Field and Satellite radiometry of Soil Erodibility along the climatic gradient of the Judean Desert, Israel

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ABSTARCT
Soil and vegetation loss are the most fundamental characteristics of desertification processes. The intensity and extent of land degradation attract major attention as a global change phenomenon and as regional Mediterranean phenomenon. Satellite remote sensing is most suitable therefore for monitoring such widespread environmental threat provided that there are suitable inferential models. This study aims at the assessment of a TM band ratio index which allows mapping of soil erodibility across areas representing transition between humid and arid climatic conditions such as existing at the margins of the Judean Desert. Measurements of spectral and bio-chemical properties of soil samples where carried out for this purpose both in the field laboratory. Relationships between the Landsat TM band ratio index and bio-chemical soil properties are analyzed.

1 INTRODUCTION

Soil erosion is commonly assessed with regard to rainfall (average annual and storm frequencies), soil erodibility, slope length, slope gradient and landuse. Between these parameters, soil erodibility as the "resistance to sediment detachment and transport" (Kirkby, 1999) is determined by the physical, chemical and biological soil properties. Increase in the soil erodibility is followed by higher potential of erosion to develop in the presence of certain combinations of environmental conditions (storm event and slope gradient for example). Between these properties, soil aggregates size and organic matter content are commonly regarded as having direct relationships with soil stability.

Several studies have indicated that a decrease in the organic matter content and in soil particle size causes increase of the reflectance in the visible and the NIR spectral range. Stoner and Baumgardner (1981) and more recent studies by Escadfal (1994) have shown that the reflectance sensitivity to organic matter content is high at the visible range. Relationships between aggregates size and spectral reflectance of soils have been investigated by Bowers and Hanks (1965) and by Hunt and Salisbury (1976) who have found that the integrated reflectance in the visible and the Near Infra-red is sensitive to the aggregates' size.

This work aims at assessing the relationships between the multi-spectral distribution of soil reflectance and its erodibility at site scale using field radiometry and at regional scale using Landsat TM data..

2 FIELD STUDY

Field investigations included radiometric measurements with the FieldSpec radiometer with 2 nm resolution and soil sampling (Jarmer et. al., 1996). Aggregate size, organic matter and chemical compositions were determined in the laboratory for bare soil patches which were selected at the vicinity of four sites along a climatic transect running from the Judean Mountains towards the Dead Sea. The four sites, representing Mediterranean, semi-arid, mildly arid and arid conditions are as follow:

1. Giv'at Ye'arim (GIV). This site is located 11 km west of Jerusalem at an elevation of 650 m a.s.l. The average annual rainfall is 620 mm and the mean annual temperature is 17ºC.
2. Ma'ale Adumim (MAL). This site is located 6.5 km east of Jerusalem at an elevation of 330 m a.s.l. The average annual rainfall is 330 mm and the mean annual temperature is 19ºC.
3. Mishor Adumim (MIS). This site is located 6.5 km east of Jerusalem at an elevation of 330 m a.s.l. The average annual rainfall is 330 mm and the mean annual temperature is 19ºC.
4. Kalia (KAL). This site is located 4 km west of the Dead Sea at an elevation of 70 m b.s.l. The average annual rainfall is 120 mm and the mean annual temperature is 23ºC.

The bedrock at all sites is calcareous (limestone or hard chalk). In spite of the similar lithology and topographical conditions, different soil types have been developed in response to the long term effect of average climatic conditions during the last millennia. At the Mediterranean site (GIV) a red soil, Terra Rossa, has developed which contains a relatively high amount of clay (50%), small amount of calcium carbonate (6%-8%), and medium amount of organic matter (6%-8%). A Brown Rendzina soil is typical to the semi-arid site (MAL) which contains about 30% clay, 30% calcium carbonate and 2.5%-4.5% organic matter. A non saline light brown lithosol has developed in the mildly arid site (MIS). This lithosol is a shallow calcareous loamy soil with 20 % clay, 50% calcium carbonate and 2%-3% organic matter. At the arid site (KAL), a light gypsic desert lithosol has developed which contains 10% clay, 80% calcium carbonate and very small amount of organic matter (1%).

