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SOIL SPECTRAL PROPERTIES OF ARID REGION, KASHAN AREA, IRAN

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Abstract

This study determined some spectral characteristics and relationship between Landsat spectral reflectance and soil surface color in the arid region of Iran (Kashan). The study carried out in the kashan area that covers 90000 ha. Consisting of mountain, hills and flood plain. Enhanced Thematic Mapper (ETM^+) *data collected on July 2002 were used for this research. The color composite images produced from* ETM^+_{7}, ETM^+_{4} *and* ETM^+_{2} *as red, green and blue respectively used in order to choose sample sites. The twelve sample sites were chosen based on resampled 3*3 pixels (90*90 m). In each site, the soil surface conditions and the munsell color of the soil surface were investigated in the field. Some physico-chemical properties of soil samples were also determined in the laboratory. Soil surface particle sizes were categorized into three classes: bare soil <2 mm in diameter, coarse fragment >2mm in diameter and vegetated soil. The results of this study indicates that munsell notation of hue, value and chroma are significantly correlated to the visible bands of Landsat* (ETM^+) *data. From this study it may be concluded that visible reflectance of Landsat can be used to estimate soil color, if very precise result is not expected .More investigation are necessary in order to improve the obtained results.*

Keywords: *Landsat7* (ETM^+)*, visible bands, spectral properties, arid region, soil color*

Introduction

Arid and semi-arid regions include 36% of the earth based on climatic and vegetation cover parameters. According to climatic map of the world,these lands are situated in north America, Australia, Namibia, Iran, Turkmenistan and other arid regions of the world. The most imporamt reasons for the aridity of such regions include topographic effects, being distance from water resources, existence of dry and stable air masses, lack of ocean streams and moisture. The apparent features of arid lands are high evapotranspiration compared to precipitation, sparse vegetation cover and bare areas among vegetation cover. Because of deficit moisture and limited biological and physico –chemical reactions, pedogenic process and soil developmemt in these areas is relatively slow. So, most of the soils have preserved their parent material characteristics and soil profile is in the early stages of evolution. Then, there is a little evidence of carbonates and salts transportation and deposition in subsurface horizons, especially top of the profile. Therefore, investigation of surface features in these soils is a useful guideline for soil zonation. The specteral characteristics of soil is highly dependent on composition (Fe, organic matters, soil moisture), smoothness and roghness of soil surface (peds and grain size).

In arid regions, due to the prolonged sunny days, low soil moistute, sparse vegetation cover and close relation between land units and soils, there is an ideal condition for application of remote sensing data especially for study of relation between sattelite data and color of surface features. The soil color and the most effective factors on color and spectral reflectance of soil are explained in brief.

Color:

One of the apparent characteristics of soil is color which shows high correlation with soil characteristics and specteral reflectance. Soil color is identified using visual comparison of sample and colored chips of Munsel color charts.

The color factor in Munsel method consists of Hue , value and chroma. Hue is an index of color spectrum composition and includes five sub division such as R(red), Y(yellow), G(green), B(blue), P(purple) in addition to five inter-classes that finally results in ten major hue classes for example YR (yellow-red) or GB (green-blue). In standard tables, Hue classes are shown from 10R to 5Y. Value shows darkness/brightness of a color in a range including 0 (pure black) to 10 (pure white). Chroma is relative purity or spectral power of a color which shows degree of grey saturation by spetral color (Shields et al, 1966).

Measurment of material color is, infact, the observation of mass and energy reaction. It means that color depends on the solar energy and reflectance of materials. The reflected energy is related to soil, rock and surface gravel characteristics including chemical composition, particle size and surface relief. These factors determine specteral reflectance properties of soil and the reflectances are recorded as color of materials. Although visible spectrum is a small part of electromagnetic spectral but it plays a major role in soil classification. Soil color or reflectance in visible limit band one of the classifying properties in soil classification systems. Meanwhile,soil color mesurement is one of the essential parts of charachterizing of surface and subsurface horizon (Baumgardner et al., 1985).

The common method for measurement of soil color is visual comparison of samples with the standard soil colors. This method is limited to specific number of colors reported in Munsel color charts and then is a semi-quantitative technique.

Post et al (1994) found that soil scientists agreed only %52 of the time on the same color chip for all three color components. Such variability may result in serious error in the application of soil color criteria in soil classification (Shields et al .1966). Frnandez and Schulze (1987) suggested more accurate and precise measurements of soil color to develop relationships between color and the kind and amount of organic matter or Fe oxide mineral present in soil. When the first earth resources sattelite was launched in 1972, many researches were conducted to apply sattelite data for earth resources monitoring. The results of these reseaches especially during 1980 and 1981 showed that color and soil particle size are highly correlated with measured spectral reflectance of sattelite device or manual radiometer. The Hue, value, chroma, particle size and percentage of rock and gravel are very important and will have the highest precision if vegetation cover is less than 25%.

