Estimation of Different Soil Properties by Using Reflectance Values of TERRA-ASTER Bands

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The aim of this study was to determine the relationship between the soil properties and spectral reflectance values obtained from VNIR, SWIR and TIR bands of ASTER-TERRA. For this purpose, 40 soil samples formed on different landscapes were collected. Soil parameters were analyzed for pH, organic matter, total salinity, lime contents and particle sizes. Coordinates of these samples were overlaid on ASTER data using ERDAS Imagine software. The spectral values of VNIR, SWIR and TIR bands of ASTER-TERRA for total 9 pixel point neighboring to each sample were obtained. To determine the relationship between spectral values and soil properties correlation analysis techniques were developed using statistical software program SAS. Finally, the correlations fitted to soil contents and their highly correlated spectral bands were used to produce maps using supervised classification method showing soil properties. The results showed that there was a good agreement between the reflectance values of soil and their properties. The highest correlation coefficient value was found between silty particle and TIR band 3. Similarly there was a high correlation between organic matter and VNIR-Band 2.

Key Words: TERRA-ASTER, Soil properties, Soil survey.

INTRODUCTION

With the developments in the satellite technology, a great number of studies are now being conducted to identify the properties of the materials on earth by means of the suppressed sensors installed on the satellites. Among these studies, the agricultural ones have held their own place, as well[1]. Surface reflections have proved to be the indispensable means in obtaining the essential information required for the agricultural practices[2]. These reflections, which are of different wavelengths in different regions, provide information[3] on the properties of the different soil classes.

Soil survey involves the studies may be performed in the office, on the land and in the laboratory. The leading factor which complicates the soil surveys conducted through the traditional methods is the separation of the boundaries of soil series. Remote sensing techniques have facilitated the definition of the boundaries of the soil series to a great extent, which had previously leaded the field studies to last longer and cost more[4]. Spectral reflectance values of the soil classes refer to their distinct characteristics. These properties play a crucial role in conducting soil surveys and mapping by means of satellite data. With the increasing use of the satellite technologies, the success in the preparation of the detailed soil maps has improved considerably and as a result of the study conducted through LANDSAT MSS data, the boundaries of the soil series have been determined[5] at an accuracy rate of 93.3 %. The study which was conducted using unsupervised classification method using LANDSAT TM, the soil phases were distinguished at an accuracy rate of 90 % and the boundaries of the soil series which refer to the dissimilarity of such properties as slope, rocks, salinity, drainage and upper soil texture were determined[6] at an accuracy rate of 90 %. The medium-spatial-resolution satellites (20-30 m) such as SPOT, LANDSAT and IRS have been defined as the optimal ones for the solutions in the agricultural practices. In addition, the most widely used bands in the soil survey and mapping using these satellites have been the ones located in VNIR and SWIR areas. However, in recent years, spectroradiometric and spectroscopic studies have showed that a large number of the properties of the soil classes could be determined in TIR areas, as well[7].

In the related studies, the wavelengths 1720, 2180 and 2309 nm are reported to be appropriate for determining the organic matter contents in soils and many studies have turned out to prove that the most sensitive area for the determination of the organic matter is that of SWIR[8]. The inverse correlation between the increase in the organic matter and the reflectance values in this area has been reported to result from the effect of the dark organic matter on the soil colour. In addition, a linear correlation between the lime content within the arid soils of the Mediterranean and bands 3, 5, 7 of LANDSAT TM satellite has been reported[9].

However, data acquisition depending on the land surface warming using thermal bands points out that it could be practical in estimating the properties which affect the land surface temperature. Whereas land surface temperature is essentially related with the water in the soil, texture and organic matter content are effective in keeping the moisture in the soil, which connotes that TIR bands may be used with respect to these properties.

Data acquisition of the ASTER sensor from total 14 bands in VNIR, SWIR and TIR areas enables it to prove usable in the determination and definition of the properties of the soil classes. This study also aims to determine the relationship between the spectral reflections of the bands and the different properties of the soil classes which throw light on the preparation of the thematic maps concerning the soil properties.

EXPERIMENTAL

In this study, ASTER satellite data and the detailed soil map at 1:25,000 scale which was previously prepared using VNIR bands of ASTER data[10] were used. The soil samples which had been collected from 40 different landscapes were analyzed and the results of these analysis were given. The correlation between the reflections from all the bands of ASTER data obtained from the landscapes where the samples had been collected and the analysis results were studied. In this study, a classification was made using the bands which are statistically important for the selected soil properties and then the classified images were converted into mapping calculation using 7 × 7 median filters. Finally, sample points, soil map and the classified image were overlaid and checked.

