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Behavior of Landsat Thematic Mapper Wavebands on Lut Desert (Iran)

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ABSTRACT

To study the capabilities of remotely sensed data in discriminating land cover types and geomorphologic features of desert, the southeast of Lut Desert was selected. In this study, seven bands of Landsat Thematic Mapper (TM), data and other sources of information such as topographic maps (1:50,000), aerial photos (1:20,000) and field data were used. The visual image interpretation was performed based on photomorphic unit analysis and interpretation keys. To classify the images, 10 training classes were used for maximum likelihood classification algorithm. Then the classified images were assessed with the test areas and the overall accuracy was about 92 percent. Based on the obtained results it may be concluded that Landsat TM thermal and reflective bands could be useful for studying Lut Desert conditions especially in the Yardang and sand dune regions. From the results obtained we may also conclude that such a hyper arid climatic and bare land are suitable conditions for a better understanding of the behavior of TM wavebands on different surfaces and soil conditions.

Key words: Desert, Image classification, Lut Desert, Sand dune, TM wavebands, Yardang.

INTRODUCTION

Recently, considerable effort has been put into the development, operation, and use of spaceborne image spectrometers. These advances in technology can provide a near-laboratory-quality spectrum of every pixel in the image and very soon will permit remote sensing of soil and weathered material in deserts to be improved. Experience has shown that many earth surface features of deserts can be identified, mapped and studied on the basis of their spectral characteristics of the particular features under investigations (Alavi Panah, 1996; Alavi Panah, *et al*. 2001). Therefore a better understanding of the behavior of different wavelength regions on different materials and surface conditions in deserts may increase the efficiency of the study of land cover types on the basis of remote sensing. Understanding weathered material and soil spectra principles is crucial to the application of remote sensing procedures for soil and geomorphologic studies. Therefore, in this study we will make our attempt to study behavior of TM reflective and thermal bands on Lut Desert features.

Lut Desert with an extent of about 80000 Km^2 is the largest playa in Iran and includes great diversity of hydroaeolian processes with a very interesting pattern of landforms, such as Yardangs which are wind-abraded ridges of cohesive materials. Yardangs are most commonly developed in soft lithology, such as lacustrine sediments. The Lut mega Yardangs have been cut recently in pleistocene lake deposits (Bobek, 1969). To the authors knowledge not much research about the striking features of Lut Desert has been performed. Application of remotely sensed

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data for geomorphologic mapping in such regions requires a knowledge of the influence of some land cover types, such as desert varnish on the surface reflectance in order to yield more reliable results. Spectral analysis shows the paucity and Mn/Fe proportion in composition, and the wavelength under consideration control the effect of desert varnish on Landsat TM data (Keneam, 2001). To assist in management of the desert, information is required about land cover types especially eroded land, sand sheet, sand dune and salt affected land. Drake (1995) found that remote sensing may be a useful tool for locating economic evaporative deposits. Remote sensing has shown its greatest value where fieldwork has been difficult. Therefore, in this study it was attempted to study the eastern part of the poorly accessible Lut Desert using remotely sensed data. In fact, the main purpose of this study is to evaluate the capability of Landsat TM data for studying land cover types and the geomorphology of deserts.

STUDY AREA

The study area that covers about 25439 square Km was located in Lut Desert (Figure 1). The Lut Desert, particularly its central part and Yardang region, is characterized by an extremely arid climate, with excessive summer heat, and winter temperatures below freezing point and an annual rainfall of less than 50 mm. Alavi Panah, *et al*. (2002) has shown that some part of Yardangs contain a great amount of gypsum and salts on the surface or very close to the eroded surfaces. The study area includes two main regions of Yardang and sand dune which are rare and striking features (Figure 2). The hyper-arid south-east of the Yardang region consists of large gravel plain and desert pavement, sand dune, salt affected wet lands. Sand regions in the east of Lut Desert form the largest body of sand in Iran with probably the greatest diversity to be found.

MATERIALS AND METHODS

In this study, the available seven Landsat Thematic Mapper bands dated June 1989 were used. The number of row and column are 1960 and 2028 pixels respectively. For visual image interpretation of the whole part of Yardang area, Landsat TM bands 7-4-2 combination (TM7-red, TM4-green, TM2-blue) dated 1987 and 1988 were used for land cover discrimination.

