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Accuracy Assessment of Soil Salinity Map in Yazd-Ardakan Plain, Central Iran, Based on Landsat ETM+ Imagery

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Abstract: Soil salinity is an important factor which limits plant growth and reduces crop production at different levels. It pronouncedly occurs in arid and semiarid regions and, therefore with correct information and up to date maps about it, mapping, evaluating and monitoring of soil salinity can be conducted. 48 surface soil samples representing Yazd-Ardakan plain were collected and surface soil salinity was measured. Landsat ETM+ data, that cover the area, were acquired in 2002. Results showed high correlation between ETM+ band 3 and salt concentration expressed by the exponential equation: $y = 0.001e^{0.058x}$ and correlation coefficient R=0.58. Thus, applying this equation to Landsat band 3, a soil salinity map was prepared.Ten soil samples for investigation of map accuracy was applied. The obtained soil samples and other more ten soil samples which basically had high similarity in spectral reflectance and geomorphological characteristics were used to examine the produced soil salinity map and to assess its accuracy. According to results the produced soil salinity map had an overall accuracy equal to 87% and Kappa index equal to 47% indicating an acceptable accuracy for this classification.

Key words: ETM+ images % Soil salinity % Yazd-Ardakan plain

INTRODUCTION

Soil salinity is a severe environmental hazard [1] that affects the growth of many crops. It, pronouncedly, occurs in arid and semiarid regions and reduces crop production with different levels. It is also a major limiting factor for crop yield in poorly drained soils [2-5].

There are mainly two kinds of soil salinity: naturally occurring dryland salinity and human-induced salinity which are leading to low yields. In Iran, salt accumulation, groundwater and inadequate drainage conditions are the major causes of the land salinization. Generally, the classical soil survey methods, especially in large areas are relatively expensive and time consuming. Remote sensing has proved to be an effecient tool to overcome these problems. Remotely sensed data have great potentials for monitoring dynamic processes, such as salinization. The ability to detect soil salinity accurately from remote sensing data is important because it saves labor, time and effort as it is compared with conventional methods of soil salinity survey [6]. The integration of remotely sensed data, Geographic Information Systems (GIS) and spatial statistics provides useful tools for modeling variability to predict the distribution, presence and pattern of soil characteristics [7]. This integration also provides tools for assessing the landscape-scale structure of forest and rangelands [8]. Dwivedi [9] used Landsat MSS and TM data for more detailed mapping and monitoring of the salt affected soils in the frame of the reconnaissance soil map of India [9]. Also, De Dapper and Goossens [10], indicated the development of GIS and remote sensing for monitoring and predicting soil salinity in the Nile Delta fringes of Egypt [10]. Spectral characteristic of salt crusts in saline soil has been studied by Howari *et al*., [11]. Spectral analysis of samples shows gypsum crust and their absorption characteristics of around 1023, 1225, 1475, 1800 and 2336 nm wavelengths; while the absorption characteristics of salt crust are seen to be around 1442, 1851, 1958 and 2226 nm. TM and JERS-1SAR data, (visible and infrared regions) are the best to distinguish saline, alkaline and non saline soils [12]. Studies show that TM band 6 demonstrates gypsic soil clearly, [13,14]. Indian experience of the application of satellite remote sensing for the study of saline soils is based mostly on data acquired from Landsat 1, 2, 3, 4, 5, 7, IRS series and SPOT. Singh and Dwivewdi [15] used Landsat MSS

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digital data to delineate saline soils [15]. Northrop [16] concluded that Landsat could be used to detect salinity features when it is incorporated with extensive ground data. He also stated that the techniques he used had limitations concerning accuracy due to the spatial and spectral resolutions of the MSS sensor [16]. Csillag and Beil [17], used a modified stepwise principal components analysis to access the effectiveness of individual bands for discriminating salinity status from high resolution spectra provided by narrow absorption band (10 nm) within the range of 495-239 nm [17]. Working with a large data set from California and Hungary. They achieved 80-90% overall recognition accuracy.

The present study is, therefore, carried out to evaluate the accuracy of Landsat ETM+ imagery for producing soil salinity map of the study area using numerical analysis method.

MATERIALS AND METHODS

The study area is located at approximately 30 km of the Taft city of Yazd province in center of Iran (longitudes 53° 43´ 33´´- 54° 12´ 00´´ E, latitudes 31° 35´ 00´´- 32° 12´ 00´´ N) which covers 16900 ha. The dominant landforms of the study area consist of two main types: plains and mountains. The maximum elevation of the region is 2783 m a. s. l. and the minimum elevation is 1131 m a. s. l. The area is characterized by arid cold conditions. The annual total rainfall varies between 100 and 134 mm. The mean monthly temperature of the region is 13.2°C. The study area is located in the EW Slope with mean slope value of 6%.