Satellite data: Multi-band ASTER sensor was collects data in a total of 14 bands in visible and near infrared, shortwave infrared and thermal infrared region has a spectral resolution of 0.52 and 11.65 μm.

In this study, ASTER 3 AO1 data (dated October 20, 2006) was used. The atmospheric correction of the data was made by provider data. Geographical correction was realized by the measuring both on the topographic map and on land using hand GPS. Geographical correction was made according to UTM zone 36, North/WGS84. Polynomial equation was used for the conversion process and the rearrangement of the pixels was assured according to the nearest neighbour resampling method. Standard error in the geographical correction was set to a value not exceeding 15 m.

Study field and the soils: Study field is located 120 km to the east of Isparta Province, to the north of Lake Beysehir, between the UTM coordinates of 4,200,000-4,222,000 meters North and 333,000-347,000 meters East. There exist 11 different major soil groups in the study field. Of all the groups located in the above mentioned field, alluvial soils have the highest rate (55.7 %), located in the central plain portion, followed by the colluvial soils (21.4 %) being these two soil groups make up the three-fourth of the study field. Colluvial soils are extensively found on the outskirts of the mountains neighboring to the alluvial soils and surrounding the plain in the north-west direction. In addition to these two soil groups, maroon, brown, limy brown and lime-free brown forest soils, lime-free reddish brown soils and hydromorphic alluvial soils are the other soil groups found in the study field. ASTER image of the study field and the boundaries of the detailed soil map are given in Fig. 1.

In present study, soil samples were collected from 40 different landscapes in August 2002 and surface soil samples were used. Soil parameters were analyzed for pH, organic matter, salinity, lime contents and particle sizes. pH analysis was performed in the 1:1 soil-water mixture by pH meter[11]. Organic matter was determined by the modified Walkey-Black method[12], salt content by the conversion of the obtained value using 1 N KCl Coleman probe and lime content by the Shiebler calcimeter method[13]. Soil particle distribution was determined according to the analysis hydrometer method[14].

pH value of the soil classes in the study field varies between 7.9 and 8.6, organic matter content 1.0 and 8.9 %, amount of salt 0.01 and 0.1 %, lime content 1.0 and 33.0 %. With regard to the texture, the soils contain clay (17.4-65.0 %), silt (23.7-60.6 %) and sand (12.4-57.6 %).

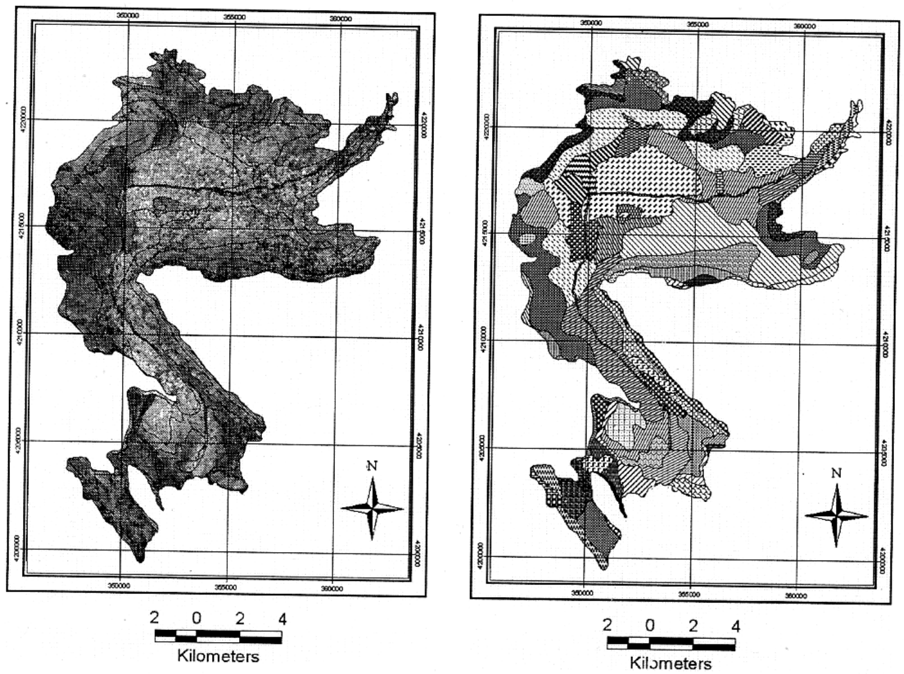

Fig. 1. Sample points overlaid on the image formed by the 3-band (4, 2, 1) combinations of ASTER VNIR data of the study field and the soil boundaries of this field

