THE USE OF REMOTE SENSING TECHNIQUES IN COMBINATION WITH A GEOGRAPHIC INFORMATION SYSTEM FOR SOIL STUDIES WITH EMPHASIS ON QUANTIFICATION OF SALINITY AND ALKALINITY IN THE NORTHERN PART OF THE NILE DELTA, EGYPT

BY

MAHER A. ABDEL- HAMID

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BY

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THESIS

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IN

Soil Survey Using Aerial Photography
And Other Remote Sensing Techniques

TO

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TO MY WIFE,
INAS

for bravely bearing the burden of
my absence during work

for her efforts in preventing me from occupying
my self with things other than my work

for our friendship
for our love
for our life

WITH LOVE AND GRATITUDE

MAHER

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ABSTRACT

Visual and digital interpretation of Landsat Thematic Mapper data of 18th of April 1989 were used to delineate saline and alkaline soils in the northern part of the Nile Delta, Egypt.

Visual interpretation provided a suitable method to rapidly assess the location of saline areas. The accurate estimates of salt affected soils was easily obtained by digital interpretation procedures.

Spectral classification and spectral correlation procedures are very good in making accurate classes in relation to salinity and alkalinity hazard. Use of thermal band proved to be good for soil moisture and water logged areas as well as areas with salt crusts.

The results obtained from field spectro-radiometer measurements are significantly correlated with corresponding TM bands .

Incorporating the results from all procedures and field work data in a Geographic information system improved the results. Final soil salinity, alkalinity and land use/cover maps were obtained. The salinity map was compared with the existing soil salinity map of Egypt from 1966 for the following:

1) evaluate the salinity/alkalinity map and
2) monitor the changes in salinity through time.

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1-INTRODUCTION

Remote Sensing is the science of deriving information about objects from measurements made at distance,without actually coming in contact with it. The quantity most frequently measured in remote sensing systems is the electromagnetic energy emitted or reflected from an object of interest.

The great advantage of having remotely sensed data available in digital form is the possibility to process the data by computer for information extraction.

Salt affected soils have received the attention of scientists and development workers in Egypt and in other countries having similar problems in salinity. The problem has been a subject matter of study by a number of scientific commissions . In spite of all these researches carried out all over the country , a definite solution to the problem has not been formulated.

The application of satellite imagery to agricultural fields detection and delineation of problematic soils by such techniques would help in the proper planning of land use , reclamation and improvement. Conventional ground survey procedures are time consuming and costly. Remote sensing techniques, if proved for the application in diagnosis and monitoring of salt affected soils,will make a break through in terms of efficiency and the extent of coverage.

The objective of this study is to develop a methodology incorporating spectral and spatial information obtained from satellite data and ancillary information from the field work and previous surveys to investigate , identify and delineate soils with salinity and alkalinity problem.

Egypt is facing many challenges in raising the standard of living of its population. In this point agriculture serves two major goals: i) self sufficiency in food and ii) generation of foreign exchange through export of cash crops.The horizontal expansion is a major policy of agricultural development in Egypt. However, the Egyptian Government had achieved a desirable plan for the addition of 2,818,000 feddans(1,183,560 ha). More than 25% of this new areas are concentrated around the northern lakes which are mainly saline. On the other hand, the major agricultural problem in Egypt is the degradation of soils through salinity and alkalinity. The high evapotranspiration in combination with a high ground water level causes salinity problem especially in the northern part of the Nile Delta.

The selection of the study area is based on the agricultural importance for Egypt with the occurrence of bare saline soils. The study area ,a part from the northern plain, is mainly deltaic sedimentation of the River Nile and Burullus lake which was in brackish saline environment.The area has poor natural drainage. An additional problem arises from the combination of high evaporation and shallow depth of ground water. So, considerable salts are accumulated in the top soil.

The study area covers about 253,321 feddans(106,339 hectares), more than 100,000 feddans (42,000 ha) are subjected to salinity/alkalinity hazard.

The applied methodology were i) visual interpretation of enhanced satellite images, ii) computer assisted multispectral classification (spectral classification and spectral correlation), iii) use of thermal infrared data to extract information on drainage condition and detection of salinity and alkalinity; and iv) multispectral surface reflectance measurements of soil and plants by using Spectro-radiometer.

To improve the quality and reliability of multispectral classification, results were combined with the soil data, obtained from the field work and previous surveys, using a geographic information system. For this purpose the Integrated Land and Watershed Management Information System (ILWIS) at ITC was used.

2. REVIEW OF LITERATURES

2.1 REFLECTANCE AS A QUANTITATIVE MEASUREMENTS OF SOIL PROPERTIES:

Since the early stages of earth resources satellites, digital analysis of remotely sensed data was used for identification of crop and yield predictions, mainly because of the possibility of having repetitive coverage . However, the delineation of soil boundaries was mainly done by visual interpretation. At the same time, numerous studies on soil reflectance properties were carried out by using spectro-radiometer.

Studies on different soil types indicated that there are a number of interactive properties which determine the amplitude of soil reflectance such as organic matter content , soil moisture, particle size distribution, soil structure,iron oxides content, clay mineralogy and parent material (Obuvkhov and orlov 1964, Gates 1965, Bowers and Smith 1972, Gausman et al.1975, Bauer 1980, Stoner and Baumgardner 1981,....).

Curcio and Petty (1951) reported that water absorption bands occur at 0.76, 0.97, 1.19, 1.45 and 1.94 um. Specifically these bands are overtones and combinations of the three fundamental vibrational frequencies of H2O molecule and strongly absorbed by water. Soils appear darker when wet than when dry and there is decrease in reflectance with increasing moisture content (Bowers and Hanks,1965; Cipra et al.,1971; Peterson et al.,1979) Bowers and Smith (1972) found a linear relation between absorbance and percent soil water for moisture determinations from air dry to the moisture equivalent. For soil moisture exceeding 30% a curvilinear relation may be preferable

Ward(1972) subjected the sugar maple seedings to treatments of drought and salinity in greenhouse. An analysis of variance of data from nine wavelengths indicated that reflectance at wavelength of 1430-1940 and 2190 nm significantly increased by both treatments, even before visible symptoms appeared. Reflectance at wavelength of 530 and 640 nm significantly increased only in cases where visible symptoms were obvious. Reflectance at wavelength of 800,1000 and 1200 nm significantly increased by low salinity in the presence of drought or high salinity, even after visible symptoms had developed The results suggested that remote sensors at wavelength of 1430 nm. or longer provide the greatest likelihood of pre-visual detection of plants affected by drought and salinity.

Soil organic matter contents are also known to be strongly influencing soil reflectance. As the organic matter content increases, soil reflectance decreases throughout the 0.4-2.5 um. wavelength (Cipra et al.,1971; Condit,1972).

An increase in iron oxide can cause a decrease in visible reflectance and the intensity of reflection in the region from 0.5-0.64 um has been found to be inversely proportional to iron content (Obukhov and Orlov,1964).

Soil texture and the size and shape of the soil aggregates influence soil reflectance in varying manner (Bowers and Hanks,1965).

The influence of surface roughness and the occurrence of crop residues in soil reflectance was studied by many researchers. Hoffer and Johannsen(1969) showed that corn leaves with a low water content have generally 10 to 15 % higher reflectance than a dry soil in the 1.35-2.6 um wave band. The difference in reflectance values between leaves and dry soil is more than 30% within the 0.8-0.9 um wavelength. Gausman et al.(1975) reported that standing residues have lower reflectance than dry soils because of shadows, however littered residues have higher reflectance.They added that the residue covered soils were best discriminated from bare soils by using Landsat-MSS band 4(0.5-0.6 um). Surface roughness also affects the reflectance of soils. Coarse aggregates having irregular shape, from a complex surface with large number of inter-aggregate space gives generally lower values, since much of the radiant energy is absorbed(Cipra et al.,1971). They added that crusted surfaces gave higher reflectance values than the soils with the crust broken.They also added that either or both of these factors could have the lower reflectance for soils with crust broken. Seeley et al.,(1984) showed that soil roughness had little effect on TM spectral characteristics,but differential weathering of variably tilled soils was detectable. They also reported that soils covered with dense crop residues, such as corn and oats, change soil reflectance as much as 80%.

Many studies were carried out to relate the soil reflectance with soil properties and their Taxonomic classification. Condit(1970,1972) classifies all soil spectra into three general types based on 160 samples with respect to their curve shape, but he does not relate these curves to soil characteristics or soil classification.

Cipra et al.(1971) conducted field spectro-radiometric studies and described the properties and classification of seven soil series in terms of Condit's spectral curve types.They reported that Mollisols could be easily distinguished from Alfisols by their reflectance curves.However, a light coloured, very sandy Entisols had curves similar to those of Alfisols. A very dark coloured, sandy Mollisols had curves similar to silty clay loam Mollisols,but had a higher reflectance throughout the visible spectrum. A Histosols was almost indistinguishable from silty clay loam Mollisols.

Stoner and Baumgardner(1981) showed that the soil reflectance curves from examination of 485 bidirectional reflectance spectra of surface soil samples collected from 39 states in US and Brazil were represented by five characteristic soil reflectance curve forms.These curves are identified by curve shape and the presence or absence of absorption bands. Soil properties associated with each curve characterize soil reflectance in a manner which facilitates comparison with higher categories of Soil Taxonomy.

2.2 THE APPLICATION OF REMOTE SENSING DATA FOR THE INVESTIGATION OF SALINE SOILS:

2.2.1 THE APPLICATION OF LANDSAT DATA:

Visual interpretation of satellite imagery have been used by many workers for delineating salt affected soils (Printice,1972; Colewell,1974; Massoud,1977; Venkataratnam,1980 &1983; Makin,1984;......).

For differentiation between the saline and non-saline soils data from relevant season and MSS bands are important. (Printice,1972; Colewell,1974; Massoud,1977). A careful selection of specific wavelength band could highly improve the delineation of salt affected soils.It is the vegetated salt affected soils that require proper timing for obtaining data during growing season(Massoud,1977). Colewell(1974) showed that MSS band 5 of Landsat was useful and accurate in detecting and delineating the real extent of saline soils. Richardson et al.(1976) found that measuring the contrast between vegetated and bare soils may provide a better method for detecting saline levels and that reflective infrared wavelengths are superior to visible wavelengths for soil salinity detection.

Landsat MSS data have been used for the delineation and mapping of the unproductive/barren areas which are affected by soil hazards like salinity and alkalinity, water logging, high water table(Venkataratnam,1980). He showed that delineation and mapping of salt affected areas of high water table could be done accurately at much faster rate.Two degrees of soil salinity/alkalinity in Indo-Gangetic plains could be separated in addition to normal soils.He added that the use of linear and non-linear contrast were found to be extremely useful in distinguishing various levels of soil salinity. Manachanda(1981) reported that the use of multi-spectral and multi-temporal MSS data is helpful in identification and delineation of salt affected areas. His study indicated that MSS band 5 in hot dry-season gave the maximum information of salinity hazard, while band 7 of the same season gave the minimum information. Venkataratnam(1983) developed methodology for the monitoring of the salinity/alkalinity levels for a part of the district Sangrur in India, where Landsat multi-spectral data of different dates and season have been analyzed on computer aided Bendix MDAS system. He concluded that this methodology could be extended to other areas affected by salinity/alkalinity. Jawara(1983) indicated that combined use of Landsat imagery and aerial photographs has been useful in detecting and mapping the extent of salinization in the Allahein river catchment in Gambia. Dominquez and Carballo(1983) studied soil deterioration by salinization in Buenos Aires,Argentina using visual interpretation of MSS band 5 image. Makin(1984) used digital enhancement and classification of landsat imagery for the delineation of salt affected soils in the deteriorated areas.

Many workers used Landsat Thematic Mapper(TM) in the detection and delineation of salt affected soils.
Menenti et al.(1986) used TM data to study the Kaerine and Seftimi ares in Indonesia. They indicated that TM data in band 1 through 5 and 7 are good for identifying salt minerals, at least when they are a dominant soil constituents. Epema(1986) indicated that TM bands provide useful information and that the total reflectance and difference between red and infrared are important for differentiating land units. He added that the data structure from semi-arid Seftimi area is influenced mainly by differences in soil surface. Especially the presence of gypsum sand provides new information in band 5 and 7, which is represented in Principle Component 2(PC2). Mulders and Epema(1986) showed that TM is a valuable aid for soil mapping in arid areas when used in conjunction with aerial photographs. The low vegetation cover can be used advantageously for detecting clayey, calcareous, gypsiferous and saline soils.Tricatsoula(1988) in studying the salinity in Greece reported that salinity/alkalinity problems were identified not because of the differences in reflectance or emittance but mainly due to the different land use and their position in the physiographic units.

2.2.2 USE OF THERMAL INFRARED DATA:

Soil moisture is a very important factor for crop growth. It influences crop production and resistance to soil erosion in arid and semi-arid areas.

Thermography, is based on the measurements of emitted thermal radiation of objects at earth surface. Meyers et al.(1970) used the thermal imagery obtained at different times and different seasons, variation in the imagery is strongly influenced by the sub-surface conditions indicating soil moisture in the upper 50 cm of bare soil. Watson(1975) showed that thermal infrared appears to be feasible for studying soil conditions indicating the detection of moisture stress on plants/crops, the proximity of water table to the surface and the identification and delineation of salt affected soils.

In desert areas or in areas with low vegetation cover, the thermal inertia mapped this way can be used to map volumetric content in the soil. This knowledge should be completed by a good knowledge of the physical properties of soil especially texture, because the same volumetric water content can mean very different moisture availability for vegetation according to soil texture. On areas with dense vegetation cover the correlation between remotely sensed black body temperature and surface temperature is much lower than on bare soil, and the regression lines vary according to the seasons (Bonn,1978).

Axelsson and Lunden(1986) studied the soil moisture correlation with thermal IR data for an agriculture area with great variations in soil water content (9 to 60 percent by volume) and soil composition (sand content 29 to 90 percent by weight; clay content 2 to 44 percent and humus content 1 to 37%). The results of the analysis show that there is a definite correlation between soil water content and both day and night temperature ($r=-0.65$ and 0.69 , respectively). Significant improvements are found using processed data such as net radiation, evaporation and thermal inertia ($r=0.72$ to 0.81).

Nieuwenhuis(1986) reported that analysis of the fluctuations of soil surface temperature provides information about soil characteristics at different depths. If vegetation is present, crop temperature can provide information, empirically or by means of numerical simulation models on the availability of soil moisture integrated over the whole root zone.Soil moisture estimations based on remote sensing techniques should carefully be interpreted for both bare and vegetation covered soils because of the variation in soil types and local meteorologic conditions.

Lynn(1986) showed that the maximum diurnal temperature range and the greatest variation between different soils and surface materials occur during mid-morning and after-noon.The results of studies from arid and semi-arid environments also suggested the post-noon period as being suitable for thermal data acquisition.

The presence and type of salts are very important characteristics of soils in arid areas. Salts affect to a varying extent the thermal behaviour of soil surface. Menenti et al., (1986) showed that surface temperature pattern areas where salts are dominant soil constituents can be related more to the interaction between the surface of salt crusts and water vapour of the actual bulk soil thermal properties.

Carlson and Perry(1987) showed that radiometric surface temperature variations, because of the variation in vegetation density can reflect the vertical profile of soil moisture (surface versus root zone). Although horizontal variations in soil moisture were small, the vertical differences between a dry surface and a wet root zone were large. Horizontal temperature differences between bare soil, corn and oats reflect differences in the fractional vegetation cover, as seen by radiometer.

Tricatsoula(1988)reported that the values of thermal band are influenced by salinity only if there is a salt concentration on the soil surface.

2.3 GEOGRAPHIC INFORMATION SYSTEM (GIS) AS AN AID TO IMPROVE THE QUALITY OF THE RESULTS:

2.3.1 GEOGRAPHIC INFORMATION SYSTEM IN GENERAL:

The demand for the storage ,analysis and display of complex and voluminous environmental data has led, in recent years,to the use of computers for data handling and creation of sophisticated information systems (Tomlinson,1976). Effective use of large spatial data is dependent upon the existence of efficient systems that can transform these data into usable information (Marble and Peuquet,1983).

Geographic information system (GIS), a new technology is becoming essential tool for analyzing and graphically transferring knowledge about the world.Geographic information can be related to specific location (defined in terms of points, lines and areas) on the earth.Burrough(1986) defined GIS as "a powerful set of tools for collecting, storing, retrieving at will,transforming and displaying spatial data from the real for a particular set of purposes".
Locational data storage can be divided into two categories: vector storage, where the location of each object is stored explicitly with the object and raster storage, where the location of an object implicity follows its position in the data structure.

From a technical point of view, a geo-information system is a combination of computer hardware and software that is capable of manipulating entities having both locational(where is it?) and non-locational(what is there?) properties. The prefix "GEO" means that the objects are geographic in nature. It distinguishes a GIS from other computer applications.

The need for geographic information in national economic development activities and a variety of other decision making purposes is highlighted.GIS is required for development and conservation of natural resources. GIS's are changing spatial data collection procedures and analytical processes.They are used to assist decision makers by indicating various alternatives in development and conservation planning and modelling the potential out-comes as a series of scenarios. Basic knowledge on the location ,quantity and availability of natural resources is thus indispensable for more rational planning.(Burrough,1986).They have not only facilitated the automation of repetitive processes in conventional map production ,but they have also provided possibilities for new products.

2.3.2 THE USE OF REMOTE SENSING AND GEOGRAPHIC INFORMATION SYSTEMS FOR NATURAL RESOURCES:

In order to extent valuable information from remotely sensed data, they have to be linked to ground truth information ,otherwise the information cannot be related to a definite place.In a geographic information system , a set of mapping tools,the link between remote sensing, earthbound survey and cartography is provided (Burrough,1986). The combination of remote sensing with GIS have been used in several fields, such as soils, land management, watershed management, etc. with very good results(Best and Westin,1984; Cisse et al.,1984; DeVries,1985.....).

Spanner et al.(1983) reported that a geographic information system including Landsat and ancillary data can accurately map soil loss.This system can inventories large areas for predicted soil loss with saving time and money.

Cisse et al.(1984) demonstrated the ability of GIS for natural resources management.A soil map ,land use map ,forest and pasture reserves map and administrative boundary map served as input to the GIS.Tabular data which were used included agriculture production statistics, demographic data, soil capability and suitability information and crop management data. DeVaries(1985) indicated that GIS creates a digital data base which is capable of producing high quality maps and other outputs for natural resources. He added that remote sensing data are the most commonly entered data into GIS in the form of computer classification or visual interpretation which has been transferred to a base map. Fernandez et al.(1986) used the application of GIS for irrigation development in Neuquen Province,Argentina. Laurin et al.(1987) describe a methodology designed to utilize landsat data and geographic information system (GIS) for improving a sediment-yield -index based watershed delineation scheme. Soil and land use maps obtained from Landsat and maps derived information were merged into a georeferenced data base.

3-GENERAL DESCRIPTION OF THE AREA

3-1 LOCATION:

Egypt forms the northern corner of Africa situated between Latitudes 22° and 32° north. The study area is located in the northern part of Egypt(the most northern part of the Nile Delta between the two Nile branches). Its northern limit is the Mediterranean coast while the southern boundary is the present limit of cultivation in the Nile Delta. the area lies between 30° 40' 01" and 31° 00' 46" E.Longitude and between 31° 10' 29" and 31° 30' 17" N.Latitude. The study area is between zero and 4 meters above sea level. The area is separated from the Mediterranean Sea by Lake Burullus.The lake is shallow with presumably clayey bottom. The area covers about 253321 feddans (106339 hectares).
The location of the study area is shown in Fig.(3.1).

3-2 GEOLOGY, GEOMORPHOLOGY AND PHYSIOGRAPHY :

3.2.1 GEOLOGY:

According to Ball(1939) and Said(1962), the region of the Nile Delta is essentially occupied by sedimentary rocks belonging to late secondary to the Tertiary and the Quaternary Eras. Sedimentation is mainly complex of marl,limestone,shales and sandstone facies of shallow marine and /or continental plain.

In a tectonic sense Harms and Wray (In Said,1990) indicate that the coastal area has behaved mainly a passive continental margin. The oldest clearly defined seismic event which can be traced regionally is a prominent reflection that makes the top of the Cretaceous units. This reflector dips northward and can be traced into the mid-Delta area where the rate of dip, in terms of time increases (Fig. 3.2). Two additional tectonics influences overprint this simple subsiding margin scenario. First, a belt of apparently compressional folds extends regionally from Sinai to the Western Desert suggesting a late Cretaceous-Eocene event.Second uplift,rifting and transform faulting occurred in late Oligocene to Miocene time in the Gulf of Suez-Red Sea area.

The evolution of major structural features for a typical north-south cross section of the Delta is Shown in Fig.(3.3). From Jurassic through Cretaceous time a carbonate platform developed south of an east-west lime through the mid-Delta.The carbonate platform is replaced by basinal facies toward the Mediterranean.

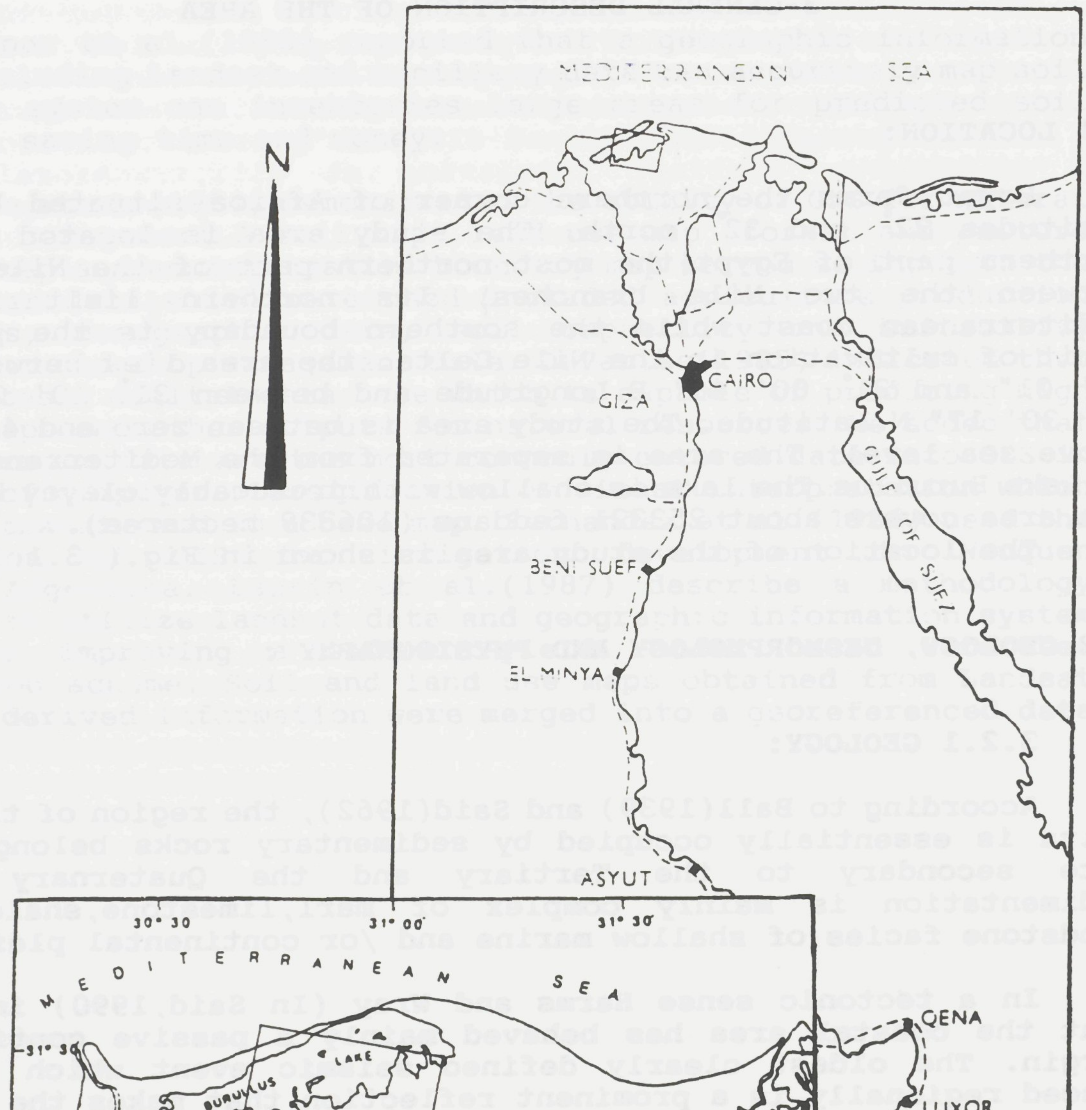

Figure (3.1) Location map of the study area.

Following fault movement,erosion formed a broad angular unconformity in late middle Miocene to early late Miocene time. This angular unconformity is clearly evident on seismic records throughout the mid-Delta. The rocks below the unconformity have been definitely dated as early to middle miocene in the eastern delta.Near the beginning of the Miocene,sea level rose and marine sediments were deposited far to the south over the previously eroded conformity. The area was exposed during the Messinian of salinity crisis, a valley was entrenched, and a thick Pliocene to Pleistocene deltaic wedge was deposited when sea level was restored to near present position of up to 3500 m of sediment in the last four or five million years.

There is no doubt that the growth of the Delta was related to the change in the level of the Mediterranean. The deposition history of the Nile Delta area can be fairly completely reconstructed from the Miocene and Pliocene,but is less known for the early Tertiary.

Early Miocene depositional facies range from non-marine in the south to shelf and slope to the north. During this time period, sea level first rose, then fell slightly, then rose continuously world wide. Probably as a result of this eustatic rise in the sea level, marine waters transgressed far to the south. A middle or early Miocene sandy section at Kafr El-Shiekh may have an associated bathyal fauna and could represent proximal turbidites deposited on a slope or shallow sediments deposited during the low stand in sea level.The thickness of Early Miocene beds is highly influenced by rotational block faulting in the east and west central parts of the delta.

Middle Miocene depositional environments are similar to the early Miocene in that the non-marine deposits occupy the southern part of the delta and rang from paralic to shelf and slope in the northern direction. During this time period,eustatic sea level continued rising to a level higher than present accounting for some marine MIocene outcrops at the south edge of the modern delta plain. Middle Miocene beds are thin or absent over much of the Delta area with a few thicker areas in the east of northeast.

During the Late Miocene time, then was an overall progradation that caused paralic and shelf facies to advance from the mid-Delta to the north-east Delta area. The interval is most noteworthy for the deposition of a sequence of large clinoforms which can be recognized on seismic data in the northeast part of the Delta.There is wide spread evidence of non-marine,shallow marine or evaporite deposition during the latest Messinian in most wells in the area.The late Miocene is Thin in the north-central Delta area because of the removal of Late Miocene during the Messinian lowering of the sea level (five million years before present).

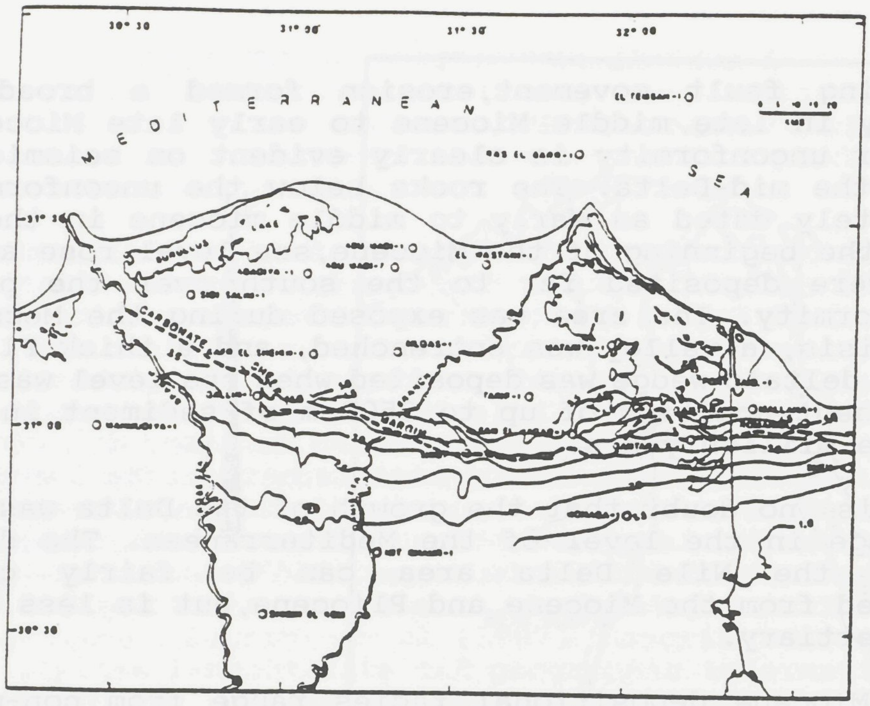

Figure (3.2): Contour map on the top of Cretaceous. The dashed line indicate the probable edge of the Cretaceous massive shelf carbonates. (after Said, 1990).

