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Effects of Soil Salinity on Soil Spectral Behaviour

[Hilal Soydan, H. Şebnem Düzgün]

***Abstract*—This paper focuses on the utilization of Advanced Spaceborne Thermal Emission and Reflection Radiometer (ASTER) data to predict soil salinity. After the necessary geometric and radiometric corrections were implemented, it is aimed to model the changes of electrical conductivity of soil samples, with related spectral profiles extracted from the satellite data. An electrical conductivity meter was employed for measuring the salinity levels of extracts acquired from the saturated soil samples. Statistical methods (stepwise regression – backward elimination) were used to reveal the significant bands for soil salinity and to diagnose the soil salinity related variances through the spectrum. The correlation between the selected soil samples having highest & lowest soil salinity levels was found to be consistent with each other. There seems to be a negative relation with the increased electrical conductivity content and spectral responses in shortwave infrared region. Furthermore, multivariate regression analysis showed that second and sixth band of the ASTER imagery make a significant contribution to the equation (p<.001) that models salinity and spectral profiles.**

Keywords— ***ASTER, Electrical conductivity (EC), Soil salinity***

I. Introduction

Being a multispectral sensor reaching thermal infrared region, Advanced Spaceborne Thermal Emission and Reflection Radiometer (ASTER) satellite imagery serves as a useful tool for studying soil properties. Soil salinity, at that point, stands as an important parameter for the evaluation of sustainable agricultural management. In order to measure the salinity levels, the soil samples were dried, crushed, saturated with distilled water and vacuumed to get extract of the soil samples. Finally, electrical conductivity meter was utilized to measure the salinity levels of the soil sample extracts (µs/cm). The relationship between the spectral profiles extracted from the satellite data and laboratory salinity contents were investigated in the study.

II. Materials and Methodology

A. *Study Area*

The study area is located in Central Anatolia, 140 km east of the capital city Ankara, Turkey. Soil samples were collected from an abandoned coal mine site with locations acquired by a differential global positioning system. Fig. 1 illustrates the location of the study area.

Hilal Soydan, Research Assistant
Middle East Technical University
Turkey

H. Şebnem Düzgün, Professor
Middle East Technical University
Turkey

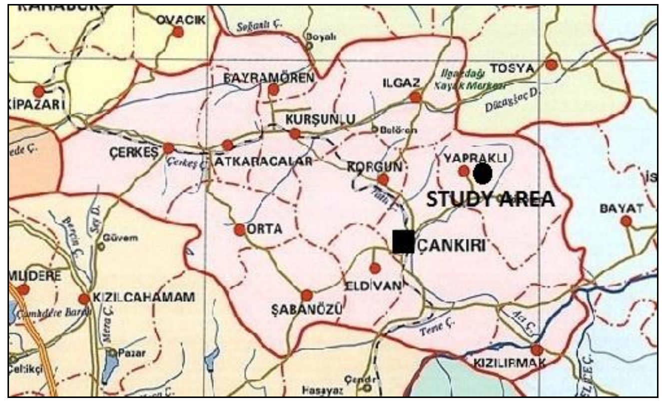

Figure 1. Location of the study

The topography of the region incorporates small hills with an average elevation of 1300m. The climate of the area is continental with a mean annual rainfall of 400 kg/m2 (Soydan, 2013).

B. *Laboratory Experiment*

As stated earlier, the soil samples were crushed under 2 mm and dried in 105° oven for 24 hours. The samples were saturated slowly adding distilled water. The soil pastes were utilized to get soil-paste extracts with a vacuum extraction device. Fig. 2 and Fig. 3 demonstrate the saturation and vacuum phases of the experiment.