The correlation between propertis (color and particle size) with spectral reflectance of sattelite is decreased in higher vegetation cover and slope condition.

Escadafal et al (1988) studied the relation between spectral reflectance of Landsat and soil color and the results showed that in arid and semi arid regions, the Hue, value and chroma parameters have high correlation with Landsat data.

Kamrunhahor Islam et al. (2004) evaluated visual inspection and spectroscopic methods for soil color using 25 samples (0-30 and 30-60-cm depth) of different farms and color spectrum. The comparison of results showed that mean of differences among Hue, value and chroma are 0.6, 2.2 and 1.4 respectively. Furthermore, the correlation between measured values using visual and spectroscopic methods is signifcant and positive ($R^2>0.84$) which means that high correlation exists between soil color and visible spectral reflectance.

Moisture:

Generally, wet soil has darker visual spectrum than dry soil because of low spectral reflectance.The reason of darkness is water film and its effect on soil particles. Angstrom (1925) showed that some parts of enengy received by the earth is not reflected by soil particles but will have reflection between soil and surrounding water surfaces because of iterative reflection of energy between soil particles and surrounding water that increases enengy adsorption while decreases soil reflectance to the atmosphere which increases darkness of soils.

Bowers & Smith (1972) and Beck (1976) observed that among some studied factors, soil moisture (moisture in 1/3 bar suction) has the highest effect on spectral reflectamce of soil. The soil spectral reflectance curve for different moisture condition are relatively similar but for dry soil is maximum and it has minimum value in wet soil.

As shown in figure 1, dry soil(a) has the highest reflectance and appears brighter but wet soil(d) has the lowest reflectance and seems darker.

As shown in figures 1 and 2, spectral reflectance curve of soil in 1.45 and 1.95 MicroM bands have the highest absorption related to water while 0.97 and1.2 MicroM bands had weak absroption. Therefore, in similar condition for a given soil, these bands appears darker.

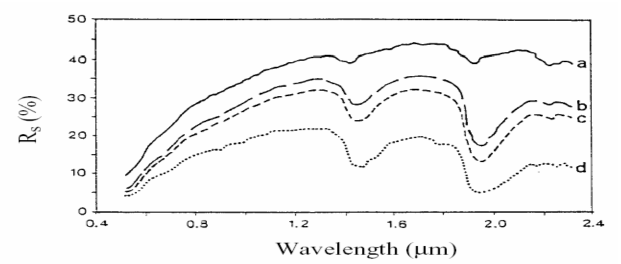

Figure 1: Spectra curve of Typic Haplludalf soil at four different moisture tensions: a; oven dry; b; 15 bar; c, 0.3 bar; d, 0.1 bar

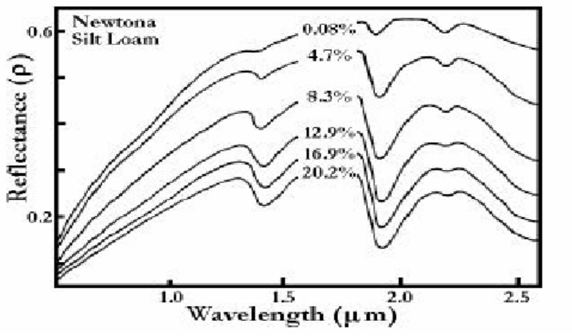

Figure 2: Effect of percent soil moisture content by weight on soil reflectance. Note that the ratio of moist soil reflectance to that of dry soil remains practically constant in large parts of the spectrum

Organic matter:

one of the important components of soil which has effect on color is organic matter. It will have strong effect on soil sepectral reflectance if the organic matter content of soil is greater than 2% (Baumgardner et al., 1970). Decrease of soil oraganic matter to less than 2% will have additional effect on reflectance of other soil components. The spectral reflectance of soil for 0.4 _ 2.5 MicroM bands limitations will reduce in case of high organic matter (Figure 3). Percent of spectral reflectance has an exponential relation near to linear with organic matter content of soil (Figure 4). Consequently, increase of organic matter in topsoil will decrease spectral reflectance and soil will appear darker.