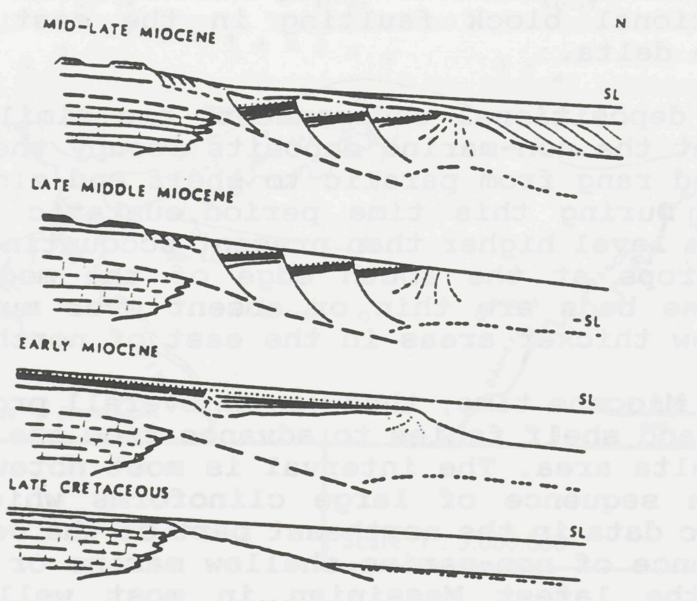

Figure (3.3): Simplified north-south cross-section of the Nile Delta showing the sequence of deposition and deformation from Cretaceous to mid-late Miocene. (after Said, 1990).

The coastal deposits of the area are truly deltaic only in the Pliocene and Pleistocene, in the sense of being caused by large focused supply of sand and mud from an integer river. The initial transgression flooded the ancient Nile Canyon as far as Aswan where Pliocene sediments within the incised area are marine. Muddy sediments occur near the base of the Pliocene section and are overlain by inclined beds of prodelta muds and finally fluvial and shoreline sandy sediments.

3.2.2 GEOMORPHOLOGY AND PHYSIOGRAPHY:

The northern part of the Nile Delta close to the Mediterranean Sea contains of five wide salty lakes occupying an area of about 600 000 feddans.Burullus lake contributes with the majority of this area with the dimension of about 60 Km from the west to the east-north. The lake is located in the middle between the two Nile branches north of the Nile Delta. The lake like other Deltaic lakes is shallow.

The topography of the area is level,except for the sand dunes, towards the north, there is a gradual fall in relative elevation and the natural drainage becomes worse.

Two main landscapes may be distinguished in the area:

1-the fluvio-marine plain
2-the coastal plain

The fluvio-marine plain forms the natural extension of the Delta,but because they are low laying and consequently badly drained, they are very saline.The soils consists of sedimentation which is lacustrine and fluvio-marine origin.The formation of this plain is influenced by both the River Nile and The Mediterranean Sea.

The soils of the coastal plain are predominantly sandy of marine origin. The topography is basically flat except for the sand dunes.

3.3 CLIMATE :

The climate of the northern part of the Nile Delta is characterized by a typical Mediterranean one, with dry summers and cool and wet winters.

The climatic data of the study area are presented in Table(3.1) indicate that:

In summers the temperature becomes higher reaching its maximum in July and August with the maximum (30.8 °C) and minimum (22.9 °C). The mean average temperature in summer is 26.8 °C , while in winter it is 14.5 °C .

The average annual rain fall is less than 190 mm At Baltim (towards the north) it is only 160 mm and at Sakha it is even less (66 mm.) There is precipitation gradient ranging from 200 mm in the north coast to less than 25 mm /year in Cairo (see Fig. 3.4).

The mean annual relative humidity is 70%. The lowest values were recorded in March and April.

Data of daily evaporation ranges from 3.6 to 5.8 mm/day. The daily evaporation is relatively high during summer.

Table (3.1): Meteorological data for the Alexandria station in the northern Nile Delta for the period of 1951- 1983.

	Temperature °C			Rain Fall	Evapo-ration	Relative Humidity
	Max.	Min.	Mean	mm	mm	%
Jan.	18.5	9.2	13.8	48.6	3.6	72
Feb.	19.2	9.4	14.3	28.8	3.4	71
Mar.	21.1	11.1	16.1	9.4	4.1	66
Apr.	24.0	13.2	18.6	3.2	5.0	67
May	27.1	15.1	21.1	1.8	5.8	68
Jun.	29.0	20.0	24.5	0.0	5.6	70
July	30.0	22.6	26.3	0.0	5.5	71
Aug.	30.8	22.9	26.8	0.0	5.6	72
Sep.	29.8	21.0	22.5	0.5	5.1	69
Oct.	28.1	17.6	22.8	8.2	4.3	68
Nov.	24.7	14.4	19.5	35.0	3.7	72
Dec.	20.3	10.6	15.4	54.5	3.6	73
Annual	25.4	15.8	20.4	190.0	4.6	70

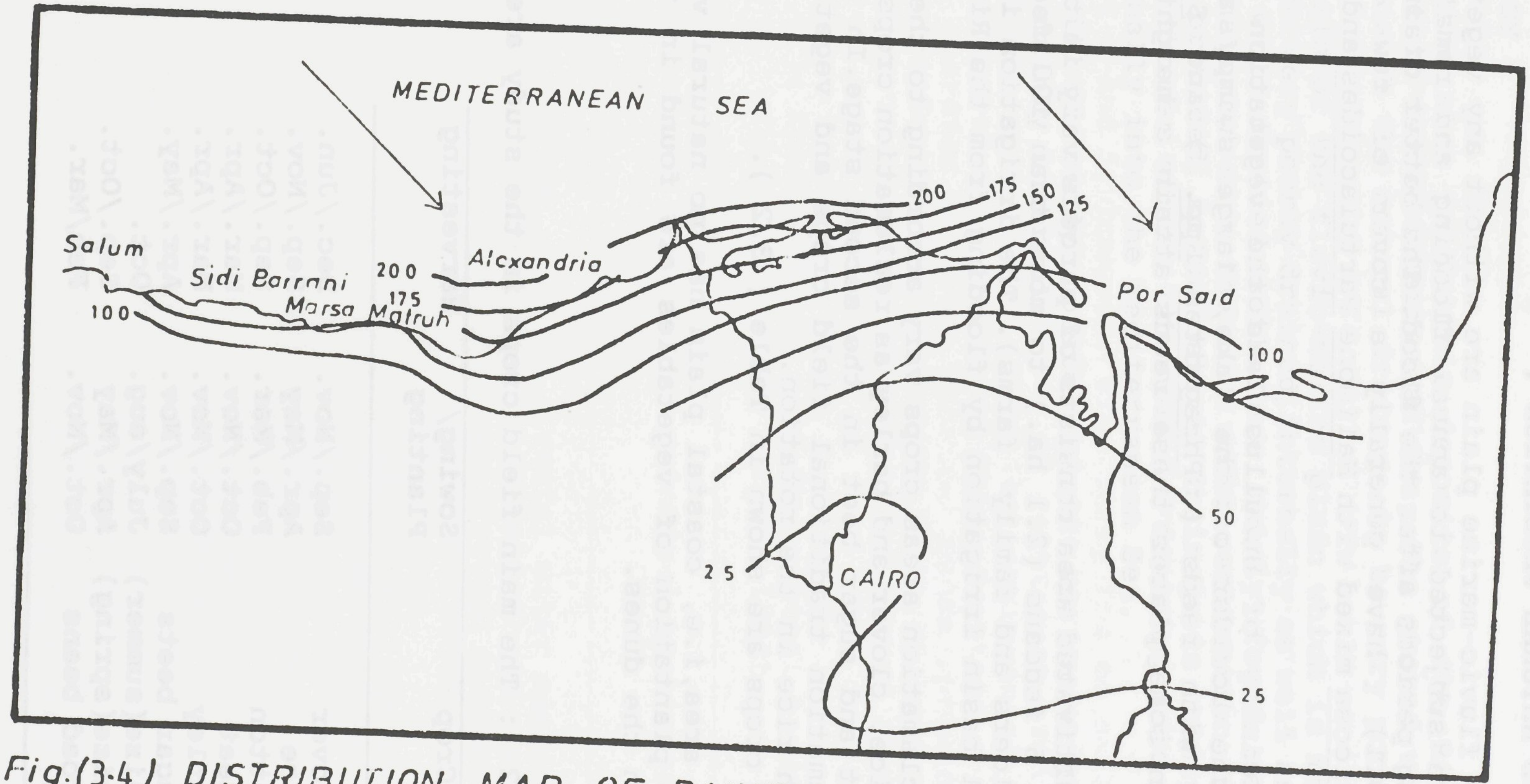

Fig.(3.4) DISTRIBUTION MAB OF RAINFALL ALONG THE NORTHERN COAST OF EGYPT.

3.4 LAND USE AND NATURAL VEGETATION :

The clayey fluvio-marine plain are without any vegetation as far as they are subjected to annual flooding and remain poorly drained for long periods after the flood. The better drained (with cracking topsoil) have generally a cover of few scattered Salicornia Fruticosa mixed with Halimone Partulacoides and Atriplex Spp.

In the vicinity of Burullus lake the vegetation cover is dense. Along the boulder of the lake, large swampy areas are covered mainly with reeds (Phragmites Spp.) and Salicornia Fructicosa . In some places these reeds attain a height of over 2.5 meters.

The old cultivated area consists of parcels vary in their size from lees than 5 feddans (2.1 ha.) to more than 100 feddans (42 ha.),(small holders and family farms). The irrigation is done by the traditional basin irrigation by flooding from the River Nile.

In the reclamation areas crops vary according to the stage of reclamation. Rice, clover and barley as reclamation crops followed by cotton,wheat and sugar beet in the second stage.In the final stage of reclamation traditional field crops and vegetables are cultivated with rice in the rotation.
The main field crops are shown in Table (3.2).

The sandy area,i.e, coastal plain has no natural vegetation at all. Small plantation of vegetables are found in the small valleys between the dunes.

Table (3.2): The main field crops in the study area.

Crop	Sowing/ Planting	Harvesting
Clover	Sep./Nov.	Dec./Jun.
Rice	Apr./May	Sep./Nov.
Cotton	Feb./Mar.	Sep./Oct.
Wheat	Oct./Nov.	Mar./Apr.
Barley	Oct./Nov.	Mar./Apr.
Sugar beets	Sep./Nov.	Apr./May.
Maize(summer)	July/aug.	Oct.
Maize(spring)	Apr./May	Sep./Oct.
broad beans	Oct./Nov.	Feb/Mar.

3.5 HYDROLOGY :

Since the area is deltaic deposits of the River Nile and laying close to the Mediterranean Sea, the ground water table is high which cause the natural drainage to be very poor.

The soils of the fluvio-marine plain which is mainly clayey, are poorly or very poorly drained,internally as well as externally. Moderately well drained soils are mainly found near the main drainage canals.Out side the area under reclamation, no artificial drainage is provided, so the natural drainage is mainly through few gullies and former stream channels is draining into the Burullus lake and finally into the Mediterranean Sea.

The soil of sandy coastal plain are more permeable and drainage is mainly internal.

4-MATERIALS AND METHODS

4.1 MATERIALS:

4.1.1 Landsat Thematic Mapper (TM):

Landsat imagery has been used in soil survey because of its synoptic view and multi-spectral and multi-temporal characteristics. The landsat satellites have proved to be valuable source of remote sensing data since the first one was lunched in 1972 .The multi-spectral scanning (MSS) system of landsat 1,2 and 3 with four bands(4,5,6 and 7), was retained for landsat 4 (lunched in July 1982) and landsat 5 (lunched in March 1984).

Landsat 4 and 5, however, also carry the so called "Thematic Mapper"(TM) which has more bands that are narrow and more properly allocated for the identification of vegetation, soils and rocks than the first generation (MSS).The improvement in spectral resolution compared with MSS is another advantage.

The TM operates in seven spectral bands ,provides new bands in blue, near infrared and thermal parts in the spectrum. The information on band designation is presented in (Table 4.1).

Table (4.1): Characteristics of TM spectral bands. (U.S. Geological Survey, 1982).

band	spectral resolution um		spatial resolution meters	principal applications
TM1	0.45-0.52	V.Blue	30	costal water mapping,soil/ vegetation and deciduous/ coniferous differentiation
TM2	0.52-0.60	V.Green	30	green reflectance by healthy vegetation.
TM3	0.63-0.69	V.Red	30	chlorophyll absorption for plant species differentiation
TM4	0.76-0.96	NIR	30	biomass survey, water bodies delineation
TM5	1.55-1.75	NIR	30	vegetation and soil moisture measurements , snow/cloud differentiation
TM6	10.4-12.5	TIR	120	plant heat stress measurement, soil moisture,thermal mapping,
TM7	2.08-2.35	MIR	30	hydrothermal mapping, lithological studies(rock types)

4.1.2 Choice of the Imagery

The selection of the imagery should be based strictly on the purpose of the work. The basis for the selection of landsat imagery was determined by factors such as time of year or season (climate), cropping pattern, cloud cover, image quality, etc..

A computer compatible tape (CCT) of a quarter of a scene was ordered. The selection of the data based on the need to have not cloudy image with the maximum bare soil.

The data recording parameters are listed below:

1-	Landsat	5
	Path	177
	Row	38
	Quadrant	4
2-	Centre Latitude	31.2518500
3-	Centre Longitude	31.0821800
4-	Scene Acquired at	ITA-FUCINO
	on	18-04-1989
5-	Scene Processed at	ITA-FUCINO
	on	14-02-1990
6-	Format T	BSQ
7-	Tape Density is	1600
8-	Cloud Cover	0000

The data were corrected at the receiving station Telespazzio for the geometric errors listed below:

- Forward/Reverse Alignment	- ADS data
- Mirror Scan Profile	- Ephemeris data
- ACS data	- Detector Placement and delay
- Scan gap	- Line Length Information
- Altitude & Pan Distortion	- Earth Rotation
- Gyro data	- PCD used for correction

4.1.3 Other relevant materials:

The following maps and reports were also conducted:

* Topographic maps of the study area, scale 1:100 000.
* Geological map of Egypt, scale 1:1000 000.
* Soil Survey Reports and Maps covering the main part of the area done in (1962) and (1984) .

4.1.4 Equipment:

A): For image processing and geographic information system (**GIS**), the facility of the Integrated Land and Water management Information System (**ILWIS**) was used. **ILWIS** is a software package which has the capability of combining conventional GIS procedure with image processing capabilities and a relational data base. The system is designed for use with micro computers. It uses both vector and raster graphics data storage.The scheme of its various component is presented in Fig.(4.1), (Valenzuela,1988).

ILWIS was used for the following purposes:

1-Data capture or digitizing for creating an acceptable machine readable data file from a variety of sources,i.e., data from soils, topographic maps and visual interpretation maps (vector format) into computer compatible form ,digital format (raster file).

2-Digital image processing of remotely sensed data.

3-Soil data input (field observations and laboratory determinations) in various tables.

4-Data analysis (map overlay procedures, spatial analysis,etc.)

B): A field Spectro-radiometer (An EXOTECH MODEL) with wave bands (0.5-0.6, 0.6-0.7, 0.7-0.8 and 0.8-1.1 um) was use to measure the reflected radiation from soils and plants.

4.2 METHODS:

4.2.1 Field Work:

4.2.1.1 Field work preparation and observations:

A physiographic analysis was carried out on the false colour composites images of the study area (Zinck, 1989). The detail of the interpretation was such as to bring all the important units of each landscape.

In the first week of the field period a reconnaissance survey was made to get acquainted with broad landscape, the existing roads and to have preliminary knowledge of the soils.

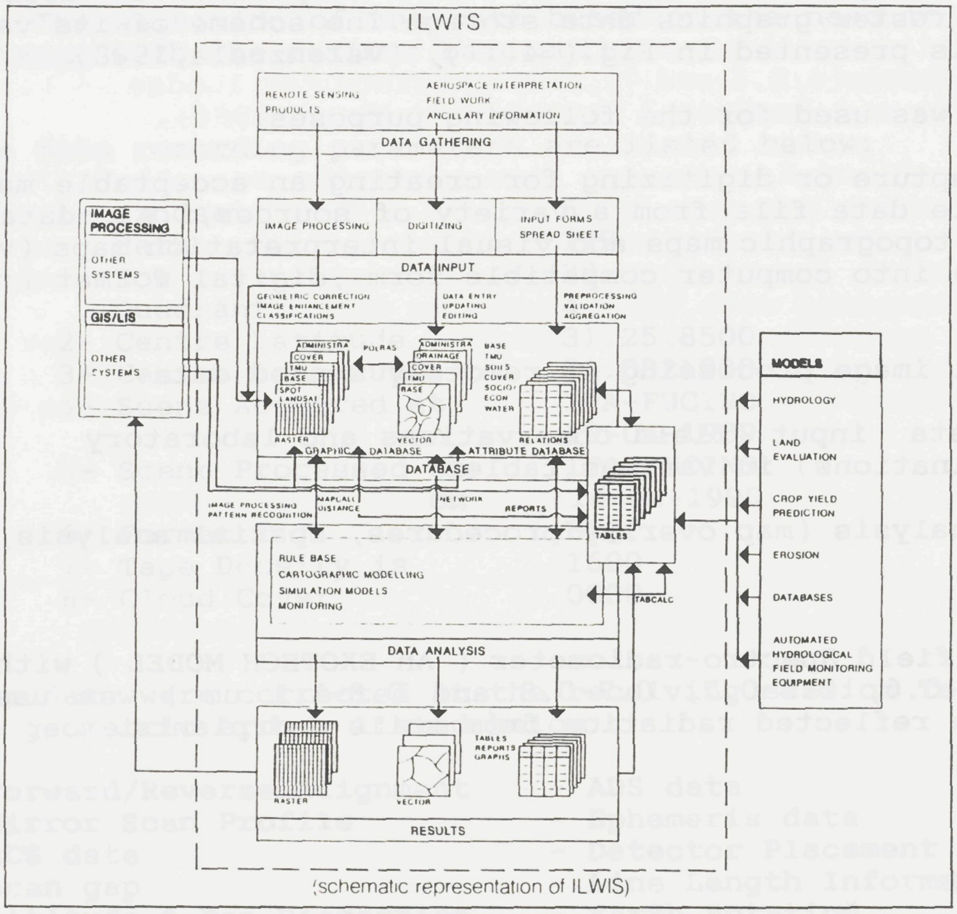

Figure (4.1) Schematic representation of ILWIS.

Observations were located to cover as much as possible all important land forms. Three types of observations were made:

a) Identification observations were made by auguring to 120 cm depth . They were used for checking the boundaries between mapping units.

b) Full profiles observations: eight profiles were selected to represent some of the major soils occurring in the area. Profiles description were made according to the FAO Guideline (1977) and classifications were made according to USDA Soil Taxonomy (1975).

c) Surface soil samples (0-25 cm) were collected. They were used mainly for separating the different saline/alkaline areas.

Soil samples collected from the full profiles and soil surface samples (0-25 Cm) were subjected to the following analysis:

- Particle size distribution (Piper,1950).
- Electrical conductivity in paste extracts (Jackson,1967).
- Soluble cations and anions (Jackson,1967).
- Organic matter,Walkely/Black method (Jackson,1967).
- Exchangeable cations (Gohar,1954).

4.2.1.2 Field spectro-radiometer measurements:

The solar radiation reflected by soils and plants were measured in the field using an EXOTHECH MODEL radiometer with spectral bands (0.5-0.6, 0.6-0.7, 0.7-0.8 and 0.8-1.1 um).

Irradiance measurements were taken from a standard $BaSO_4$ plate as a reference for 100% reflectance. The measurements of $BaSO_4$ plate and the object were taken in very short time to remove the temporal variation in data.

The data were entered in a field computer (SHARP PC 1500), using a program called spectra data (developed by soil survey staff). The program compute the reflectance and there is the possibility to print the reflectance curves.

Reflectance was calculated as follows:

$$\text{Reflectance} = \frac{i}{I}$$

Where:

i= intensity of radiation reflected by the object.
I= intensity of radiation falling on the object.

4.2.2 Visual Interpretation:

Visual interpretation is the simplest and cheapest method of applying remotely sensed data. In the application discussed here, the intention is to provide a technique to assist ground based surveyors to concentrate limited resources in the areas of most pressing demand. It is therefore essential to identify areas of saline soils, but not essential to precisely define the exact extent of any given area. If accurate estimates of affected areas are required then digital techniques are more suitable.

The procedure of visual interpretation was as follows:

1): False colour composite of bands 4,5 and 3 with scale of 1:100 000 was used .
The accurate delineation of different areas was made with the help of different combinations of FFC's obtained from the computer print (scale 1:145 000).
These FCC's are of bands 541, 432, 534, 743, 751, 123 (Fig.4.2 a and b), and also a FCC of PC1, PC2 and PC3.

2): Location of control points on the image which used for the map overlay procedure.

3): Main roads, canals and the location of the main towns and villages were defined.

4): location of known occurrences of target feature, in our case saline areas, cultivated areas, swamps,flooded areas,sandy areas,..were identified.

5): A map of target feature is built by simply tracing the areas that show the same visual appearance on the FCCs.

6): Obviously, with such a simple technique,errors will exit in the classification. However, providing the target feature appearance with ground truth and field work data, these errors should not be too serious.

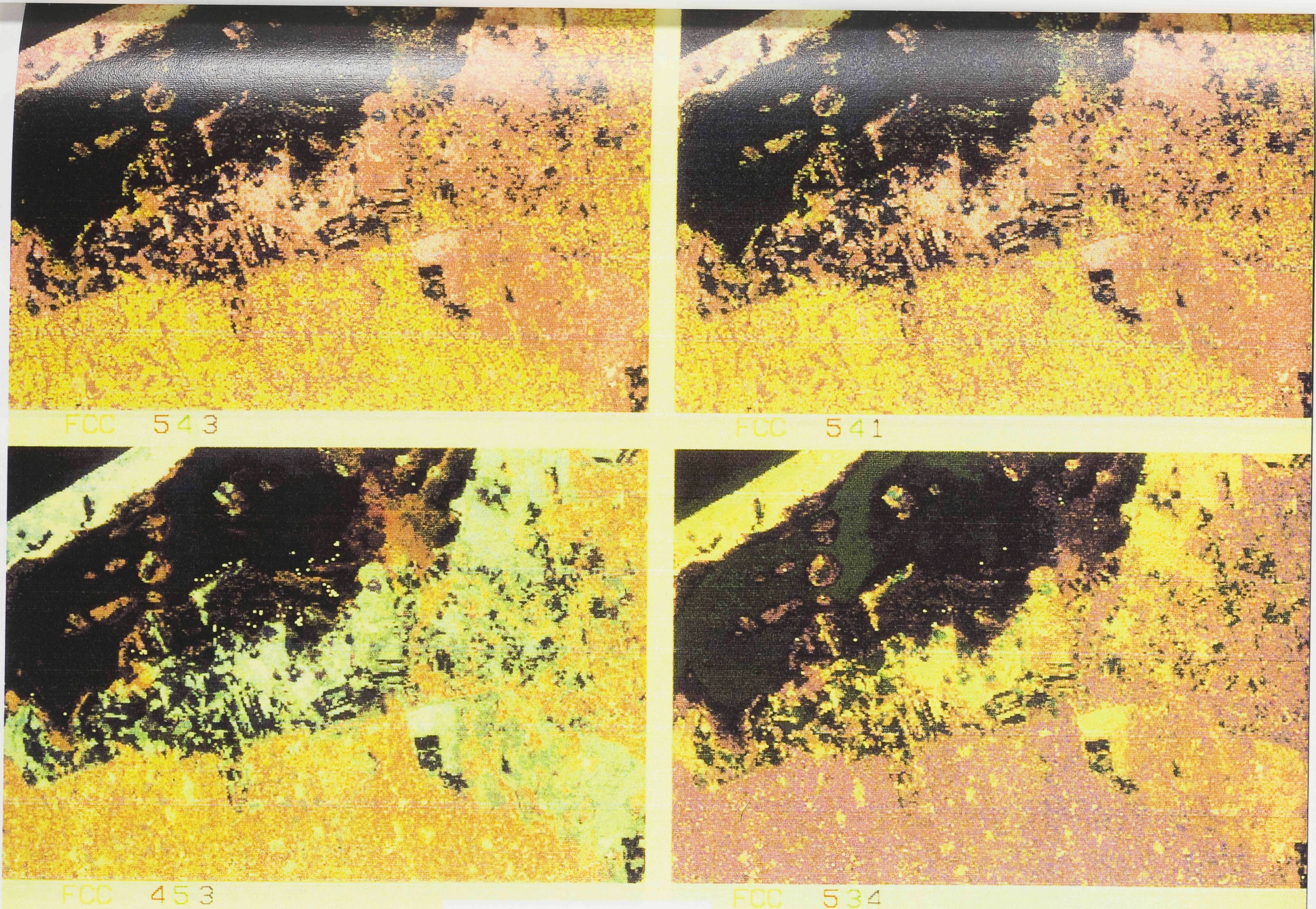

Figure (4.2 b):

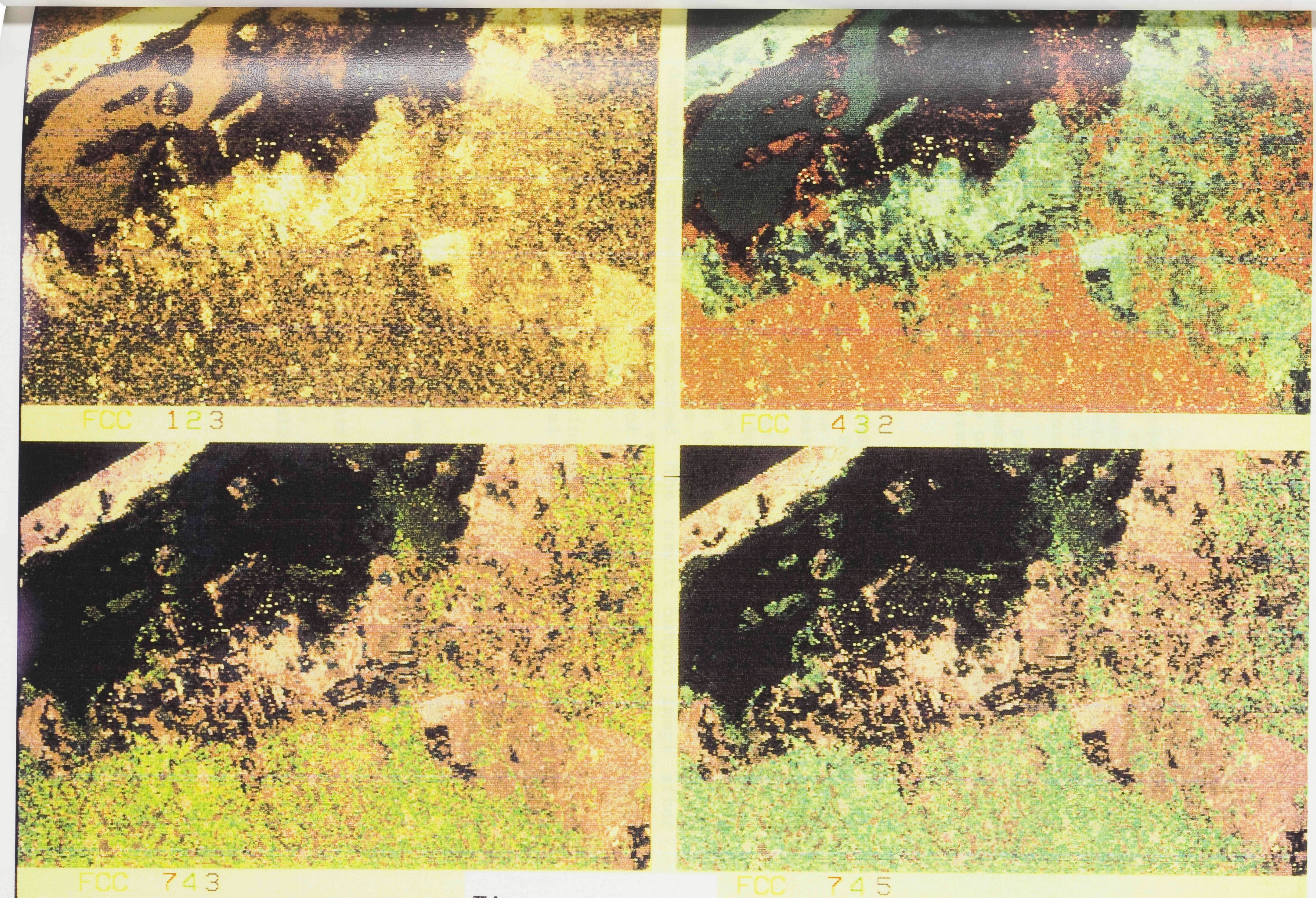

Figure (4.2 a):

4.2.3 Image Processing:

Image processing techniques provide the tools to transform more efficiently the remotely sensed data into information. The image processing procedures were followed to produce the best possible, enhanced image for visual interpretation. Also various statistics can be obtained which are put to use in manipulation of the data and in extracting information from them.