Determination of the reflections and classification of the satellite data: Coordinates of the sampling points were determined by a hand GPS and these data were overlaid on the image obtained by the satellite data using ERDAS Imagine software. Subsequently, the related correlations (r) were established using statistical software program SAS through the average reflection values obtained from 14 different bands for each sampling point and through the results of pH, organic matter, salinity, lime and texture analysis made on the soil samples collected from the same landscapes. Finally, satellite data were grouped by supervised classification method using soil properties as well as statistically important bands and then a soil map was produced.

In the classification, maximum likelihood method was used. The map produced from the classified image, analysis results of the soil properties and the soil map were overlaid using ARC GIS software and then the results were compared.

RESULTS AND DISCUSSION

Reflection characters and soil properties: As a result of this study, a correlation between the soil properties (organic matter, pH, lime and silt content) and ASTER bands was detected, but such correlation couldn't be found between clay, sand content and salt content (Table-1).

TABLE-1
CORRELATION VALUES BETWEEN THE BANDS AND SOIL PROPERTIES

	Band	μm	Organic matter	pH	Salt	$CaCO_3$	Clay	Silt	Sand
VNIR	1	0.52-0.60	-0.33*	-0.27	-0.11	0.03	-0.23	0.37*	0.0100
	2	0.63-0.69	-0.41**	-0.28	-0.17	0.04	-0.27	0.31*	0.0800
	3	0.76-0.89	-0.35*	-0.23	-0.16	0.01	-0.22	0.23	0.0700
SWIR	1	1.60-1.70	-0.12	-0.31*	0.19	0.31*	-0.10	0.18	0.0002
	2	2.145-2.185	-0.18	-0.29	0.07	0.24	-0.08	0.26	-0.0500
	3	2.185-2.225	-0.11	-0.25	0.13	0.28	-0.07	0.26	-0.0600
	4	2.235-2.295	-0.16	-0.29	0.06	0.10	-0.11	0.39*	-0.0900
	5	2.295-2.365	-0.17	-0.31*	0.06	0.06	-0.12	0.37*	-0.0700
	6	2.365-2.430	-0.24	-0.39*	0.04	0.26	-0.07	0.24	-0.0500
TIR	1	8.125-8.475	-0.30*	-0.02	-0.27	0.25	-0.01	-0.31*	0.1600
	2	8.475-8.825	-0.30*	-0.09	-0.26	0.22	0.02	-0.38*	0.1600
	3	8.925-9.275	-0.33*	-0.09	-0.26	0.25	-0.06	-0.42**	0.2600
	4	10.25-10.95	-0.34*	0.06	-0.24	0.06	-0.13	-0.30*	0.2500
	5	10.95-11.60	-0.39*	-0.12	-0.30	0.17	-0.08	-0.39*	0.2500

*Important between the bands and properties. **very important between the bands and properties.

A negative correlation was found between the organic matter and VNIR-Band 1, 2, 3 and TIR-Band 1, 2, 3, 4, 5 (Fig. 2). The correlation coefficient values for VNIR-Band 1, 2, 3 were found r = -0.33, -0.41 and -0.35, respectively. As for TIR-Band 1, 2, 3, 4, 5, the correlation coefficient values were found r = -0.30, -0.30, -0.33, -0.34 and -0.39, respectively. The diagram, which shows the organic matter content and the reflection values of the bands in which the correlation is statistically important or very important, is given in Fig. 2.

