

Selection of Best Band Combination for Soil Salinity Studies using ETM⁺ Satellite Images (A Case study: Nyshaboor Region, Iran)

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Abstract—One of the main environmental problems which affect extensive areas in the world is soil salinity. Traditional data collection methods are neither enough for considering this important environmental problem nor accurate for soil studies. Remote sensing data could overcome most of these problems. Although satellite images are commonly used for these studies, however there are still needs to find the best calibration between the data and real situations in each specified area. Neyshaboor area, North East of Iran was selected as a field study of this research. Landsat satellite images for this area were used in order to prepare suitable learning samples for processing and classifying the images. 300 locations were selected randomly in the area to collect soil samples and finally 273 locations were reselected for further laboratory works and image processing analysis. Electrical conductivity of all samples was measured. Six reflective bands of ETM⁺ satellite images taken from the study area in 2002 were used for soil salinity classification. The classification was carried out using common algorithms based on the best composition bands. The results showed that the reflective bands 7, 3, 4 and 1 are the best band composition for preparing the color composite images. We also found out, that hybrid classification is a suitable method for identifying and delineation of different salinity classes in the area.

Keywords—Soil salinity, Remote sensing, Image processing, ETM⁺, Nyshaboor

I. INTRODUCTION

SOIL salinity is a critical environmental problem in many countries around the world. Obviously this problem has a great impact on soil fertility which in turns has a great impact

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on soil productivity [1], [2]. Most of recent studies have been directed toward mapping soils salinity in the very salted areas, while it is essential to quantify different soil salinities in different areas [2]. On the other hand soil data collection by traditional methods is very problematic and Remote Sensing (RS) is an inevitable way for this. RS methods developed very much during recent years for soil studies and also in mapping soil salinity implementing different satellite sensors such as MSS¹, TM² and SPOT³.

Tagizadeh et al. [1] used Landsat TM+ taken in 2002 to map soil salinity in Ardakane Yazd by using an exponential model. They used band 3 of the images and soil salinity parameter in a regression analysis ($R^2=0.58$) and reported a map accuracy of 0.87% and K coefficient equal to 0.47%.

Dwivedi and Sreenivas [3] also used IRS-IC LISSIII for zoning soil salinity in India. They used field data to process digital images for classifying different soil salinities. Darvishsefat et al. [4] used different image enhancement methods such as image proportional and principal component analysis to classify soil salinity based on ETM+ images for Hoze Soltan Ghom area. They reported $R^2=0.54$ in 1% certainty and concluded that their method is not suitable for image classification for soil salinity application. Saha, et al. [5] also used TM images for classifying salted moorland areas in India and found that bands 3, 4, 5 and 7 of the images are useful to classify the lands with an accuracy of 95%. Fernaldez-Bucesa et al. [6] used ETM+ for preparing soil salinity for Texaco in Mexico. They used an index called COSRI and an exponential model to derive a high correlation coefficient between soil characteristics and spectral values of the multi-bands index. They reported -0.885 and 0.857 for EC and SAR as a correlation coefficient respectively. They also derived a variance of 82.6% and 75.1 % for EC and SAR as respectively.

II. METHODS AND MATERIALS

The study area is located in Neyshaboor plane of Khorasan Razavi province, northeast of Iran, ($58^\circ, 34'$ to $59^\circ, 08'$ latitude and $35^\circ, 51'$ to $36^\circ, 15'$ longitude). The mean annual precipitation is 250 mm. Its vegetation cover varies from low to medium. There are some salinity resistant plants in some

¹ Multi-spectral Scanner

² Thematic Mapper

³ System Pour l'Observation de la Terre

parts and irrigated farms and also gardens are in some other parts of the area SWRI [7]. An image from Landsat ETM+ taken in 10th of July 2002 in row 160 and column 35 was used for this study. The image was revised in each of the reflectance bands (1-5 and 7) before any other geometric and radiometric corrections. For collecting soil samples from the field random classification method was considered. In each random sampling point 3 points were considered in 100 meters apart. Soil samples were collected from surface to nearly 15 centimeters in depth. The study area was divided into three zones based on hypothetical soil salinity from low to high salinity. A grid with 1000 meter cell size was considered to cover all the area and 300 cells were selected randomly by JAMP software for sampling points. At the end 279 points remained fault free for the laboratory and analysis procedure. The images were processed using different enhancement methods such as increasing contrast, different filtering, band combination and principal component analysis which are common in these sorts of studies [4]

Geographical position of the sampling points was recorded by using a Garmin E-Trex GPS. In this study 39 soil samples were analyzed. For making the soil samples ready for laboratory analysis, air dried soils were sieved by a 2 mm mesh size. The prepared soil samples were used for measuring the electrical conductivity based on standard methods in the laboratory.