Some of the tasks of image processing are directed at removing distortions resulting from imperfect means of gathering data. The preliminary corrections in the obtained data were already done at the receiving station, Telespazzio.

4.2.3.1 Spatial Enhancement:

In this study spatial enhancement aims to have an output image with enhanced edge that are related to soil and land use differences and use it for the visual interpretation.It is also involved in improving the appearance of the spatial distribution of the data in digital images.

In this procedure the pixel values are not manipulated individually, but in relation to their neighbourhood. Each pixel is supposed to have 8 neighbours in 8 connectivity. So dealing each time with a local minimum area of 3x3 pixels and applying various filters, spatial features as lines, edges or points can be detected, enhanced or smoothed. The result output image after various trails can be used for visual or machine interpretation.

There are several types of filters. In our study the linear and rank filters were used.

A): Linear filters replacing the digital values of each pixel with the average of the digital values of the surrounding pixels in the output image.

$$\text{if an Image} = \begin{bmatrix} a11 & a12 & a13 \\ a21 & a21 & a23 \\ a31 & a32 & a33 \end{bmatrix} \quad \text{and a Filter} = \begin{bmatrix} f11 & f12 & f13 \\ f21 & f22 & f23 \\ f31 & f32 & f33 \end{bmatrix}$$

the resulting value of the central pixel of the image is:

$$\text{Output Image} = [a11\ f11 + a12\ f12 + \ldots\ldots\ldots + a33\ f33]$$

After several trails to find filters that can enhanced the subtle differences which are related to soil properties, the EDGESENH filter was used for spatial enhancement.

$$\begin{bmatrix} -1 & -1 & -1 \\ -1 & 16 & -1 \\ -1 & -1 & -1 \end{bmatrix}$$

EDGESENH FILTER

B): In rank filters the pixel values of the input image are stored in an increasing order, and the middle pixel of the resulting output takes the value of the defined rank. The reassigned existing values to new positions of the image are always integer numbers and not fractional as the normal case in linear filters. So the resulting output pixel values of rank filters keep their physical meaning of photon counts.

In our study **MEDIAN 5** was used as rank filters to reduce the noise in the results obtained from the spectral, thermal and spectral correlation classifications.

An example of how these filters work can be explained as follows in Fig. (4.3) :

The filter (A) with 3x3 matrix is passed over a 3x3 array of original pixels (B). Each pixel value is multiplied by the corresponding value in the filter as shown in (C). The resulting values are summed and the resulting value is assigned to the central pixel.

The filter moves one column to the right and the processes repeat until the filter matches the right margin of the pixel array. The result of this part of the image is shown in (D).

1/9	1/9	1/9
1/9	1/9	1/9
1/9	1/9	1/9

or

1/9

1	1	1
1	1	1
1	1	1

(A)

27	19	25	22	18
26	24	26	22	22
25	28	30	27	25
22	28	32	29	27
19	25	27	30	31

(B)

$$\text{Central pixel} = 1/9 \begin{bmatrix} 24+26+22 \\ +28+30+27 \\ +28+32+29 \end{bmatrix} = 27$$

(C)

26	25	23	22	22
25	26	26	24	26
25	27	27	27	26
23	26	28	29	27
22	25	27	27	25

(D)

Fig.(4.3): The convolution matrices for a low pass filter.

4.2.3.2 Colour Enhancement:

This procedures was done to create new images from original bands in order to increase the amount of information that can be visually interpreted from the data. It aims to produce an image that optimally uses the full dynamic range of display device and at the same time the maximum colour separability using the three primary colours red, green and blue.

In this procedure three bands were selected for red, green, and blue to create different False Colour Composites (FCC 541, 432, 745, 743, 123, 543, 534, and 453). Also a false colour composite of Principal Components PC1, PC2, PC3 was created.

4.2.3.3 Principle Component Analysis:

This procedure is used to improve the speared of the data and to redistribute them about another set of axes in multi-dimensional space, which maximises the separation of differences in the data. In a bi-variant scatter diagram (Fig.4.4),the distribution of points can be expressed by means and variance of the data from the two bands. The variance of a single variable expresses the spread of its values about the mean. A measure of the joint variation of two variables is known as their covariance.When covariance is positive the data are positively correlated, when negative an inverse relationship is present. When it is zero, the two Channels of data are completely independent of each other.

The first step of principle component transformation is to set the means to zero (Fig. 4.4) by shifting the axes. At this stage the axes can be rotated so that one coincides with the line along which the data have the greatest spread.
This new rotated axis is the first principle component (PC1).
An axis at the right angles to this new now define a line along which all the remaining variation is expressed. This is the second principle component (PC2). In space with more than two dimensions this operation continuous to define orthogonal axes which progressively consume all the variations that does not fall on lower order principal components,giving as many principle components as there were original bands of data.

The original n bands of data are projected onto n new principle components as linear additive combinations by using eighnvectors. Each of these is a loading for the contribution of each band to a component. This decorrelation process has the effect of spreading the data to the limits of the new principle components axes.

Principle components (PC1, PC2 and PC3) were used to create a false colour composite image , which is of great help in the visual interpretation procedure.

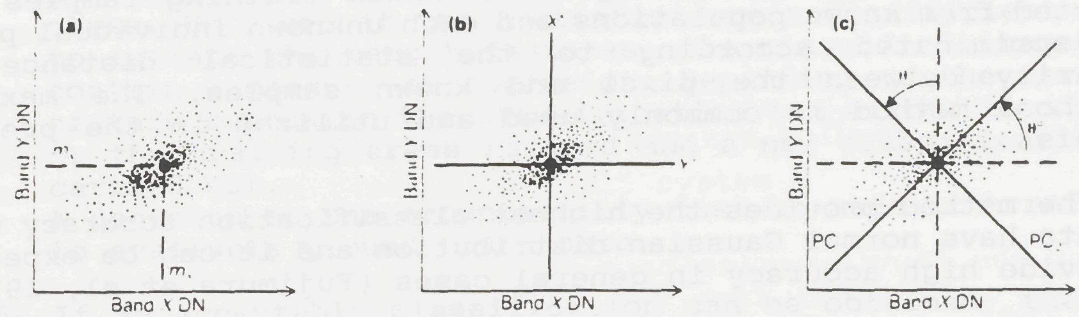

Figure 4.4 Bivariate plots of data from any two bands in the visible and near infrared generally produce an elongate ellipse of points (a) because of strong correlation. Principal component analysis begins by shifting the origin of the plot to the point defining the means (m_x, m_y) of the two sets of data (b). The axes are then rotated through an angle of θ so that one is aligned with the maximum variance in the data (c). This axis becomes the first principal component onto which new values of the data, combining contributions from both bands, are projected. The second axis expresses the variance that cannot be expressed by the first principal component. When these residual data are projected onto this axis they comprise DN for the second principal component.

4.2.3.4 Thermal Infrared Band (TM 6):

The thermal band was dealt separately due to its physical meaning (emissive) and spatial resolution (120 m). The Digital Numbers (DN) values are from 111-212 in the study area. The thermal band was printed in black and white by stretching the pixel values of 1% to 99% (124-177) from 0 to 255 respectively. The image also was filtered for spatial enhancement.

The printed image was used to understand the meaning of the differences in temperature and emmitance of land cover and surface properties.

Using the image processing the thermal band was sliced in 11 levels of pixel values based on the differences in surface properties relating to soil salinity and land cover.

4.2.4 Spectral Classification:

There are two basic approaches to multi-spectral images classification, supervised and unsupervised classification.

Supervised classification generally falls into the field of statistical discriminate analysis in which training samples are extracted from known populations and each unknown individual pixel is discriminated according to the statistical distance or similarity between the pixel and known samples. The maximum likelihood method is commonly used and utilized in the present analysis.

The method provides the highest classification accuracy when the data have normal Gaussian distribution and it can be expected to provide high accuracy in general cases (Fujimura et al, 1978).

The problem in the maximum likelihood classification lies in the development of a routine method which is able to properly and comprehensively inspect the training fields and to ensure the uniformity of the processing (Koda and Shibano,1984). Thus the training data set should satisfy the following requirements: The data should 1): fully reflect the categorical theme information which is visually interpretated and recognized, 2): contain all possible multi-spectral features inherent in each category, and 3): satisfy the priori statistical assumptions/ conditions of mathematical classification procedures.

The spectral classification was performed using ILWIS. The entire area was classified using a supervised Maximum Likelihood classification approach .

The procedure of spectral classification was as follows:

1- Enhanced FCC image is located in ILWIS

2- The next step is to identify the area of target feature.

3- It has to inform the system which bands are to be included in the analysis.If the bands involved are chosen carefully the classification could be enhanced and improved.It seems that using all of the bands available from remotely sensed system would sharpen the discrimination between classes. What happens in practice in the 0.4-2.5 um range of spectrum that as the number of bands used in classification increases beyond certain limit, the accuracy of the result actually declines. A strategy need to be devised to use only those bands which do the job well. In this study using the raw data of bands TM3, TM4, TM5 and TM7 are able to separate different classes with bare soils. Band TM2, TM3, TM4 and TM5 are quite good for the discrimination in cultivated areas.

4- From the statistics obtained using (ML classifier), the system examines each pixel of the image being analyzed and either assigns the pixel to or excludes the pixel from the class.

5- It assumed that the statistics of the training areas are such that only the target features are included into the class. However, if the statistics are not sufficient unique to isolate the target features, the classified image will contain a measure of confusion. Depending on the severity of this confusion the classification can either be accepted or the training areas refined and a new classification carried out.
A decision on the acceptability must be made with reference to available ground truth data.

6- If an acceptable classification can be obtained, then the complete image can be classified to produce a map.

7- Because of the variety of target features in the study area and because of the need to have detailed map of saline areas, masking is made and the study area was separated into three main parts as follows:

a): Coastal plain
b): Fluvio-marine plain with the maximum bare soils. (Recent Reclaimed Area)

c): The cultivated fluvio-marine area. (Old Reclaimed and Cultivated area)

Spectral classification was made for each part individually.

4.2.5 Spectral Correlation:

Spectral correlation is an analysis of reflectance data in terms of known reference spectra (reference vectors). It is a transformation used as a basis for the processing technique (Mulder,1981). The transformation is based on two reference samples. For the fluvio-marine plain (bare soils), moderately saline (**MS**) (EC < (4-8 mmhos/cm) and strongly saline(**HS**),(>200 mmhos/cm) were used. For the cultivated area, bare soil(non saline), (**NS**) and pure vegetation (**V**) were used. These samples were located during the field work and marked on the Landsat images. The corresponding digital values of all six TM bands (TM1,TM2,TM3,TM4,TM5 and TM7) were obtained for these four locations. These values are given below in vector notations:

$$\overrightarrow{HS} = [219\ 123\ 165\ 156\ 210\ 100]$$

$$\overrightarrow{MS} = [\ 81\ \ 36\ \ 40\ \ 39\ \ 51\ \ 27]$$

$$\overrightarrow{V} = [\ 67\ \ 29\ \ 22\ 139\ \ 84\ \ 25]$$

$$\overrightarrow{NS} = [\ 76\ \ 32\ \ 33\ \ 40\ \ 48\ \ 25]$$

The values in each pixel are normalized by the total intensity. The results are the normalized vectors $\overrightarrow{HS}'$, $\overrightarrow{MS}'$, $\overrightarrow{V}'$ and $\overrightarrow{NS}'$.

For the fluvio-marine(bare soils) the normalized soil vector ($\overrightarrow{MS}'$) is subtracted from the soil vector ($\overrightarrow{HS}'$). The resulting vector ($\overrightarrow{DS}$) gives the scale for salinity and is used as the transformation vector, which serve as the weight function in the data compression from the six multi-spectral bands into one.

$$\overrightarrow{DS}' = \overrightarrow{HS}' - \overrightarrow{MS}'$$

The same mathematical procedure mentioned above were also used in the cultivated areas (Nieuwenhuis and Shrestha,1984 and Bakx and Mulder, 1989). The ($\overrightarrow{NS}'$) vector was subtracted from the ($\overrightarrow{V}'$) vector resulting in ($\overrightarrow{DVS}$)' vector which gives the scale of green vegetation index.

$$\overrightarrow{DVS}' = \overrightarrow{V}' - \overrightarrow{NS}'$$

The transformation vectors is thus performed for each pixel as follows resulting in two new images:

For bare soil (image 1) = [$\overrightarrow{DS}'$] [$\overrightarrow{TM}$]

For the cultivated and bare soil(image 2) = [$\overrightarrow{DVS}'$] [$\overrightarrow{TM}$]

By this method the characteristics spectral vectors for soil and crops are mapped into one image.

4.2.6 Integration Of The Results Using Geographic Information System (GIS):

The real utility of remotely sensed data can be achieved when it can be associated with other spatial information (GIS). In order to improve the results obtained from spectral classification, spectral correlation and thermal infrared classification and to transform it into soil salinity map and land use/cover map an additional information from the field data had to be incorporated. This was done using the GIS of ILWIS system.

Two main steps have to be followed:

1): Data Input:

The input data for the procedure were:

A: spectral classification results.
B: spectral correlation results.
C: the thermal infrared classification.
D: the physiographic map resulting from the visual interpretation.
E: digitized maps of the main roads and main canals.
F: soil data.
G: Field Reflectance Measurement From Spectro-radiometer
I: Existing Map of Egypt.

Remote sensing data are in raster formate, so it can be put directly in GIS system.

Physiographic map resulting from the visual interpretation was digitized and rasterized to the grid size of 30 m adjusting to the spatial resolution of TM bands. So they were ready to be used in map overlay program.

In order to have georeferenced data, 11 control points were identified in the topographic map of the study area and in both the TM bands and the physiographic map using the **Addcoordinate** system. So, the resulting TM bands and physiographic map were registered to the topographic map of the area.

2): Data Manipulation:

Ilwis was intensively used to improve the classification and to have a map free of known errors. The analysis were done using **MAPCALC** program.

The remote sensing results were combined with the physiographic map to get two different maps,i.e., soil salinity map and land use/cover map.

Using the technique of overlaid maps and by cross program, tables were produced, showing the classes of remote sensing results occurring in each physiographic unit. Then the number of classes was eliminated by neglecting those with very low percentages in coverage.

The relationship of the remote sensing results (spectral classification, spectral correlation and thermal band classification) and the physiographic mapping units were studied with respect to the soil salinity/alkalinity hazard and land cover differences. Two dimensional tables were created resulting in two output maps, a soil salinity/alkalinity map and land use/cover map.

The salinity map was studied with an existing soil salinity map of Egypt from 1966, to compare them to:

a) evaluate the salinity/alkalinity map
b) monitor the changes in salinity through time.

5- RESULT AND DISCUSSION

5.1 VISUAL INTERPRETATION AND SOIL MAP COMPILATION:

Saline areas usually show high spectral reflectance compared with non- affected ones. The higher the salinity the higher the reflectance. This is clear in all FCC's (Fig. 4.2 a and b). FCC of bands 534 and 541 gave the best help in making delineation of different salinity levels and water logging areas followed by FCC 432. FCC 123 was only useful to separate saline ares from others, but we could not make any sub-divisions with this image .

Sandy saline soils and dunes have the similar appearance on the images as the strongly saline clay soils with whitish surfaces. Differentiation between these areas was made mainly in FCC obtained from principle components (PC1, PC2 and PC3) , and the field observations.

Cultivated area is easily separated from others by the signature of vegetation in FCC 432 and FCC 541. It was possible to separate the highly saline soils (EC 8-16 mmhos/cm) from the moderately ones (EC 4-8 mmhos/cm), the boundary was corrected with the help of the field work data. The separation of the non saline soils within this unit is very difficult and was made according to the field work data and results of other works done in the area.

The area is separated into two main landscapes:

I- the fluvio-marine plain (D).
II- the coastal plain (Co).

Figure (5.1) shows the physiographic map resulting from the visual interpretation procedure.The description of the visual map is presented in Table (5.1) and the field work data are given in Appendix (2 and 3).

After incorporating the field data and the existing data, a general reconnaissance level soil map is compiled. The description of the units is as follows:

I- The Fluvio Marine Plain:

The formation of this landscape is influenced by both the River Nile and the Mediterranean Sea. This plain forms the natural extension of the Nile Delta. It is separated from the Mediterranean Sea by Lake Burullus and a narrow sandy strip with low sand dunes.

This unit covers 190244 feddans (79902 ha). It represents 75.1 % of the study area.

This landscape has a flat topography with a relative few centimetres differences in elevation. The plain is low laying and consequently poorly drained. Towards the north, there is a gradual decrease in elevation and the natural drainage becomes worse, finally resulting into a large body of water,e.g., lake Burullus.

The texture range between clay and clay loam. The soils have locally a medium textured sub-soil of loam, silty loam or sandy clay loam. The variation existing in different areas are mainly variation in the fine sand content. These variations are greater in the sub-soils. The occurrence of a light texture sub-soil in some areas is an important property for soil drainage and reclamation.

The main land forms in this unit are:

1- Association of overflow and decantation basins (D1) and,
2- The swampy areas (D2).

1): Association of Overflow and Decantation Basins:

The subdivisions made in this land form is according to the reclamation stages with emphasis on the salinity/ alkalinity hazard and the surface characteristics related to this hazard.

The main subdivisions made in relation to reclamation stage are:

A): Recently reclaimed lands (D11).
B): Old reclaimed and cultivated lands (D12).

A): The Recent Reclaimed Soils (D11):

This unit comprises the areas under reclamation.It represents 33.6 % of the study area and it covers 85115 feddans (35748 ha)

It was possible visually to separate and map 4 phases based on degrees of soil salinity/alkalinity hazard:

1- (D111): strongly saline/alkaline soils with whitish surfaces and salt crusts (EC >150 mmhos/cm).
2- (D112): strongly saline/alkaline soils with puffed surfaces. (EC from 70-120 mmhos/cm).
3- (D113): very highly saline/alkaline soils , (EC from 40-60 mmhos/cm).
4- (D114): very highly saline/strongly alkaline soils, (Ec from 16-30 mmhos/cm).

The description of the units in this landscape is discussed in the following paragraphs.

SYMBOL: D111
AREA : 9879 feddans (4149 ha) , 3.9 %
MAPPING UNIT: Association of Typic Salorthids and Aquollic Salorthids.

This unit has a flat topography. It occupies the northern part of the fluvio-marine plain. Its northern border is the Burullus Lake. It has abrupt boundary with association D112, association D113 and the flooded areas D117. This unit can be also found in small areas scattering in D116.

The main soils belonging to this unit are deep,dark brown (10YR 3/3, moist) in the top surface and increasing in greyish below 50 cm. After this depth gley phenomena increases with depth. The unit is very poorly drained and the soils are fine textured (clay). The soils are strongly saline/alkaline (EC >150 mmhos/cm, and ESP from 60-85 %). The pH of the soils ranges from 7.5 to 7.8.

The surface is covered by salt crust (whitish surfaces). Locally the salt crust is snow white. Locally, however, the surface may crack to a depth of 50 cm. The cracking is closely connected with relative few centimetres differences in elevation.

SYMBOL: D112
AREA : 9372 feddans (3936 ha), 3.7 %
MAPPING UNIT: Association of Aquollic Salorthids and Typic Salorthids.

This unit has a flat topography . It occupies the north east part (with abrupt boundary with D111 and D113 and a diffuse boundary with D115), and the south east part of the fluvio-marine plain (with diffuse boundary with D113).

The soils are deep and very dark grey (10YR 3/1, moist) to dark brown (10YR 3/3, moist)in colour. They are very poorly drained. The texture is fine (clay to clay loam), strongly saline and alkaline (EC from 70-100 mmhos/cm ,and ESP from 65-70 %). The pH ranges from 7.6-7.9.

Within the units D111 and D112 soils are uniform in surface colour and texture (clay to clay loam). The sub-soils show a wider range in colour and texture. Because of the poor drainage conditions (hydromorphic soils) the colour ranges from very dark grey (10YR 3/1,moist) to black (10YR2/1, moist) and gley colours such as blue (5BG4/1, moist) occur below 40-50 cm depth.

Both units as mentioned above are strongly saline and alkaline soils. The low pH values is due to the buffering effect of the high soluble salts. So, it is obvious that the reclamation of these units need excellent drainage facilities with the addition of gypsum to control the alkalinity hazard.

The two units were easily delineated by their top soil conditions. Soils of D111 have whitish surfaces and locally salt crusts which give these soils higher reflectance and appear very light in the images. The soils of D112 have fluffy appearance (puffed surfaces).Salts are mixed with soil particles and soil surface is greyish,so the soils reflect less than D111 and appear less lighter than D111.

SYMBOL: D113
AREA : 18999 feddans (7979 ha), 7.5 %
MAPPING UNIT: Association of Typic Natrargids , Typic Torrifluvents and Vertic Torrifluvents.

The unit has a flat topography. It occupies the middle and the south east part of the fluvio-marine plain. It is also found in the west and north east of the plain.It has abrupt boundary with D111, D112 and D114 and diffuse boundary with D115 and D116.

The soils are deep and very dark brown (10YR3/2, moist) to dark brown (10YR 3/3, moist) in colour. They are fine textured (clay to clay loam). The soils are very highly saline and alkaline (EC from 40-60 mmhos/cm, and ESP ranges from 40-48 %). The pH ranges between 8.0 and 8.1.

SYMBOL: D114
AREA : 15959 feddans (6702 ha), 6.3 %
MAPPING UNIT: Association of Aquic Natrargids,
Typic Natrargids and Typic Torrifluvents,

This unit has a flat topography. It is found close to D113 with abrupt boundary.

The soils are deep with grey colour. The colour tends to become very dark (10YR2/2, moist). In the sub soil the colour is blue (5BG4/1, moist) and this starts below 20 cm depth (black alkali).The soils have fine texture (clay to clay loam). The soils are v.highly saline and strongly alkaline (EC from 16-30, and ESP from 50-60). The pH ranges from 8.3-8.6.

Within the units D113 and D114 the soils are better drained than in D111 due to the higher drainage net-work provided to the area. As a result of leaching processes in these two units the soluble salts decreased especially in D114. But because of the insufficient addition of gypsum during the reclamation processes the alkalinity becomes a problem in D113 and D114 more than in D111 and D112 (buffering effect of soluble salts in D111 and D112).

The units are easily separated by their surface characteristics. The soluble salts in D113 still have a slight buffering effect for alkalinity. The higher ESP in D114 result in dispersing the organic matter (humus) and clay in the surface resulting in so called black alkali in some areas of D114.As a result the surface of D114 becomes darker with less reflectance and so appear darker than in D113.

SYMBOL: D115
AREA : 1773 feddans (774 ha), 0.7 %

This unit is complex between units of D112 and D113. It is occurred mainly in the north east part close to unit D112 with diffuse boundary.

SYMBOL: D116
AREA : 9119 feddans (3830 ha), 3.6 %

This unit is complex of units D113 and D114. It occupies the part of the area under reclamation close to D113 and D114 with diffuse boundary.

SYMBOL: D117
AREA : 20012 feddans (8405 ha), 7.9 %

This unit comprises the flooded areas. The soils are very highly saline and alkaline with fine texture. These soils are used for fish farming.

B): The Old Reclaimed And Cultivated SoilS (D12) :

The unit comprise the old cultivated lands. It represents 29.9 % of the study area and covers 75742 feddans (31812 ha). The area is easily separated from other unit due to the vegetation cover, so the area appear very clear in all the images.It has abrupt boundary with D11.

The unit covers the south and east part of the plain forming the extension of Nile Delta.

Visually it was not easy to make subdivisions related to salinity in this unit. Delineating the high saline from the moderately saline ones was made visually but the exact boundary was done with the help of the field work data.Separation of the non saline soils was only made in the base of salinity obtained from the field work data and other surveys done in this area.

The unit has flat topography. The soils are moderately well drained. The texture is clay loam to clay.

Three subdivisions were made in this unit:

SYMBOL: D121
AREA : 20012 feddans (8405 ha), 7.9 %
MAPPING UNIT: Association of Typic Torrifluvents, Vertic Torrifluvents.

This unit represent the cultivated area with highly saline and slightly alkaline soils (EC from 8-16 mmhos/cm and ESP from 16-19 %). The pH of the soils ranges from 8.3-8.5.

SYMBOL: D122
AREA : 51930 feddans (21810 ha), 20.5 %
MAPPING UNIT: Association of typic Torrifluvents, Vertic Torrifluvents.

This unit represents the cultivated area which is moderately saline (EC from 4-8 mmhos/cm.). The pH ranges from 8-8.2.

SYMBOL: D123
AREA : 3799 feddans (1595 ha), 1.5 %
MAPPING UNIT: Association of typic Torrifluvents, Vertic Torrifluvents.

This unit represents the cultivated soils which are non saline (EC <4 mmhos/cm). The pH range from 7.9-8.0.

2): Swampy areas (D21):

SYMBOL: D211
AREA : 29385 feddans (12341 ha), 11.6 %

The swamps are bordering the shore of the Burullus Lake. The swamps are mainly covered with reeds (Phragmites Spp.). In some places the reeds attain a height of 2.5 m. The swamps covered with reeds are hardly become dry. The parts of the swamps covered with Salicornia Spp. are dry for part of the year.The soils of the swamps are clayey.

II): The Coastal Plain (Co):

This landscape forms the north west limit of the study area. The soils are sandy texture with marine origin which is formed as an off shore barrier by the Mediterranean Sea.The topography is basically flat with locally low sand dunes. The unit represents 19.1 % of the study area covering 48384 feddans (20321 ha.).

The subdivisions made in this landscape according to the topography are described in the following paragraphs.

SYMBOL: Co111
AREA : 4559 feddans (1915 ha), 1.8 %

This unit has a flat topography. The soils are sandy, well drained. This unit is occasionally flooded by the high sea tide. The soils are deep, light grey brown (10YR6/2, moist) to pale brown(10YR6/3, moist).The soils are well drained . The ground water table varies between 50-100 cm, the soils are highly saline (EC >16 mmhos/cm.)

SYMBOL: Co112
AREA : 506 feddans (212 ha), 0.2 %

The unit has a flat topography .The texture is sandy. It comprises the depression parts which are permanently flooded by the sea water.

SYMBOL: Co121
AREA : 253 feddans (1063 ha), 1 %

The topography of this unit is undulating. It comprises the shifting low sand dunes. The dunes are crescent shaped (barkhan dunes). Locally date palm are planted for stabilizing the dunes. Small plantations of vegetables, figs and grapes are found in the valley between the dunes.

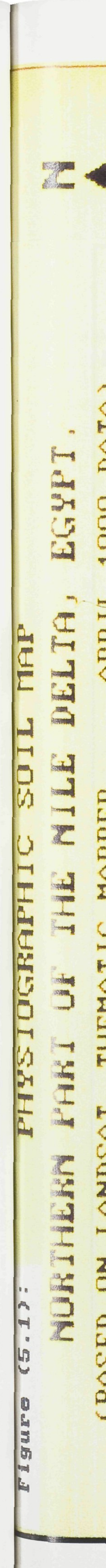

Figure (5.1): PHYSIOGRAPHIC SOIL MAP
NORTHERN PART OF THE NILE DELTA, EGYPT.
(BASED ON LANDSAT THEMATIC MAPPER , APRIL 1989 DATA)

Figure (5.1): PHYSIOGRAPHIC SOIL MAP

NORTHERN PART OF THE NILE DELTA, EGYPT.