The used Landsat ETM+ data, that cover the study area, were acquired in 2002. The data were geo-referenced to UTM coordinate system (zone 39). The studied soils were sampled following the topography in the direction from high to low areas along 55 kilometers length and 27 kilometers width.

A number of 48 surface soil samples were collected and analyzed to determine some physico-chemical properties such as salinity (Fig. 1). Coordinates of soil samples sites were measured and inserted into attribute table, in ArcGIS environment, along with the soil analytical data, to produce a location map of the soil samples.

Geometric correction, of the satellite imagery using ground control points, was carried out. All bands of Landsat imagery were intersected with all soil sample location points and with the soil analytical data in the attribute table. Information of all bands in this attribute

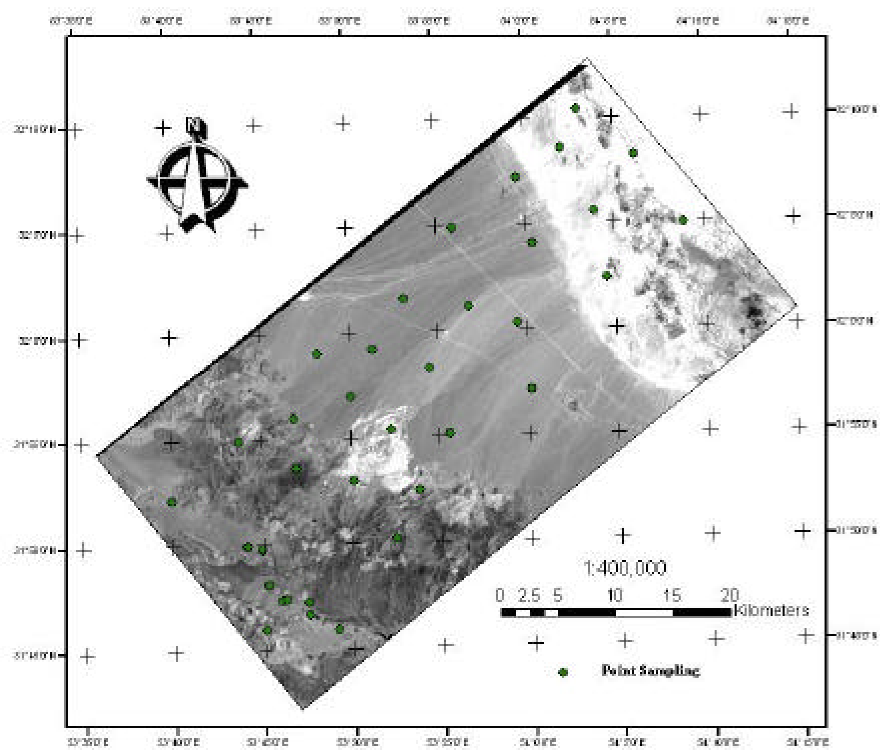

Fig. 1: Distribution of soil samples in the study area

table was completed and analyzed using SPSS. Among the ETM+ bands 1, 2,3,4,5 and 7, only band 3 was used in the regression model and exponential relation was found to be the best model, which had the highest correlation. The obtained model was applied to band 3 in ArcGIS environment and classified soil salinity map was produced. For examining of the produced map, using false color image with same values of sampling sites, resampling was done. A false color composite of bands 1, 4 and 5 coded into RGB was prepared and crossed with the soil samples data. It had the lowest correlation and consequently the highest distinction. Other more ten soil samples which basically had high similarity in spectral reflectance and geomorphological characteristics were collected from field sites, calibrated based on type of geomorphological units of the study area and used to examine and assess the accuracy the produced soil salinity map.

RESULTS AND DISCUSSION

Salt concentration of the soil samples as obtained from laboratory analysis and digital numbers as extracted from band 3 had the highest correlation. Figure 2 shows the relation and the representative equation.

Accordingly, using this model, the digital numbers of band 3 pixels were converted into soil salinity values in ds/m and a soil salinity map of the study area was, then, produced, (Fig. 3).

The accuracy assessment of the produced map was carried out by conducting map verification through a ground truth in the field. In this comparison, two data series were considered. Training points and sampling points on false color composite which has been applied based on spectral correlation among different bands, (Table 1).