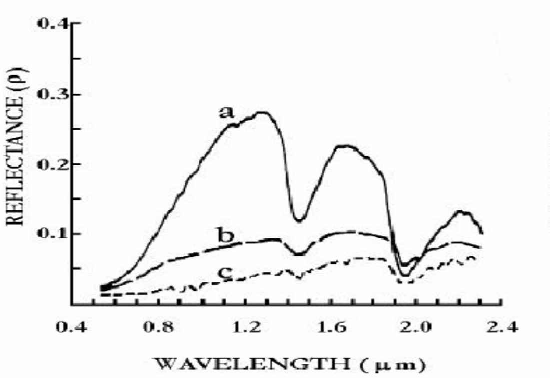

Figure 3 : Spectral reflectance of three organic soils exhibiting significantly different levels of decomposition. Curve a, fibric; curve b, hemic; curve c, sapric decomposition level

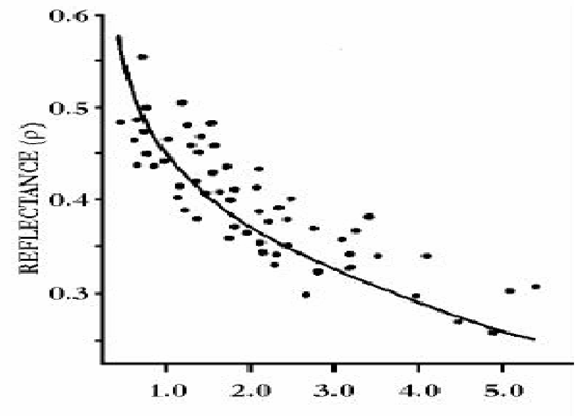

Figure 4: Experimental relation-ship between soil organic matter content and hemispherical reflectance in the visible wavelengths

Oxides of Iron:

The type and content of these oxides make soil color yellow or red. Absorption of electromagnetic energy in 0.87 MicroM band is completely apparent even for fine sandy soil with oxides of iron surface on sand particles. The soil with higher content of Fe have broader absorption band in 0.87 MicroM while in soil with lower amount of Fe, the absorption region will be narrow. In 0. 5-0. 64 MicroM band limit, higher content of Fe will reduce spectral reflectance of soil (Figure5).

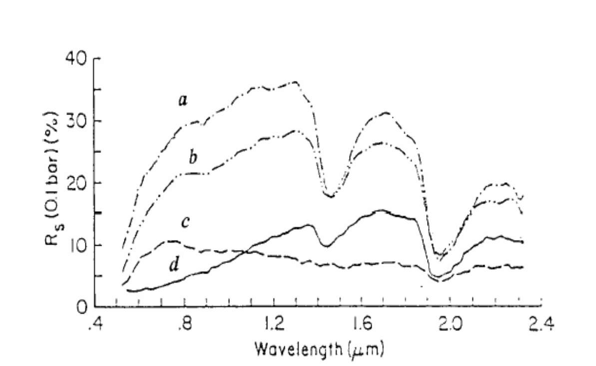

Figure 5: Reflectance spectra of soils consisting of different textures but exhibiting iron absorption bands. a, fine sand, 0.20% Fe2O3; b, sandy loam, 0.64% Fe2O3; c, silty loam, 0.76% Fe2O3; d, clay,25.6% Fe2O3

Escadafal (1996) examinad the effects of two oxides of iron including Hematite and Geotite. The absorption band limit for Hematite is up to 0.55 MicroM and appears as red in soil but Geotite has lower absorptive rate and its variation in two points is within shortwave length region (figure 6).

The purpose of current research is to study the spectral reflectance of soils in arid regions of kashan to find a relation between soil color and spectral reflectance of Landsat7 (ETM$^+$) bands. Since application of landsat remotely sensed data in research projects of Iran is commonly accepted then the results of current research is useful for such data users.

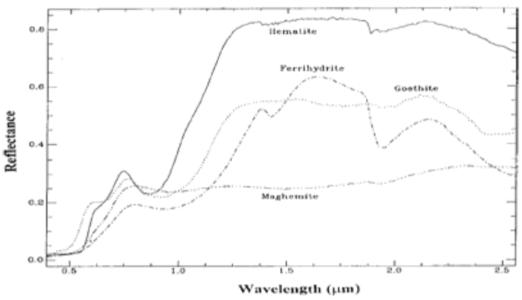

Figure 6: Reflectance spectra of representative iron oxide minerals in soils.