(BASED ON LANDSAT THEMATIC MAPPER , APRIL 1989 DATA)

N

0 2 4 6 8 10 km

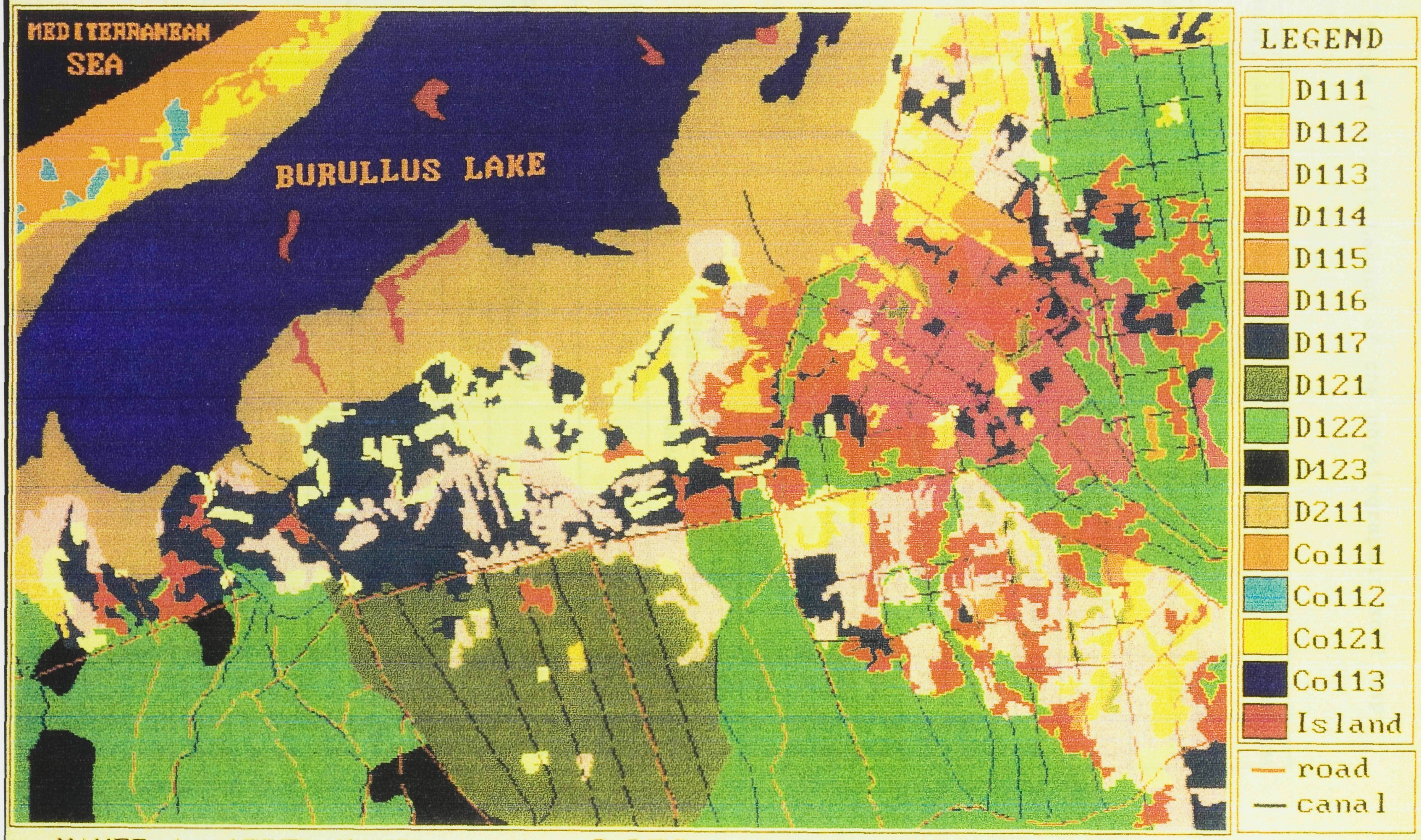

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Table (5.1): Legend of the physiographic soil map.

Land-scape	Relief	Lithology/ Origin	Land Form	Phase	Description	Symbol	Area %
PLAIN	DELTAIC	Fluvio-Marine	Association of Overflow and Decantation Basins	Recently Reclaimed Soils	strongly saline/alkaline with whitish surfaces	D112	3.9
					strongly saline/alkaline with puffed surfaces	D112	3.7
					very highly saline/alkaline	D113	7.5
					very highly saline/strongly alkaline soils	D114	6.3
					complex of D112 + D113	D115	0.7
					complex of D113 + D114	D116	3.6
					permanently flooded soils	D117	7.9
				Old Reclaimed and Cultivated Soils	highly saline soils	D121	7.9
					moderately saline soils	D122	20.5
					non saline soils	D123	1.5
			Swamps			D211	11.6
	COASTAL	Marine	Barrier	occasionally flooded		Co111	1.8
				flooded		Co112	0.2
			Low Dunes			Co121	1.0
			Lagoon			Co131	16.1
					Sea		1.9
					Island		0.5
					Man made features:		
					Roads		1.0
					Canals		3.0

Table (5.1): Cont.

Symbol	Area feddan	Main Soils	Surface Characteristics Texture	Colour	ECe mmhos/cm.	pH	ESP	Remarks
D111	9879	Typic Salorthids Aquollic Salorthids	clay to clay loam	dark brown 10YR3/3	>150	7.5-7.8	60-85	whitish surface locally cracked gley phenomenon
D112	9372	Aquollic Salorthids Typic Salorthids	clay to clay loam	v.dark grey 10YR3/1 to dark brown 10YR3/3	70-100	7.6-7.9	65-70	puffed surface gley phenomenon
D113	18999	Typic Natrargids Typic Torrifluvents Vertic Torrifluvents	clay to clay loam	v.dark grayish brown 10YR3/2 to dark brown 10YR3/3	40-60	8.0-8.1	40-48	
D114	15959	Aquic Natrargids Typic Natrargids Typic Torrifluvents	clay to clay loam	v.dark grey 10YR2/2	16-30	8.3-8.6	50-60	gley phenomenon
D115	1773	Aquollic Salorthids Typic Natrargids Typic Torrifluvents	clay to clay loam	v.dark grayish brown 10YR3/2 to dark brown 10YR3/3	40-80	7.6-7.9	50-60	complex of units D112 and D113
D116	9119	Aquic Natrargids Typic Natrargids Typic Torrifluvents Vertic Torrifluvents	clay to clay loam	dark brown 10YR3/3	16-60	8.1-8.5	50-60	complex of units D113 and D114
D117	20012		clay to clay loam					flooded
D121	20012	Typic Torrifluvents Vertic Torrifluvents	clay to clay loam	v.dark grayish brown 10YR3/2 dark grayish brown 10YR4/2	8-16	8.3-8.5	16-19	cultivated
D122	51930	Typic Torrifluvents Vertic Torrifluvents	clay to clay loam	v.dark grayish brown 10YR3/2	4-8	8.0-8.2	<15	cultivated
D123	3799	Typic Torrifluvents Vertic Torrifluvents	clay to clay loam	dark grayish brown 10YR4/2 to grayish brown 10YR5/2	<4	7.9-8.0	<15	cultivated
D211	29385		clay					swamps
Col11	4559	Typic Torripasamment	sand	light grey brown 10YR6/2 to pale brown 10YR6/3	16-24	7.7-8.0		
Col12	506		sand					flooded
Col21	2533		sand					low dunes
Col31	40784							lagoon

1 feddan = 4200 m²

5.2 DIGITAL INTERPRETATION:

Digital interpretation is more sophisticated method of analyzing remotely sensed data. It involves dealing with the large quantities of digital numbers that make up the image recorded by the satellite. Digital interpretation can only be conducted using computers and thus the costs are much higher than those in the visual interpretation techniques described before.

5.2.1 Spectral Classification:

Image classification aims at replacing the visual analysis of the image data with a quantitative technique. It categorizes all pixels in a digital image into one of several classes which may be used to produce a thematic map of the area. A number of target features can be identified from the image and mapped from their spectral signature.

The digital classification is based on the spectral properties of the surface materials.

In the spectral classification discussed below computer has been used :

1- To generate a simplified image of the study area indicating those areas which may be affected by salinity or water logging. This effectively replicates the results obtained in the visual interpretation.

2- To generate a more detailed map of the area indicating where possible the severity of the saline effects.

The initial results of the spectral classification using the supervised maximum likelihood classification gave 58 spectral classes.

The final spectral classes was selected first by eliminating those classes with very low percentages. The result of this step reduced the number of classes to 44 classes. Then the spectral curves were compared in pairs. If the spectral curves were similar then the classes were compared visually taking into account the field work observation and the percentage of coverage of each class, and finally one class was kept instead of two.If the spectral curves were different or visually the classes were covering different types of land cover both classes were kept.

The initial number of classes reduced to 27 classes according to the above mentioned measures are as follows:

Coastal plain classes	from	14	to	5	classes.
Fluvio-marine (bare soils)	from	27	to	13	classes.
Fluvio-marine(cultivated)	from	17	to	6	classes
Lake				1	class.
Swamp				1	class.
island				1	class.

The final stage was giving the descriptive names to the final classes.

The spectral classes were fully transformed to information classes and final evaluation of the classes was done. The final classification is presented in Fig.(5.2) and Table (5.2).

In general the spectral classification can be evaluated as very good for the detection of different salinity/alkalinity hazard levels. Soils with salinity/ alkalinity hazard were well identified because of the differences in reflectance in the visible and near infrared bands. Infrared bands are more helpful in this differentiation especially TM5 and TM7. It was possible to separate 12 classes of salinity/alkalinity hazard using the spectral classification methods (Table 5.2).

Because of the encrustation of salts on the surface, these areas appear white as they reflect very high in all spectral bands compared to the neighbouring saline soils and so these areas are easily separable.

According to the surface characteristics it is also possible to separate two classes within the same salinity level (EC 70-100 mmhos/cm.), the first one with Whitish surface which reflect more in all bands than the second soils which have puffed surfaces.

Within the very highly saline soils it was possible to separate 6 classes related to the severity of alkalinity and water logged. Leaching of salts during the reclamation processes with the insufficient addition of gypsum lead to the increase of the alkalinity, especially in classes 10,11 and 12. Increasing the alkalinity reduce the reflectance in all bands and especially in bands TM5 and TM7. The best example for that is class 11 and class 12.

Water logged areas could be detected with reasonable accuracy owing to their lower reflectance in all bands, resulting in darker tone on the images compared to the adjacent soils . The best examples of these areas are in classes 9, 11 and 12.

With the spectral classification it was also possible to identify the different types of land cover,i.e. green crops, crop residues, dry crops, ploughed areas,rice fields and the urban areas(villages). The main problem was the confusion of the irrigated ploughed areas and rice fields .

From the above mentioned discussion several levels of soil salinity and cover types were successfully classified by the supervised maximum likelihood multispectral classification.

It is expected that TM data would exhibit an improved performance in multi-spectral classification due to the improved characteristics compared with the first generation of Landsat satellites. These improvement are 1): increased spatial resolution, 2): higher resolution and 3): inclusion of thermal band.

The improved spectral and radiometric characteristics of TM increases the classification accuracy (Williams et al,1984 ; Iron et al,1985 and Toll,1985). The increase in spatial resolution reduce the number of mixed or boundary pixel and hence higher accuracy may be achieved (Pitts and Badhwar,1980 and Jackson et al,1983).

Figure(5.2): FINAL SPECTRAL CLASSIFICATION CLASSES NORTHERN PART OF THE NILE DELTA, EGYPT. (BASED ON LANDSAT THEMATIC MAPPER, APRIL 1989 DATA)

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Figure(5.2): FINAL SPECTRAL CLASSIFICATION CLASSES
NORTHERN PART OF THE NILE DELTA, EGYPT.
(BASED ON LANDSAT THEMATIC MAPPER , APRIL 1989 DATA)

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Table (5.2): Final spectral classification classes

class	area	Spectral Signature mean digital number					Description	Eva.
	%	TM2	TM3	TM4	TM5	TM7		
1	0.9	80	105	95	154	96	salt crust	++++
2	0.7	60	74	70	117	71	very whitish soils	++++
3	0.2	59	76	70	103	64	whitish soils	++++
4	0.6	58	69	64	96	61	white grayish soils	+++
5	2.1	52	60	56	92	58	light grayish soils	+++
6	1.5	49	60	54	81	54	light grayish soils	+++
7	2.9	49	52	51	80	52	grayish soils	++++
8	4.2	45	51	48	78	50	dark grayish soils	+++
9	3.6	40	47	43	70	45	v.dark grayish soils	++++
10	3.1	39	46	42	63	38	light dark soils	++++
11	3.9	37	41	38	57	33	dark soils	+++
12	0.9	36	38	33	45	26	very dark soils	++++
13	9.0	38	38	20	10	5	flooded soils	++++
14	3.2	30	24	120	78	24	green crops	+++
15	9.8	32	30	90	65	26	crop residues	+++
16	7.0	33	32	70	60	29	dry crops	+++
17	6.0	38	42	47	62	30	bare soils	++++
18	1.3	31	36	40	45	23	irrigated bare soils	++
19	11.6	29	25	25	25	20	swampy areas	++
20	0.7	58	77	67	100	74	coastal sand dry	+++
21	0.7	53	60	50	75	44	coastal sand moist	+++

+ = poor ++ = moderate +++ = good ++++ = v.good

Table (5.2): Cont.

Class	Area %	Spectral Signature mean digital number TM2	TM3	TM4	TM5	TM7	Description	Eva.
22	0.2	36	40	25	16	8	coastal sand flooded	++++
23	1.3	72	96	90	144	94	sand dunes	++++
24	16.1	36	34	17	10	5	lake	++
25	1.9	33	29	12	10	5	sea	++++
26	1.9	46	58	66	110	80	urban, villages	+++
	0.5						Island	
	1.0 3.0						man made features: roads canals	

+ = poor   ++ = moderate   +++ = good   ++++ = v.good

5.2.2 Spectral Correlation:

Spectral correlation was evaluated as good for the discrimination of salinity/alkalinity hazard as well as water logged areas and land cover/use classes.

With the spectral correlation procedure 28 levels were obtained. These were reduced to 16 classes taking into account the same steps followed in the spectral classification. The final classes transformed into information classes and are presented in Fig.(5.3) and Table (5.3).

The spectral correlation classes are similar in their boundary and percentages to that of the spectral classification classes methods (>70 % similarity).

In this method it was not possible to separate the salt crust areas individually like in the spectral classification technique. But the confusion of the rice field and the irrigated ploughed areas which was found in the spectral classification was solved. The method clearly classified both as ploughed areas.

The method is very accurate in delineating the flooded areas and the alkaline soils (water logged areas). It is also good in the land cover units, especially with the green crops.

An important problem for the spectral correlation is the presence of class boundary whose persistent effects might be often over looked by empirical treatments. For the pure pixel there exits little difficult in the determining the appropriate classification categories. However, for the impure or boundary pixel there can be considerable difficultly associated with the treatment of class mixture or boundary effects. This is clear in the urban situation which has class boundary with the crops and the whitish soils resulting in class confused the urban areas with soils and crops.

The result obtained from the spectral classification and spectral correlation indicate that both methods are not helpful in detecting and locating the salinity level less than 8 mmhos/cm. This becomes more difficult in the cultivated areas as the reflectance is mainly related to the standing crops and not from the soils.

For that we decided to improve the classification results interactively by incorporating these results with the visual interpretation results and the field work data using the Geographic Information System (GIS)to have more accurate classes about the area.

Figure (5.3): FINAL SPECTRAL CORRELATION CLASSES
NORTHERN PART OF THE NILE DELTA, EGYPT.
(BASED ON LANDSAT THEMATIC MAPPER , APRIL 1989 DATA)

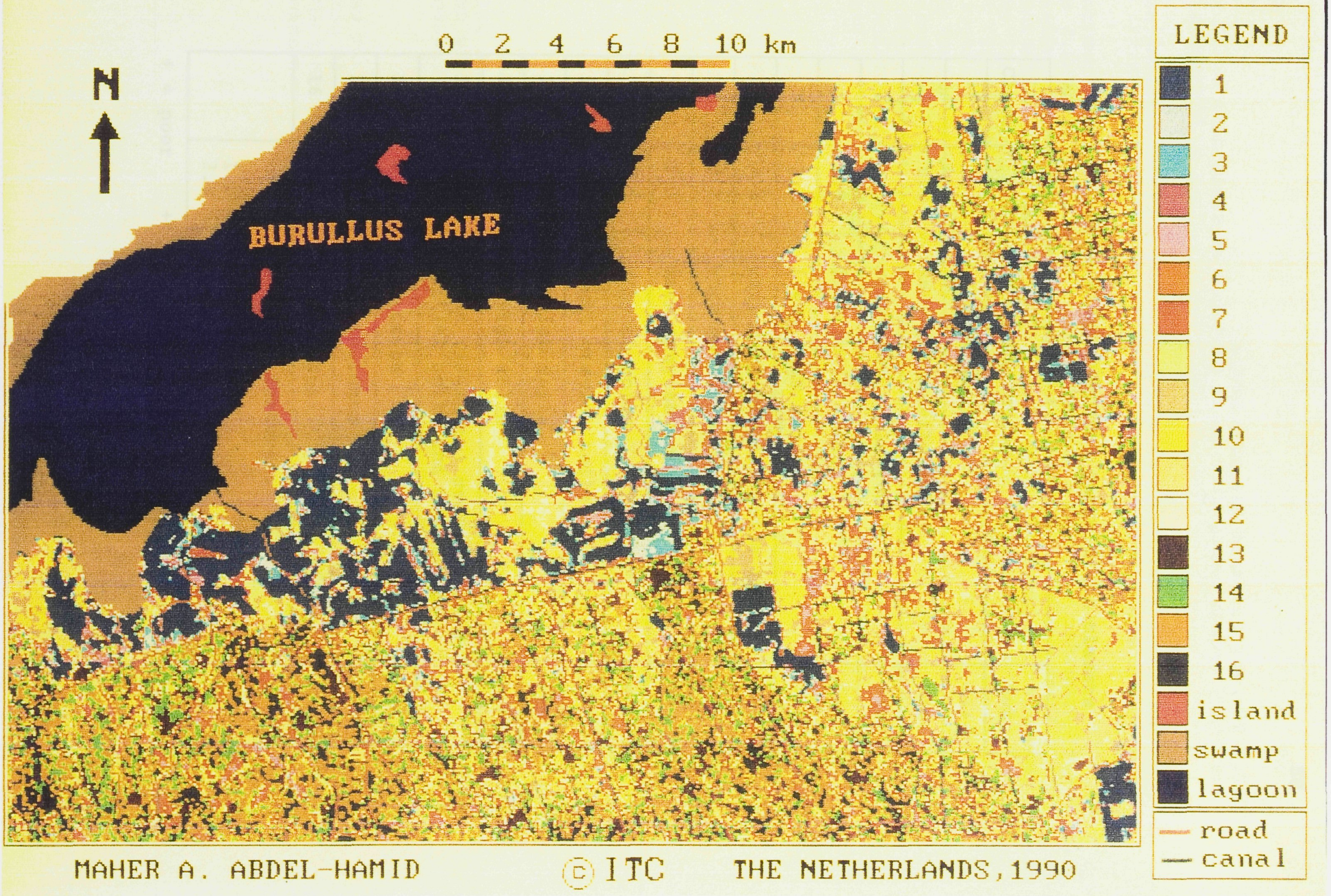

Table (5.3): Final spectral correlation classes

Class	Area %	description	Eva.
1	8.2	flooded soils	++++
2	0.9	very dark soils (wet)	++++
3	1.3	very dark soils (wet)	++++
4	0.9	dark soils (moist)	+++
5	1.4	light dark soils	+++
6	2.4	very dark grayish soils (moist)	+++
7	3.8	very dark grayish soils	+++
8	5.2	dark grayish soils	++
9	5.9	grayish soils	++
10	5.9	light grayish soils	++
11	4.6	whitish soils	+++
12	2.1	whitish soils	+++
13	6.5	urban (villages) confused with whitish soils and some crops.	+
14	6.4	dry crops	+++
15	5.8	crop residues	+++
16	3.4	green crops	++++
		man made features:	
	1.0 3.0	roads canals	

+ = poor ++ = moderate +++ = good ++++ = v.good

5.2.3 Thermal Infrared Classification:

Thermography is based on the measurements of emitted thermal radiation from the objects at the Earth's surface.

The thermal properties of surface material which control energy transfer are very different from those in the 0.4-2.5 um region of the electromagnetic spectrum. As a result, the thermal images are often poorly correlated with those from visible and near infrared images. They provide an extra dimension for the discrimination of different soils and vegetation. (Fig.5.4).

The interpretation of the thermal image shows that the temperatures of bare soils are different from that of vegetation covered areas. Surface temperature of bare soils are directly related to surface characteristics and processes at the surfaces. The clay soils appear cooler than the sandy soils, due to high water retention of clay.

The variation in tone or digital number in the thermal image are measure of the radiant emission of the surface. Table (5.4) shows the level slicing of the thermal band which is based on the differences in land cover and surfaces characteristics of bare soils. Unlike the images of the shorter wave length radiation, the thermal band (Fig.5.4) expresses variations in surface temperatures and not reflectance. Cooler areas(sea, lake and flooded areas) have darker tone while the warmer(salt crust and strongly saline areas) appear light. Similarity, the green crops is cooler than the dry ones.

The problem in the thermal infrared interpretation is that the very highly saline/alkaline soils(EC from 40-60 mmhos/cm.) appear more warmer than other areas including the areas with salt crust. This was verified in the field since this area is very dry (<7 % moisture content) and thus appears in the thermal image light (warmer) in black and white thermal image.

Delineating of swampy area is very easy using thermal. It was also possible to separate two types of swampy areas. The main part of swamps which covered with Phragmites Spp appear cooler than the part covered by Salicornia Spp. This is due to the permanent present of water in the first case.

It is also clear to separate areas with green crops, residues and dry crops.

Ploughed areas are not identified in the thermal image as they are irrigated and thus classified within moist bare soils.

In conclusion the values of the thermal band is more effective in detecting the strongly saline areas (EC > 100 mmhos/c) and more clear if the soils have salt crust on the surface. The soils with salt crust emit very low because of their higher reflectance and so appear more warmer than the neighbour soils. With soils with less salinity (EC < 80 mmhos/cm) confusion may occur with dry soils especially saline ones (EC from 40-60 mmhos/cm.), as these dry soils appear warmer as the strongly saline ones.

The following chapter will explain how the results obtained from thermal, spectral classification and spectral correlation were used in GIS to compile the final maps.

Figure (5.4): SLICING OF THERMAL BAND (TM6)

NORTHERN PART OF THE NILE DELTA, EGYPT.

THEMATIC MAPPER APRIL, 1989.

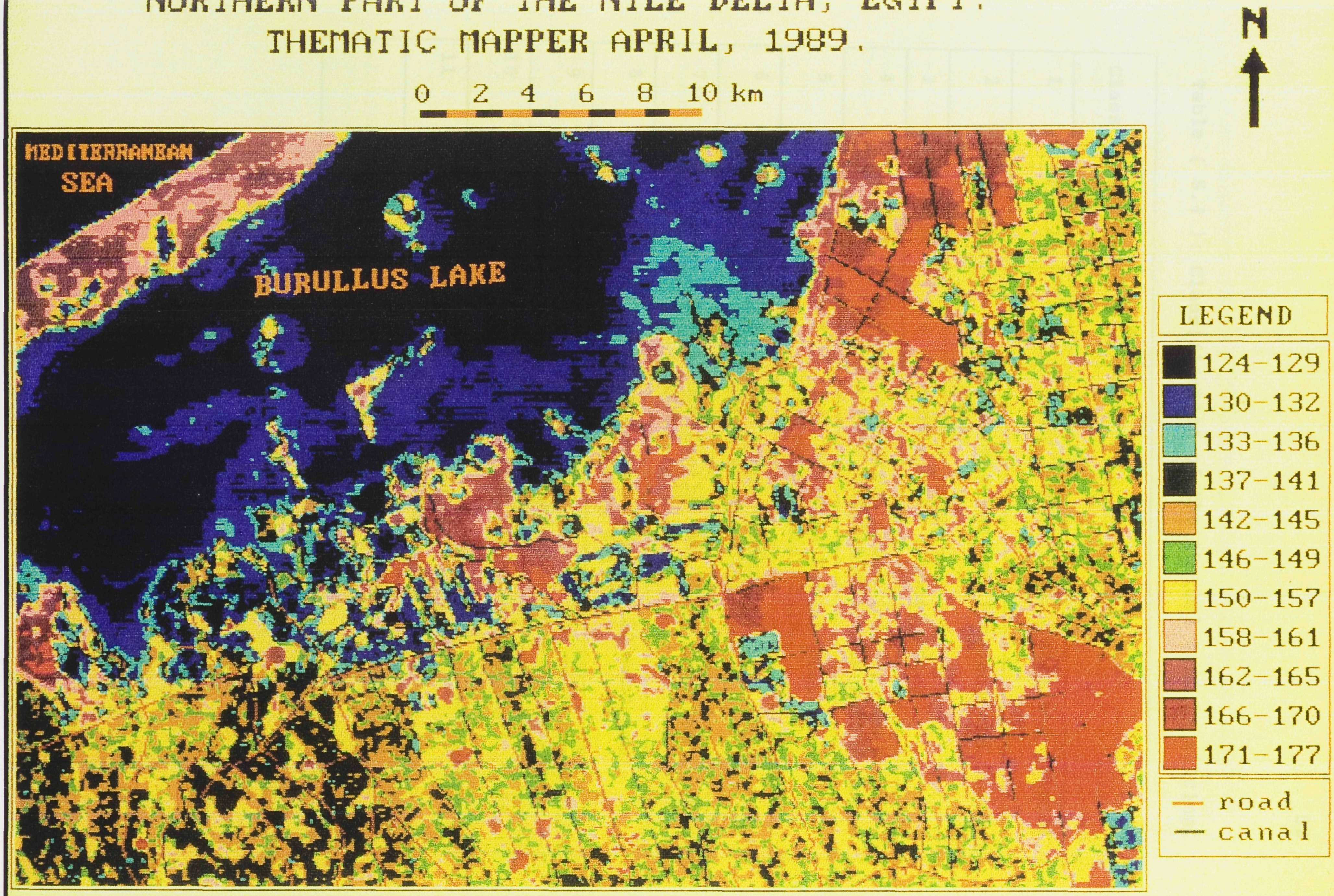

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Table (5.4): Classification of the thermal band by slicing.

Class	DN value range	Area %	Description
1	124-129	18.1	water bodies (sea, lake) and flooded areas
2	130-132	11.1	swamps(permanent flooded) and flooded areas
3	133-136	3.8	swamps, few flooded areas
4	137-141	9.6	dark green crops (clover,few sugar beets, vegetables), few wetted areas
5	142-145	10.3	crop residues (sugar beets), few irrigated bare soils
6	146-149	11.3	dry crops (wheat, barley), bare soils, urban areas(villages).
7	150-157	13.4	bare soils (EC 40-60 mmhos/cm), urban areas (villages)
8	158-161	4.3	bare soils (EC 70-100 mmhos/cm), moist sandy soils
9	162-165	5.2	bare soils (EC 70-100 mmhos/cm with whitish surfaces), dry sandy soils
10	166-170	4.3	bare soils (EC >150 mmhos.cm), salt crust.
11	171-177	4.2	very dry bare soils (EC 40-60 mmhos/cm)
		1.0 3.0	man made features: roads canals

5.3 INTEGRATION OF THE RESULTS USING GEOGRAPHIC INFORMATION SYSTEM (GIS) :

The main objective is to generate final maps using all the information and results from all the different procedures previously discussed,i.e, visual interpretation, spectral classification, spectral correlation and thermal information with the result of the field work .

These final maps are :

1- Soil salinity/alkalinity map.
   a) soil salinity map
   b) soil alkalinity map

2- Land use/cover map.

3- reality of the soil salinity classes

To get these maps the facility of a geographic information system is needed. The Integrated Land and Water management Information System (ILWIS) has the capability to integrate remote sensing data as well. It has the capability to integrate raster , vector and non-spatial data.

The system was used to integrate the results obtained from the spectral classification , spectral correlation , thermal band and the visual interpretation maps (raster and vectors) together with the data and information gathered from the field work.The complex model can be transformed using operators such as the conditional (IF, THEN, ELSE), relational (=, < , >, >=, <=), logical (AND, OR, XOR) or mathematical functions.

The procedures followed to integrate all the available information in order to have the final soil salinity/alkalinity hazard map as well as the land use/cover map are presented in Fig.(5.5).

