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Analysis of Spectral Reflectance for Estimation of Soil Quality along a Climatic Gradient in the Eastern Mediterranean Region

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1. Introduction

Applications of optical remote sensing for soil studies are limited to the surface layer (Escadafal, 1994), while typical soil classification approach takes into consideration both the surface and sub-surface horizons. Spectrometry measurements have been used successfully in different soil studies and offer the prospect of modelling soil chemical properties and improving precision farming (Milton et al., 1995). Since, as the reflectance curve characteristics in an optical remote sensing is determined by the objects properties, such curve can offer information on the conditions and characteristics of soil surface (Lee et al., 2003). The variations in climatic conditions along the studied area are more heavily impact the soil characteristics than other factors such as geology and parent material.

Among the soil minerals, carbonate content plays an important role in soils having developed from limestone parent materials especially in arid and semi-arid areas. Calcium carbonate tends to increase soil brightness (Ben-Dor and Banin, 1994) and also exhibits diagnostic features in the infrared wavelength region, with the strongest absorption in the 2.3-2.35 µm (Hunt and Salisbury, 1971). Organic matter content and composition have a significant effect on the soil reflection curve. In general, as organic matter content increases, soil reflectance decreases throughout the 0.4-2.5 µm wavelength range (Al-Abbas et al., 1972). Accordingly, the absorption curves for each soil property can be used to quantify the content and composition of soils in relation to their spectral reflectance. Therefore, the objective of this paper is to assess the soil surface quality in the northern Jordan by means of optical remote sensing.

2. Materials and Methods

2.1 Study area

The study area occupies the eastern part of the Mediterranean region in northern Jordan. It is located between Latitudes 32^{o} 15´ and 32^{o} 30´ North and Longitudes 35^{o} 45´ and 36^{o} 15´ East.

The prevailing climate is of arid Mediterranean type and characterized by dry hot summers and mild wet winters. Most of the precipitation occurs during the winter months November to April. The general pattern of precipitation characterise by high diversity and interannual variability. This diversity ranges from semi-arid conditions where average rainfall amounts are about 200 mm, to semi-humid conditions where the average rainfall is about 600 mm.

The land cover types vary between natural, semi-natural, and cultivated areas. The dominant natural vegetation types are forest and shrubs. Cultivated lands are characterized by rainfed agriculture, which depends on the rainfall amounts and distribution. The main subdivisions of rainfed agriculture are fruit trees and field crops. The dominant fruit trees are olives, grapes and orchards, while the dominant field crops are wheat, barley and legumes.

2.2 Soil measurements

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Soil samples from surface layer 0-1 cm were collected from the studied area. The sampling sites were carefully selected to represent all varieties of soil types subject to the different pattern of land use. In total, 47 samples were selected along the west-east transects. Each soil sample was split into two sub-samples. One was used for spectral measurements, the other analyzed to study soil chemical properties.

The soil samples were air-dried and sieved using 2 mm sieves. Sub-samples were carefully homogenized to a standard grain size providing for precise and standardized measurements of diffuse soil reflectivity (Fernandez and Schulze, 1987). Spectral reflectance of soil samples were measured in the laboratory under sieved and homogenized conditions with an ASD Field Spec II spectrometer in 10 nm intervals between 0.35-2.5 µm using a reflectance standard of known reflectivity. The illumination source was positioned at 30 degrees zenith angle and a 1000 W quartz-halogen lamp was putted at a distance of approximately 30 cm. The samples were laid out on a black coated board to minimize the external reflectance or backscattering.

Soil chemical analysis including the organic and inorganic carbon content was analyzed by using an infrared cell in a high-frequency induction oven (LECO). The analysis involved two phases, one between 200 °C and 550 °C for organic carbon and the other between 550 °C and 1050 °C for inorganic carbon. The CO_2 flow is continuously detected by an infrared cell while the temperature is increased at a rate of 200 °C min^{-1}.

3. Result and Discussion

Examination the behaviour of soil reflectance properties in the studied area in relation to their organic carbon content tend to form triangle, the corners of this triangle representing different soil groups as illustrated in figure 1. The major soil groups are soil group one (G1), soil group three (G3), and soil group four (G5).

