SOIL SALINITY MAPPING IN THE NILE DELTA, EGYPT
USING REMOTE SENSING TECHNIQUES

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ABSTRACT

Digital image processing techniques supported by visual interpretation and field checking were used to delineate saline soils in the northern part of the Nile Delta in Egypt. Spectral classification and spectral correlation methods were used. The thermal data was useful in assessing soil moisture and water logged areas as well as the areas affected by salinity.

KEYWORDS: Soil salinity, water logging, spectral classification, spectral correlation.

1 INTRODUCTION

Salt affected soils have received the attention of scientists and development workers throughout the world. The problem has been a subject matter of interest which is evidenced by a number of scientific commissions (FAO, 1971; University of Engineering and Technology, 1976) as well as by various works done in this field (Menenti et al., 1986; Epema, 1986; Mulders and Epema, 1986; Manchanda, 1981; Tricatsoula, 1988; Massoud, 1977; etc.).

Saline soils are characterised by an excess amount of soluble salts with electrical conductivity measurement of more than 4 ds/m. Salt accumulation takes place in low lying areas in drier climatic regions where evaporation is higher than precipitation and when there is not surface run off and also when the ground water level approaches the surface. Irrigation water is another source of soil salinity if there is not enough water for leaching.

In Egypt all the agricultural areas are under irrigation. Agriculture is of prime importance for the livelihood of Egyptian population. However, degradation of soils through salinity and alkalinity has been a major agricultural problem. The high evapotranspiration rate in combination with high ground water level causes salinity development especially in the northern part of the Nile Delta.

The objective of this study is to apply various methods incorporating spectral and spatial information obtained from satellite data and ancillary information to investigate, identify and delineate soils with salinity and alkalinity problems.

2 DESCRIPTION OF THE STUDY AREA

The study area lies in the northern part of the Nile Delta between the two Nile branches (longitude between 30°40'00" and 31°00'46" East and latitude between 31°10'29" and 31° 30'17" North). Its northern limit is the Mediterranean sea while the southern boundary is the present limit of cultivation in the Delta. The general topography is level, except for the rolling to undulating sand dunes, towards the north, which separate the deltaic plain from the Mediterranean sea. Two main landscape units may be distinguished in the area ; a) deltaic plain with marine influence and b) coastal plain.

The climate is typically mediterranean with dry and hot summers and cool and wet winters. The average summer temperature is 26 degree celsius and mean winter temperature is 14.5 degree celsius. Annual precipitation is 190 mm., mainly falling in the months of November through February (source: Alexandria Meteorological Station data 1951-1983).

Cultivation of various crops such as rice, cotton, wheat, barley, sugar beet, maize, clover are under gravity irrigation. The natural vegetation types are mainly reeds (*Phragmites spp.*) and salt loving plants such as *Salicornia fructicosa* and *Atriplex spp.* surrounding the swampy areas.

3 MATERIALS AND METHODS

Landsat Thematic Mapper data was used not only because of improved spatial (30 meter) and spectral (7 bands) resolution but also because many researchers have found TM data very valuable in mapping soil (Menenti et al., 1986; Epema, 1986; Mulders and Epema, 1986; etc). Besides, the presence of a thermal band in the sensor gives another dimension especially for the detection of soil moisture conditions. Thus, a computer compatible tape of a quarter scene obtained on 18 April 1989 was acquired. The date of the image taken coincides with the field work period.

After the regular pre-processing procedures of the data, a false colour composite, at scale 1:100,000, of TM band combinations of 4, 5 and 3 was prepared on which visual interpretation was carried out. False colour composites using other TM band combinations were also used to discern minor features. For processing the data 'The Integrated Land and Watershed Management Information System' (ILWIS), a software package having capability of integrating image processing and geographic information system, was used (see Valenzuela, 1988). Work was carried out on an IBM PC AT compatible with proper hardware requirement for ILWIS (see Gorte et al., 1988).

3.1 Field work

In the field, observations were made on the type of soil, depth to ground water table, evidence of saline features, land use and/or land cover, etc. Some representative soil profiles were also described. Soil samples were collected from various locations under different land use/land cover types. In total 124 soil samples were collected and analyzed at the laboratory of the Department of Soil Science at the Cairo University. Analyses performed were soil particle size distribution, soil pH, electrical conductivity, organic matter content, soluble cations and anions as well as exchangeable sodium.