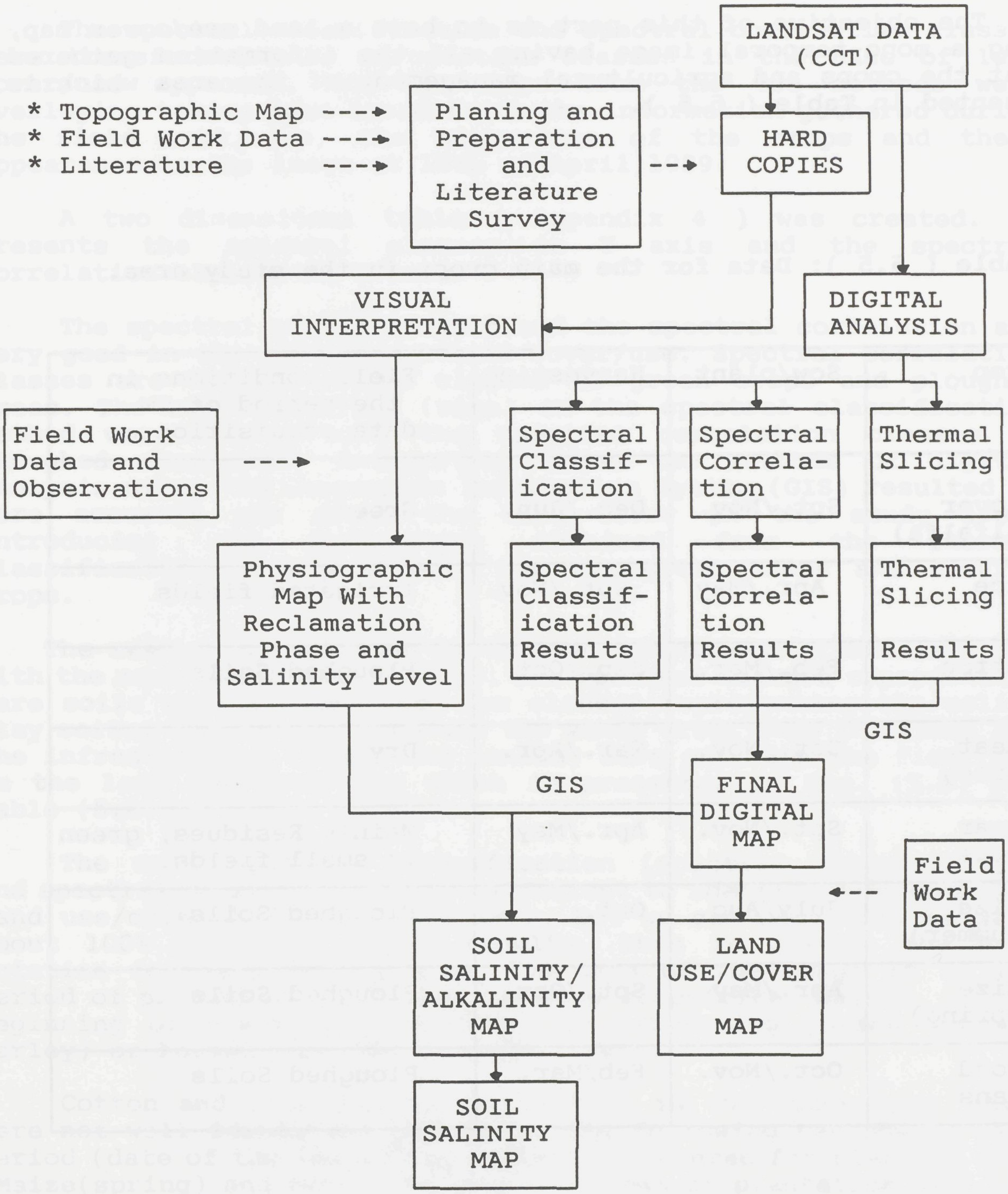

Figure (5.5): Flow chart showing various methods used and combinations of the results using GIS.

5.3.1 Land Use/Cover Map:

The objective of this part is to have a land use/cover map, using a mono-temporal image having all the information gathered about the crops and agricultural management of the area which is presented in Table (5.5).

Table (5.5): Data for the main crops in the study area.

crop	Sow/plant	Harvesting	Field conditions in the period of TM data acquisition
Clover (Alfalfa)	Spt./Nov.	Dec./Jun.	Green
Rice	Apr./May	Spt./Nov.	Irrigated fields
Cotton	Feb./Mar.	Sep./Oct	Ploughed Soils
Wheat Barley	Oct./Nov.	Mar./Apr.	Dry
Sugar Beets	Spt./Nov.	Apr./May	Mainly Residues, green in small fields.
Maize (summer)	July/Aug.	Oct.	Ploughed Soils
Maize (spring)	Apr./May	Spt./Oct	Ploughed Soils
Broad Beans	Oct./Nov.	Feb/Mar.	Ploughed Soils

The spectral classification and spectral correlation classes were transformed into information classes in the base of land cover/use approach. The two maps from the two methods were overlaying taking into account all the information gathered during the field work,.i.e, the occurrence of the crops and their appearance in the image at 18th of April,1989.

A two dimensional table (Appendix 4) was created. It presents the spectral classes in Y axis and the spectral correlation classes in X axis.

The spectral classification and the spectral correlation are very good in the classes of land cover/use. Spectral correlation classes are better in the classes of green crops and ploughed areas. The confused class (rice) in the spectral classification method were solved with the spectral correlation classes as ploughed areas. So, integrating these two methods of digital analysis using the Geographic Information System (GIS) resulted in more accurate map about the land cover in the study area. Introducing the information obtained from the thermal classification gave good help for the green crops and matured crops.

The result map obtained by the two dimensional table is a map with the most acceptable classes. The spectral classes representing bare soils were grouped into few classes representing the saline clay soils, the flooded area and the sandy area. Onto the final map the infrastructure (roads and canals) were put, and the final map is the land use/cover map which is presented in Fig. (5.6) and Table (5.6).

The multi-spectral classification (spectral classification and spectral correlation) were sufficient to identify many detailed land use/cover classes in the area. But we can not still be sure about 100% accuracy in the results. This is due to the crop rotation followed in the area. The date of the image is in the period of preparing the fields for many crops(rice, maize), or the beginning of plantation (cotton), or harvesting period (wheat, Barley) or harvesting time of sugar beets.

Cotton and rice are two main crops in the study area. They were not well identified because of the following reasons.In this period (date of the image) the farms are prepared for planting rice ,Maize(spring) and cotton is only 2-3 weeks of plantation time. So the reflectance of these fields is mainly due to the soils. For that all the three crops are in the group of ploughed soils.

Comparing the land use map with the classification of the thermal band in agricultural area, it was found that the green crops cover larger area in the thermal image than in the land use map. This can be explained from the area of ploughed soils which is well identified in the reflective bands by the spectral correlation and the spectral classification methods. This was not well identified in the thermal band due to their moisture content and for that they appear cooler (darker) and confused with the green crops.

Figure (5.6): LAND USE/COVER MAP

NORTHERN PART OF THE NILE DELTA, EGYPT.

(BASED ON LANDSAT THEMATIC MAPPER , APRIL 1989 DATA)

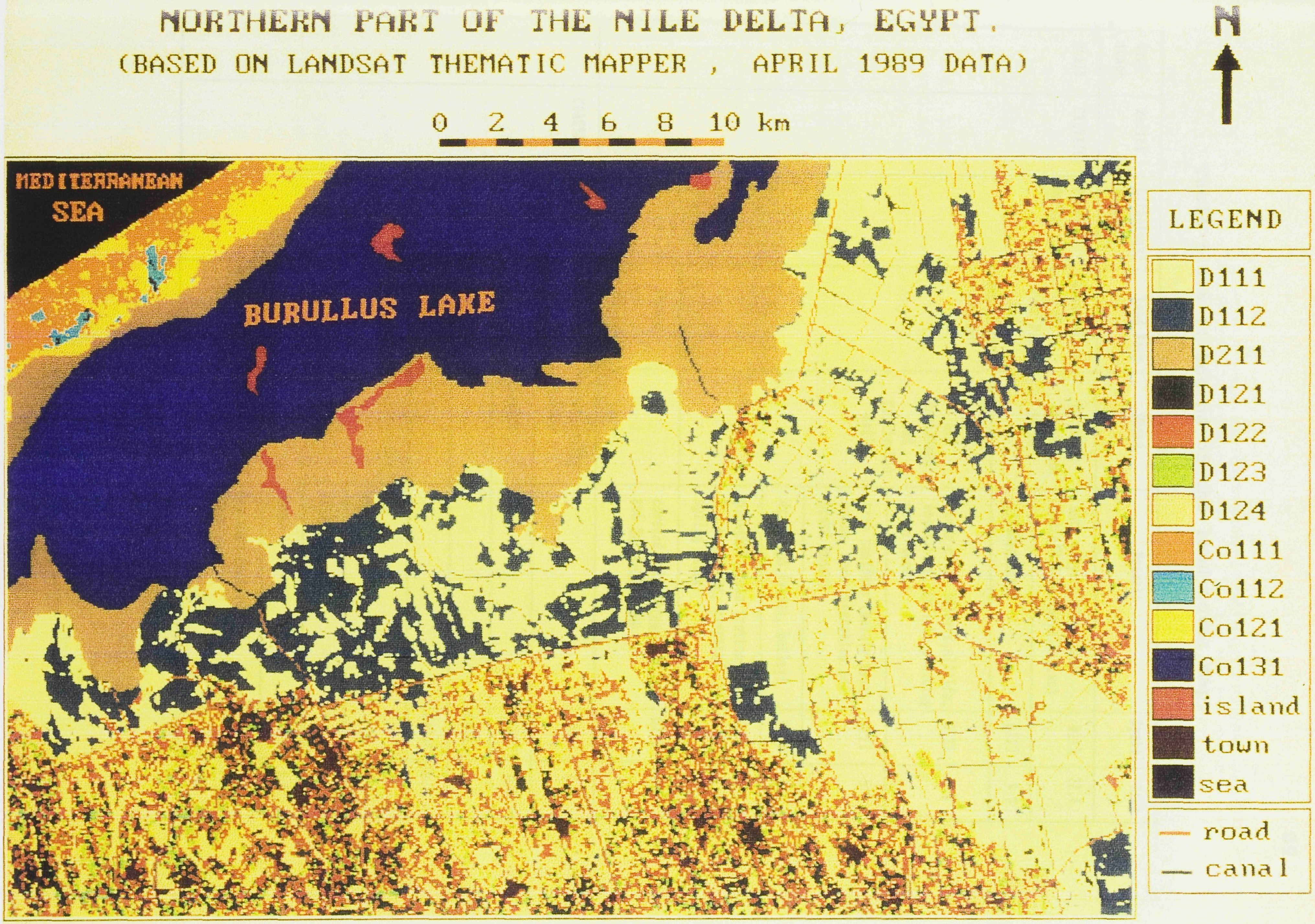

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Table (5.6): Legend of the land cover map.

Land-scape	Relief	Lithology/ origin	Land Form	Phase	Remarks	Symbol	Area %
PLAIN	DELTAIC	Fluvio-Marine	Association of Over Flow and Decantation Basins	Recently Reclaimed Soils	bare clay to clay loam soils(V.H.saline/alkaline)	D111	22.6
					flooded areas	D112	9.8
				Old Reclaimed and Cultivated Soils	green crops (clover,alfalfa, vegetables,few late planting sugar beets)	D121	7.8
					crop residues (mainly sugar beets, some vegetables and broad beans)	D122	5.5
					dry crops (wheat, barley)	D123	4.5
					ploughed areas (cotton with 2-3 weeks age, prepared for spring maize)	D124	10.7
			Swamps		covered with Phragmites Spp and Salicornia Spp	D211	11.6
	COASTAL	Marine	Barrier	occasionally flooded		Co111	1.4
				flooded		Co112	0.3
			Low Dunes			Co121	1.3
			Lagoon			Co131	16.1
					Sea		1.9
					Island		0.5
					Towns		1.9
					Man made features roads canals		1.0 3.0

5.3.2 Soil Salinity/Alkalinity Map :

The procedure followed to get the salinity/alkalinity map was improved in four steps :

1): The information classes obtained from both the spectral classification and spectral correlation were integrated using GIS. For this purpose a two dimensional table (Appendix 4) was created. It represents the spectral classification classes in the Y axis and the spectral correlation classes in X axis. This procedure lead to a map with detailed classes about salinity/alkalinity hazard.

2): Thermal band slicing was used in the same procedure. It was overlaid onto the map obtained from step 1 to add information about the soil moisture and drainage condition within the same class in the obtained map.

3): Because of the difficulties in getting information from the spectral classification and spectral correlation results about the lower salinity levels(< 4, 4-8, an 8-16 mmhos/cm) within the cultivated area , these units were taken from the visual map and the field work data. For that the resulting map obtained from step 2 was integrated with the physiographic map (visual interpretation). For that purpose a two dimensional table was created (Appendix 5).

If the classes of the green crops, residues, matured crops and ploughed areas in the resulting map from step 2 covering a physiographic unit, then these classes will represent in the salinity map as this physiographic unit.

4): The out put map result from the previously procedures (steps 1,2 and 3), was passed by MAJORITY filter to reduce the noise of one pixel pattern. After filtering the map was overlaid with the terrain features (road and canals) and the final result is the soil salinity/alkalinity map which is presented in Fig.(5.7) and Table (5.7).

The final salinity map present soils with different salinity/alkalinity hazard with information about moisture and drainage condition within the same physiographic unit. The best example is the units D115d, D115m, D116d and D116w indicating the moisture condition within D115 and the drainage condition within D116.

Figure (5.7): SOIL SALINITY/ALKALINITY MAP
NORTHERN PART OF THE NILE DELTA, EGYPT.
(BASED ON LANDSAT THEMATIC MAPPER , APRIL 1989 DATA)

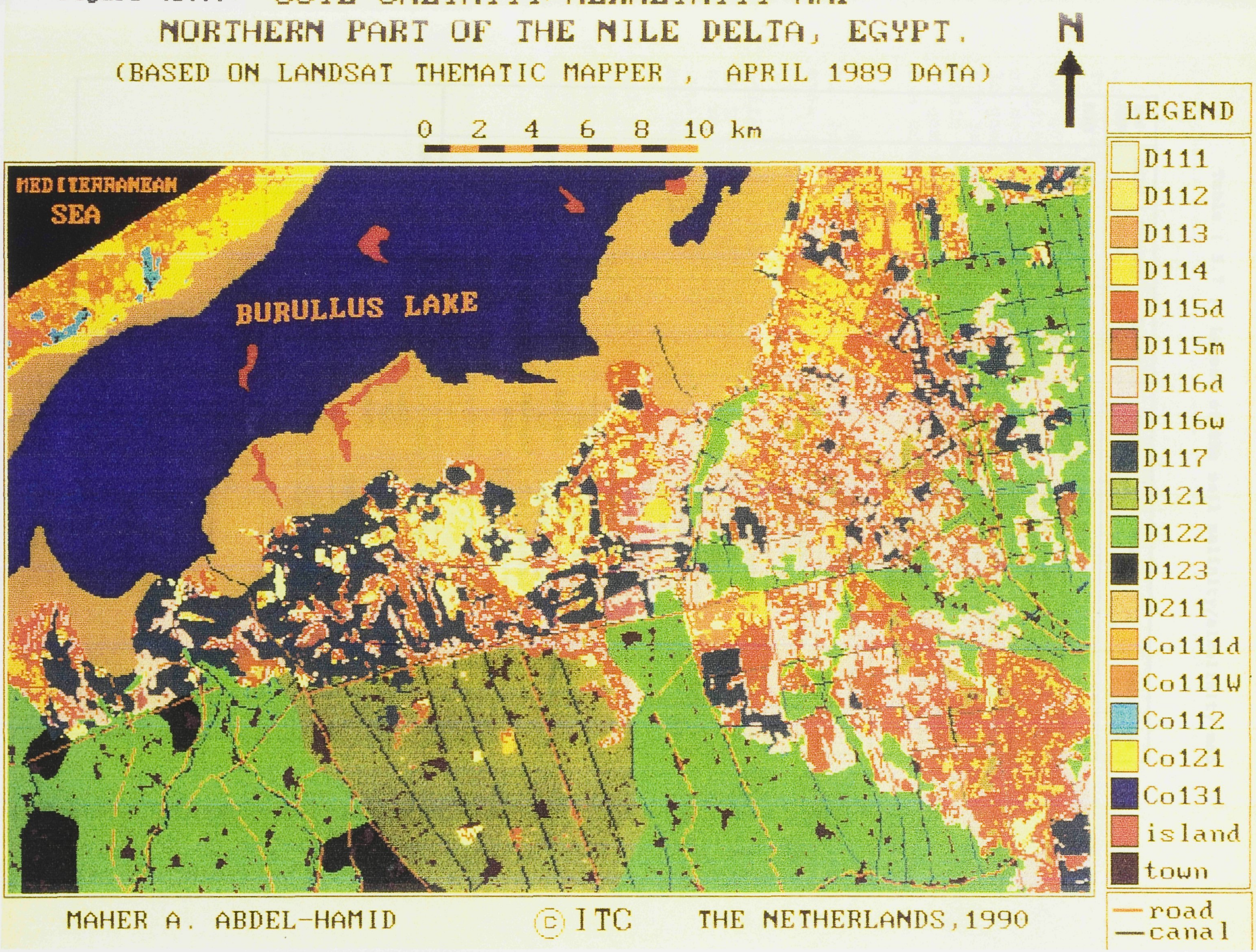

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Table (5.7): Legend of the soil salinity/alkalinity map.

Land-scape	Relief	Lithology/ Origin	Land Form	Phase	Remarks	Symbol	Area %
PLAIN	DELTAIC	Fluvio-Marine	Association of Over Flow and Decantation Basins	Recently Reclaimed Soils	salt crust	D111	1.3
					strongly saline/alkaline (EC >150 mmhos/cm)	D112	0.7
					Strongly saline/alkaline with whitish surfaces (EC 70-100 mmhos/cm)	D113	0.8
					Strongly saline/alkaline with puffed surfaces (EC 70-100 mmhos/cm)	D114	2.7
					V.H. saline/alkaline(dry) (EC 40-60 mmhos/cm.)	D115d	7.9
					V.H saline/alkaline(moist) (EC 40-60 mmhos/cm.)	D115m	2.6
					V.H. saline/strongly alkaline(dry) (EC 16-30 mmhos/cm)	D116d	7.8
					V.H. saline/strongly alkaline(wet) (Ec 16-30 mmhos/cm)	D116w	0.4
					flooded areas	D117	0.1
				Old Reclaimed and Cultivated Soils	H.saline(EC 8-16 mmhos/cm)	D121	8.2
					moderately saline (EC 4-8 mmhos/cm.)	D122	19.1
					non-saline(EC <4 mmhos/cm)	D123	1.4
			Swamps			D211	11.6
	COASTAL	Marine	Barrier	occasionally flooded EC 16-24 mmhos/cm.	V.H. saline (dry)	Co111d	0.7
					V.H. saline(wet)	Co111w	0.7
					flooded	Co112	0.2
			Low Dunes			Co121	1.3
			Lagoon			Co131	16.1
					Sea		1.9
					Island		0.5
					Towns		1.9
					Man made features		
					Roads		1.0
					Canals		3.0

5.3.3 Comparing the final salinity map with the ground truth data:

Two aggregation processes with different characteristics were applied; aggregation of spatial resolution and aggregation of classification categories. The existing soil salinity map of Egypt (published in scale of 1:300 000, in 1966) was aggregated into the 30 m pixel resolution of TM. In the second aggregation classification categories were merged using the cross program in ILWIS. This technique compares class value of the existing map of Egypt and the TM map. Accuracy was measured by the ratio of the number of TM pixels classified into a particular aggregated class to the number of pixels occurring in the existing salinity map of Egypt belonging to the same class. Note that these two maps are separated by a time span of 24 years.

Figure (5.9) shows the existing salinity map of Egypt which created with four salinity levels (<4, 4-8, 8-16 and >16 mmhos/cm.) and Figure (5.8) shows the TM map with the same classes.

The results indicated that the boundary of the V.H. saline soils (>16 mmhos/cm.) is the same in both maps with accuracy of 80%. However, the existing map of Egypt was made 24 years prior to the obtained TM map, this explain the 20% different in this class. 16.5% of this class became moderately saline (4-8 mmhos/cm) and 3.5% became H.saline (8-16 mmhos/cm), Fig.(5.10 a).
The shift in some areas towards the lower classes is due to the reclamation processes within a period of 24 years. The Final salinity/alkalinity map obtained in this study (fig.5.7) produced more salinity levels (6 classes in areas having ECe <16 mmhos/cm) which is of great importance for the planning of reclamation and leaching of these soils.

The accuracy obtained with the H.saline soils (8-16 mmhos/cm) is about 70%. Also the reclamation processes in the area indicate the differences. 30% of this area became moderately saline (4-8 mmhos/cm), where as only 1.6% became non saline (<4 mmhos/cm), (fig.5.10 b)

The accuracy within the moderately saline soils (4-8 mmhos/cm) is also about 80%. 45% of the area is changed to non saline. The problem in this class is that about 13% are found to be H.saline in the TM map, (Fig.5.10 c). This may be because that the existing map is very general (scale 1:300 000).

SOIL SALINITY MAP

NORTHERN PART OF THE NILE DELTA, EGYPT.

(BASED ON LANDSAT THEMATIC MAPPER , APRIL 1989 DATA)

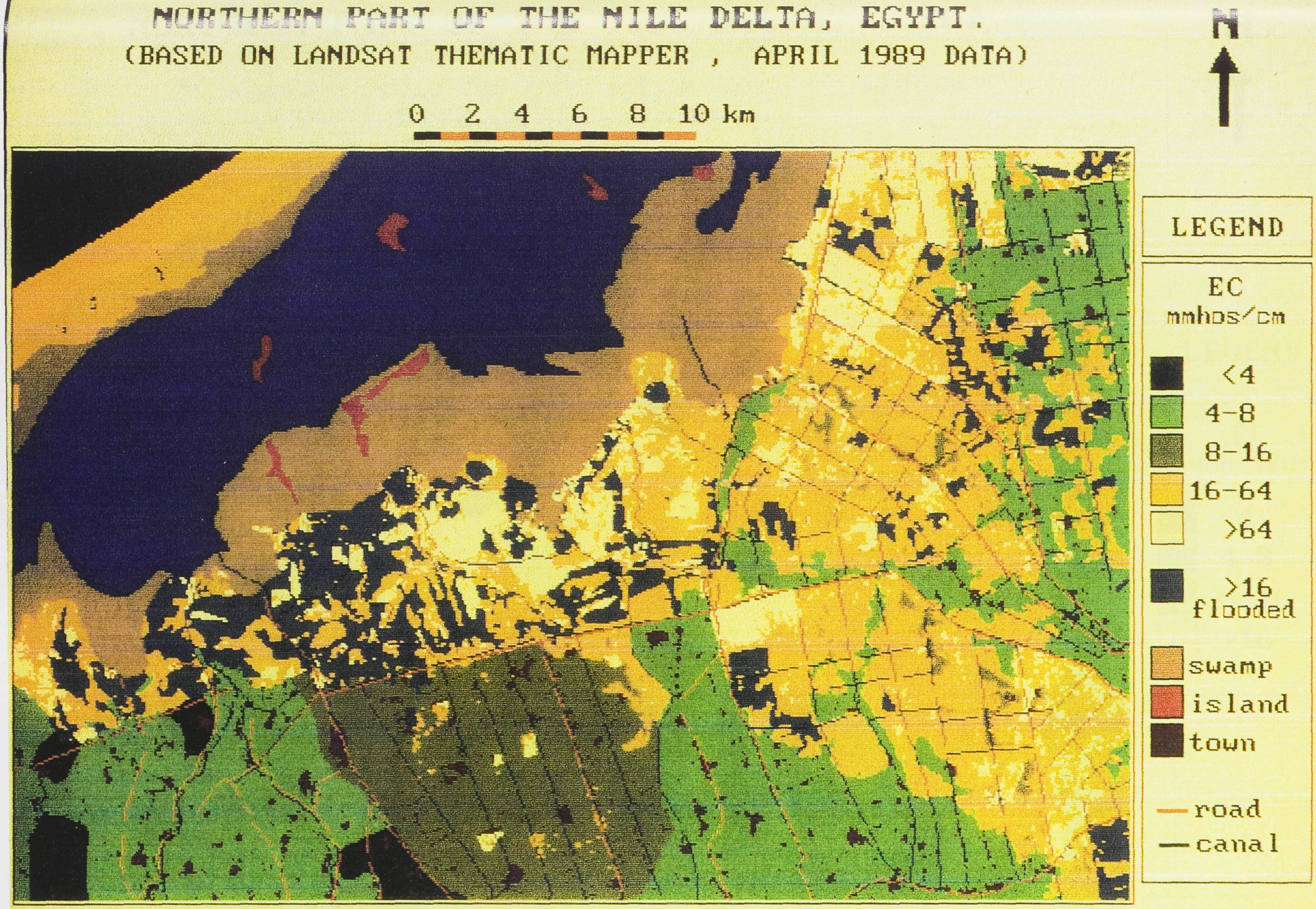

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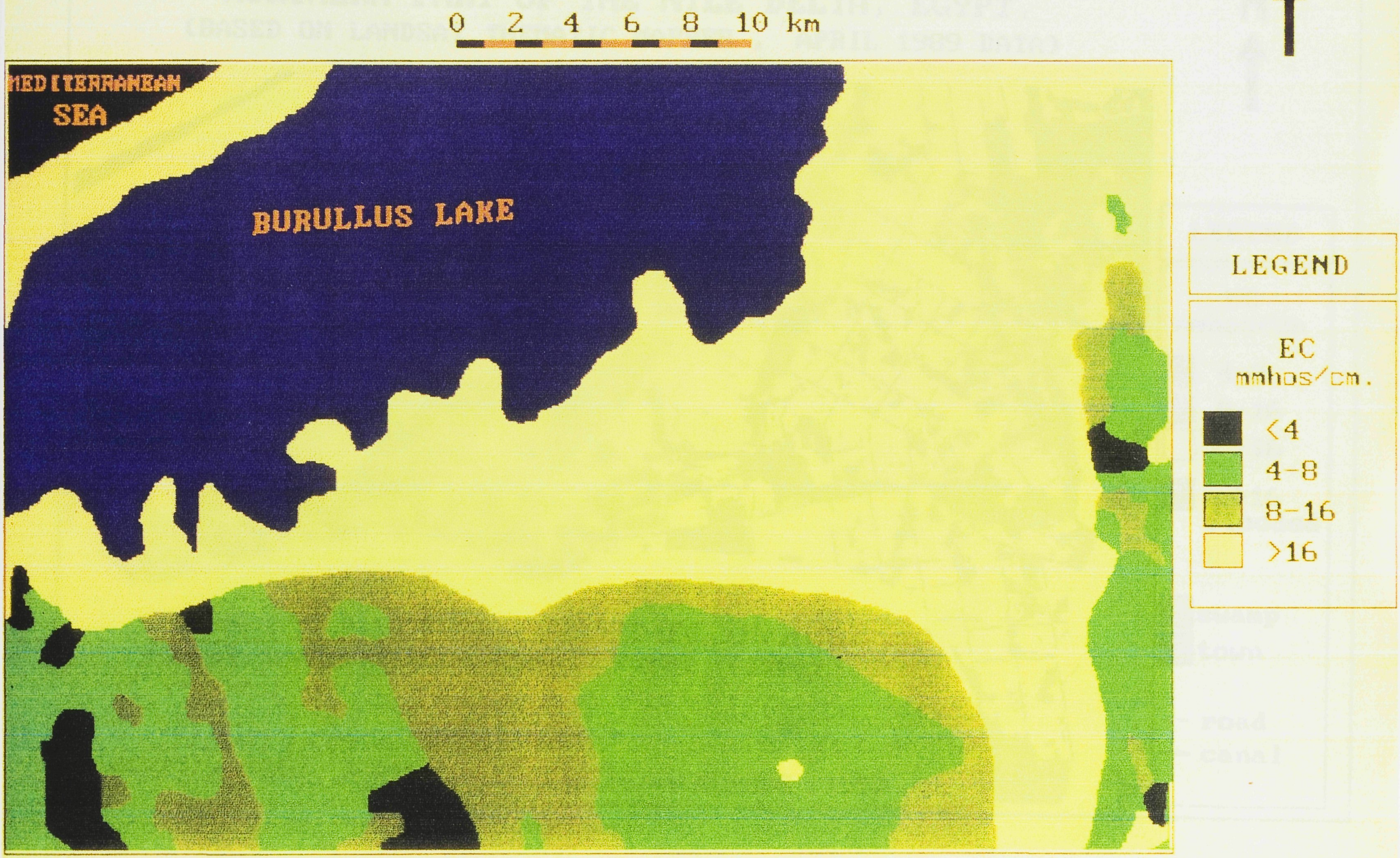
Figure (5.9): EXISTING SOIL SALINITY MAP
NORTHERN PART OF THE NILE DELTA, EGYPT.
(1966)