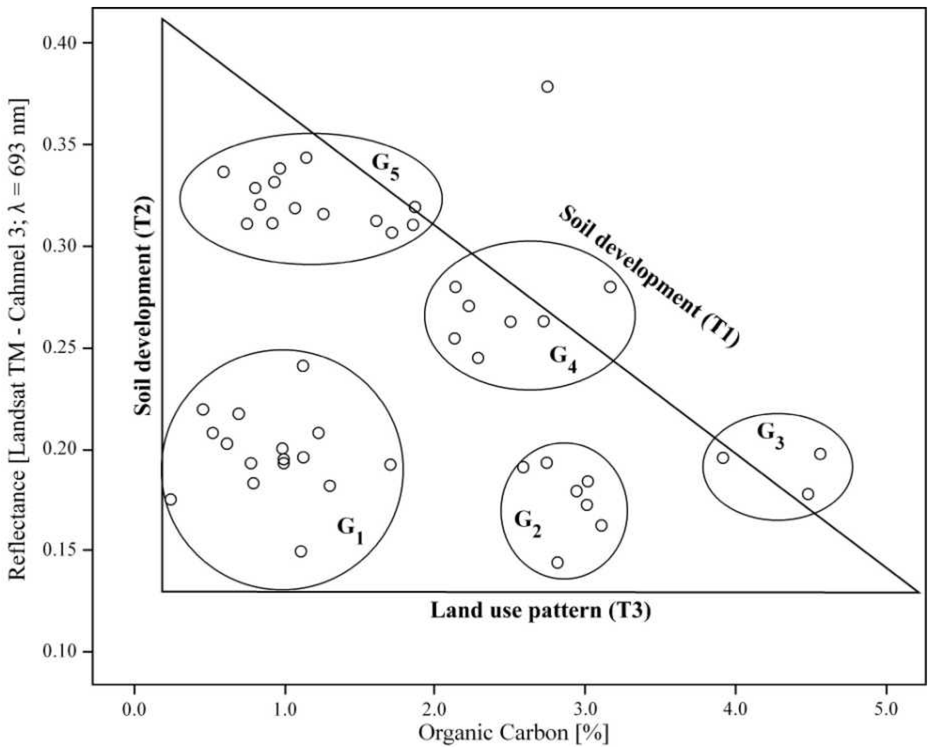

Figure 1: The main soil groups in the northern Jordan as classified according to their reflectance characteristics in relation to soil organic carbon content.

This difference in soil types and accordingly in soil quality can be explained by the soil reflectance characteristics in relation to their chemical composition in the 0.4-2.5 µm spectral range. Figure (2) illustrates the spectral characteristics of representative soil samples for G1, G3, and G5 soils in the 0.4-2.5 µm spectral range.

The red line represents soils G1, which display a clear absorption feature at 0.90 µm and a concave curve in the 0.5 regions. Furthermore, this group has low absorption curve in the total wavelength range; both features are an indication for presence of iron oxide. The green line shows the G3 soil which demonstrates a convex absorption curve in the visible wavelength, which is an indication for the dominant of soil organic matter. The yellow curve indicate the carbonated affected soils G5, having a high absorption curve at the total wavelength and absorption feature at 2.3 µm.

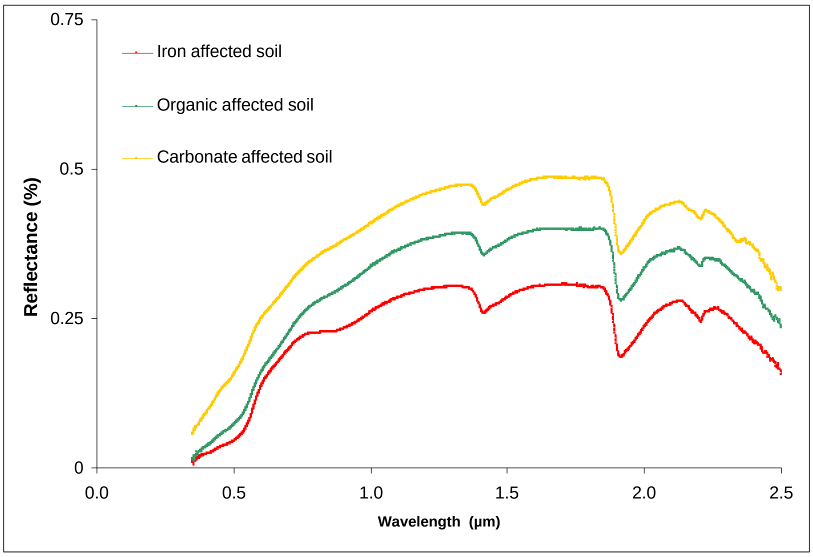

Figure 2: Spectral characteristics of the main soil groupsG1, G2, and G3 in the northern Jordan.