The spatial resolution of all bands (except band 6) is 30 m, therefore TM6 was only used for visual interpretation by using diffent false colure composites. This study

Figure 1. Location map of the study area

(a)

(b)

Figure 2. The terrestrial photographs of two land cover types in the area, a) Yardangs with gully erosion and b) mobile sand in between the broad ridges of Yardang.

was concentrated on using Landsat TM data because ground resolution of 30 m seems suitable for studying large areas in this study. Other information sources, such as topographic maps (at the scale of 1/50,000), geologic map (at the scale of 1/250,000),) and aerial photos (at the scales of 1/50,000 and 1/20,000) were applied. The fieldwork as one of the most important steps was carried out in autumn season of 2000. The methodology used comprises of 1) correlation between TM bands, 2) image processing techniques, 3) two dimensional feature space (FS) analysis and 4) image classification and accuracy assessment. In this study, the three-band combinations were ranked based on Optimum Index Factor (OIF) and the different False Color Composites (FCC, s) were created. The application of the OIF criteria to seven TM bands resulted in 35 band combinations. The FCC,s were evaluated visually based on the information content on field work and image interpretation.

Based on our experience, the land cover types were defined (Figure 2) and the training sets were identified and spectral patterns of different types of land covers were generated. Different aeolian features such as Yardangs, desert pavements, sand dunes, sand sheets and erg were defined (Cooke and Goudi, 1993) as indicators of the wind effect on the morphology of the study areas. Yardangs a term used for abraded ridges of cohesive materials that occur in unidirectional regime were also defined. Desert pavements, soils containing coarse fragments on the surface and salt affected lands with two different surface conditions of salinity and salt crust, were defined. Wet lands the places where water table lies at shallow depth were also defined. The class separability analysis was carried out by computing the statistics (mean and standard deviation). Based on the results obtained, TM reflective bands 1, 4, 5, 7 were selected as the most informative. TM reflective bands and then all data sets were classified using a per pixel maximum likelihood classification algorithm and finally the land cover map was produced.

RESULTS AND DISCUSSION

Color Composites

In order to select the most suitable three band combinations for creating color composites, the OIF criteria was applied to 7 TM bands (Table 1). It is evident from Table 1 that the band combinations 1, 5, 6 and 1, 6, 7 ranks first in terms of the OIF value. In this study, the color composites were created and were displayed on monitor and their capabilities were compared for discrimination of the land cover types. Two color composites of Landsat TM scene over a portion of Lut Desert are shown in Figure 3. In image **a**, TM band 6 is displayed in red, band 4 in green and band 2 in blue. In contrast, image **b** shows the same region, but uses TM band 7 in red, band 4 in green and band 2 in blue. Comparison between these color composites reveals that color composite **a** exhibits wet land, sand dune and sand sheet better than color composites 7, 4, 2 (a) and the regions rich in sand sheets exhibit the distinctive color and wet lands between the Yardang and sand dune regions is shown with a high reflectance in blue and appears blue. Results from visual interpretation of various combinations of bands (FCC,s) improve our knowledge of the spectral properties of materials or may provide an opportunity for assessment of the land cover units in a region.

Soil Line

The highest correlation of coefficients was found between the TM3 and TM4 which forms a soil line and a very low negative correlation was obtained between TM red and TM thermal band which forms a clustered shape. Due to the lack of vegetation (zero vegetation cover) in the study area, the strong relationship between TM3 and TM4 leads to a very high correlation coefficient of 0.996 (Table 2). The result obtained from the high correlation coefficient between TM3 and TM4 (r = 0.996) reveals a lack of vegetation that normally exhibits low reflection value in near infrared band and high reflectance value in red band.

Table 1. The rank of 35 possible band combinations of the TM bands based on their OIF values.