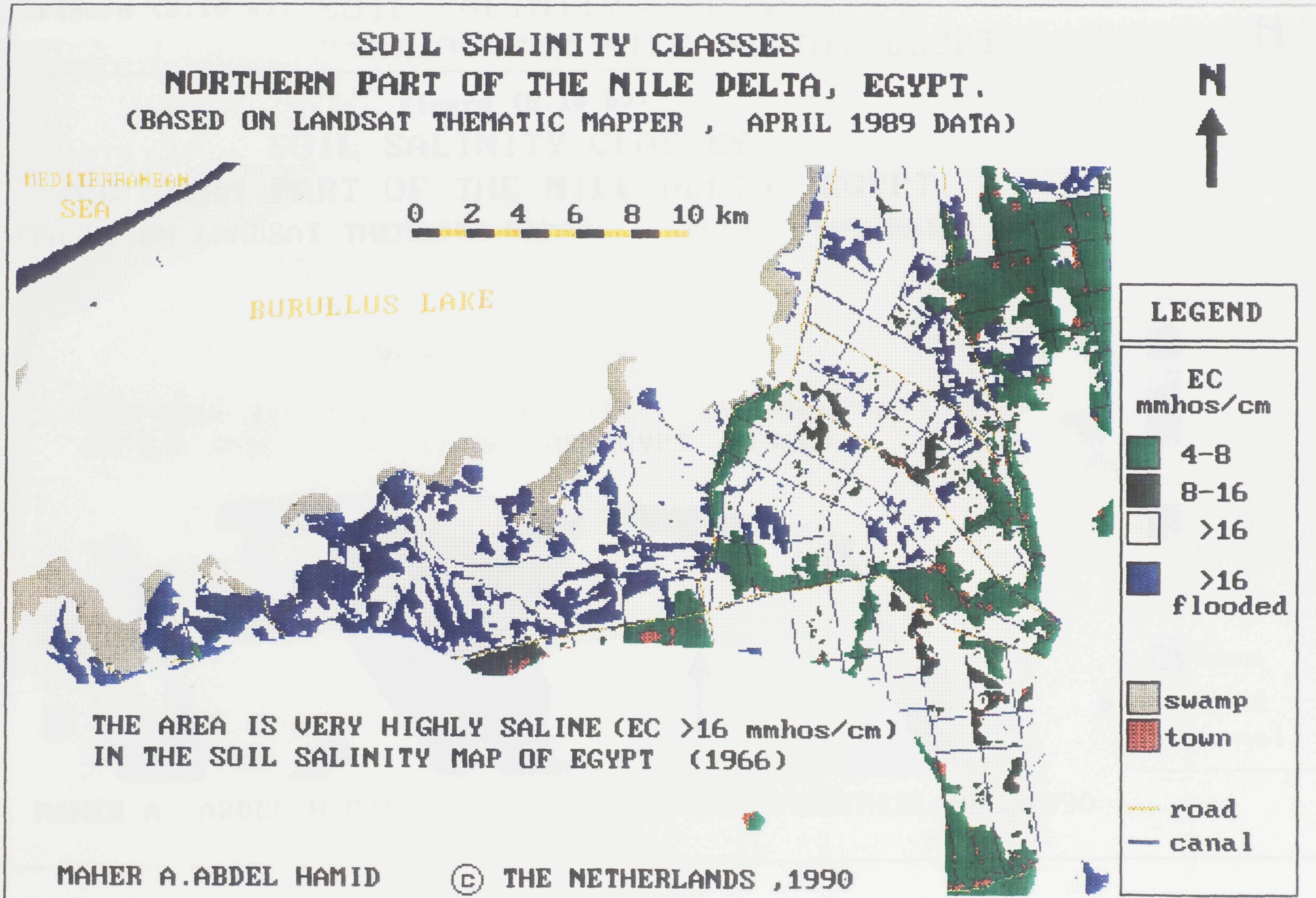

SOIL SALINITY CLASSES
NORTHERN PART OF THE NILE DELTA, EGYPT.
(BASED ON LANDSAT THEMATIC MAPPER , APRIL 1989 DATA)
N
MEDITERRANEAN
SEA
0 2 4 6 8 10 km
BURULLUS LAKE
LEGEND
EC
mmhos/cm
4-8
8-16
>16
>16
flooded
swamp
town
road
canal
THE AREA IS VERY HIGHLY SALINE (EC >16 mmhos/cm)
IN THE SOIL SALINITY MAP OF EGYPT (1966)
MAHER A.ABDEL HAMID
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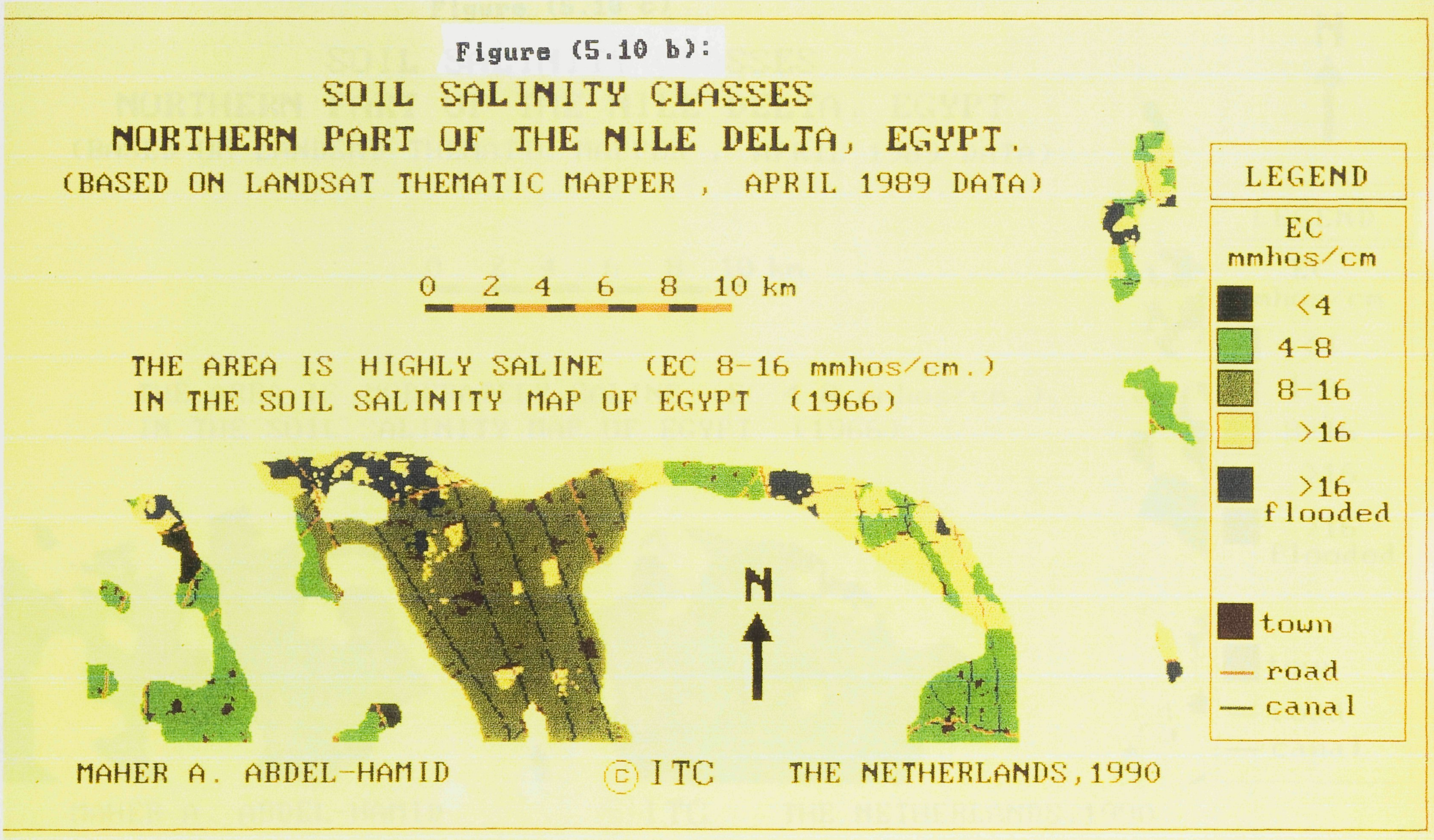
Figure (5.10 b):


SOIL SALINITY CLASSES
NORTHERN PART OF THE NILE DELTA, EGYPT.
(BASED ON LANDSAT THEMATIC MAPPER , APRIL 1989 DATA)
0 2 4 6 8 10 km
THE AREA IS HIGHLY SALINE (EC 8-16 mmhos/cm.)
IN THE SOIL SALINITY MAP OF EGYPT (1966)
N
LEGEND
EC mmhos/cm
<4
4-8
8-16
>16
>16 flooded
town
road
canal
MAHER A. ABDEL-HAMID
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SOIL SALINITY CLASSES
NORTHERN PART OF THE NILE DELTA, EGYPT.
(BASED ON LANDSAT THEMATIC MAPPER , APRIL 1989 DATA)
0 2 4 6 8 10 km
THE AREA IS MODERATELY SALINE (EC 4-8 mmhos/cm.)
IN THE SOIL SALINITY MAP OF EGYPT (1966)
N
LEGEND
EC
mmhos/cm
<4
4-8
8-16
>16
>16
flooded
town
road
canal
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Figure (5.10 c)

5.4 REFLECTANCE AS A QUANTITATIVE MEASUREMENTS OF THE EFFECT OF SALINITY ON SOIL AND VEGETATION SPECTRAL PROPERTIES:

5.4.1 Soil and Vegetation Reflectance Curves:

Soil reflectance is a cumulative property which derives from inherent spectral behaviour of the heterogeneous combination of minerals, organic matter and fluid matter that comprises mineral soils.

Spectro-radiometer studies of soils under field conditions contributes to an understanding of some factors influencing soil reflectance.

The objective of this part of the study is to investigate the spectral reflectance properties of several saline soils under field conditions in relation to their physical and chemical properties. A field spectro-radiometer was used to measure the reflectance from 80 saline soils. The soils are grouped in nine level of soil salinity. The description of the investigated soils is presented in Table (5.8).

Typical spectral curves for various saline/alkaline soils are presented in Fig. (5.11). It is possible to separate two different types of curves based on their shape. This is closely related to surface salinity of the soils.

Reflectance curves for samples with ECe less than 12 mmhos/cm (non saline to moderately saline) are similar to type 1 curve described by Condit (1970 and 1972). The curve exhibit rather low reflectance with a slightly increasing slope throughout the spectral range from 0.5 to 1.1 um wave bands, which gives the characteristics of concave form in this region. This curve seems to be characteristic of dark coloured soils.

Reflectance in this group ranged only from 6-12 %. The difference in reflectance from the Typic Torrifluvents is due to the difference in their surface colour. The higher the Munsell value or chroma of the soil , the higher is the reflectance of these soils (Stoner and Baumgardner 1980).

Table (5.8): Characteristics of the investigated soil samples used for the field sepctro-radiometer measurements.

SURFACE SAMPLE (0- 20 cm)					
Site	ECe mmhos/ cm.	Texture	Munsell Colour (dry)	O.M %	Soil Order (USDA)
1	2.2	Clay	10YR 3/2	1.8	Entisol
2	6.8	Clay	10YR 4/2	1.8	Entisol
3	11.0	Clay Loam	10YR 4/3	1.7	Entisol
4	20.3	Clay	10YR 5/1	1.3	Aridisol
5	40.1	Clay	10YR 6/1	1.2	Aridisol
6	55.5	Clay	10YR 6/3	0.6	Aridisol
7	77.6	Clay	10YR 7/1	0.6	Aridisol
8	93.6	Clay Loam	10YR 7/2	0.5	Aridisol
9	173.6	Clay	10YR 8/1	0.4	Aridisol
10	21.5	sand	10YR 7/3	--	Entisol

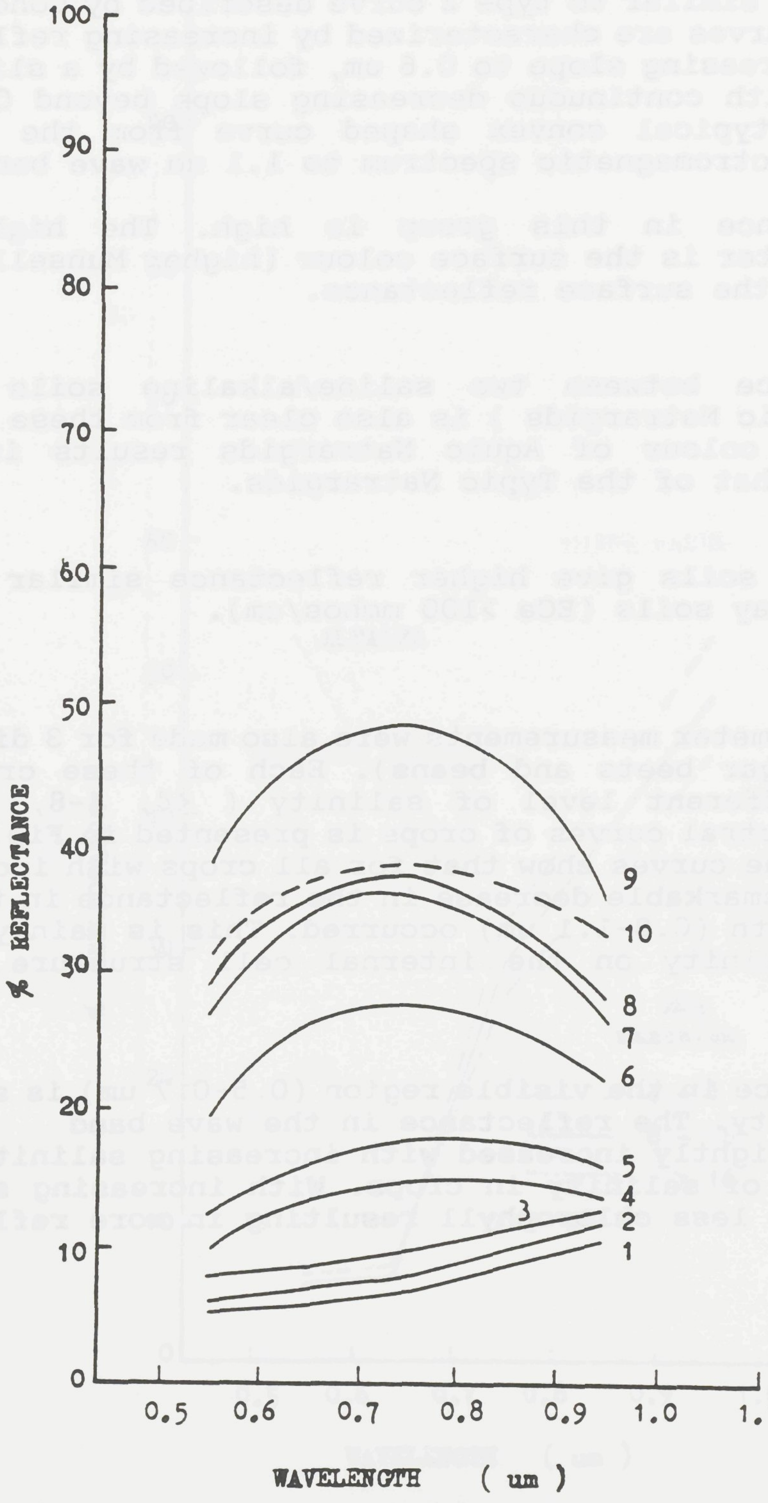

Fig. (5.11) FIELD SPECTRO-RADIOMETER REFLECTANCE MEASUREMENTS OF VARIOUS SALINE SOILS .

Soils with Ece more than 16 mmhos/cm (highly saline) have reflectance curves similar to type 2 curve described by Condit(1970 and 1972). These curves are characterized by increasing reflectance with generally decreasing slope to 0.6 um, followed by a slight dip from 0.6-0.7 um with continuous decreasing slope beyond 0.75 um. The result is a typical convex shaped curve from the visible portion of the electromagnetic spectrum to 1.1 um wave band.

The reflectance in this group is high. The higher the salinity, the lighter is the surface colour (higher Munsell value) and the higher is the surface reflectance.

The difference between two saline/alkaline soils (Typic Natrargids and Aquic Natrargids) is also clear from these curves. The dark surface colour of Aquic Natrargids results in lower reflectance than that of the Typic Natrargids.

Saline sandy soils give higher reflectance similar to the strongly saline clay soils (ECe >100 mmhos/cm).

Spectro-radiometer measurements were also made for 3 different crops (clover, sugar beets and beans). Each of these crops was grown under 3 different level of salinity (<4, 4-8, and >16 mmhos/cm). The spectral curves of crops is presented in Fig. (5.12, 5.13 and 5.14). The curves show that for all crops with increasing salinity level a remarkable decrease in the reflectance in the near infrared wave length (0.8-1.1 um) occurred. This is mainly due to the effect of salinity on the internal cell structure of the leaves.

The reflectance in the visible region (0.5-0.7 um) is slightly affected by salinity. The reflectance in the wave band (0.5-0.7 um) is slightly increased with increasing salinity level due to the effect of salinity in crops. With increasing salinity level , crops have less chlorophyll resulting in more reflectance in red band.

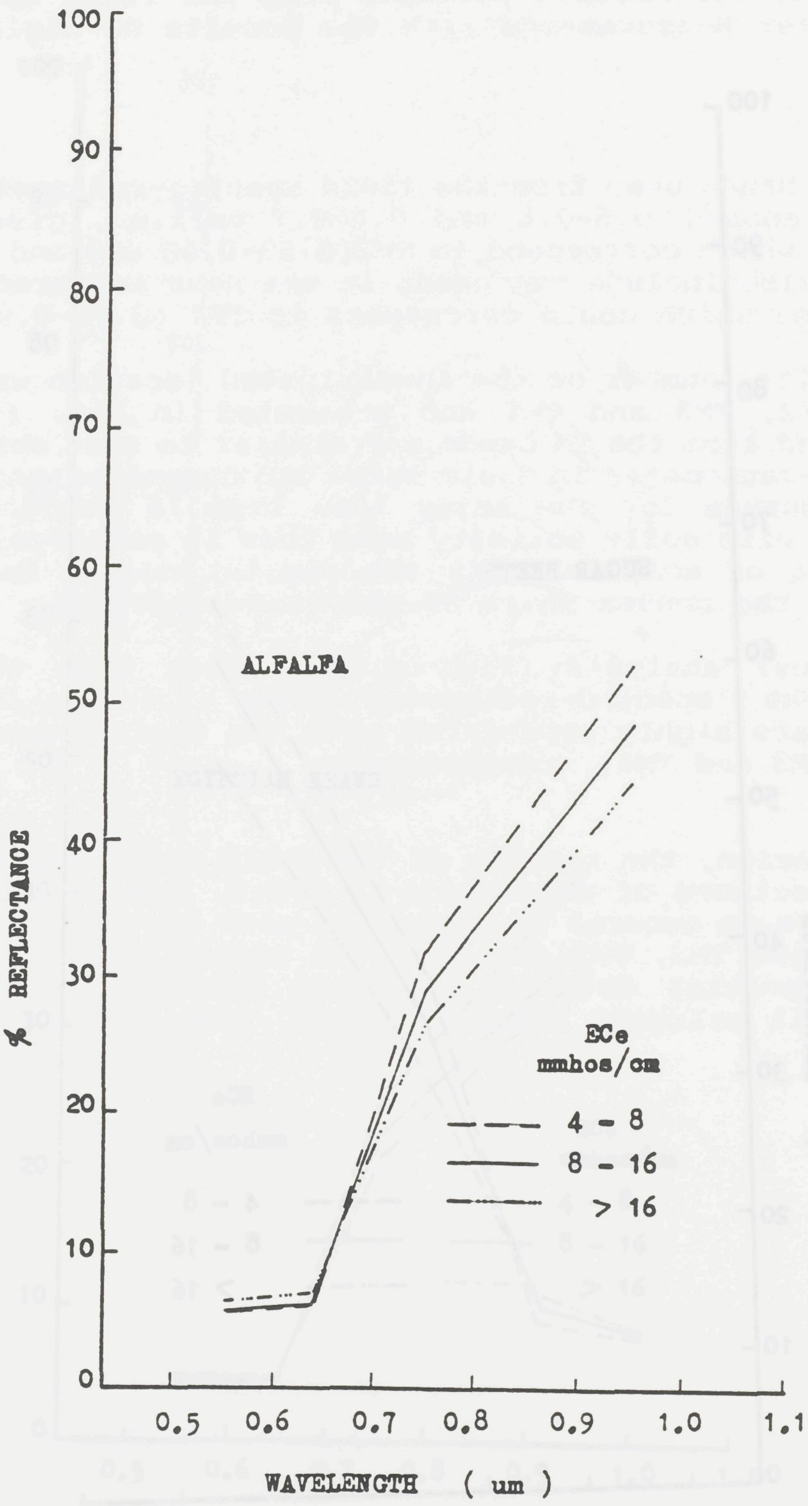

Fig. (5.12) FIELD SPECTRO-RADIOMETER REFLECTANCE MEASUREMENTS OF ALFALFA GROWN IN DIFFERENT SALINE SOILS.

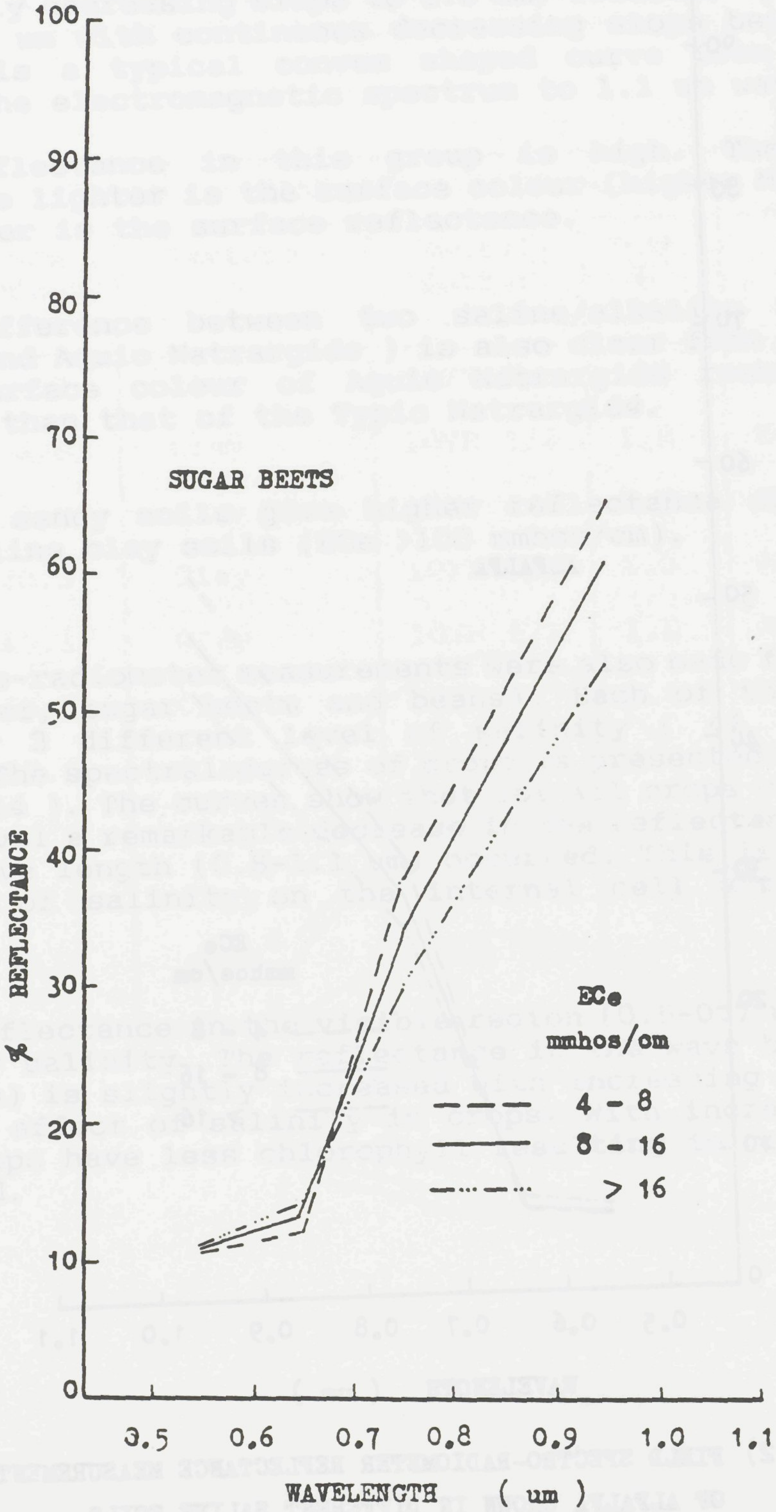

Fig. (5.13) FIELD SPECTRO-RADIOMETER REFLECTANCE MEASUREMENTS OF SUGAR BEETS GROWN IN DIFFERENT SALINE SOILS.

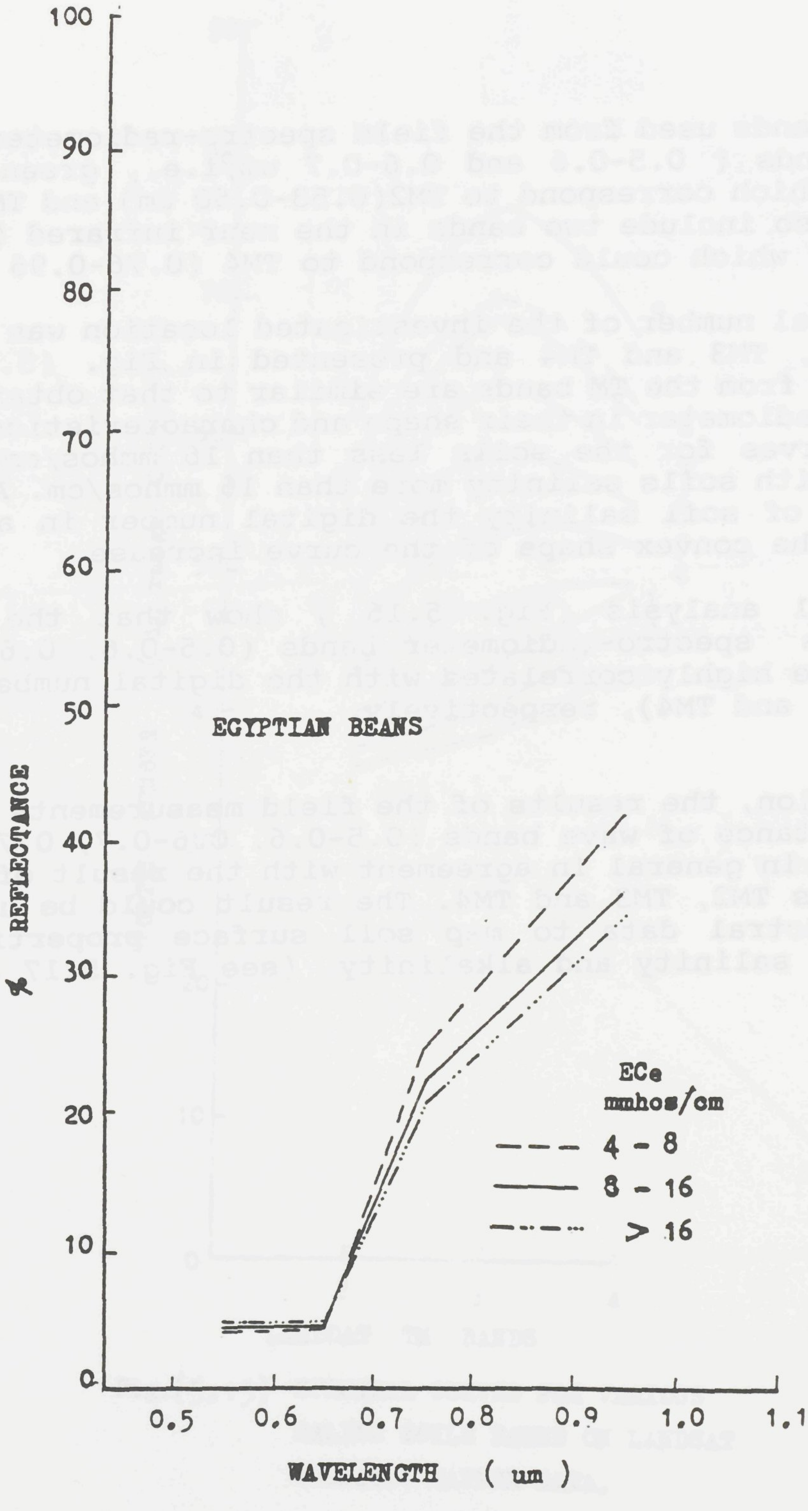

Fig.(5.14) FIELD SPECTRO-RADIOMETER REFLECTANCE MEASUREMENTS OF EGYPTIAN BEANS PLANTS GROWN IN DIFFERENT SALINE SOILS .

5.4.2 Comparing The Results Obtained From The Field Spectro-Radiometer Measurements With The Results Of Digital TM Bands:

The wave bands used from the field spectro-radiometer include two visible bands (0.5-0.6 and 0.6-0.7 um,i.e., green and red respectively) which correspond to TM2(0.53-0.60 um) and TM3 (0.63-0.69 um). It also include two bands in the near infrared (0.70-0.8 and 0.8-1.1 um) which could correspond to TM4 (0.76-0.96 um).

The digital number of the investigated location was obtained from bands TM2, TM3 and TM4 and presented in Fig. (5.15). The curves obtained from the TM bands are similar to that obtained with field spectro-radiometer in their shape and characteristics.It show the concave curves for the soils less than 16 mmhos/cm and the convex curves with soils salinity more than 16 mmhos/cm. Also with the increasing of soil salinity the digital number in all bands increased and the convex shape of the curve increase.