Materials and Methods

The study area is Kashan and Aran region located in Isfahan province 0f 34°-34° 30′ and 51°-51°,30′ E. The region has relatively long and warm summer and moderate winters. Acoording to 20 years meteorological records, the mean annual precipitation is 139.5 mm that starts on November and ends on June. Also, the temperature regime of soils in thermic and moisture regime is considered as Aridic.

Based on previous research and field studies, soils are categorized as Entisols and Aridisols under the sub-orders of Psamments, Fluvents, Orthents, Calcids, Gypsids and Salids in the region. Weak accumulation of lime , gypsum as well as other salts is also obvious in some profile in the study area.

Bands 1-7 of ETM$^+$ sensor of landsat 7 satellite for Aug 9, 2002 were used as well as topographic, soil , land use, salinity and alkalinity maps with scale of 1:50000 and geology map of 1:100000 for sampling. The ILWIS and R2V softwares were used for image processing while statistical analysis was conducted using EXCEL.

At first stage, the images were georeferenced using ground control points and topography map with a precision of 0.345 pixels. Then, 12 sampling sites were selected based on thematic maps and field surveys. At least four samples in an area measuring 3×3 pixels around a point were selected at the center of each site and visual comparison of the samples using Muncel color charts was conducted. The percentage of surface particles and vegetation cover was determined based on manual common methods. the physico-chemical properties of soils were obtained in laboratory using standard methods. Since conversion of spectral reflectance of Hue to numerical values is essential for statistical comparison, the method proposed by Hurst (1977) was approached at this stage. The average brightness degrees of each sampling site for ETM^+ bands was computed using overlay of site maps and satellite bands of EMT^+ in ILWIS. It was associated with numerical values of color components of Munsel standard to obtain correlation of the samples.

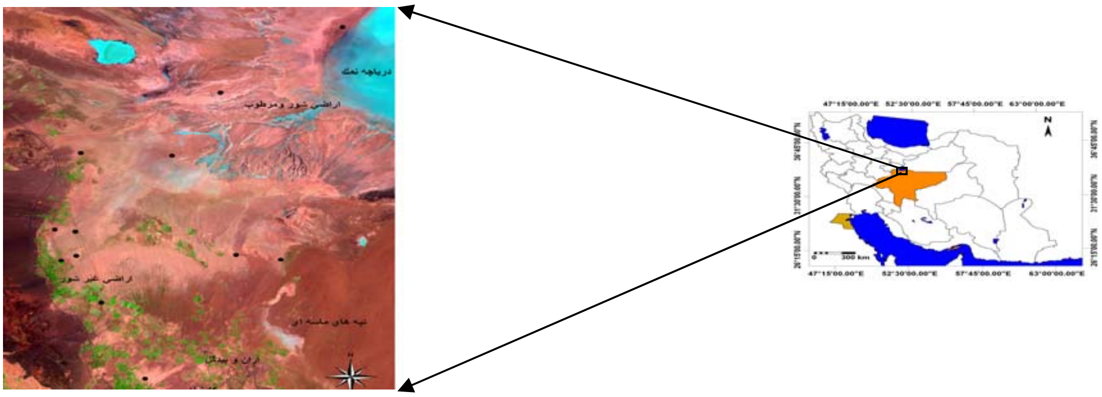

Figure 7: The color image of ETM^+_{742}, location of the region and studied siles

Results and Discussion

In the study region, the properties of 12 area were examined and the data of 9 indicator site were analyzed varying from humid to arid fine grain alluvials that was resulted in 4 classes of spectral reflectance variation (Figure 8). According to figure 8, all classes have similar spectral reflectance graph while the precentage of reflectance is different. It means that arid regions have higher reflectance than humid ones. To obtain the relation between soil color and spectral reflectance of ETM+ sensor (Bands 1-7) Hue, value and chroma properties of samples were determined using visual and Munsel standard manual in each site (Table 1). Meanwhile, percentage of vegetation cover, particle size less the 2 mm, percentage of $CaCo_3$ and soil salinity were also measured (Tables 2 and 3). Based on Hurst method (1977), the measured Hue was converted to numerical values. The average brightness value of each ETM+ bands were calculated in each site (Table 4). The linear correlation among average brightness value of ETM+ bands and color components (Hue, value and chroma) were computed (Table 5) which showed positive correlation in all bands except for thermal band, but for chroma and the ETM^+ bands the correlation was negative. Hue and value have the highest correlation

Table1: Munsell color notation measured in each site

Munsell Color notation	Sampling Site								
	1	**2**	**3**	**4**	**5**	**6**	**7**	**8**	**9**
Hue	7.5YR	5YR	10YR	10YR	7.5YR	10YR	7.5YR	7.5YR	10YR
Hue Number	17.5	15	20	20	17.5	20	17.5	17.5	20
Value	7	5	7	8	7	7	7	7	6
Chroma	2	2	4	2	4	3	4	4	2

