments and Recommendations for Future Study

Landsat and other satellite data are considered as effective and suited for surveillance of expanding bareland and increasing damages from salinization of soils in Northeast Thailand. There are two ways of application, analog and digital, the latter being the case of the present study. Analog application means providing images easy for interpretation whereas digital application allows analysis of data in numerical values. As for the former application, there have been developed many ways and methods to output imagery to suit specific needs and purposes. Here digital analysis is discussed.

In this study, elevation data were generated additionally for overlay on Landsat imagery to help analysis. In view of the considerations given in VI, analysis can be best performed in the procedure given in Figure 17.

Before Landsat image analysis, transformation of existing data on elevation, geology, soils, etc. into raster data to create basic data files. Then in accordance with a set of specifications, they are overlaid on Landsat imagery for analysis. As for discrepancies, SPOT data (resolution 10 m or 20 m) might as well be referred to for more details.

In addition to the study to be perfomed on the basis of salt concentrations as they appear on the ground surface, analysis of saline conditions will be given an added dimension by undertaking a study in the following terms.

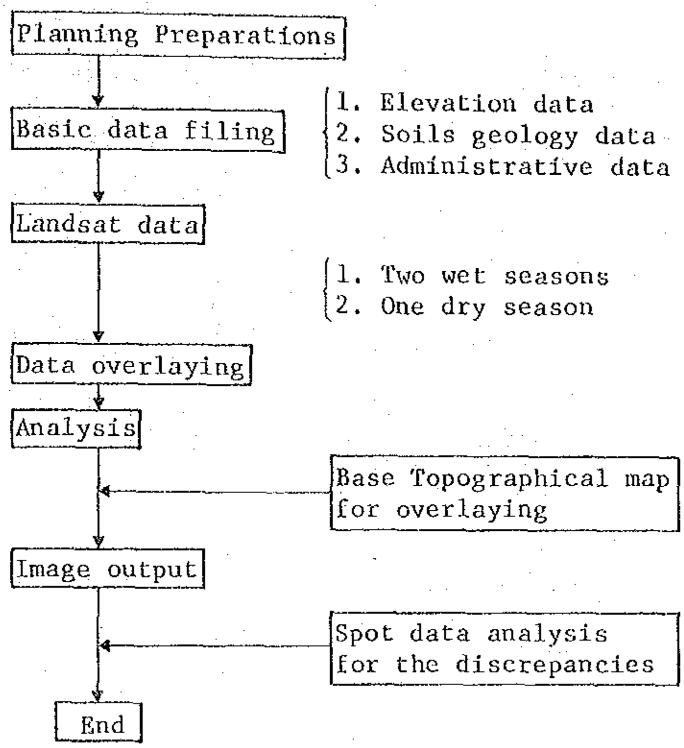


Figure 17

Most of salt that appears in lowland is said to originate in the Maha Sarakham Formation distributed in hilly uplands and to be carried over in the ground water where it seeps out and resolves. During the dry season, salt accumulated in lowland rises to the ground surface by way of water in capillary tubes. Thus saline accumulation is closely related to the movement of water. And therefore it will be necessary to continue with the research focusing on the land-bound water such as groundwater and water contents of soils in terms of their behavior and quality. In other words, the following can be subjects for study.

a. Level, movement, quality, of groundwater
b. Moisture contents and water quality of soils
c. Characteristics of river flows, water quality

Not only by studying data over time but also by intensive observations, mechanism for salt accumulation and appearance will be better understood. Also by conducting boring at more locations, distributions of the Mahasarakam Formation will be identified enabling a future study to find and estimate levels and impacts of salinization.

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GLOSSARY

Landsat : The Landsat sattelite, or Earth Resources Technology Sattelite as formerly called, was launched by the US National Aeronautics and Space Administration (NASA) for observation of the earth. Landsat 1 was launched in 1972. Presently Lnadsats 4 and 5 are operational. Landsat 5 has TM (Thematic Mapper) on board in addition to MSS (Multispectral Scanner Systems). TM has a spatial resolution of 30 meters (exept for the termal band which has 120 meters), an improvement over MSS, and seven bands covering a wider range of wavelength. At present, with no receiving facilities for TM, MSS data alone are received in Thailand.

SPOT : The sattelite launched by France has an increased spatial resolution of 10 meters or 20 meters, a still further improvement over Landsat. Since data can be taken at different angles, topographic maps of up to about 1/50,000 can be developed based on these data.

Pixel : Smallest unit of picture elements that make up image data.

Spectral radiance level : Expressed in a value obtained from intensity of spectral radiance from a micro plane out in a certain direction to be divided by area of orthographic projection.

Spectral reflection rate : Light of a certain specific wavelength is given to a test piece, coming from the surface of a hemisphere in all directions. The spectral reflection rate is the proportion of the light that reflects in all directions..

CCT : Computer Compatible Tape

CCRS : Canadian Center for Remote Sensing

BIL : It stands for Band Interleaved by Line. MSS image CCT data are recorded with Band 4 through Band 7 interleaved by one line each starting with Band 4 and proceeding in that order.

Histogram	: A graph of frequency distribution in the form of a series of rectangles, each proportional in width to the range of values of physical quantyties to represent a certain phenomenon and in height to the number of observations of that phenomenon.
Geometric correction	: Landsat image data have distortions of various kinds. Geometric correction compensates for distortions to bring the data closer to the coordinate system of map projection.
Pre-processing	: It refers to the process performed preceding data analysis, including radiometric and geometric corretions. It is critical to the level of accuracy of the final analysis.
Spectrometer	: Instrument to observe spectral reflective characteristics of a subject matter. Resulting data serve as basic information for study of the subject matter.

Remote sensing	: A technology to acquire information on a subject matter or phenomenon without coming into contact with them and to apply the information for recognition, classification, and interpretation of phenomena under study.
Sun-synchronous	: A sattelite in an orbit as defined by the orbital plane and altitude, that is synchronized with local solar times.