Potentials and constraints of soil salinity studies in two different conditions of Iran using Landsat TM data

S.K.Alavi Panah [a] , A.M.Pouyafar [b]

[a] Associate Professor, College of Geography, Department of Cartography, University of Tehran, Tehran, Iran. salavipa@chmran.ut.ac.ir. [b] The Bureau of Sand Dune Fixation & Combating Desertification, Forest Rangeland and Watershed Management Organization (FRWO),Iran. pouyafaramir@yahoo.com.

Abstract-Soil degradation including soil salinity, erosion and waterloging are among the main factors of desertification. The main aim of this study was to evaluate the efficiency of Landsat TM data for soil salinity mapping in the Karaj Roudkhaneh Shour catchment in the west of Tehran, an area of semi-arid condition, and Ardakan area as a sample of arid area using the same method and algorithm. The optimum band combination was elected for image classification using optimum index factor, two dimensional feature space analysis and principal component analysis. The training classes were selected based on the soil salinity levels. Then spectral classes were classified by maximum likelihood method and these classes were regrouped in the information classes. The results have shown that the accuracy of image classification in the extreme arid condition is significantly higher than Karaj Roudkhaneh Shour catchment for severe saline soil, while the accuracy of non- saline soil condition in the Karaj Roudkhaneh Shour catchment is relatively higher than Ardakan area. Based on the results obtained, it could be also concluded that arid regions are more suitable for soil salinity studies than semi-arid using the TM data.

Keywords: soil salinity, constraints, image classification, Vegetation.

1. INTRODUCTION

Soil degradation is one of the main problems of many countries faced to it. In this case some of the most important effective factors are erosion , waterlogging and specially salinity. Soil salinity is considered as an environmental hazard and one of the factors in desertification in arid, semi-arid and dry sub-humid areas both dry and irrigated regions. It causes decreasing or losing agricultural productivity.

In Iran, salt-affected regions are included the vast ones of eastern, central and southern areas. It is estimated that 15% of the total land surface of Iran and about 30% of the plains of it are affected by salinity. The soils of these areas are so heavy (clay) without improper drainage, having high-level aquifer and high salinity, particularly in surface and among soil different layers. In general, these lands have bare soils and are improper for cultivation. But in some parts, due to having lower salinity concentrations, they are cultivated by salt-tolerant crops such as cotton, sugar cane, wheat, barely and etc.

According to the recent research carried out in Iran (BSDFCD,2005)* the soil-affected areas constitute six types features (Figure 1):

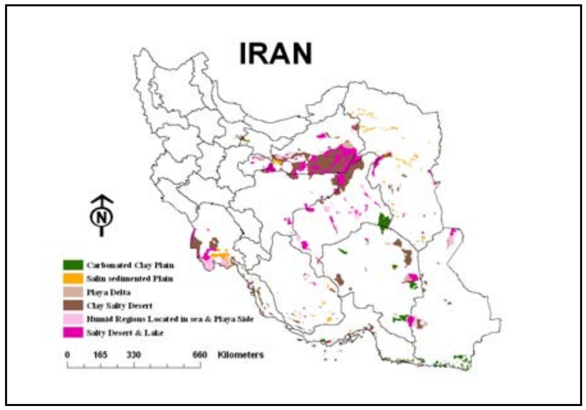


Figure 1. Six types features of salt-affected areas in arid, semi-arid and dry sub-humid of Iran.

(1) Carbonated clay plain, (2) Saline sedimented plain, (3) Playa delta, (4) Clay salty desert, (5) Humid regions located in sea and playa side, (6) Salty desert and lake.

There are so many studies based on satellite data on soil salinity. In this regard, some problems can be distinguished:

1) Soil salinity is a function of time and space.
2) The spectral overlap among different soil types, e.g, gravelly soil surface, desert crust and salt crust.

Zinck (2001) reported that monitoring of salinity spatial changes for anticipate further soil degradation is needed. It means that first identifying the places where salts concentrate and second detecting the temporal and spatial changes in this occurrence must be done. Eldiery A. (2005) showed that, the green band, the near infrared band, and divided by the red band ratio are strongly related to soil salinity.

