Application of Remote Sensing and Geographic Information System Technologies in the Study of Yardangs of Lut Desert, Iran

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Key words:

ABSTRACT

Lut Desert Eastern Iran with an extent of about 80,000 square Kilometers includes a great diversity of hydroaeolian processes with a very striking pattern of landforms. Due to very poor or non- accessibility of some landforms in Lut Desert, it has not received much attention. To the authors knowledge not so many research was published about Lut Desert, specially no particular study was performed on Yardangs using Landsat satellite Thematic Mapper (TM) data. Yardang which is a wind abraded ridges of cohesive materials (Mc Cauley et al., 1976), is one of the most interesting geomorphological features in Deserts. Yardangs are parallel ridges of Lacustrine sediments between wind -scoured furrows aligned with the dominant wind. Deserts have experienced great temporal and spatial variability of these endogenetic process in Iran, the Lut Desert are apparently tectonically unstable area (Cooke et al., 1993). There have been several recent studies of Desert air/soil surface/rock temperatures (Alavi panah, 1997).

Thermal property of a material is representative of upper several centimeters of the surface. As in thermal remote sensing we measure the emitted radiation, it proves to be complementary to other remote sensing data and even unique in contributing the identification of surface materials and features such as geothermal anomalies, rock types, soil moisture etc. (Prakash. 2000). Thus, though still not fully explored, thermal remote sensing reserves potentials for a variety of applications. In general the 8 to 14 micro meter atmospheric window is utilized for the broad band thermal sensing. However in some space-borne thermal sensors, such as Landsat TM Band 6 operate in the wavelength range of 10.4 to 12.4 micro meter to avoid the ozone absorption peak which is located at 9.6 micrometer. In this study, to evaluate the capability of Landsat TM data in extracting some information on characteristics of Yardangs as on of the most striking erosion form in the world within western part of Lut Desert was selected.

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1. INTRODUCTION

Lut Desert Eastern Iran with an extent of about 80,000 square Kilometers includes a great diversity of hydroaeolian processes with a very striking pattern of landforms. Due to very poor or non- accessibility of some landforms in Lut Desert, it has not received much attention. To the authors knowledge not so many research was published about Lut Desert, specially no particular study was performed on Yardangs using Landsat satellite Thematic Mapper (TM) data. Yardang which is a wind abraded ridges of cohesive materials (Mc Cauley et al., 1976), is one of the most interesting geomorphological features in Deserts. Yardangs are parallel ridges of Lacustrine sediments between wind -scoured furrows aligned with the dominant wind. Deserts have experienced great temporal and spatial variability of these endogenetic process in Iran, the Lut Desert are apparently tectonically unstable area (Cooke et al., 1993). There have been several recent studies of Desert air/soil surface/rock temperatures (Alavi panah, 1997).

Thermal property of a material is representative of upper several centimeters of the surface. As in thermal remote sensing we measure the emitted radiation, it proves to be complementary to other remote sensing data and even unique in contributing the identification of surface materials and features such as geothermal anomalies, rock types, soil moisture etc. (Prakash. 2000). Thus, though still not fully explored, thermal remote sensing reserves potentials for a variety of applications. In general the 8 to 14 micro meter atmospheric window is utilized for the broad band thermal sensing. However in some space-borne thermal sensors, such as Landsat TM Band 6 operate in the wavelength range of 10.4 to 12.4 micro meter to avoid the ozone absorption peak which is located at 9.6 micrometer. In this study, to evaluate the capability of Landsat TM data in extracting some information on characteristics of Yardangs as on of the most striking erosion form in the world within western part of Lut Desert was selected.

2. STUDY AREA

The area under study with an extent of almost 600 square kilometers is located in the western half of Lut watershed, close to Kerman Mountains which receives up to 200 mm precipitation annually. This precipitation which decreases toward east (estimating to be less than 50 mm) over the Yardang covered zone, are carried by NW-SE, E-W and SW-NE flowing rivers terminating in existing western and northern playa covered margins of Yardangs. Other climatological factor which is governing on the study area is a NW-SE blowing prevailing wind which starts almost in June and lasts 120-days up to September annually.