Rank	Band combination	OIF value
1	1-5-6	24.12
2	1-6-7	21.60
3	3-5-6	21.50
4	5-6-7	21.25
5	4-5-6	21.09
6	1-5-7	20.80
7	1-3-6	20.53
8	1-4-6	20.09
9	1-4-5	19.96
10	2-5-6	19.76
11	3-6-7	19.33
12	1-2-5	18.79
13	1-3-7	18.48
14	3-5-7	18.46
15	4-6-7	18.34
16	3-4-6	18.28
17	3-4-5	17.92
18	1-4-7	17.87
19	1-3-5	17.79
20	1-2-6	17.73
21	4-5-7	17.59
22	2-3-5	17.32
23	2-5-7	17.28
24	2-6-7	17.14
25	1-3-4	17.13
26	1-2-7	16.81
27	2-3-6	16.70
28	2-4-5	16.69
29	2-4-6	16.07
30	1-2-3	15.86
31	3-4-7	15.84
32	1-2-4	15.50
33	2-3-7	15.28
34	2-4-7	14.61
35	2-3-4	14.26

Figure 3. Comparison of color composites from Landsat TM for the eastern part of Lut Desert.

Table 2. Correlation matrix of TM bands of southeast of Lut Desert.

Bands	TM1	TM2	TM3	TM4	TM5	TM6	TM7
TM1	1.00						
TM2	0.98	1.00					
TM3	0.95	0.98	1.00				
TM4	0.91	0.96	0.99	1.00			
TM5	0.85	0.92	0.95	0.96	1.00		
TM6	-0.56	-0.58	-0.55	-0.53	-0.57	1.00	
TM7	0.82	0.89	0.93	0.95	0.99	-0.53	1.00

Spectral Separability

The validity of training data was evaluated from visual examination of FS and quantitative characterization (Table 3). Table 3 shows the mean and standard deviation of the training classes. Among the 10 training classes, classes no. 10 (wet land) shows the highest SD (SD = 17.8) for TM 1 which is due to the heterogeneity of the soil surface, moisture and salinity variation and lithologies. This training class shows the lowest SD (SD = 6.6) in TM reflective band 7.

Spectral separability helps to refine the digital classification and it has long been used as an index of the efficiency of remotely sensed data to distinguish various terrain features and phenomena. Figure 4 shows the feature space between TM bands. A close look at this FS indicates that the behavior of TM bands is different from the view-point of spectral separability. For example, FS bands1 and 3 indicate a fairly good spectral separability of training classes, while FS bands 1 and 2 show confusion between the training classes. It means that the overall separability of classes is poor in TM1 and TM2 data set.

Image Classification and Accuracy Assessment

The training samples which are used to estimate the statistical characteristics of the classes were used to classify the TM scene. The result of the maximum likelihood classification is shown in Figure 5.

For the quantitative estimates of the classified map, randomly selected samples representing different land cover types were used randomly. Many sample points SD (from 63 to 317) representing all types of investigated land cover were identified on the FCC for accuracy estimation. A one to one comparison was made between the ground truth data and the information available in reports, fieldwork and maps. The overall accuracy was calculated after generating a confusion matrix. Table 4 indicates the error matrix resulting from the maximum likelihood classification. In this study, areas different from training samples are used for classification accuracy. As Table 4 indicates the pixels that are properly classified are located along the major diagonal of the error matrix. The result of percentage accuracy per category from class no.1 (Yardang) to class no.10 (wet lands) shows that the accuracy of class no.1(Yardang) and class no.2 (salt effected land) is 85.04 and 80.13 percent respectively which is relatively low. That is due to great confusion between these two classes. The reason for confusion between Yardang and salt affected land may be due to the very similar surface condition of some Yardangs with a high amount of salt and gypsum.

CONCLUSION

This study has demonstrated the utility of TM data for mapping Lut Desert features including Yardang, sand dune land cover types with relatively high spatial resolution satellite data. Lut Desert land cover types, such as Yardangs, sand dunes and salt

Table 3. Statistics (mean and standard deviation) of the training classes.