Lillesand and Kiefer (1994) used the TM thermal band and the TM reflective bands independently, because the TM thermal band is related to the thermal properties of the materials (e.g. soil, lithdogy). Goossens and Van Ranst (1996) proved that the choice of thermal band is very important for the detection of different soil types, especially gypsiferous soils.

Naseri, (1998) used MSS bands 3,4 and 5 salt detection in addition to TM bands 3,4,5 and 7.

Menenti, Lorkeers and Vissers (1986) reported that TM bands 1 through 5 and 7 are suitable for detecting salt minerals, in particularly when they are a dominate soil constituent.

* Bureau of Sand Dune Fixation and Combating Desertification.

This paper intends to show the efficiency, potentials and constraints of satellite data in mapping soil salinity in two various areas of Iran and comparing obtained results. Those selected areas are as follows (Figure 2):

Figure 2. Localization of the study areas (1&2)

1) Karaj Roundkhaneh shour catchment in the west of Tehran, an area of semi-arid condition.
2) The other selected area is located in the central Iranian deserts. This area is part of the Ardakan that is located in the Ardakan playa margin as a sample of arid area.

2. MATERIALS AND METHODS

In this research the following materials were used:
1) The obtained data form 7 bands of TM (Landsat) , 2) Topographic maps and DEM , 3) Thematic maps about soil, soil salinity, geological and other maps , 4) Field data and 5) Other ancillary data.
Figure 3. illustrate the organism of the field investigation in both of areas (area 1 & 2).
In this study, the classes were primarily defined based on field observations, soil and soil salinity maps, the geologic maps, some soil physico-chemical properties condition vegetation (specially in area 1), reports, interviews of farmers and a general landuse map of the study areas.

2.1. Selection of training classes

The training classes in the cultivated areas are described and defined based on the type and density of vegetation and associated soil salinity. In case of bare soil, the classes were mainly based on the degree soil salinity. For this purpose soil salinity observation (ds/m) at the different soil depth divide from the soil salinity map were digitized and then rasterized. Due to the large heterogeneity of some land cover types (soil surface condition in area 1 and vegetation condition in area 2). In both of areas, 26 classes for area 1 and 18 classes for area 2 were necessary to be trained (Tables 1 & 2).