3. GEOLOGICAL ASPECT

Geologically, Yardangs are formed in Pliocene Lut formation, which is composed of fine-grained horizontally bed red to light-brown and limy gypsiferous sands with an estimated thickness of 135 to 200 m. Salt, gypsum, and silty clay encrust the unit (Krinsley, 1970). These sediments as deposits of Lut are made as alternation of dry and wet period deposits. These alternation, coupled with tectonic compression of the Lut basin fill sediments into scarcely perceptible folds, resulted in unusual types of relief being formed during second half of the Quaternary. Resulting erosional activities on this widespread sediments is the formation and appearance of ridge-furrow morphology which extends about 60 kilometers toward Lut basin center.

4. MATERIALS AND METHODS

In this study, seven bands of Landsat TM data acquired on December 5, 1998, aerial photographs (at the scales of 1:55,000 and 1:20,000) and geologic map at the scale of 1:1,000,000 and field work carried out to confirm the nature of findings. Due to poorly accessible desert, the east part of Yardangs close to the shaded that was thought to be a representative area was selected. Field work was carried out in December, 2000 to confirm the nature of the findings and image interpretations.
The color photographs taken from the field work was used to show important landforms, such as mega Yardangs, mud Yardangs, sand dunes and ripples on the surface appear on the aerial photos (1:20,000) and false color composites (1:100,000). To extract some information content of TM bands and their relationship, the correlation matrices and correlation coefficients between TM thermal and TM reflective bands were calculated. Level slicing is used to show discrete thermal range classes obtained from TM6. To study the relationship between the TM thermal and TM reflective bands and Normalized Difference Vegetation Index (NDVI), the NDVI was computed as following:

$$NDVI = (TM4-TM3)/ (TM+TM3)*255$$

Image processing techniques such as, contrast stretching was used to identify faults and thermally different zones. A series of transacts on the Yardang zones were selected to correlate geomorphologic units to their related surface temperature.

5. RESULTS AND DISCUSSIONS

To estimate the degree of interrelation between bands the correlation coefficients are used (table 1).

Table 1. correlation matrix of TM bands of the study area

	TM1	TM2	TM3	TM4	TM5	TM6	TM7
TM1	1.00						
TM2	0.957	1.00					
TM3	0.934	0.977	1.00				
TM4	0.920	0.959	0.996	1.00			
TM5	0.797	0.876	0.890	0.905	1.00		
TM6	0.195	0.089	0.070	0.036	0.046	1.00	
TM7	0.817	0.890	0.907	0.916	0.981	-0.003	1.00

This table shows that six TM reflective bands are highly correlated. The highest correlation coefficients are obvious between the TM3 and TM4 (0.996). The Feature Space (FS) between red and infrared bands forms a soil line, but the FS between TM red and TM6 and NDVI forms a cluster which means no significant correlation exists between them. A very high correlation coefficients between TM red and TM infrared bands can be due to non vegetation, and lack of organic matters and mainly dry condition of surface materials. The result obtained by the lack of significant relationship between NDVI and thermal band confirms the absence of vegetation, because the negative correlation coefficient between NDVI and TM6 is an indicator of plant effect on lowering of the surface temperature in Desert (Alavi panah, 1995). Meanwhile, there exist significant positive correlation coefficiant (r=0.756) between NDVI and TM7. A significant correlation was not found between the NDVI and TM6 on the Yardang area. This result does not correspond to the obtained result by Lo et al. (1997) and Alavi panah (1997) for agriculture regions. They found that NDVI is a good indicator of surface radiant temperature. They also stated that the relationship between the NDVI and TM thermal band is very useful, because the values of the TM thermal band can be predicted based on NDVI. This relationship is important, because thermal infrared data are not always available, while NDVI which are derived from image data in the visible reflected infrared bands are more easy to obtain (Lo et al., 1997). Due to differences in the thermal properties and spectral reflectance of materials, the two dimensional feature space between TM thermal and NDVI and TM reflective bands were used.

Variation of the correlation coefficients over the TM wavebands shows completely different behavior of TM thermal band with the behavior of TM reflective bands. The results obtained from the reverse behavior of the TM thermal and TM reflective bands on the Yardang region suggest that the information content of the two different TM thermal and TM reflective bands may be complementary to each other.