In addition, in order to study the spectral reflectance characteristics of various saline soils, measurement of spectral reflectance from soil and vegetation was done by help of a field spectro-radiometer, Exotech Model 100, having spectral bands compatible to Landsat MSS. Data were entered in a field computer (SHARP PC 1500) using a program called Spectro-data which can draw reflectance curves in addition to storing of data (Shrestha, 1987).

3.2 Spectral classification

Salinity mapping is not an easy task. In many cases salinity cannot be detected directly on an image, especially if the grade is not severe (Shrestha, 1990). There is always problem of mixed pixel because salinity is often scattered in isolated spots. In bare and dry areas however, it is easier but if the area is covered by crops it can not be directly detected. Salinity has then to be inferred from the crop vigour. In the study area two distinct conditions exist; bare land and cultivated area. In order to segregate various degrees of salinity, masking of the area was done to separate: 1) the formerly reclaimed cultivated land, 2) the recently reclaimed land and 3) the coastal plain. Masking procedure was done by using the visual interpretation map. From the field knowledge as well as after checking the soil laboratory analysis data, training samples were taken for different salinity classes. Classification was then carried out for each area individually using parametric approach which takes into account mean vector and covariance matrix for each training class. Five TM bands (TM2, TM3, TM4, TM5, TM7) were used and the classification algorithm chosen was maximum likelihood which is based on Bayes rule. It links a-priory class probability to a posterior class probability (Mulder and Kostwinder, 1987).

In order to remove some possible noises from the classification result, post classification processing was done by running a majority filter. The obtained results from three areas were finally mosaiced. In doing so, some classes were overlapping and they were combined. Some cases also existed where a certain class had only a low coverage. They were then eliminated.

3.3 Spectral correlation

Spectral correlation, also called spectral filters by means of known reference spectra in the analysis of reflectance data (Mulder, 1981) were used in generating a normalised vegetation index (Nieuwenhuis and Shrestha, 1984; Bakx and Mulder, 1989). The transformation is based on known reference samples. In the present study, the method was used to map soil salinity. Two reference samples were used: one with low salinity level and the other with high salinity level. In case of cultivated area one sample consisted of non-saline bare soil and the other sample consisted of pure vegetation. Transformation vector is computed by the sum normalized difference between the reflectance data from the highly saline sample and that of the non-saline sample. The resulting data is simply the inner product of the transformation vector with the pixel spectral vector. Finally a colour lookup table is generated to print the resulting image.

4 RESULTS AND DISCUSSION

As we can see from above, both procedures (classification and spectral correlation) resulted into two output images. They were evaluated and combined using the two dimensional table calculation procedure available within ILWIS which works making use of simple conditional and logical statements (IF, THEN, ELSE, AND). The final map was geometrically corrected to fit a topographic base map of scale 1:100,000.

From the topographic map, the infrastructure such as roads, villages and the canal network, etc. was digitized and rasterized. This information was then added to the final map. The resulting image is given in plate 1 and the legend can be found in table 1.

It shows various levels of salinity in the recently reclaimed as well as in the old reclaimed cultivated land. The problem seems to be severe in the recently reclaimed areas where soil conductivity measurement often exceeds 15 ds/m and some cases well above 100 ds/m. The soils are usually deep and fine textured (clay to clay loam). The drainage is often poor with shallow ground water table (ground water table may start already at 50 cm. depth). The pH ranges from 7.5 to 8.5. The laboratory analysis of these soils indicates high amount of exchangeable sodium leading to high exchangeable sodium percentage (often more than 15%) which shows both saline and alkaline conditions.

In the formerly reclaimed areas, though, the condition is not that severe. The soils are deep and fine textured (clay loam to clay) and only slightly affected by salinity (EC 4-8 ds/m) with deep ground water table (more than 150 cm.). The pH ranges from 7.9 to 8.5. Some soils are moderately affected by salinity (EC 8-15 ds/m). Salt free areas also do exist but the coverage is very little (<10 per cent). Exchangeable sodium percentage is less than 15, addressing only the salinity problem in the area.