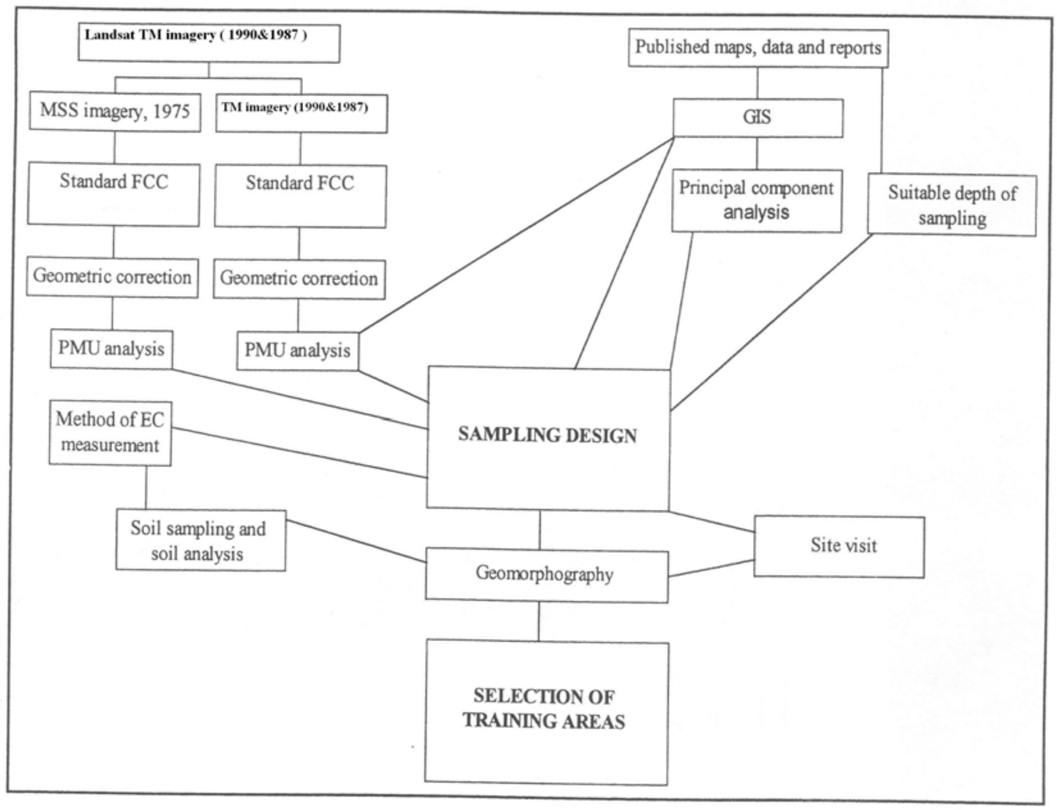


Figure 3. Flowchart showing the methodology of field investigation.

2.2. Selection of training classes

Registration of images and selection of optimum spectral bands .It is notable that the defined classes might be separable, not correctly separable and/or non-separable. Therefore it is needed to examine the separability of the defined classes and to selected the most appropriate bands for the land cover classification. The validity of the training

Table 1. The training classes based on field observations, maps and reports used in the field works (area 2).

Land cover	Class nr.	Class symbols and description	Land cover	Class no.	Class symbols and description
Vegetation	1	Veg-salt: salt affected vegetation	Very severe saline soil	10	S4-1: very severe saline soil1
	3	Veg-sparse: sparse vegetation		24	S4-2: very severe saline soil 2
	15	Pist-1: Pistachio	Gravely saline soil	6	S4-lowg: very severe saline soil with low gravely surface
	18	Pist-2: affected pistachio	Pavement	11	Gr: Desert pavement
	14	Healthy-veg: Healthy vegetation	Soil with gypsum	17	Gr-gyp: soil with gypsum (gypsum very close to the surface)
Non to slightly saline soil	8	S0-1: non saline soil		13	S4-gr1: soil with gypsum (gypsum in the sub-surface)
	12	S0-DC: non saline soil with covered by desert crust	Salt crust	16	Salt-crust: whitish colour salt crust
	9	S0-ER1: eroded non saline soil		20	Dark crust: dark colour salt crust
	19	S0-ER2: highly eroded non saline soil)	Alluvial fan	2	Alluv-2: alluvial fan 1
	23	S0-2: non saline soil 2		5	Alluv-1: alluvial fan 2
	26	S0-3: non saline soil 3	Neogene	7	Neogene
	21	S1: slightly saline soil	Mountain	25	Mountain
Severe saline soil	22	S3: severe saline soil	Urban	4	Urban

Table 2. The training classes based on field observations, maps and reports used in the field works (area 1).

ame of Class	Class symbol	Class (No.)	Land cover
Agronomy 1-S0	Fl1s0	1	Vegetation- non to slightly saline soil
Agronomy 1-S1	Fl1s0	2	Vegetation- non to slightly saline soil
Agronomy 1-S2	Fl1s2	3	Vegetation- moderately saline soil
Agronomy 1-S3	Fl1s3	4	Vegetation-severe saline soil
Agronomy2	Fl2	5	Vegetation- non to slightly saline soil
Agronomy3	Fl3	6	Vegetation- non to slightly saline soil
Fallow land	Fol	7	Vegetation- non to slightly saline soil
Pistachio garden-S0	Gr1so	8	Vegetation- non to slightly saline soil
Pistachio garden-S1	Gr1s1	9	Vegetation- non to slightly saline soil
Pistachio garden-S2	Gr1s2	10	Vegetation- moderately saline soil
Apple garden	Gr2	11	Vegetation- non to slightly saline soil
Vine garden	Gr3	12	Vegetation- non to slightly saline soil
Rangeland 1	Rg1	13	Vegetation- non to slightly saline soil
Rangeland 2-S2	Rg2s2	14	Vegetation- moderately saline soil
Rangeland 2-S3	Rg2s3	15	Vegetation-severe saline soil
Rangeland 2-S4	Rg2s4	16	Vegetation-very severe saline soil
Haloxylon	Ta	17	Vegetation- moderately saline soil
Saline lands	sl	18	very severe saline soil

data was evaluated from the 2D-featyre spaces, while quantitative evaluation involved statistical separability analysis and classification accuracy assessment. The by using the 4 TM reflective bands as well as the TM thermal band.