Statistical analysis (Fig. 5.16) show that the results obtained by the spectro-radiometer bands (0.5-0.6, 0.6-0.7 and 0.8-1.1 um) are highly correlated with the digital numbers of TM bands (TM2, TM3 and TM4), respectively.

In conclusion, the results of the field measurements from the spectral reflectance of wave bands (0.5-0.6, 0.6-0.7, 0.7-0.8 and 0.8-1.1 um) are in general in agreement with the result of digital numbers of bands TM2, TM3 and TM4. The result could be useful in using multi-spectral data to map soil surface properties with respect to soil salinity and alkalinity. (see Fig. 5.17 a, b and c).

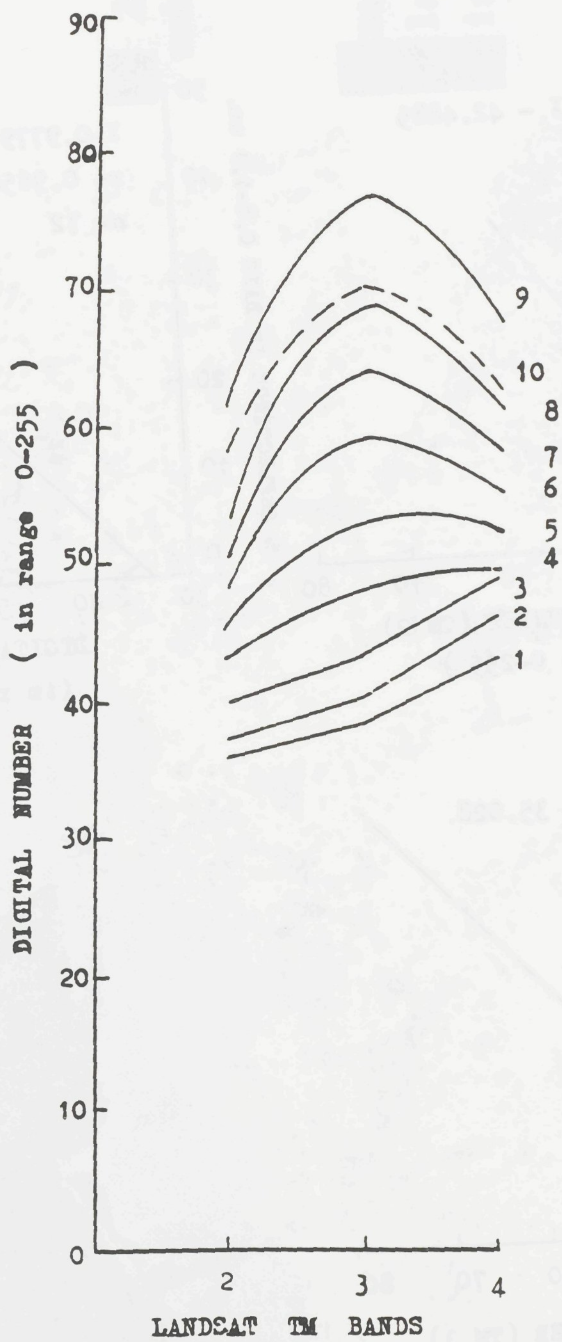

Fig.(5.15) SPECTRAL CURVES FOR VARIOUS SALINE SOILS BASED ON LANDSAT THEMATIC MAPPER DATA.

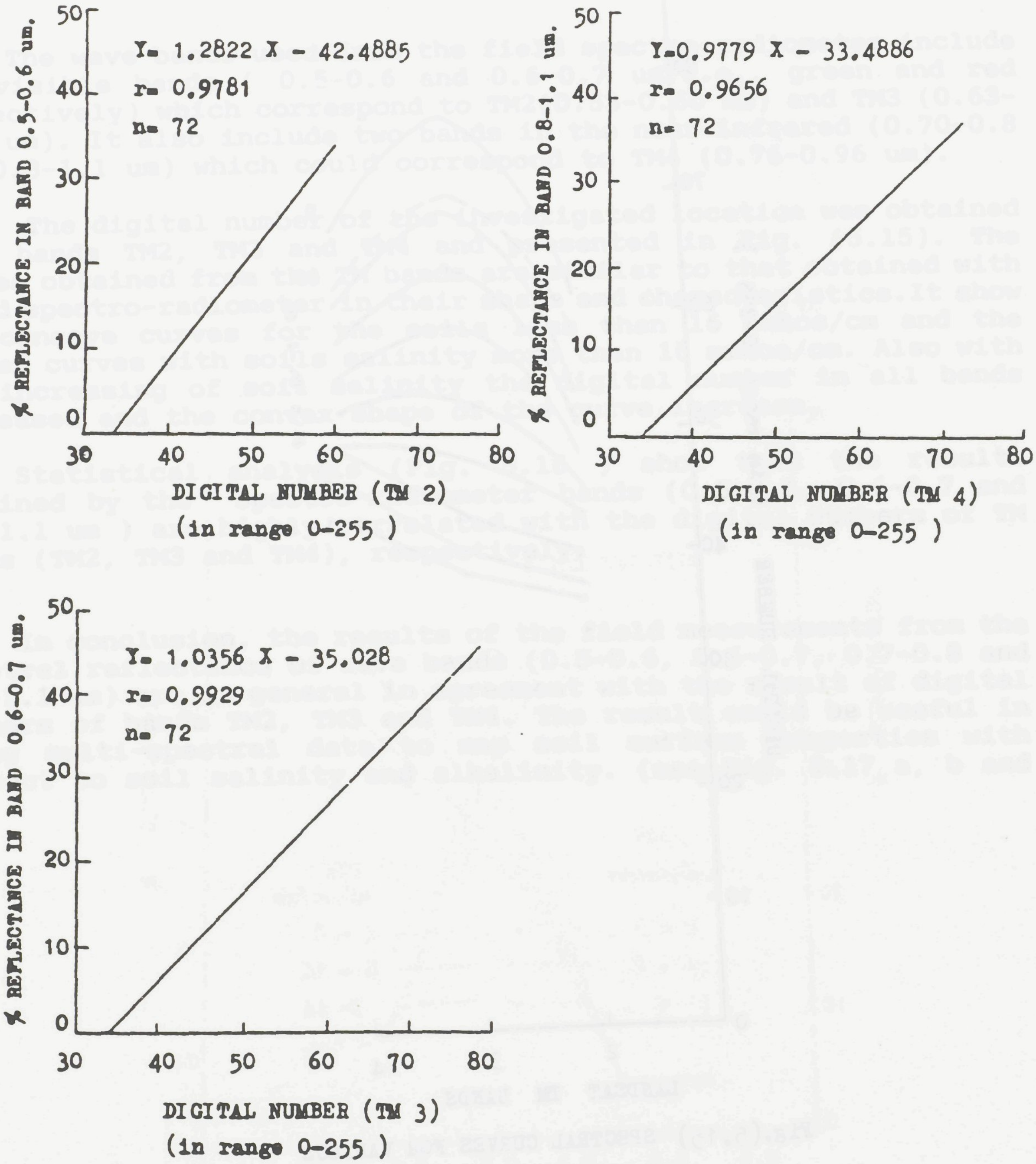

Fig.(5.16) RELATIONSHIPS BETWEEN FIELD SPECTRO-RADIOMETER REFLECTANCE MEASUREMENTS AND THE CORRESPONDING LANDSAT THEMATIC MAPPER DATA .

SOILS WITH EC (20-60 mmhos/cm.)
NORTHERN PART OF THE NILE DELTA, EGYPT.
0 2 4 6 8 10 km

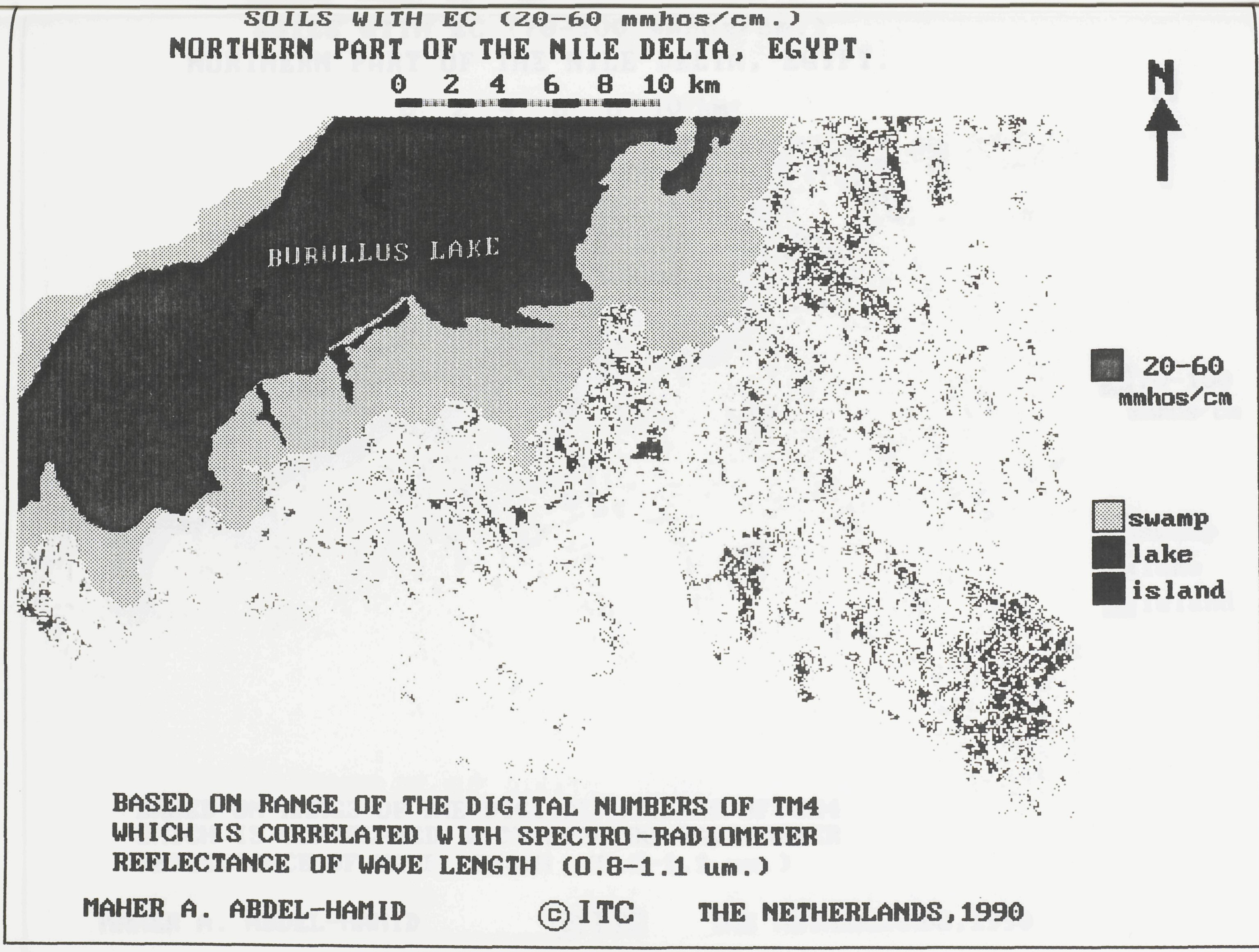
SOILS WITH EC (20-60 mmhos/cm.)
NORTHERN PART OF THE NILE DELTA, EGYPT.
0 2 4 6 8 10 km
N
BURULLUS LAKE
20-60 mmhos/cm
swamp
lake
island
BASED ON RANGE OF THE DIGITAL NUMBERS OF TM4
WHICH IS CORRELATED WITH SPECTRO-RADIOMETER
REFLECTANCE OF WAVE LENGTH (0.8-1.1 um.)
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Figure (5.17 a)

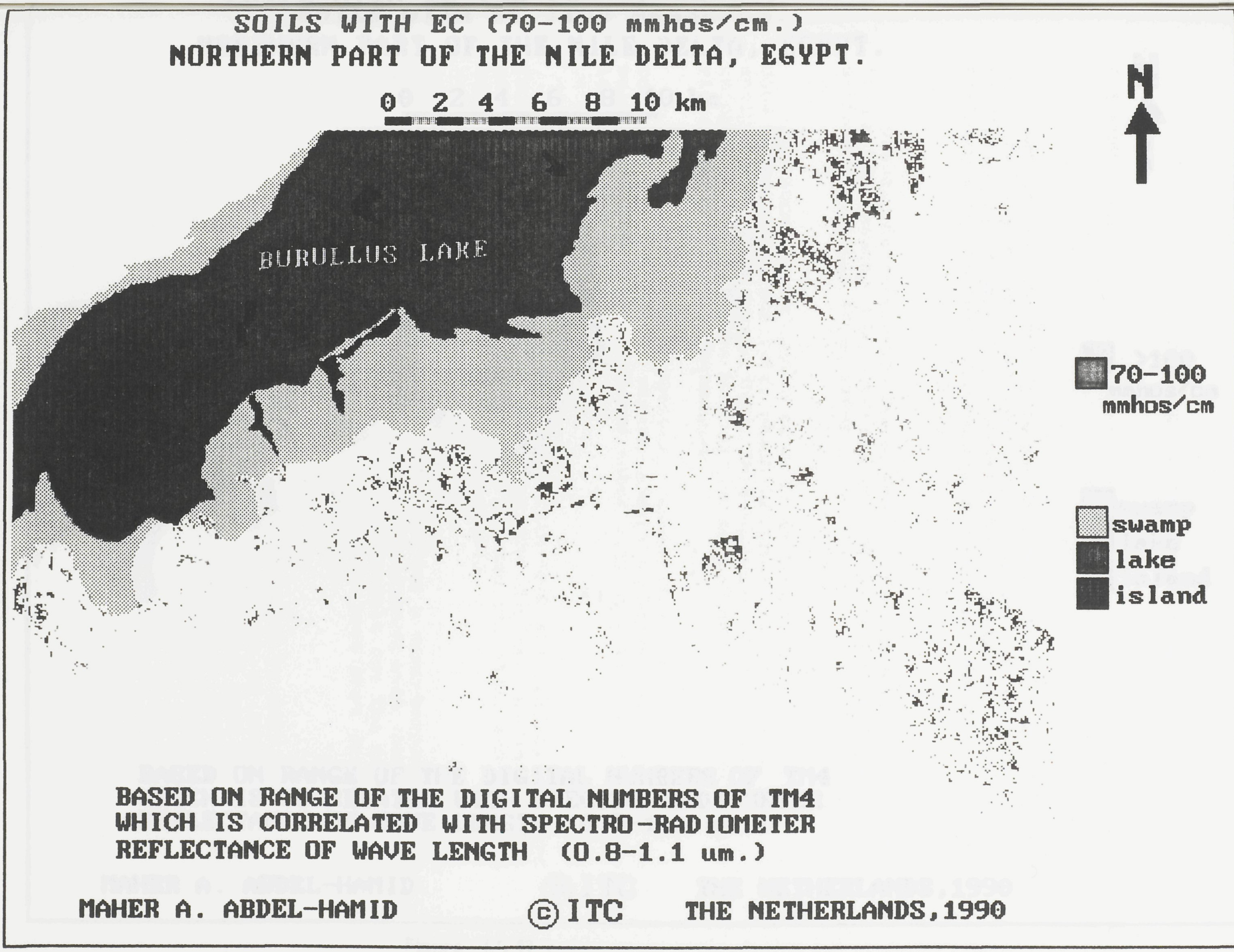
SOILS WITH EC (70-100 mmhos/cm.)
NORTHERN PART OF THE NILE DELTA, EGYPT.
0 2 4 6 8 10 km
N
BURULLUS LAKE
70-100 mmhos/cm
swamp
lake
island
BASED ON RANGE OF THE DIGITAL NUMBERS OF TM4 WHICH IS CORRELATED WITH SPECTRO-RADIOMETER REFLECTANCE OF WAVE LENGTH (0.8-1.1 um.)
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Figure (5.17 b)

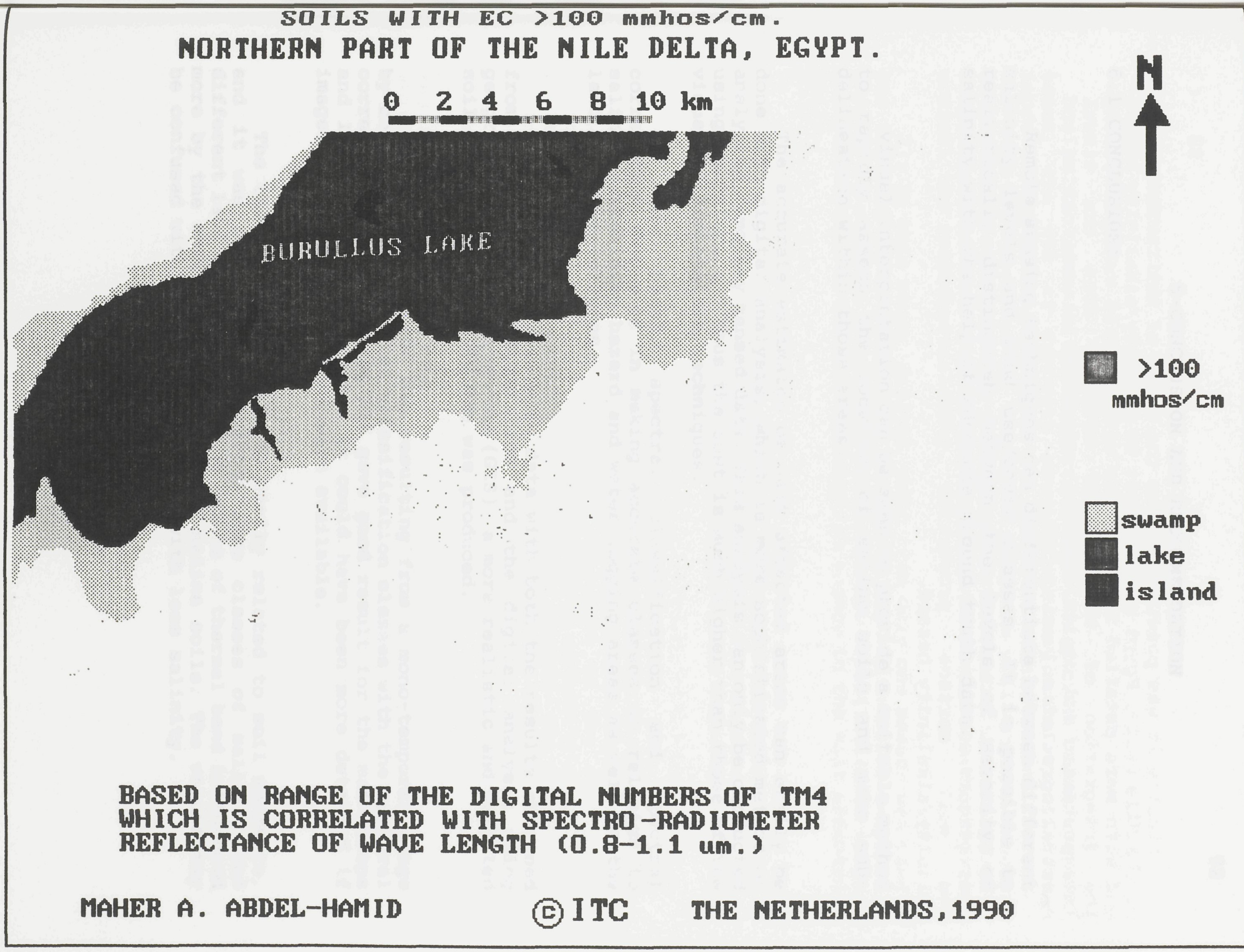
SOILS WITH EC >100 mmhos/cm.
NORTHERN PART OF THE NILE DELTA, EGYPT.
0 2 4 6 8 10 km
N
BURULLUS LAKE
>100 mmhos/cm
swamp
lake
island
BASED ON RANGE OF THE DIGITAL NUMBERS OF TM4
WHICH IS CORRELATED WITH SPECTRO-RADIOMETER
REFLECTANCE OF WAVE LENGTH (0.8-1.1 um.)
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Figure (5.17 c)

6-CONCLUSION AND RECOMMENDATION

6.1 CONCLUSION:

Remote sensing techniques can differentiate between different salinity levels and land use/cover classes. It is possible to realistically distinguish between the levels of severity of salinity with the help of adequate ground truth data.

visual interpretation can be seen to provide a suitable method to rapidly assess the location of saline soils and make sub-delineation within those areas.

The accurate estimates of salt affected areas can easily be done with digital analysis, which is more sophisticated method of analyzing remotely sensed data. This analysis can only be conducted using computers and thus the cost is much higher than those of the visual interpretation techniques.

In this point, spectral classification and spectral correlation are good in making accurate classes in relation to salinity/alkalinity hazard and water logging areas as well as the land use/cover classes.

Combining the field work data with both the results obtained from the visual interpretation and the digital analysis using geographic information system (GIS) a more realistic and detailed soil salinity/alkalinity map was produced.

The land use/cover map resulting from a mono-temporal image by combining the spectral classification classes with the spectral correlation classes using GIS gave good result for the main crops and land cover in the area. It could have been more detailed if images of different seasons were available.

The thermal band data were easily related to soil moisture, and it was possible to separate some classes of salinity and different land cover classes. The values of thermal band influenced more by the salt crust and strongly saline soils. The values may be confused with the very dry soils with less salinity.

Finally it was possible to map the soils of the northern part of the Nile Delta, Egypt with respect to salinity/alkalinity hazard and with more detailed in the areas with ECe >16 mmhos/cm.,using the integration of the results obtained from the visual interpretation and digital analysis (spectral classification and spectral correlation) using GIS.

The result obtained from the field by using spectro-radiometer measurements could be useful in using multi-spectral techniques to map soil surface properties with respect to soil salinity/alkalinity hazard.

6.2 RECOMMENDATION:

1): In terms of providing guidance to ground based survey teams, the use of remotely sensed data may make significant improvements to monitoring of the spread of saline soils. The repeat coverage of regular intervals will enable annual estimates of the extent of salinity affected soils to be made in subjective manner. This will assist the Government authority to control the spread of salinity.

2): In this study digital image from only one season was used for the purpose of generating a salinity map. With multi-temporal images, it would be possible to use different capabilities of image analysis system to monitor the temporal change in the salt affected soils.

3): For further investigations to verify the salt affected soils, the general techniques discussed here will be of more value if adequate additional ground truth data obtained close to the time of imaging are available.

4): The low cost of the visual interpretation can be under taken, make it feasible to repeat the operation annually if it felt to be required. This is of great important in the developing countries. There by offering the responsible authority a valuable tools in their efforts to monitor and control the spread of salinity in their countries.

5): The study show that it is possible to differentiate different levels of soil salinity/alkalinity, and that there is a good relationship between field spectro-radiometer measurements and landsat Thematic Mapper data. It will be important to study which property of the saline soils is responsible for this relationship,i.e.salt concentration, crystalization, chemical composition,......etc.

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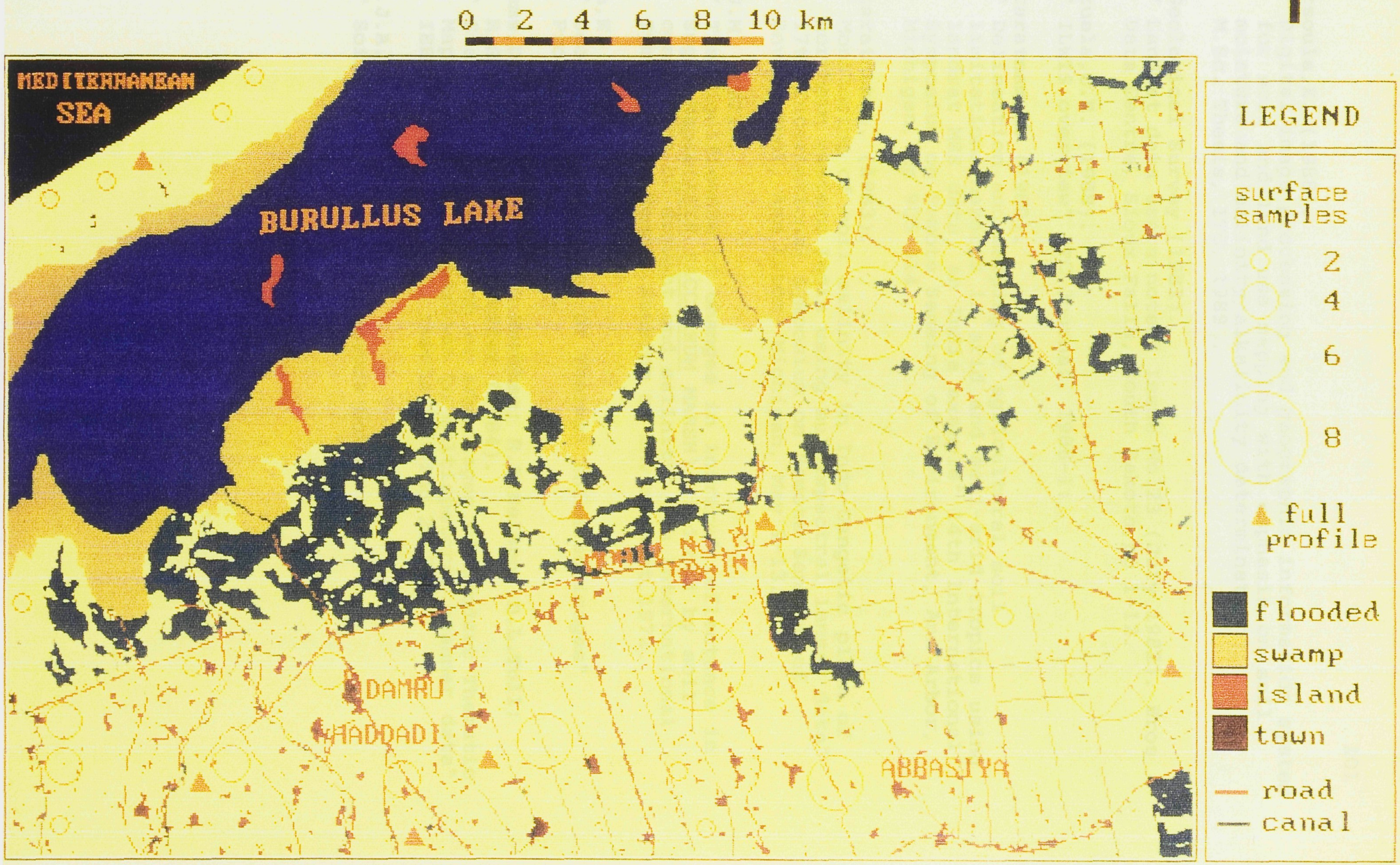
Appendix (1):

SOIL SAMPLING
NORTHERN PART OF THE NILE DELTA, EGYPT.
APRIL, 1989.



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Appendix(2):Chemical composition of surface soil samples (0-25 Cm)
collected from different units in the study area.