In the coastal areas, the soils are deep and sandy in texture with common fine shell fragments. The pH varies from 7.9 to 8.4 and the electrical conductivity readings vary from 24 to 53 ds/m. The area is poorly drained with ground water table nearly at the surface (50 cm.).

Thermal data was also used for the study. Linear stretching of the data was carried out (see plate 2). The wetter parts including swampy areas are clearly visible. The cultivated areas can also be separated easily. The warmer areas are surprisingly the areas most affected by salinity.

Results of the field spectral reflectance measurements indicate that the highly saline soils (conductivity reading more than 20 ds/m) reflect high amount of radiation as compared to the soils with low salinity level. The amount of salt crystal formation on the surface of the highly saline soils contributes directly to high surface reflectance. Since the field spectrometer used is compatible to Landsat MSS data, the data obtained by the spectrometer is compared to the data obtained from the comparable TM bands (TM bands 2,3 and 4). Statistical analysis shows that the spectrometer bands are highly correlated to the corresponding Landsat TM bands with correlation coefficient of 0.96.

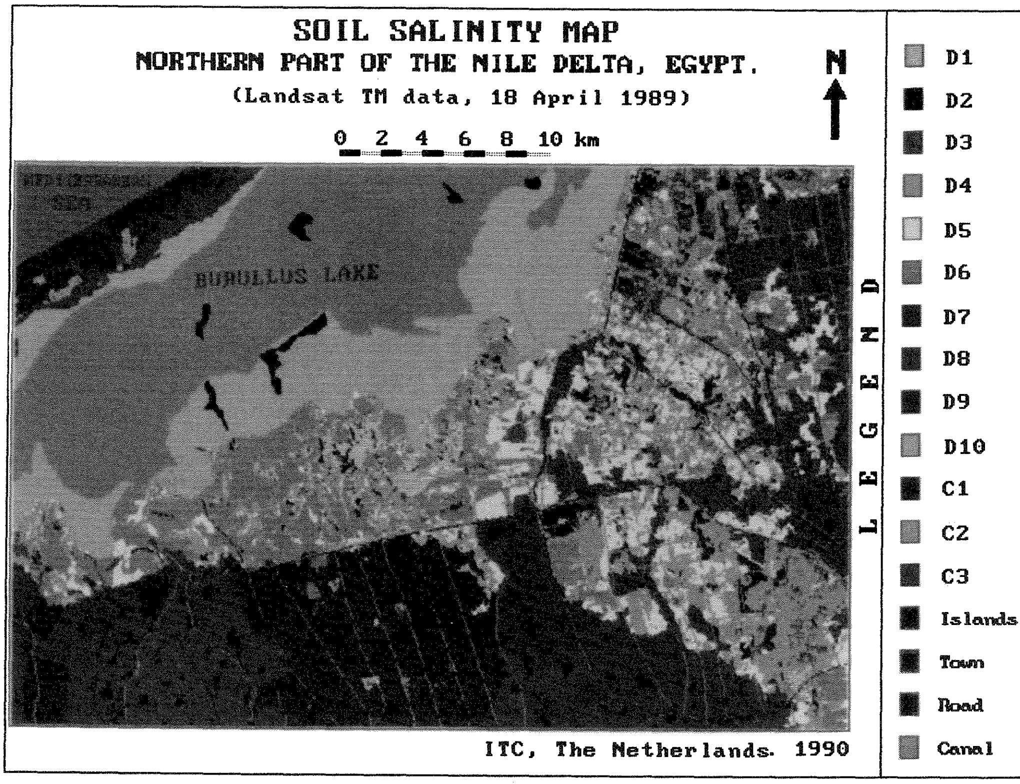

Plate 1: Soil salinity map

Landscape	Relief	Lithology/ Origin	Landform	Phase	Mapping unit	Salinity level	Area %
Plain	Deltaic	Alluvial/ Marine	Association of overflow and decantation basins	Recently reclaimed land	D1	Extr. saline EC > 150 ds/m	2.0
					D2	V.highly saline EC 70-100 ds/m	0.8
					D3	V.highly saline with puffed surface EC 70-100 ds/m	2.7
					D4	Highly saline EC 40-|0 ds/m	10.5
					D5	Highly saline EC 16-30 ds/m	8.2
					D6	Flooded areas	8.1
				Old reclaimed and cultivated land	D7	Mod.saline EC 8-15 ds/m	8.2
					D8	Sl.saline EC 4-8 ds/m	19.1
					D9	None saline EC <4 ds/m	1.4
			Swampy areas		D10		11.6
	Coastal	Marine	Swales		C1	Highly saline	1.6
			Low dunes		C2	None saline	1.3
			Lagoon		C3		16.1