Figure 2. Saturation of soil with distilled water (TGAE, 2012)

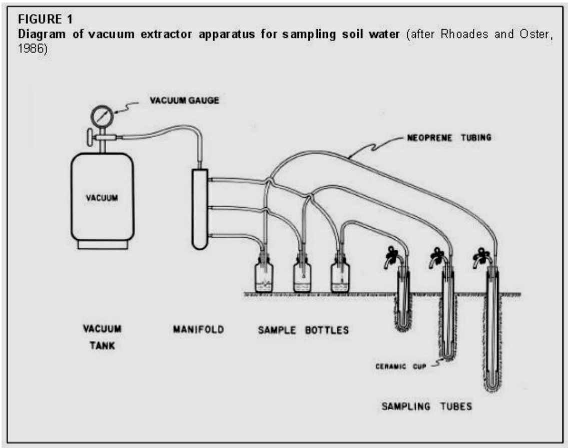

Figure 3. Vacuum Extraction Design (Rhoades and Oster, 1986)

C. *Spectral Data Acquisition*

Multispectral Advanced Spaceborne Thermal Emission and Reflection Radiometer (ASTER) imagery was evaluated to detect the relationship of spectral data with soil salinity. ASTER level 3A imagery is delivered, radiometrically calibrated and geometrically registered. It is radiance at sensor data having three subsystems which are NIR, SWIR and TIR regions. The satellite imagery was geometrically and atmospherically corrected in order to acquire reflectance values. In the analysis, the only region reaching to short wave infrared across electromagnetic spectrum was utilized to assess the performance of the reflectance data to predict soil salinity levels. In Fig. 4, ASTER bands across electromagnetic spectrum is given.

III. Analysis and Results

Spectral data coupled with electrical conductivity laboratory analysis results were analyzed to determine the significant bands contributing the soil salinity. For that, stepwise regression-backward elimination technique was utilized. The technique starts with all defined variables (spectral signatures), eliminating them one by one until the point that there is no improvement in the performance of the model (Minitab, 2014).

Furthermore, correlations between the soil profiles having highest and lowest electrical conductivity values were calculated.

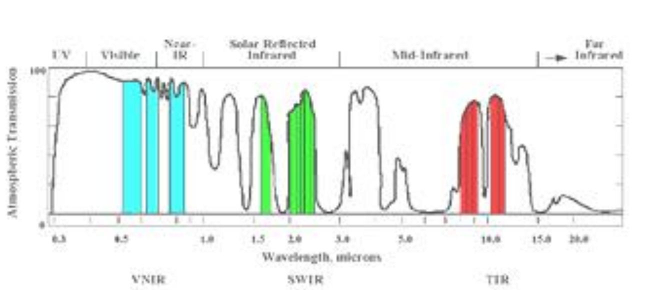

Figure 4 ASTER Bands across EMS

TABLE I. MULTIVARIATE REGRESSION MODEL

Term	Coef	SE Coef	T-Value	P-Value	VIF
Constant	0,3235	0,0746	4,34	0	
B2	-0,438	0,119	-3,68	0,001	2,22
B6	0,554	0,169	3,27	0,003	2,22

TABLE II. ANALYSIS OF VARIANCE

Source	DF	Adj SS	Adj MS	F-Value	P-Value
Regression	2	0,094	0,047	7,09	0,004
B2	1	0,090	0,090	13,51	0,001
B6	1	0,071	0,0714	10,72	0,003
Error	25	0,166	0,006		
Total	27	0,261			

According to the regression model, the constant, Band 2 and Band 6 were found to be significant ($p<.001$). The analysis of variance table also shows that the model is significant as well (($F(2,25)=7,09$, $p<.001$). The resulting variance inflation factor values revealed that there is no correlation between the input spectral profiles. The modelled regression equation is given in

$$Extract\_EC(\mu s/cm) = 0,3235 - 0,438\ B2 + 0,554\ B6 \quad (1)$$

The normal P-P plot and histogram given in Fig.5 indicate that the data are normally distributed. Trend as positive correlation due to ascending/descending behavior, or negative correlation, due to reverse trend of data in sequential measurement, can cause autocorrelation. Residual vs. observation order graph shows that there is no strict autocorrelation since the residuals are distributed randomly without any trend.