A careful inspection to the relationship between TM thermal and TM reflective bands reveals three trends of the correlation coefficient. Although in this study the trend of the correlation coefficients of each two consequent reflective bands seems to be the same on the Yardang zone, but the rate of increasing or decreasing curve are meaningfully different. It means that blue and green bands with comparable trend may show a decreasing rate, but middle infrared bands (TM 5, TM7), show the same trend but the reverse trend with the TM1, TM2, TM3 and TM4 which are in between TM1, TM2 and TM5, TM7 behaves meaningfully the same as

TM1, TM2, TM5 and TM7. It means that the correlation coefficients between TM5, TM7 with other TM reflective bands shows increasing and decreasing rates. Although the decreasing or increasing rate of correlation coefficients is not well known, but it may be attributed to the absence of vegetation and some other factors affecting the correlation coefficients. Futher research is needed to confirm these findings. Therfore the spectral data may be divided into the main sub-bands from the aspect of the physical factors which determine the characteristic of spectral signature of surface element.

1) In the short-wave band (from visible towards near infrared, the spectral signature corresponds to the spectral reflection coefficient weighted by the illuminating spectrum.

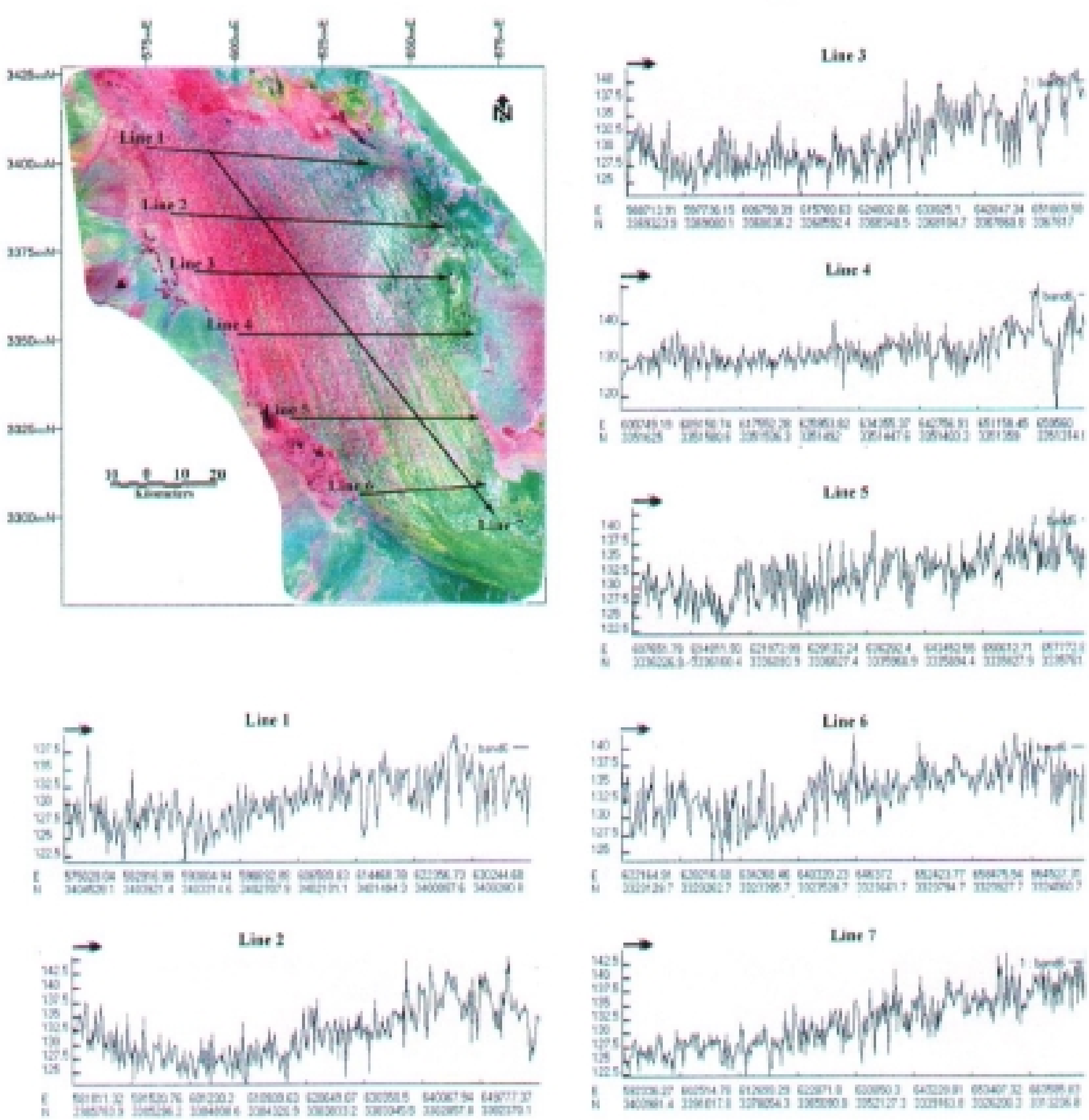
2) In the wavelengths beyond about 3.5 , spectral signatures is related to self emitted radiation from surface elements.