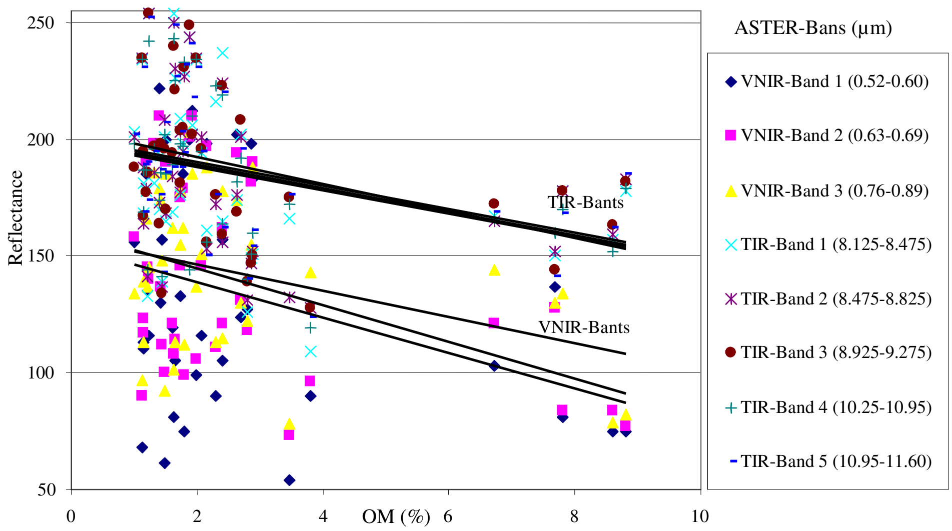

Fig. 2. Organic matter (OM) contents and reflection values of the bands

A correlation was found between the silt content and VNIR-Band 1, 2, SWIR-Band 5, 6 and TIR-Band 1, 2, 3, 4, 5 (Fig. 3). The correlation coefficient values of these bands were found as follows; in the VNIR region, r = 0.37 and 0.31, in the SWIR region, r = 0.39 and 0.37 and in the TIR region; r = -0.31, -0.38, -0.42, -0.30 and -0.39, respectively. The diagram, which shows the silt content and the reflection values of the bands in which the correlation is statistically important or very important, is given in Fig. 3.

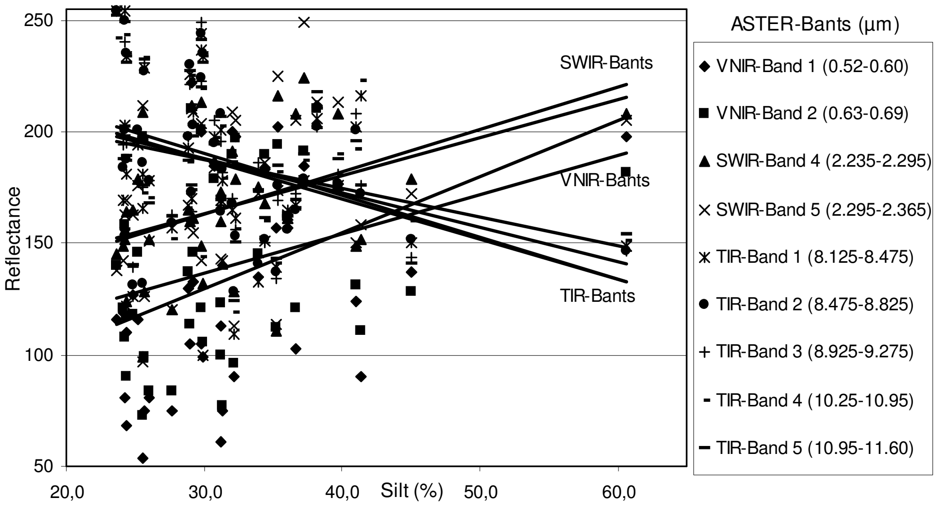

Fig. 3. Silt content and reflection values of the bands

As a result of this study, a correlation was found between pH and SWIR-Band 1, 5, 6 and between lime content and SWIR-Band 1.

In the study, maps were produced for the remarkable organic matter and silt content of the reflection in the TIR region. In mapping, r values of the bands in which the correlation was statistically important were used as the highest ones. A supervised classification was made for soil organic matter map using TIR-Band 3, 4, 5 and 6 different classes were distinguished. In the classification, organic matter content was grouped as 1-2, 2-4, 4-6, 6-7, 7-8 and 8-9 %. The pixels selected as the reference ones for the supervised classification were determined as the sampling points which are the most neighboring ones to the average value for the group it would represent with respect to organic matter content. Organic matter distribution, organic matter content at the sampling points and the soil boundaries are given in Figure 4 according to the classified image.