S.No	soil unit	pH	EC mmhos/ Cm	soluble cations *(meq./l) Ca	Mg	Na	K	soluble anions *(meq./l) HCO	Cl	SO	ESP	textural clas
1	D123	8.0	2.0	3.1	5.0	11.9	0.2	2.5	13.5	4.1	6	C
2		8.0	3.0	4.0	8.0	18.0	0.2	3.0	17.0	10.1	8	Cl
3		7.9	1.6	5.6	5.6	4.1	0.4	2.1	9.9	3.7	3	CL
4		7.9	1.1	3.1	4.9	4.3	0.3	2.9	6.0	3.7	4	C
5		8.0	1.7	2.0	5.1	10.2	0.1	3.0	10.0	5.3	6	C
6		7.9	1.9	4.0	4.0	10.9	0.3	2.2	12.0	5.0	6	C
7		7.9	2.3	6.5	5.5	11.0	0.3	4.0	10.1	9.2	6	C
8		8.0	2.2	3.0	5.1	12.9	0.8	3.0	15.0	3.8	8	C
9		7.9	1.5	2.2	5.8	6.8	0.4	3.0	11.0	1.3	6	C
10		7.9	1.3	2.4	2.6	5.2	0.2	3.0	9.0	0.5	6	C
11		8.0	3.2	4.0	6.2	21.5	0.4	3.1	21.0	8.0	10	C
12		8.0	2.9	4.4	5.6	19.0	0.5	4.0	17.0	8.5	10	C
13		8.0	2.4	3.6	7.4	13.9	0.3	5.0	12.1	8.2	9	C
14		7.9	1.9	2.8	4.2	11.3	0.5	3.0	9.0	6.8	6	C
15		7.9	1.8	2.0	4.6	11.0	0.7	4.5	9.0	4.4	6	CL
16	D122	8.1	5.1	7.1	8.9	33.0	0.3	4.0	30.1	15.3	12	C
17		8.1	7.3	14.0	16.0	42.7	0.6	5.0	45.0	22.7	12	C
18		8.2	5.5	8.0	7.6	37.4	0.5	5.5	36.0	12.0	13	C
19		8.1	8.0	17.1	18.0	44.2	0.7	6.0	54.0	19.9	11	C
20		8.1	6.8	14.3	13.7	40.0	1.0	6.3	44.5	18.3	11	C
21		8.2	6.1	9.9	10.1	40.1	0.2	6.5	40.0	13.8	13	C
22		8.2	7.5	12.8	11.2	51.0	0.3	6.5	55.1	13.7	14	C
23		8.3	4.8	4.5	7.0	35.6	0.5	4.0	33.0	10.6	14	C
24		8.0	7.9	20.8	18.6	38.0	0.8	2.5	50.0	25.7	9	CL
25		8.0	6.8	19.8	19.0	28.7	0.6	4.0	40.0	25.1	6	Cl
26		8.0	7.0	13.9	15.9	40.0	0.6	4.0	42.0	23.0	10	C
27		8.1	5.8	8.5	9.1	38.4	0.6	5.5	38.1	13.0	13	C
28		8.0	6.2	10.1	10.1	40.0	0.5	6.0	40.0	14.8	11	C
29		8.2	4.9	6.0	6.5	35.5	0.5	4.0	33.6	11.0	14	C
30		8.1	7.1	13.9	16.0	41.0	0.6	4.1	41.0	25.0	12	C
31		8.1	7.6	14.2	18.7	43.1	0.5	4.5	44.0	26.6	12	C
32		8.2	7.7	14.7	18.0	43.6	0.6	4.7	43.1	27.5	13	C
33		8.2	6.0	10.0	9.9	36.5	0.5	5.4	38.0	16.2	13	C
34		8.0	4.4	9.8	10.2	23.2	0.6	4.0	20.6	19.0	8	CL
35		8.0	5.8	13.8	14.2	30.0	1.0	6.0	30.0	23.0	9	CL
37		8.0	7.3	14.0	16.0	42.5	0.6	5.0	44.5	22.7	11	CL

C= Clay CL= Clay Loam S= Sand

Appendix (2): Cont.

S.No	soil unit	pH	EC mmhos/ Cm	soluble cations *(meq./L) Ca	Mg	Na	K	soluble anions *(meq./l) HCO	Cl	SO	ESP	textural clas
38	D121	8.4	8.4	20.8	13.2	51.0	0.8	5.1	65.1	15.1	17	C
39		8.4	10.8	30.6	36.1	71.6	1.3	5.7	98.2	25.7	18	CL
40		8.4	12.8	39.5	38.0	75.5	1.7	5.6	104.3	44.8	18	C
41		8.5	14.1	41.7	46.1	79.4	1.9	6.2	116.5	46.4	19	C
42		8.5	15.6	47.9	52.6	85.4	1.9	7.0	130.8	50.0	19	C
43		8.3	11.0	31.0	36.0	71.7	1.3	5.8	98.0	25.9	16	CL
44		8.3	13.7	42.9	47.5	81.5	2.3	6.4	119.0	48.4	18	CL
45		8.3	9.8	29.6	30.1	66.6	1.3	5.0	88.1	23.5	16	C
46		8.3	14.7	47.7	50.0	78.3	1.7	6.2	120.0	50.4	17	C
47		8.3	15.4	47.8	52.0	83.3	1.9	6.2	128.0	50.8	16	C
48		8.4	14.0	41.7	46.0	78.9	1.9	6.0	117.0	45.8	18	C
49		8.3	13.2	42.5	47.0	82.0	2.0	6.4	117.0	49.0	18	CL
50		8.3	11.5	32.0	37.0	72.2	1.3	5.8	99.0	26.0	16	C
51		8.4	14.7	48.0	51.0	78.5	1.7	6.0	123.0	50.5	17	C
52		8.3	10.8	31.0	35.9	73.0	1.2	5.9	98.0	26.0	18	C
53	D114	8.4	20.3	20.1	24.6	206	4.2	4.5	246.0	46.9	51	C
54		8.3	29.3	31.1	46.2	286	6.0	4.0	298.7	46.5	51	C
55		8.3	24.2	20.1	32.6	237	6.5	4.5	248.0	43.9	52	C
56		8.3	19.5	18.6	17.1	204	4.4	4.0	241.0	40.4	54	C
57		8.4	29.2	29.6	42.7	273	5.0	4.0	301.7	47.7	50	CL
58		8.3	23.7	17.3	29.3	236	6.5	4.7	245.0	40.7	55	C
59		8.3	24.5	19.1	31.6	243	6.7	5.5	246.4	48.1	55	C
60		8.4	29.1	26.6	41.7	276	5.1	4.7	301.0	47.7	53	C
61		8.5	35.3	15.2	92.5	312	4.0	4.5	342.0	76.5	52	C
62		8.4	35.5	15.2	92.5	312	4.0	4.5	342.0	76.5	53	CL
63		8.2	29.6	30.0	43.0	275	5.1	4.5	310.0	47.0	48	C
64		8.2	25.0	19.9	32.0	245	6.7	5.5	246.5	48.0	50	C
65		8.4	19.0	18.5	16.9	205	4.4	4.2	241.0	41.0	50	CL
66		8.3	20.0	21.0	24.9	199	4.0	4.2	249.0	47.0	48	C
67		8.3	23.0	18.0	28.5	130	6.5	4.6	245.0	40.3	50	C
68	D113	8.1	43.7	21.6	104.2	394	4.5	7.9	416.5	100.0	48	C
69		8.1	46.1	23.8	110.5	414	4.8	7.9	436.5	109.6	49	C
70		8.1	36.8	17.3	95.0	322	4.5	4.5	344.0	79.5	43	C
71		8.0	37.7	18.1	98.0	329	4.5	4.8	352.0	82.0	45	CL
72		8.0	40.1	23.9	105.0	344	5.0	5.6	372.0	90.0	46	C
73		8.0	46.9	29.9	130.3	392	7.1	7.8	521.2	110.2	45	CL
74		8.0	39.6	23.8	104.5	344	5.0	5.5	371.8	89.3	45	C
75		8.1	43.2	29.9	117.5	365	5.0	5.8	392.0	117.0	45	C
76		8.1	53.6	39.8	137.6	427	9.0	9.8	551.2	157.2	47	C
77		8.0	49.0	33.9	140.3	403	7.1	7.8	521.2	134.2	44	C
78		8.0	35.2	15.1	92.5	311	3.8	4.5	341.0	76.0	44	CL
79		8.0	35.5	15.2	93.0	312	4.0	4.4	342.0	76.0	44	C
80		8.1	39.6	23.8	104.0	344	5.0	5.5	371.0	89.0	46	C
81		8.0	43.9	31.0	118.5	366	5.1	5.8	392.0	118.0	46	C
82		8.0	34.0	15.0	93.0	312	4.0	4.5	342.0	76.5	45	C

C= Clay CL= Clay Loam S= Sand

Appendix (2): Cont.

S.No	soil unit	pH	EC mmhos/ Cm	soluble cations *(meq./L) Ca	Mg	Na	K	soluble anions *(meq./l) HCO	Cl	SO	ESP	textural clas
83	D112	7.7	93.6	50.1	310	974	20.0	7.2	1134	213	72	C
84		7.8	77.6	38.0	255	828	12.2	5.5	928	200	69	CL
85		7.7	79.2	38.0	265	840	12.5	5.5	940	200	70	CL
86		7.8	86.4	40.0	299	900	14.3	5.4	1042	206	69	C
87		7.8	75.0	34.0	247	818	12.3	5.4	926	180	69	C
88		7.8	70.0	30.0	221	770	10.1	5.5	860	166	70	C
89		7.7	94.2	56.0	312	980	21.1	6.1	1101	262	72	C
90		7.7	70.6	32.0	222	771	10.2	5.2	860	170	71	CL
91		7.8	65.6	31.0	204	730	9.3	5.0	810	155	69	C
92		7.8	73.9	34.0	241	810	12.4	5.0	906	186	72	C
93		7.7	90.0	55.2	310	970	20.4	6.9	1121	243	71	C
94		7.7	93.0	51.0	312	974	20.0	7.0	1134	213	73	C
95		7.8	88.0	42.0	307	900	14.0	5.0	1050	207	68	CL
96		7.7	80.0	38.0	266	846	12.0	6.0	950	201	69	C
97		7.8	78.0	39.0	260	830	12.0	6.0	935	198	68	C
98		7.9	70.0	32.0	221	769	10.0	5.0	850	175	70	C
99		7.8	69.0	29.0	220	770	10.0	5.0	850	166	70	C
100	D111	7.7	126.4	79.5	417	1250	23.5	7.9	1450	316	83	C
101		7.8	98.6	61.1	322	997	20.5	7.0	1140	253	71	C
102		7.8	97.6	63.3	320	994	20.6	7.1	1122	241	70	CL
103		7.7	105.3	73.0	350	1054	24.0	8.0	1240	253	75	Cl
104		7.6	127.5	80.1	418	1249	30.0	9.0	1390	278	79	C
105		7.5	137.0	90.5	458	1340	30.0	8.9	1560	349	80	C
106		7.5	146.7	86.9	502	1436	29.2	8.0	1650	395	83	C
107		7.5	173.6	96.6	602	1600	33.4	9.0	1900	422	83	C
108		7.6	154.6	94.9	532	1496	29.9	9.2	1720	422	85	C
109		7.7	120.0	65.5	401	1200	26.0	8.5	1310	373	80	C
110		7.5	170.0	95.0	589	1590	33.0	9.0	1850	422	80	CL
111		7.6	127.0	80.0	417	1250	29.0	8.0	1450	316	83	C
112		7.6	147.0	89.0	505	1436	29.0	8.0	1650	395	82	C
113		7.6	139.0	91.0	459	1350	30.0	9.0	1570	349	80	C
114		7.5	150.0	96.0	540	1500	30.0	9.0	1730	425	81	C
115		7.7	105.0	73.0	356	1060	25.0	8.0	1250	260	76	C
116		7.7	99.0	62.0	325	1000	20.0	7.0	1150	250	73	C
117	Co111	7.9	27.9	54.1	53	222	5.5	5.9	249	80		S
118		7.9	20.5	42.0	45	183	4.0	6.0	201	63		S
119		7.9	22.6	39.4	46	186	5.4	7.4	211	53		S
120		7.6	21.5	18.5	61	175	4.0	6.0	217	35		S
121		7.5	15.6	16.2	30	133	7.2	4.5	146	38		S
122		7.7	19.0	14.1	42	167	5.1	5.1	192	31		S
123		7.7	12.6	12.6	26	109	3.4	3.0	118	30		S
124		7.8	22.1	17.4	62	180	5.4	7.0	218	41		S

C= Clay CL= Clay Loam S= Sand

Appendix (3): DESCRIPTION OF THE REPRESENTATIVE SOIL PROFILS.

Profile No.: 1
Soil unit : D111
Topography : Flat
Vegetation : No vegetation
Parent Material : Fluvio-marine Deposits
Drainage Condition : Very poorly drained
Moisture Condition : Moist throughout
Ground Water Depth : 50 cm.
Classification : Typic Salorthids

DEPTH (cm)	DESCRIPTION
0-2	White(10YR 8/1,dry),thin salt crust(0.2-0.5 cm),abrupt smooth boundary,
2-50	V.dark greyish brown(10YR 3/2,moist) to dark greyish brown(10YR 4/2,dry), clay loam, massive,slightly sticky and plastic,common fine salt crystals,frequent fine shell fragments, weakly effervescence with HCl,diffuse boundary,
50-80	Dark blue grey(5B 4/1,moist),clay with greenish mottles, sticky and plastic,common fine shells,strong effervescence with HCl,gley phenomenon.

CHEMICAL AND PHYSICAL PROPERTIES

DEPTH cm	pH	EC mmhos/cm	Soluble Cations and Anions							ESP	O.M	Parricle Size Distribution				Textural Class
			Ca	Mg	Na	K	Cl	SO4	HCO3			CS	FS	silt	clay	
0-2	7.5	196.1	150	550	2110	31.5	2392	450	2.5	--		1.5	28.5	31.0	39.0	Clay Loam
5-50	7.6	116.1	100	300	952	14.6	1648	240	3.5	69	0.6	13.5	24.0	27.5	35.5	Clay Loam
50-80	7.7	117.2	100	300	984	14.5	1049	243	3.7	70	0.6	6.0	12.0	21.0	61.0	Clay

Appendix (3): Cont.

Profile No. : 2
Soil Unit : D112
Topography : Flat
Vegetation : No vegetation
Parent Material : Fluvio-marine Deposits
Drainage Condition : Moist throughout
Ground Water Depth : 80 cm.
Classification : Aquollic Salorthids

DEPTH (cm)	DESCRIPTION
0-1	Light grey(10YR 7/1,dry),
0-25	V.dark greyish brown(10YR 3/2,moist) to dark greyish brown(10YR 4/2,dry),clay,massive,slightly sticky and plastic,many fine salt crystals and white salt spots, common fine shell fragments,slight effervescence with HCl,diffuse irregular boundary,
25-55	Dark brown(10YR 3/3,moist) to dark greyish brown(10YR 4/2,dry),clay,massive,sticky and plastic,many fine salt crystals,common fine shells,slight effervescence with HCl,diffuse irregular boundary,
55-80	V.dark grey(10YR 3/1,moist),loamy,massive,slight effervescence with HCl,diffuse irregular boundary,
80-110	Dark blue grey(5B4/1,moist),clay loam,sticky and plastic, gley phenomenon.

CHEMICAL AND PHYSICAL PROPERTIES

DEPTH cm	pH	EC mmhos/cm	Soluble Cations and Anions							ESP	O.M	Particle Size Distribution				Textural Class
			Ca	Mg	Na	K	Cl	SO4	HCO3			CS	FS	silt	clay	
0-25	7.7	92.5	59.5	300	974	20.5	1134	213	7.2	70	1.8	1.0	23.5	33.5	42.0	Clay
25-55	7.8	94.2	56.5	310	980	21.0	1104	260	6.0	70	1.6	3.0	15.0	22.0	61.0	Clay
55-80	7.6	90.0	55.5	310	970	20.0	1120	243	7.0	69	1.5	4.5	35.5	37.0	33.0	Loam

Appendix (3): Cont.

Profile No. : 3
Soil Unit : D113
Topography : Flat
Vegetation : No vegetation
Parent Material : Fluvio-marine Deposits
Drainage Condition : poorly drained
Moisture Condition : Moist throughout
Ground Water Depth : 90 cm.
Classification : Typic Natrargids

DEPTH (cm)	DESCRIPTION
0-20	Dark greyish brown(10YR 4/2,moist) to greyish brown(10YR 5/2,dry),clay,weak medium subangular blocky structure, sticky and plastic,weak effervescence with HCl,diffuse boundary,
20-45	V.dark greyish brown(10YR 3/2,moist) to dark greyish brown (10YR 4/2,dry),clay, weak medium subangular blocky structure,slight effervescence with HCl, gradual wavy boundary,
45-80	Dark brown(10YR 3/3,moist) to dark grey(10YR 4/1,dry), clay,weak medium subangular blocky structure,sticky and plastic,diffuse boundary,
80-120	Dark brown(10YR 3/2,moist) to greyish brown(10YR 5/2,dry),clay loam,massive,slightly sticky and plastic.

CHEMICAL AND PHYSICAL PROPERTIES

DEPTH cm	pH	EC mmhos/ cm	Soluble Cations and Anions							ESP	O.M	Particle Size Distribution				Textural Class
			Ca	Mg	Na	K	Cl	SO4	HCO3			CS	FS	silt	clay	
0-20	8.0	46.1	23.8	110	414	4.8	436	109	7.9	49	1.2	0.0	23.5	26.5	50.0	Clay
20-45	8.0	43.0	21.0	103	394	4.5	415	100	7.2	48	0.8	0.0	21.0	26.0	53.0	Clay
45-80	8.1	53.0	38.7	136	424	8.5	549	155	8.5	47	0.6	0.0	19.5	23.5	57.0	Clay
80-120	8.0	49.0	33.0	141	404	7.0	521	133	7.5	44	0.5	1.0	33.0	31.5	34.5	Clay Loam

Appendix (3): Cont.

Profile No. : 4
Soil Unit : D114
Topography : Flat
Vegetation : No vegetation
Parent Material : Fluvio-marine Deposits
Drainage Condition : poorly drained
Moisture condition : Moist throughout
Ground Water Depth : 50 cm.
Classification : Aquic Natrargids

DEPTH (cm)	DESCRIPTION
0-20	V.dark brown(10YR 2/2,moist) to dark brown(10YR 3/3,dry),clay,moderately coarse prismatic structure, v.stick and plastic,weakly effervescence with HCl, smooth clear boundary,
20-35	V.dark greyish brown(10YR 3/2,moist) to dark grey(10YR 4/1,dry),clay,moderately coarse prismatic structure, sticky and plastic,diffuse boundary,
35-55	Dark brown(10YR 3/3,moist) to dark grey(10YR 4/1,dry), silty clay loam,weak medium subangular blocky structure, common platy gypsum crystals,diffuse boundary,
55-80	Blue(5BG 4/1,moist),clay loam,v.sticky and v.plastic, below 80 cm the colour changes to black(5Y 2/1,moist).

CHEMICAL AND PHYSICAL PROPERTIES

DEPTH cm	pH	EC mmhos/cm	Soluble Cations and Anions							ESP	O.M	Particle Size Distribution				Textural Class
			Ca	Mg	Na	K	Cl	SO4	HCO3			CS	FS	silt	clay	
0-20	8.4	23.7	17.3	29.3	236	6.5	245	40.7	4.7	55	1.3	0.5	18.0	30.5	51.0	Clay
20-35	8.4	22.6	14.5	26.1	229	6.0	238	36.5	4.4	51	1.1	1.0	18.0	41.0	50.0	Clay
35-55	8.3	28.5	24.6	39.7	274	5.1	297	45.7	4.7	51	0.7	0.0	27.0	41.0	32.0	silty Clay
55-	8.4	28.0	24.5	38.5	270	5.0	293	44.5	4.3	50	0.6	0.0	30.5	33.0	36.5	Clay Loam

Appendix (3): Cont.

Profile No. : 5
Soil Unit : D121
Topography : Flat
Vegetation : Sugar beet
Parent Material : Fluvio-marine Deposits
Drainage Condition : Moderately well drained
Moisture Condition : Dry in the upper layers
Ground Water Depth : 130 cm
Classification : Typic Torrifluvents

DEPTH (CM)	DESCRIPTION
0-25	V.dark greyish brown(10YR 3/2,moist) to greyish brown(10YR 4/2,dry),clay loam,moderately medium subangular blocky structure,firm,diffuse boundary,
25-45	Dark brown(10YR 4/3,moist) to brown(10YR 5/3,dry),clay loam, moderately coarse subangular blocky structure, firm common fine gypsum crystals,clear boundary,
45-100	Dark yellowish brown(10YR 3/4,moist) to yellowish brown (10YR 5/4,dry),sandy clay loam,weak fine subangular blocky structure,clear boundary,
100-130	V.dark brown(10YR 2/2,moist),clay,v.sticky and v.plastic,spots of $CaCO_3$ and gypsum.

CHEMICAL AND PHYSICAL PROPERTIES

DEPTH cm	pH	EC mmhos/cm	Soluble Cations and Anions							ESP	O.M	Particle Size Distribution				Textural Class
			Ca	Mg	Na	K	Cl	SO4	HCO3			CS	FS	silt	clay	
0-25	8.4	10.5	30.0	35.1	70.5	1.0	97.2	24.9	5.5	17	1.8	0.0	27.5	35.5	37.0	Clay Loam
25-45	8.5	9.2	25.6	25.1	60.0	1.0	84.7	20.0	5.0	18	1.3	0.0	28.5	35.5	36.0	Clay Loam
45-100	8.5	9.2	26.0	25.5	59.2	1.0	85.0	20.0	5.0	18	1.0	1.0	52.0	22.5	24.5	Sandy Caly Loam
-130	8.5	10.2	28.5	32.5	70.4	0.9	82.3	18.5	5.0	18	0.8	0.0	12.5	29.5	58.0	Clay

Appendix (3): Cont.

Profile No. : 6
Soil Unit : D122
Topography : Flat
Vegetation : Cotton
Parent Material : Fluvio-marine Deposits
Drainage Condition : Moderately well drained
Moisture Condition : Moist in the lower layers
Ground Water Depth : > 150 cm.
Classification : Vertic Torrifluvents

DEPTH (cm)	DESCRIPTION
0-25	V.dark greyish brown(10YR 3/2,moist) to dark greyish brown(10YR 4/2,dry),clay,moderately medium subangular blocky structure,hard,diffuse boundary,
25-45	Dark brown(10YR 3/3,moist), to dark greyish brown(10YR 4/2,dry),clay,strong coarse to medium subangular block, v.firm,silken sides,gradual wavy boundary,
45-90	V.dark greyish brown(10YR 3/2,moist) to greyish brown(10YR 5/2,dry),clay,moderately medium subangular blocky,v.firm ,diffuse boundary,
90-120	Brown(10YR 5/3,moist) to Pale brown(10YR 6/3,dry),sandy clay loam,slightly sticky.

CHEMICAL AND PHYSICAL PROPERTIES

DEPTH cm	pH	EC mmhos/cm	Soluble cations and Anions							ESP	O.M	Particle Size Distribution				Textural Class
			Ca	Mg	Na	K	Cl	SO4	HCO3			CS	FS	silt	clay	
0-25	8.1	5.9	10.0	9.9	36.5	0.5	38.0	16.2	5.4	12	1.9	1.0	13.5	25.5	60.0	Clay
25-45	8.0	7.5	15.8	14.2	45.1	0.3	55.2	13.7	6.5	12	1.7	0.5	18.0	18.5	63.0	Clay
45-90	8.1	7.5	14.0	18.5	42.5	0.5	43.1	26.5	4.5	12	1.3	0.0	14.5	30.5	55.0	Clay
90-120	8.1	8.5	20.8	19.2	45.0	0.8	65.0	15.2	5.1	13	0.8	0.0	56.0	22.0	22.0	Sandy Clay Loam

Appendix (3): Cont.

Profile No. : 7
Soil Unit : D123
Topography : Flat
Vegetation : Clover (Afalfa)
Parent Material : Fluvio-marine Deposits
Drainage Condition : Moderately well drained
Moisture Condition : Moist in the lower layers
Ground Water Depth : >150 cm.
Classification : Typic Torrifluvents

DEPTH (cm)	DESCRIPTION
0-20	Dark greyish brown(10YR 4/2,moist) to greyish brown(10YR 5/2,dry),clay loam,moderately medium to coarse subangular blocky,hard,diffuse boundary,
20-50	V.dark greyish brown(10YR 3/2,moist) to dark grey(10YR 4/1,dry),clay,moderately medium to coarse subangular blocky,hard,diffuse boundary,
50-90	Dark greyish brown(10YR 4/2,moist) to greyish brown(10YR 5/2,dry),clay,weak medium subangular blocky,smooth clear boundary,
90-125	Olive brown(2.5Y 7/4,moist) ,sandy clay loam, structureless,many fine mica particles,diffuse boundary,
125-160	Dark greyish brown(10YR 4/2,moist) to greyish brown(10YR 5/2,dry),sandy clay loam.

CHEMICAL AND PHYSICAL PROPERTIES

DEPTH cm	pH	EC mmhos/cm	Soluble Cations and Anions							ESP	O.M	Particle Size Distribution				Textural Class
			Ca	Mg	Na	K	Cl	SO4	HCO3			CS	FS	silt	clay	
0-20	7.9	1.7	2.0	5.1	10.0	0.2	10.0	5.0	3.0	6	1.9	1.5	28.5	32.0	38.0	Clay Loam
20-50	8.0	1.6	2.2	5.8	7.5	0.4	11.0	8.0	3.1	6	1.6	0.0	23.5	28.0	48.5	Clay
50-90	8.0	2.4	3.6	7.4	13.9	0.3	12.1	8.2	5.0	9	1.0	0.5	23.0	26.5	50.0	Clay
90-125	8.0	2.9	4.0	5.0	19.0	0.5	17.0	8.0	4.0	10	0.8	6.0	41.0	20.0	23.0	Sandy Clay Loam
125-	8.0	3.1	3.5	6.1	21.5	0.4	21.0	7.9	3.0	10	0.7	4.0	46.0	20.0	21.0	Sandy Clay Loam

Appendix (3): Cont.

Profile No. : 8
Soil Unit : Colll
Topography : Flat
Vegetation : No vegetation
Parent Material : Marine Deposits
Drainage Condition : Well Drained
Moisture Condition : Moist Throughout
Ground Water Depth : 65 cm
Classification ; Typic Torripasamments

DEPTH (CM)	DESCRIPTION
0-15	Pale brown(10YR 6/3,moist) to very pale brown(10YR 7/3,dry),fine sand,single grains,slightly effervescence with HCl,many shells and shell fragments,clear irregular boundary,
15-60	V.dark grey(2.5Y 3/2,moist), fine sands,single grains,strong effervescence with HCl,common fine shells and shell fragments,gradual wavy boundary,
60-100	Greyish brown(10YR 5/2,moist),fine sands,single grains,common shells and shell fragments,strong effervescence with HCl.

CHEMICAL AND PHYSICAL PROPERTIES

DEPTH cm	pH	EC mmhos/cm	Soluble Cations and Anions							ESP	O.M	Particle Size Distribution			Textural Class
			Ca	Mg	Na	K	Cl	SO4	HCO3			CS	FS	silt+clay	
0-15	8.4	24.5	16.6	80.6	190	6.6	261	28.9	4.1			0.0	98.5	1.5	sand
15-60	8.4	42.2	17.2	100.0	381	8.1	463	34.6	8.2			0.0	99.0	1.0	sand
60-100	7.9	53.4	12.5	117.7	499	11.6	593	40.1	8.0			0.0	98.0	2.0	sand

Appendix (4): 2- Dimensional table of land use/cover map.

Spectral Classification Results	Spectral Correlation Results 0	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16
0	0	0	0	0	0	0	0	0	0	0	0	0	0	22	0	0	0
1	20	20	20	20	20	20	20	20	20	20	20	20	20	20	20	20	20
2	18	18	18	18	18	18	18	18	18	18	18	18	18	18	18	18	18
3	15	15	15	15	15	15	15	15	15	15	15	15	15	15	15	15	15
4	16	16	16	16	16	16	16	16	16	16	16	16	16	16	16	16	16
5	17	17	17	17	17	17	17	17	17	17	17	17	17	17	17	17	17
6	21	21	21	21	21	21	21	21	21	21	21	21	21	21	21	21	21
7	19	19	19	19	19	19	19	19	19	19	19	19	19	19	19	19	19
8	10	10	10	10	10	10	10	10	10	10	10	10	10	10	10	10	10
9	1	9	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1
10	2	9	2	2	2	2	2	2	2	2	2	2	2	2	2	2	2
11	3	9	3	3	3	3	3	3	3	3	3	3	3	3	3	3	3
12	3	9	3	3	3	3	3	3	3	3	3	3	3	3	3	3	3
13	4	9	4	4	4	4	4	4	4	4	5	4	4	4	4	4	4
14	4	9	4	4	4	4	4	4	4	4	4	4	4	4	4	4	4
15	5	9	5	5	5	5	5	5	5	5	5	5	5	5	5	5	5
16	5	9	5	5	5	5	5	5	5	5	5	5	5	5	5	5	5
17	6	9	6	6	7	6	6	6	6	6	6	6	6	6	6	6	6
18	7	9	7	7	7	7	7	7	7	7	7	7	7	7	7	7	7
19	7	9	7	7	7	7	7	7	7	7	7	7	7	7	7	7	7
20	8	9	8	8	8	8	8	8	8	8	8	8	8	8	8	8	8
21	9	9	9	9	9	9	9	9	9	9	9	9	9	9	9	9	9
22	11	9	11	11	11	11	11	11	11	11	11	11	11	111	11	11	11
23	12	9	12	12	12	12	12	12	12	12	12	12	12	12	12	12	11
24	13	9	13	13	13	13	13	13	13	13	13	13	13	13	13	13	11
25	22	9	22	22	22	22	22	22	22	22	22	22	22	22	22	22	22
26	14	9	14	14	14	14	14	14	14	14	14	14	14	14	14	14	14
27	14	9	14	14	14	14	14	14	14	14	14	14	14	14	14	14	14

Appendix (5): 2- Dimensional table of soil salinity/alkalinity map.

Final Digital Map	Physiographic mapping units (visual interpretation)																		
		Co121	Co111	Co112	island	Co131	D111	D112	D115	D113	D116	D114	D121	D122	D123	D117	sea	D211	D117
0	0	18	15	17	6	19	2	4	4	5	6	8	23	24	25	9	20	10	9
1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1
2	2	2	2	2	2	2	2	2	2	2	2	2	2	2	2	2	2	2	2
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