3 RESULTS

Application of clustering techniques on the bio-chemical properties of the sampled data allowed the identification of six clusters (Figure 1). These clusters were found to have also characteristic spectral signatures except for the differentiation between clusters 5 and 3. The main differentiating feature is the reflectance levels at the near and mid infra-red spectral channels (Figure 2).

Assessment of relationships between the soil erodibility and its reflectance properties were carried out initially with reference to Pickup and Chewings (1996) band ratios technique. Shoshany and Lavee (1998) have utilized the same technique using TM band ratios of channel 2 / channel 4 and channel 3 / channel 4 for mapping soil erodibility. Empirical assessment of these ratio data for four points representing the different erosion levels formed almost a straight line of positive correlation between the three factors : changes in these two band ratios and in the erosion levels . This pattern of change is actually orthogonal to the pattern expected according to Pickup and Chewings (1996). A new erodibility index was then formulated by Shoshany and Lavee (1998) according to this pattern of band ratios change. Mapping the band ratios' combinations of the soil samples had shown that they highly correspond to the above described linear relationships (Figure 3). From the resulting pattern it was possible to conclude that the linear combination of band ratios correlate with the organic carbon content , with low organic carbon at the highly erodible sites and moderate and high organic carbon at the low erodible sites. Further assessment of the data in Figure 3 suggest that those clusters below the line represent relatively lower ferum content and vice versa. As discussed earlier soils are much more stable when their organic matter and ferum contents are high , and therefore it is possible to suggest that the new erodibility index is of physical significance.

Figure 1. Clustering with ferrum, inorganic and organic carbon

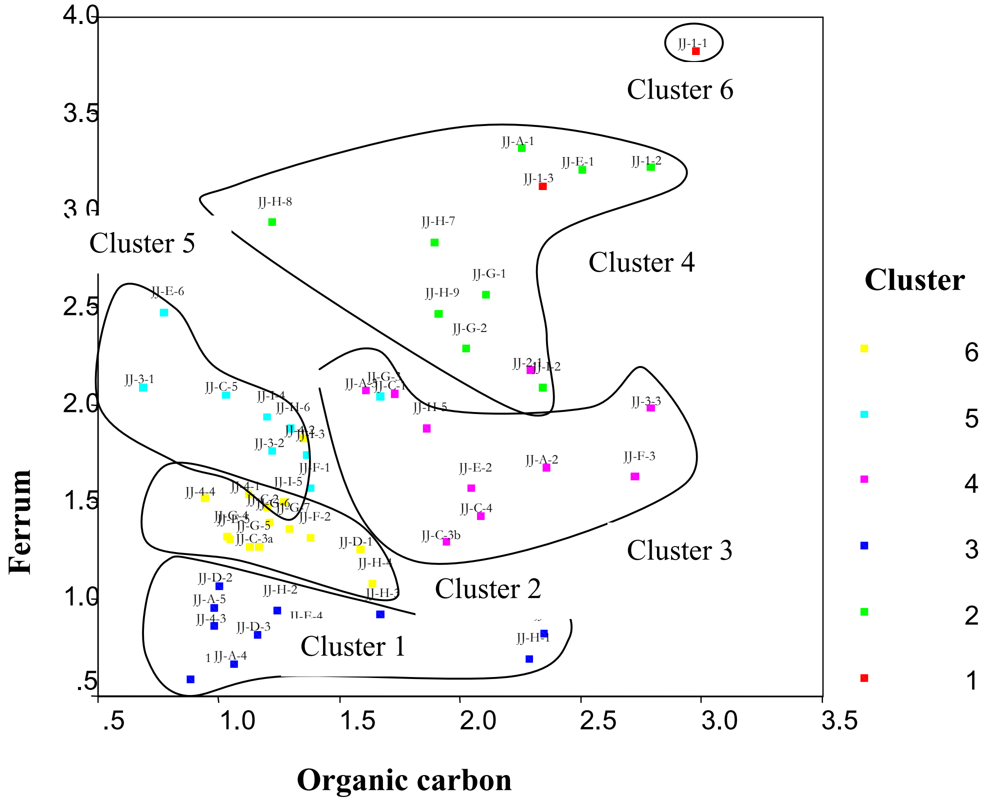


Figure 2. Mean reflectance using reduced clusters (TM channels)