Table 2: Selected characteristics of the sites

haracteristics	Sampling Site								
	1	**2**	**3**	**4**	**5**	**6**	**7**	**8**	**9**
Texture	C.L.	C.L.	S.C.L.	L.	C.L.	L.	S.L.	C.	C.L.
Lime%	24.1	17.8	17.8	14.1	10.6	14.4	16.3	15.6	14.3
EC(dS/m)	0.73	151.3	3.97	9.2	9.76	10.3	132.2	192.8	119.2

Table 3: percentage of land cover in each site

Land cover	Sampling Site								
	1	**2**	**3**	**4**	**5**	**6**	**7**	**8**	**9**
Fine particles(< 2 mm)	97	92	94	96	97	96	85	97	84
Coarse particles(>2 mm)	1	1	1	2	1	2	5	1	4
Vegetation	2	7	5	2	2	2	10	2	12

Table 4: Mean DN in each sampling site

Landsat7 Bands	Sampling Site								
	1	**2**	**3**	**4**	**5**	**6**	**7**	**8**	**9**
ETM_1	162	142	121	148	149	159	138	155	117
ETM_2	179	143	119	159	155	166	146	165	115
ETM_3	239	187	149	211	208	223	192	224	140
ETM_4	121	96	88	108	106	111	103	111	85
ETM_5	211	164	121	179	170	187	173	191	148
ETM_6	245	255	243	255	255	255	253	254	249
ETM_7	197	159	108	160	153	178	152	170	116

Table 5: Linear Correlation between munsell color notation and DN

Munsell color	**ETM$^+$ bands**						
	1	**2**	**3**	**4**	**5**	**6**	**7**
Hue	0.32	0.34	0.44	0.27	0.29	0.26	0.21
Value	0.36	0.42	0.48	0.51	0.31	-0.02	0.2
Chroma	-0.1	-0.12	-0.1	-0.04	-0.13	0.03	-0.2

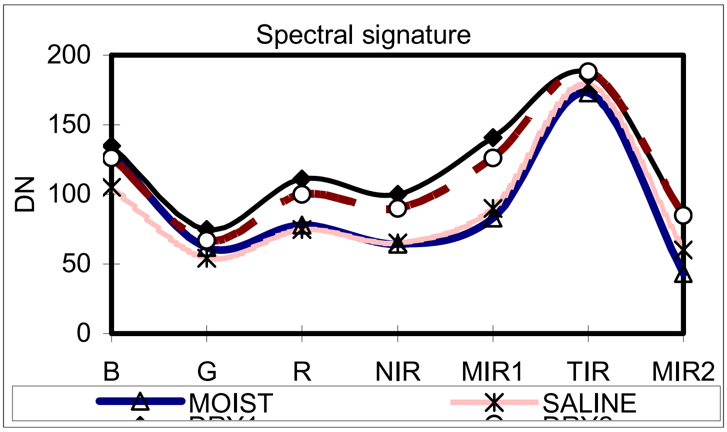

Figure 8: Spectral reflectance graphs for wet to dry soils of Kashan regions

with brightness value of blue, green and red bands. The higher correlation of visible bands and color is expected because of visibility of these wave lengths by eye.

Escadafal et al (1988,1989) have studied the relation between soil color and spectral reflectance of Landsat which showed that Munsel color components (Hue,value) have significamt relation with Landast data. Therefore, visible bands are the most useful bands to evaluate the relation between soil properties and remotely sensed data. The results of current study showed that color of arid and areas with gentle slope has high correlation with rate of reflected energy while in steep slopes(>25%) the results are different because of solar radiation degree. Value is the most important part of color that affects ground reflected energy. The effects of Hue and chroma are also noticeable. The results of correlation between ETM+ bands and Munsel color components showed that blue, green and red bands have the highest correlation with Munsel color components. The computed correlation between visible bands and visual color inspection confirms the results obtained by other researchers who have studied the relation between soil color and satellite images.

Since most of soil classification systems consider soil color as one of the important factors to categorize different profiles, it is possible to use satellite data and field measurements for classification of land units. It is suggested to define soil color exactly using visual methods based on measurement of spectral reflectance in laboratory to find differences. Also, it is possible to complete reflectance measurement methods for different orders of soil using portable experimental spectrometers for better determination of different types of soil spectral reflectance in future research and determination of soil using satellite data.

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