The image was classified by using false color and bands combination in a supervised classification algorithm (maximum likelihood classification), unsupervised classification iso-data classification and hybrid classification. Finally three different classes were recognized based on the training samples as 1) soils with no salinity ($EC < 4$ dS/m), 2)soils with medium salinity ($EC < 4 - 16$ dS/m) and 3)soils with high salinity ($EC > 16$ dS/m).

The best band composition was selected based on two different methods: Comparing of digital numbers for different classes of salinities and also using of Transform Divergence for training samples.

III. RESULTS

Comparing the results of combining 1, 2, 3 and also 3, 7, 1 bands set shows that there is a difference in the mean spectrum values between three different classes of soil salinity in the study area. However the results of error matrix and sample accuracy in the images do not show better results in relation to other bands combination sets applied (Table 1).

This shows that spectrum values are very similar in different soil salinity parts of the study area and consequently it is difficult to separate the classes based on this image processing algorithm. As it can be seen in table 1, when sample data from not saline parts is added in the analysis total accuracy is reduced for all of the combination sets. This shows that overlap between the spectrum values among different combination set is very much. However, if we use only the samples from soils with medium and high salinity, total accuracy increases. The highest accuracy (80.5%) was derived when 1,3,4,7 combination bands with hybrid method was applied. Using this method increases the classification accuracy in soils with high and medium

salinity in order of 10% in relation to using only supervised classification.

TABLE I
TOTAL ACCURACY OF SOIL SALINITY CLASSIFICATION BASED ON DIFFERENT BAND COMBINATION

Band combination	Classification	Total accuracy	Total accuracy (medium and high salinity)
1,2,3,4,5,7	Supervised (Maximum likelihood classification)	57%	66.20%
1,3,7	Supervised (Maximum likelihood classification)	51%	56.50%
1,3,4,7	Supervised (Maximum likelihood classification)	54%	71.30%
1,3,4,7	Hybrid Supervised (Maximum likelihood classification)	50%	80.50
1,2,3	Hybrid (No salinity and high Salinity)	40%	***
1,3,4,7	Hybrid (No salinity and medium Salinity)	62%	***
1,3,4,7	Hybrid (No salinity and medium Salinity)	55%	***

Therefore by using resolution index of training samples (TD) we could assess the importance and the rule of reflected bands in soil salinity classification. If all of the reflected bands are used in the classification procedure TD would be 1783.86. This index is increased to 1900, if band 2 is excluded from the analysis and with excluding band 5 it is increased to 1911. Thus we could have TD = 1911 if we only keep 1, 3, 4 and 7 bands. It was concluded from this analysis that the most suitable band combination for soil salinity classification in this area is 1, 3, 4 and 7 when hybrid classification method is applied.

The results show that soil salinity classification is not very much accurate even by using the best band combination of false color and applying the above classification method based on the training samples for each class. It also shows that separating no salinity soils from soils with low salinity is more difficult than separating soils with low salinity (accuracy = 55%) from high salinity (accuracy = 62%). Therefore it is concluded that there are more overlap between digital values of soils with no salinity and soils with low salinity. It is also concluded that mean values of reflection in all of the bands is higher in soils with high salinity than other soils.

Although there is no doubt that remote sensing and Landsat images are good tools for soil salinity studies, but this study showed that there could be some complications in classifying of soils in terms of their reflection salinities which should be considered. There are some other problems in using RS in arid and semiarid areas with soil salinity. Many parameters such as gullies and non saline crust, salinity resistant plants, gravels and so on are responsible for interfering of spectrum values between different pixels with different soil salinities [8]. Therefore reflection from soil surface is not.

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