Based upon the obtained from Optimum Index Factor (OIF) and analyzing the 2-D feature space the TM bands 3,4,5 and 7 (being the most informative bands) were selected as the optimum spectral bands for classifying the TM images.

Using both of the 26 and 18 training classes a maximum likelihood classification was made.

Different method have been suggested for the accuracy assessment. In this study, the method of the Error Matrix was used to represent the classification accuracy.

Obtained result from the Error Matrix shows that, using the band combination TM 3,4,5 and 7 , in some regions many pixels are not correctly classified. There are spectral values interference between some classes. For example:

1) In study area 1, Although the overall accuracy of this classified image is relatively high (86%), but the accuracy of some classes such as : class 8 (pistachio garden-S1), class12 (Rangeland 1) and class 15 (Rangeland 2-S3) are respectively 70% , 75% and 72%. (Figure 4).
2) In study area 2, however the total accuracy of this classified image is relatively high (92%) a careful look shows that the accuracy class 6 (Gravely Saline soil), class 7 (non saline soil with desert crust) and class 23 (non saline soil 2) are respectively, 79%, 57% and 36.9% (Figure 5).

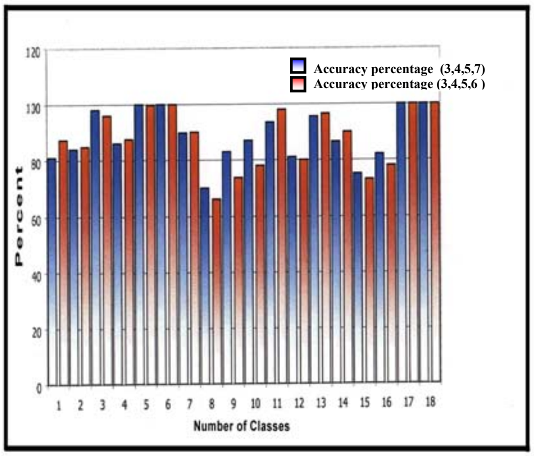
Based on (1) the preliminary interpretation of the land cover type, especially those with salt-affected vegetation (area 1) and gravely surface (area 2), (2) the 2D-feature spaces and (3) the OIF results, we concluded that the TM thermal band can be useful for the study of soil salinity and should be include in a combination with TM bands with 3,4 and 5.

In this way a combination of the TM bands 3,4,5 and 6 was used for image classification.

2.3. Classification result based TM bands 3,4,5 and 6

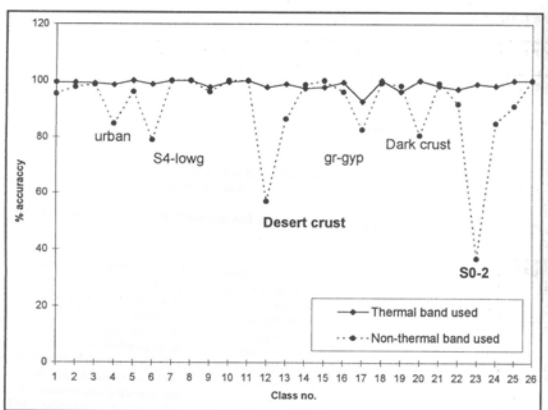
The same training areas and the same algorithm were used to classify the band combination of TM bands 3,4,5 and 6. The results obtained clearly shows that some training classes have a low accuracy in the non TM thermal based classified images, while they have a highly acceptable classification accuracy in the TM thermal based classified image. The differences were significant in particularly in area2 (Figure 4,5). The difference in types and density of vegetation and salt types in two areas can be the main reason.

The TM thermal band has a key role in separating saline soils especially in bare soils or sparse vegetation area similar



Class no. =class number (see table 2)

Figure 4. Comparison between the classification accuracy using TM included and TM excluded band combination (area 1).