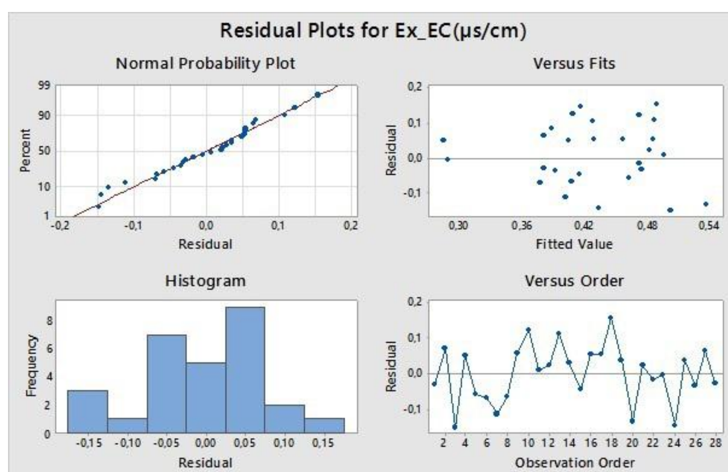

Figure 5. Residual Plots

The spectral profiles of the samples having highest and lowest EC value were drawn together in Fig. 6 and Fig. 7. Correlation analysis between those spectral profiles were found out to be consistent with each other, which is 0.60, shown in Table III and Table IV. Although this value seems to be revealing the fact that there is a consistent relation between the spectral signatures having relatively close salinity levels.

Evaluating the spectral signatures of all collected soil sample another inference is that there seem to be negative correlation between the reflectance and soil salinity levels in shortwave infrared region.

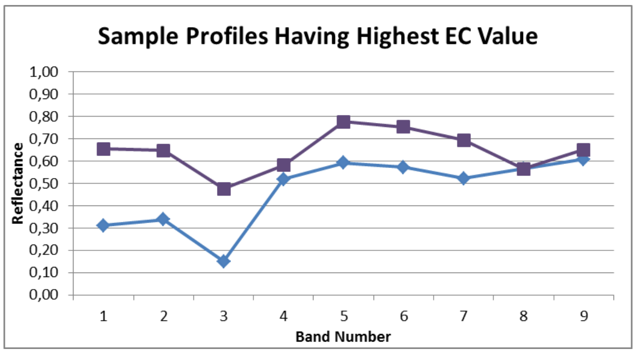

Figure 6. Comparison of sample profiles with highest value

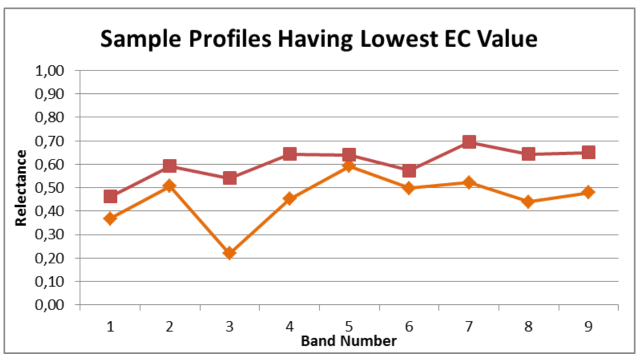

Figure 7. Comparison of sample profiles with lowest value

TABLE III. CORRELATION TABLE WITH HIGHEST EC VALUES

	Sample 14	*Sample 11*
Sample14	1	
Sample 11	0,60	1

TABLE IV. CORRELATION TABLE WITH LOWEST EC VALUES

	Sample 27	*Sample 9*
Sample 27	1	
Sample 9	0,60	1

IV. Discussion

Multispectral and hyperspectral imaging techniques has been very useful tools for the assessment of soil properties in the recent decade. Being able to use satellite data, especially hyperspectral imaging techniques, would be time and cost efficient at the same time. Tough, the spectral and spatial resolution of the data play an important role for the analysis performance. For the soil salinity determination ASTER imagery seems to give crucial indications with suitable statistical techniques. In addition, it is strongly suggested to collect different salt bearing samples and constructing a controlled experiment design.

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About Author (s):

[An accurate study on soil characteristics via remote sensing techniques is a challenge, though the interpretation of multispectral and hyperspectral imageries make it possible day by day.]
Hilal Soydan