Band	Yardang		Desert Pavement		Erg1		Erg2		Salt land1		Salt land2		Sand dune		Sand sheet		Wet land1		Wet land2	
	M	SD	M	SD	M	SD	M	SD	M	SD	M	SD	M	SD	M	SD	M	SD	M	SD
TM1	155	4.3	145.3	3.8	104	5.0	112	5.2	163	9.2	148.5	4.0	124.5	2.0	134.5	2.8	149.1	8	189.3	17.6
TM2	85	2.9	74.4	2.3	53.0	3.2	53.2	2.9	89	5.4	82	2.7	61.6	1.8	71.6	1.7	77.1	.6	97.9	99
TM3	123	4.3	97.5	3.2	76.1	4.3	69.8	3.9	124	7.6	114.3	4.2	81	2.7	97.8	2.5	101.2	6.1	128.5	123
TM4	110	4.2	83	2.7	69.4	3.8	59	3.5	108	6.5	101.4	3.8	66.7	3.0	85.6	2.4	85.9	5.3	108.3	99
TM5	164	5.5	127.8	4.7	116	6.7	84.6	6.2	160	6.7	164.3	7.0	99.7	7.6	139.2	4.3	119.6	7.7	87	90
TM6	227	3.3	223.2	3.1	243	8.6	237	7.2	221	4.9	218.8	2.5	234.44	3.3	223.5	3.1	204.8	2.7	202.6	23
TM7	116	3.6	90	3.6	84.7	5.0	6.5	4.5	114	114	117.6	4.4	70.8	6.2	99.9	3.5	732	6.3	39.5	66

Figure 4. The feature space between TM bands.

Figure 5. Land cover classification image of the southeast of Lut Desert based on the TM band combination 1, 4, 5 and 7.

affected lands carry unique and important information about many desert characteristics. This study also showed that, in some cases, only a slight spectral difference could be effective in discriminating desert land cover types on the basis of their spectral signatures. To achieve a high classification accuracy, extensive fieldwork and aerial photos would be very effective. The result of visual interpretation of various band combinations may improve our knowledge of the spectral reflectance of wet lands, sand dunes and Yardangs and therefore it may provide an opportunity for delineating a land cover unit. Based on the results obtained from FS analysis, we may conclude that hyper arid climatic conditions are ideal for a detailed mapping of land cover types and a better understanding of the behavior of TM bands.

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Table 4. Error matrix resulting from maximum likelihood classification using TM reflective bands 1,4,5,7.

no.		Y	SL1	DP	SL2	W1	SSH	E1	SD	E2	W2	Total	Accu
1	Y	108	17		2							127	85.04
2	SL1	57	254	1	4				1			317	80.13
3	DP			167			1		4			172	97.9
4	SL2	1			217							218	99.54
5	W1					46			2		4	52	88.46
6	SSH						197		9			206	95.63
7	E1							176		1		177	99.44
8	SD	7							226	15		248	91.13
9	E2					1	1	1		224		227	96.68
10	W2						1		1		61	63	96.83
Total		173	271	168	223	47	200	177	243	240	65	1807	93.20
*Accu		64.43	93.73	99.40	97.31	97.87	98.50	99.46	93.00	93.33	93.85	92.89	

*Accu =Accuracy

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رفتار باندهای طیفی TM بر روی بیابان لوت (ایران)

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چکیده

به منظور مطالعه توانایی داده‌های سنجش از دور در تفکیک انواع پوشش‌های اراضی و پدیده‌های ژئومرفولوژی بیابان، جنوب شرقی بیابان لوت، انتخاب گردید. در این مطالعه، هفت باند TM و منابع دیگر اطلاعات و داده مانند نقشه‌های توپوگرافی (۱:۵۰/۰۰۰)، عکسهای هوایی (۱:۲۰/۰۰۰) و کارهای صحرایی مورد استفاده قرار گرفت. تفسیر چشمی تصاویر ماهواره‌ای براساس تجزیه و تحلیل واحدهای فتومورفیک و کلید تفسیر انجام گرفت. جهت طبقه‌بندی تصاویر، ۱۰ کلاس طیفی برای طبقه‌بندی با روش حداکثر احتمال به کار گرفته شد. سپس نقشه‌های طبقه‌بندی شده و مناطق آزمایشی ارزیابی گردید و نتایج حاصل نشان داد که دقت کلی طبقه‌بندی حدود ۹۲ درصد می‌باشد. براساس نتایج بدست آمده می‌توان نتیجه‌گیری نمود که باندهای حرارتی و انعکاس TM برای مطالعه شرایط بیابان لوت به ویژه یاردانگ‌ها و

تپه‌های ماسه‌ای مفید می‌باشد. همچنین نتیجه‌گیری می‌شود که چنین شرایط فوق‌العاده خشک و اراضی لخت محیط مناسبی برای درک رفتار باندهای طیفی TM بر روی مواد و شرایط مختلف می‌باشد.