Based on these results, the ETM+ bands 1, 4 and 5 were found to have the lowest correlation and consequently show the best distinction of soil salinity

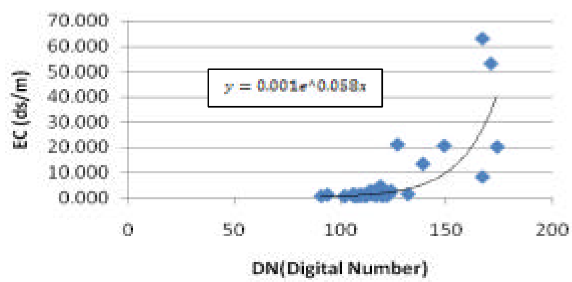

Fig. 2: Diagram of correlation between salinity (electrical conductivity) and digital numbers of band 3

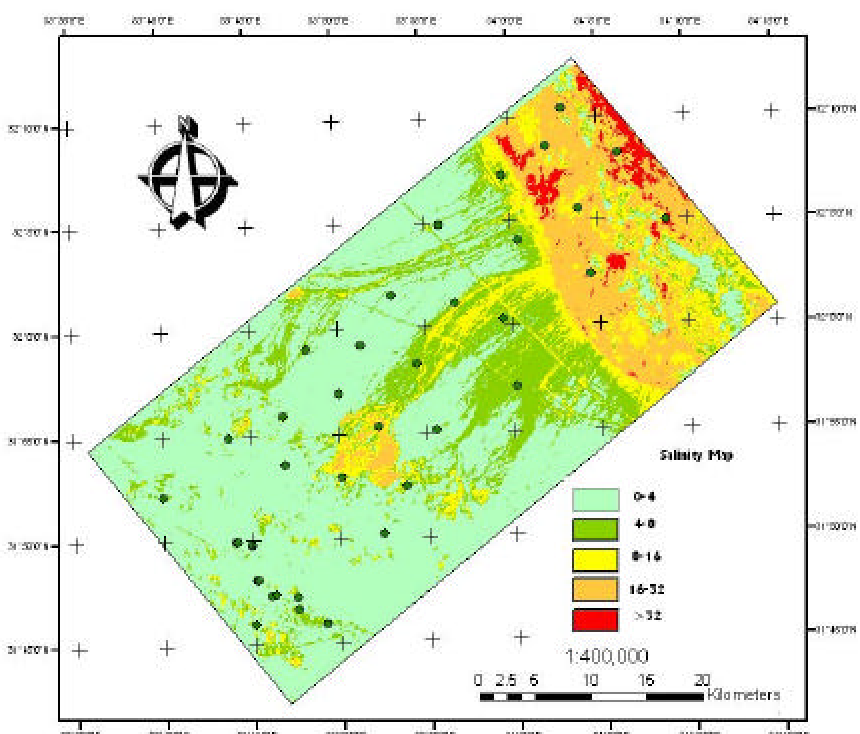

Fig. 3: Produced soil salinity map of the study area

Table 1: Correlation among different bands in study area

Correlation Matrix	b1	b2	b3	b4	b5	b7
b1	1.00	0.97	0.92	0.78	0.75	0.80
b2	0.97	1.00	0.98	0.89	0.84	0.89
b3	0.92	0.98	1.00	0.96	0.89	0.93
b4	0.78	0.89	0.96	1.00	0.91	0.94
b5	0.75	0.84	0.89	0.91	1.00	0.99
b7	0.80	0.89	0.93	0.94	0.99	1.00

levels of the area under investigation. As a result, soil salinity classification map which was produced by this approach had an overall accuracy equal to 87% and Kappa index equal to 47%. One of method for assessment of image and map accuracy is overall accuracy that its value achieved as this function: $K = \frac{q_1 - q_2}{1 - q_2}$. 2_1 = Overall accuracy and 2_2 Random agreement.

CONCLUSION

According to results of the current study some conclusions could be made as follows:

- Based on similarity between soil salinity trend and geomorphological units especially piedmonts and playa of arid and semiarid region, geomorphological unit maps could be used as base maps for preparing soil salinity maps and sampling.
- Using Landsat images, variations in soil salinity could be detected and consequently a soil salinity map could be produced. It could be also a mean of early warning about a progress of desertification process. The current study showed that Landsat ETM+ band 3 with exponential equation $y = 0.001e^{0.058x}$ and r = 0.58 can be used as a model to convert the information of this band into soil salinity map. -The produced soil salinity map have overall accuracy equal to 87% and Kappa index equal to 47% which indicate suitable accuracy in this classification.
- The correlation between digital numbers of satellite images and soil salinity could be an efficient parameter for preparing soil salinity maps from remotely sensed data.
- Changes in soil salinity result in change in surface soil color in spectral reflectance and consequently influence sensors recorded reflectance.

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