In the classified image, the first 3 classes get mixed up regarding organic matter content, whereas the last 3 classes can be distinguished more distinctly. In other words, the soils could be distinguished as organic matter more or less than 6 % by the applied method. To produce a map for the silt content, TIR-Band 2, 3, 5 were used. In the classification, 4 groups were formed as follows; 20-30, 30-40, 40-50 and 50-60 %. The classified image, the silt content at the sampling points and the soil boundaries are given in Fig. 4. The silt content could be distinguished into 4 groups. Particularly, the soils which contain low silt (20-30 %) and high silt (50-60 %) were observed to be distinguished evidently.

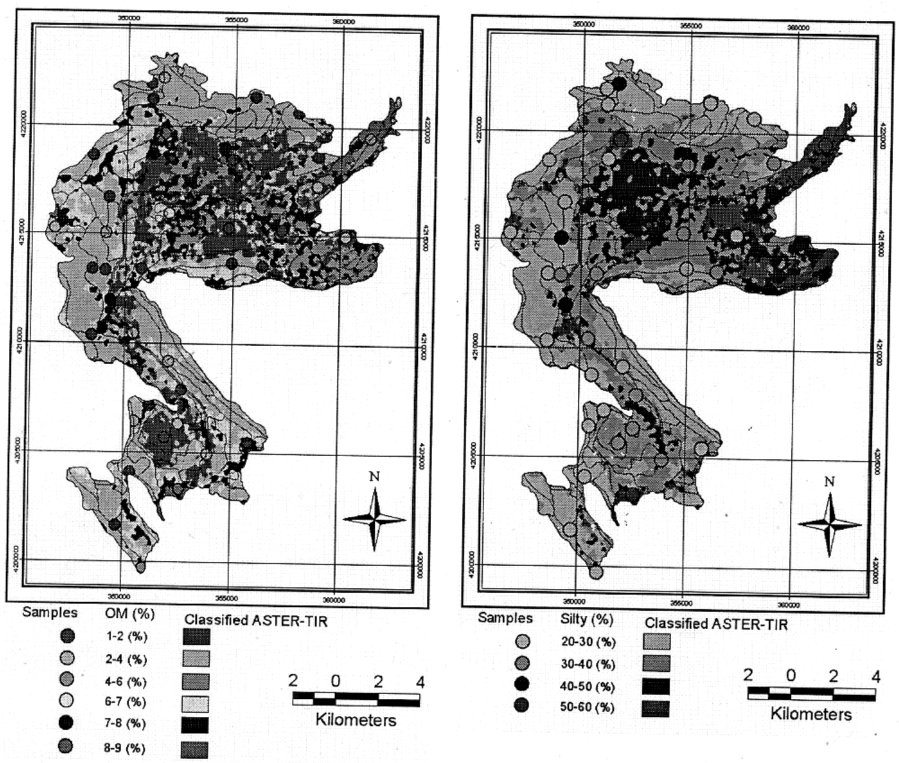

Fig. 4. Organic matter (OM) diagram formed by the classified images and sampling points of the silt maps and comparison with the soil map

The fact that the silt content proved to be significant and requires corroborant studies to be conducted.

Different from the previous studies, the clay content and the lime percentage in the soils were found insignificant in ASTER VNIR bands, which results not taking into consideration the soil colours, which is an important factor on the reflection, in the statistical correlation. However, the fact that the correlation in organic matter was also found insignificant in ASTER SWIR bands makes us think the necessity of evaluating all the satellite data depending on their technical features and acquisition times.

Thus, the soils possess a dynamic nature because of their properties and are constantly affected by the change in moisture and temperature due to its vicinity to the hydrosphere. Further, the reflections they show vary according to the seasons and even day hours. All these facts make it difficult to form

Conclusion

Soil temperature is directly correlated with the internal factors such as soil colour, soil texture and water content. The keeping of the water within the soil is correlated with organic matter and the clay content. The reflection of ASTER-TIR bands results from a component of these factors. However, in this study, organic matter and silt content were found significant. Organic matter-related result seems to be correlated with the effect oforganic matter on the soil colour and the keeping of the water within the soil. A standard legend/library in identifying the soil properties separately by the satellite data. Although ASTER-VNIR data are successfully used in distinguishing the different soil classes formed by the common effect of many soil properties and determining their boundaries, each frame of the data is required to be evaluated independently and verified by the land inspections of the studied area and soil properties in mapping and identifying the soil properties.

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