ıss no. = Class number (see table 1)

Figure 5. Comparison between the classification accuracy using TM included and TM excluded band combination (area 2).

to area 2. Allen et al. (1996) showed that the TM thermal band is a very useful tool in separating gypsum from other lithologies. In this case, Moreau (1991) reported that digital mixed classification of Landsat bands 4,5 and 7 allowed the discrimination between saline and saline-sodic soils but not the distinction of degrees of salinity/sodicity. For improving the results of the classified image, the obtained spectral classes depend on the both areas were regrouped into information classes based on the type, characterization of the classes and soil salinity types. For this purpose, 18 spectral classes on area 1 and 2 spectral class on area2 were regrouped into 10 and 3 class. In addition to, the soil salinity observations were merged based on soil and on soil salinity conditions (Table 3).

3. CONCLUSION

The results of the correlation between the filed soil salinity and TM digital data and comparison accuracy obtained in

Table 3- Similarity Percentage Resulted from Crossing Vegetation Map Effected by Salinity and Soil Salinity Map (area 1)

Information Classes of Vegetation Map Effected by Salinity	Soil Salinity Classes			Correlation (%)
	S0	Ss1 – S3	S4	
VegS0	123889	13211	3163	88.3
VegS1 – S3	91211	237224	83108	66.4
VegS4	14119	72859	61068	41.2

Percent of Total Accuracy = %60.3

both areas reveal that the total accuracy of image classification in the area 2 (92%) is higher than area 1 (60.3%). But in scrutinizing of results shows that some of similar classes in the both areas are different from each other, as if the accuracy of image classification in the severe saline soils in the area 2 is significantly higher than area 1, while the accuracy of non-saline soils condition in the area 1 is relatively higher than area 2. During the investigation stages it prove that the difference in the accuracy of classes in the both areas can be due to the climatic and geographical conditions and also limitations on the use of remote sensing data for mapping soil salinity. Metternicht, G.I. and Zinck, J.A. (2002) reported that limitation on the use of remote sensing data for mapping salt-affected areas are shown related to the spectral behaviour of salt types, spatial distribution of salts on the terrain surface, temporal changes on salinity, interference of vegetation, and spectral confusions with terrain surfaces. The vegetation condition, soil type and date of TM images recording were very different on the study areas. The vegetation of area 1 was strongly more various and more dense than area 2. It can be caused interference reflectance of vegetation with the reflectance of salinity feature. Tueller (1987) and Vinogradov (1984) reported that soils in arid regions differ wildly in their spectral response and contribute significantly to the overall spectral response when the vegetation cover threshold is below 25-35%.Wiegand et al (1994) showed that a vegetation index was useful in mapping soil salinity over a sugar cane. Wiegand, Anderson, Lingle and Escobar (1994) found a high correlation between NDVI and soil electrical conductivity, allowing to separate saline-alkaline soils from non-affected ones. In addition, salt types mineralogy and the terrain surface feature are very different in the both of areas. Thus these reasons can caused low accuracy of classification (separability). Soil physical properties such as organic mater have been correlated to specific responses (Dalal and Henry, 1986., Shonk et al., 1991). The application of remote sensing for soil mapping are limited because several of the variables can impact soil reflectance such as tillage practices and moisture content. Desert surface feature like saline sedimented plain, desert pavements, salty desert and lake, Calcium carbonate and gypsiferous surface are geomorphologocal feature which can generate high levels of reflectance, similar to those of areas with high salt concentration. In general, highly saline areas are strongly correlated with playas and lagunary flats, while non-affected areas are basically on piedmont glacis (Metternicht & Zinck, 2002). Clark et al (1990) showed that some soil properties have been related directly to a soil spectral response, or inferred based on remotely sensed measurements of crop canopies, including soil texture, nitrogen level, organic matter content, and salinity status.

Based on the obtained results from this research, we may generally conclude that:

(1) The arid regions are more suitable for soil salinity studies than semi-arid using the TM data.

(2) The TM reflective bands can not classify and discriminate saline soil upto accepted level. In this case the thermal band improved the separability of the saline areas.

(3) For improving the accuracy of remote sensing to map soil salinity it must be used some of the tools and technologies such as multiple images from the same year or different years, various sources of remote sensing data, proper recording image date, thematic maps (soil , topographical and geological maps), different image processing methods (band ratios, principal components analysis data fusion, supervise classification and etc.) and historical field and laboratory data.

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