From this analysis a proposition can be stated that G1 is an iron affected soil, G3 is an organic affected soil and G5 is a carbonate affected soil. Further evidence for this assumption can be proved by examining the soil chemical composition of the major soil groups – organic and inorganic carbon. Based on this analysis and the above discussion many ascertain can be drawn regarding the characteristics and quality of major soil groups as given below.

Soil group one has low inorganic carbon as well as organic carbon content. The average value for inorganic carbon is 0.68 % and the standard deviation is 0.59. The average value for organic carbon is 0.91 % and the standard deviation is 0.36. Low organic carbon content in the soil is an indication for the dominance of mineralogical composition in the soils. Moreover, presence of low carbonate concentration is an evidence for the soil weathering and leaching of carbonate into the subsurface horizons. The fact that most of the soil samples in this group exist under semi-humid climatic conditions provides strong evidence that those soils are in advanced development stage. Under such conditions, the effect of iron content of the soils have higher impact on the soil reflectance level than other factors as explained in figure 2. Therefore, this type of soil can be identified or characterized by presence of iron oxides.

Soil group three represents the soils, which have a relatively high content of organic matter and low inorganic carbon content. The average value for inorganic carbon is 0.23 % and the standard deviation is 0.13. The average value for organic carbon is 4.32 % and the standard deviation is 0.35. Those soils are developed under natural and protected vegetation, where the existence of high rainfall amounts and minimum human disturbance offers suitable media for the accumulation of organic matter on the surface layer. The green line in figure (2) shows the effect of organic matter on the spectral curve along the total wavelength range. Therefore, these soils can be referred as organic affected soils.

Soil group five is another significant group, which characteristically has low organic carbon and high inorganic carbon content. The average value for inorganic carbon is 3.24 % and the standard deviation is 0.59. The average value for organic carbon is 1.18 and the standard deviation is 0.36. The presence of such chemical characteristics under semi-arid conditions is an indication of the low soil development stage. The development of soils in this group is not pronounced because the climatic conditions are not favourable for effective weathering processes. Spectrally, this type of soils characterized by having a high reflection value in the total wavelength range with an absorption band at 2.3 µm and absence of iron oxide effects. These soils can be called a carbonates affected soils.

Furthermore, there are two soil groups representing a transitional development stage. Soil group 2 represents a transitional development stage between G1 and G3. Soil group 4 represents a transitional development stage between G3 and G5 as shown in figure 1.

4. Conclusion

Based on the analysis of soil chemical properties in relation to their spectral characteristics curve and the climatic conditions some conclusions can be drawn. The first trend **T1** representing the soil development dominating by effects of climate and characterized by the influence of soil organic matter and carbonate. The second trend **T2** demonstrates the effect of climate on soil development, and is also representing the difference in mineralogical composition. The third trend **T3** displays the effect of land use on soil characteristics under similar climatic conditions and represents differences of soil organic carbon content. The obtained result can be used to develop a model for prediction of soil chemical properties and hence soil quality. Accordingly the spatial distribution of soil quality can be estimated by applying the model on equivalent remote sensing sensors such as Landsat TM.

5. Literature

Escadafal, R., 1994, Soil spectral properties and their relationships with environmental parameters examples from arid regions: In: Hill, J. and Mégier, J.: Imaging Spectrometry - a tool for environmental observations, Dortrecht, Boston, London, 71-87.

Milton, E. J., Rollin, E. M. and Emery, D. R., 1995, Advances in field spectroscopy. In: Danson, F. M. and Plummer, S. E., Advances in Environmental Remote Sensing, John Wiley and Sons, Chischester, 9–32.

Lee, W. S., Sanchez, J.F., Mylavarapu, J. S., and Choe, J. S., 2003, Estimating chemical properties of Florida soils using spectral reflectance. *Transactions of the ASAE*, **46**, 1443-1453.

Ben-Dor, E., and Banin, A., 1994, Visible and near-infrared (0.4-1.1µm) analysis of arid and semiarid soils. *Remote Sensing of Environment*, **48**, 261-274.

Hunt, G. R., and Salisbury J. W., 1971, Visible and near-infrared spectra of minerals and rocks: II. Carbonates: *Modern Geology*, **2**, 23-30.

Al-Abbas, A. H., Swain, P. H., Baumgardner, M. F., 1972, Relating organic matter and clay content to the multispectral radiance of soils. *Soil Science*, **114**, 477- 485.

Fernandez, R. N., and Schulze, D. G., 1987, Calculation of soil color from reflectance spectra. *Soil Science Society of American Journal*, **51**, 1277–1282.