Table 1: Legend of the soil salinity map

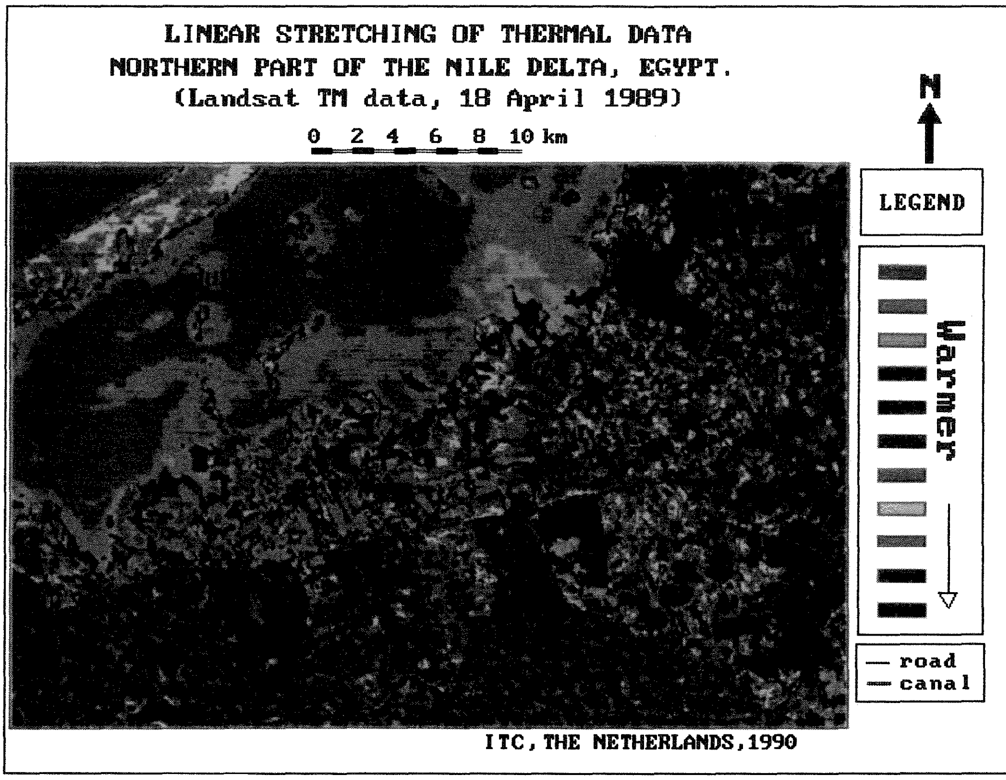

Plate 2: Thermal map

5 CONCLUSION

Salinity mapping in the bare areas was found rather easy. But still it may be tricky in case the area is not dry because salt dissolves quickly if the area is wet or flooded. So, selection of image in drier season is an important criteria. In case of the cultivated areas especially when it is irrigated one may not notice salinity problem directly. It may not be visible directly either because it may be obscured by the vegetation cover or the salt gets quickly dissolved in the irrigation water. If the problem is severe however, it shows in the crop growth. For mapping salinity in the irrigated areas context masking may be required to improve the classification.

In the recently reclaimed areas as well as in the coastal plain, high amount of sodium salt indicates the cause of the salinity development mainly due to the encroachment of the sea water from underground.

Although field spectral reflectance measurement indicates mainly two types of curves showing the soil types either highly affected or slightly to moderately affected by salinity, firm conclusion can not be made since field surface reflectance is a function of various parameters including time of the day affecting sun angle variations and soil moisture conditions. Besides, the different salt types may reflect differently in different spectral bands which is a subject in itself for further research.

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