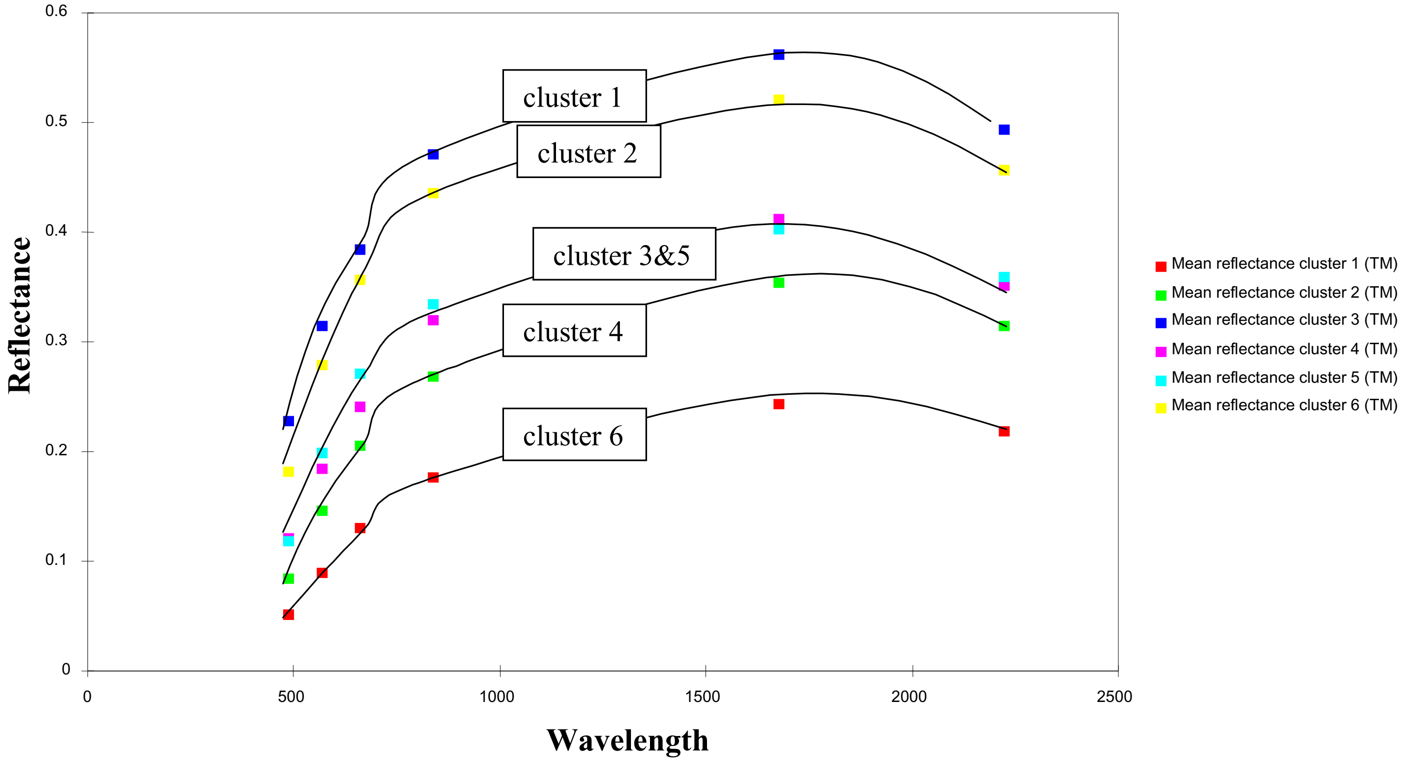
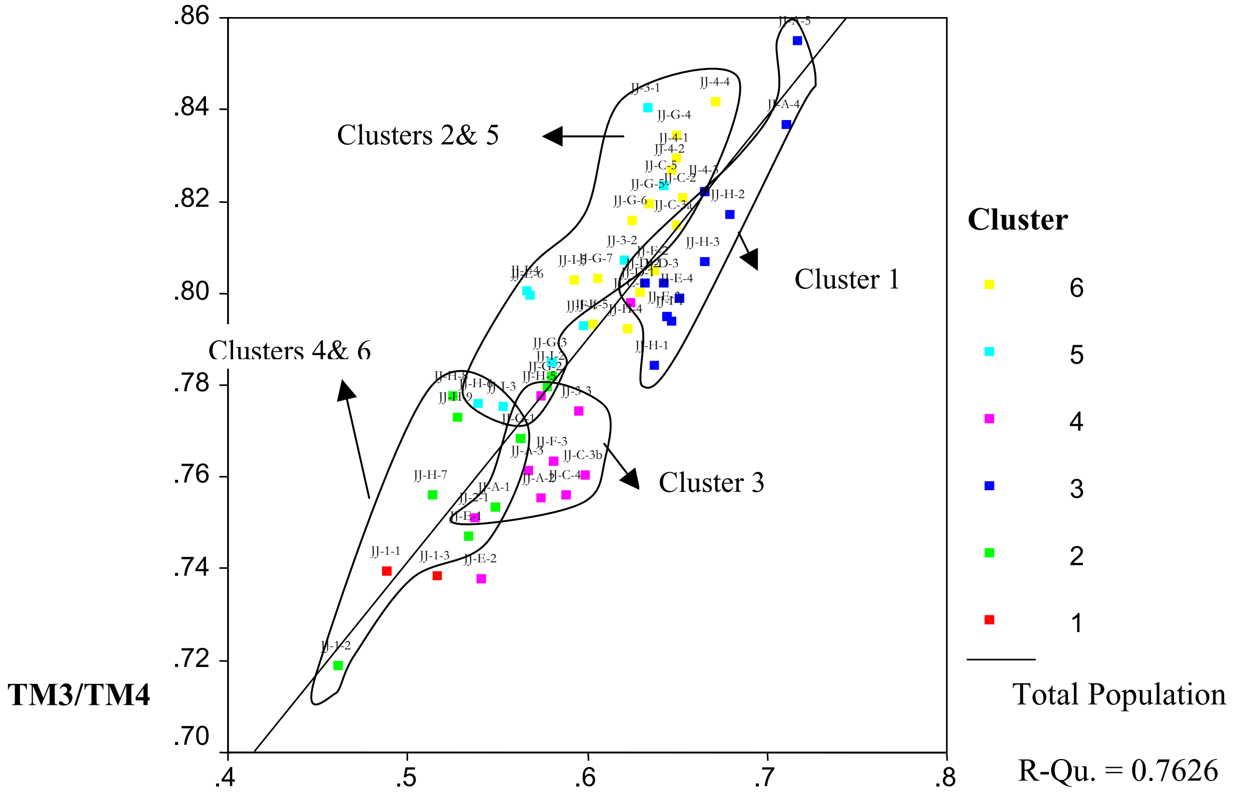


Figure 3. Biochemical clusters in relation to band ratio combinations



4 CONCLUSIONS

Application of satellite remote sensing techniques for mapping soil erosion is widespread (see for example De Jong , 1994 and Shoshany et. al., 1995). This study was aimed at strengthening the relationships between band ratios data and the soil physical properties. Field assessment of these relationships at the soil patch scale was reported here. It was shown that Landsat TM band ratios may serve as good indicators for organic matter content which govern soil erodibility. Using this band ratio combination it is possible to provide regional mapping of soil erosion potential and the progress of desertification.

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