Since emissivity variations between surface elements are low, the spectral signature is mainly related to temperature differences. Those differences depend on short wave solar energy absorption of surface element and its thermal capacity and conductivity.

A histogram of TM band 6 of the Yardang zone shows that data are compressed into a narrow range of 69 to 176 of the range 0 to 255, suggesting that it is relatively low in contrast. Figure 1m shows enhanced TM thermal image using contrast stretched. Arrows denote a near North South directed fault to interpret this low contrast image, a contrast enhancement (contrast stretch) was used to expand the original input brightness values to make use of the total range of 0 to 255 (Figure 1). This contrast stretched TM thermal image reveals a north south trending 106 kilometers long lineament within the Yardang covered zone. To find an explanation about this lineament, which follows the overall trend of two major basement faults located in eastern and western margins of Dasht_e_Lut (tectonically called Lut Block), a series of transacts on the Yardangs zone were selected and it was also attempted to correlate the possible existing difference with this newly identified feature. TM6 DN values along 6 transacts (lines 1 to 6) suggest that a zone of relatively higher thermal values could be delineated in the eastern part of Yardangs when compared with the values present in the western part. This difference in thermal values as a surrogate of surface temperature suggest that this newly identified lineament has acted as a thermally different zone divider and observed difference may be related to the fault impact.

Figure 1. shows the thermal DN value information along 6 specified transacts from west to east (line 1 to 6). Arrows on transacts 2 to 7 show the existing correlation between identified lineaments and two thermally different zone observed.

Figure 1, shows the thermal DN value information along 6 specified transacts from west to east (line 1 to 6). Transacts 1 to 6 have shown various peaks and valleys which may correspond to consequent ridges and furrows with different surface materials, topographic conditions, shadows, sunlight illumination. The peak with the highest TM6 DN values are mainly associated with sun_exposed ridges / sand sheets and sand dunes and valleys are correspond to shadow and other unknown materials. The result of evaluating transact 4 (line 4) showed that a deep valley near the endpoint of line attributed to wet zone. In order to know the relative differences in the radiant temperature within the scene, all of the TM thermal data were divided into five analyst specified intervals or slices. Class no. 1 attributes to the lowest temperature and class 5, indicates the warmest class.


Line 1
Line 2
Line 3
Line 4
Line 5
Line 6
Line 7

6. CONCLUSIONS

Based on the obtained results from enhanced thermal image and overall trend of the identified fault, we may conclude that two thermally different zones can be detected in the Yardang. Therefore observed difference in thermal values may be attributed to the fault impact. Although, the coarse spatial resolution, especially of satellite broad band thermal data poses some problems in relation to their reflective data with finer spatial resolution, the advantages and potential and a variety of possible applications of thermal remote sensing are obvious. Due to new satellite with improved thermal sensors, it is necessary to promote the understanding and use of thermal data.

Based on the obtained result, we may conclude that in determining the nature and structure of large areas and an extensive material, spectral resolution relevant to geological characteristics may be more important than spatial resolution.

Due to poor accessibility in Lut Desert, it is very efficient to use different satellite data with different spatial, spectral and multi _ temporal resolution in order to improve our understanding about diurnal temperature rang, landform characteristic and wind and water erosion forms in the Yardangs area. We may also generally conclude that further research is neccessary to confirm the obtained findings.

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