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Remote Sensing for Identification and Characterization of Zibar Sand Dunes in Sandy Alluvial Plains within Thar Desert, India

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Abstract: Zibars, a kind of small dunes with coarser particles in the desert, are often difficult to identify in field. This study was carried out in the vicinity of Jodhpur to test the use of remote sensing techniques to identify the zibars and study their major characteristics. Following satellite data were used in analysis: multi-spectral data in the form of FCCs of AWiFS and LISS-IV, hyperspectral data from Hyperion, and microwave data from RADARSAT-2. CartoDEM data were used to find out the elevation differences in the study area, while a field spectro-radiometer was used to find out the reflectance properties of different land surfaces. It was found that neither all kinds of image combinations, nor all conventional digital analysis techniques provide useful results. Spectral angle mapper classification of Hyperion data were found better than a grain size index mapping and some conventional interpretation techniques. Since there is very little control of soil moisture variation in the zibar pattern, microwave data were also of little use. The study concluded that zibar pattern gets manifested on the satellite images due to grain size variation.

Keywords: Zibar, spectral reflectance, AWiFS, LISS-IV, Hyperion, RADARSAT-2, Spectral Angle Mapper, Grain Size Index.

Thar Desert is dominated by aeolian bedforms of different shapes and sizes, which include sand dunes of ~5 to 40 m height, as well as sandy plains of different thickness. The bedforms result from a delicate balance between wind strength and direction, precipitation effectiveness, sediment supply, vegetation and land surface conditions (Kar, 1993). Depending on their shape, size, inherent characteristics, age and environmental set up, the dune-interdune landscapes and the sandy plains have their different natural resource base, use potentials, vulnerability and impact on the livelihood and built environment in the desert (Singh, 1982). While the large sand dunes of linear, transverse and parabolic shape can easily be identified in the field, some smaller dunes (mostly of 1-5 m height) often go unnoticed, although those dunes are often prone to higher mobility than the high dunes and have the potential to impact the surrounding landscape. One such small dune type is zibar, which is an almost regularly spaced transverse bedform (also classified as sand streaks), and is dominated by particles coarser than in many other dune types (Kar, 2002).

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The word zibar is derived from the Arabic word *zibara*, which means a hard sandy surface that permits passage of vehicles. It is a long-wavelength, low-amplitude bedform with low-angle stoss slope. Because of their coarse particles, mobility of the zibars over and across an alluvial plain with finer mean particle size can significantly impact the resource potentials of those plains. Remote sensing supports in uniquely distinguishing object/features. Diagnostic absorption features of soils are due to the inherent spectral behaviour of the mineralogical composition, organic matter, and water according to several reports (Baumgardner *et al.*, 1985; Irons *et al.*, 1989). Coarse sand has more albedo. Fine difference in grain size is creating variable reflectance. This, therefore, calls for proper identification of the zibars and their mobility status. The present study attempts to find out a remote sensing technique to identify the zibars in a sandy alluvial plain within Thar Desert.

Study Area

The study area (72°45′E to 72°55′E; 26°0′N to 26°5′N; approx. 180 km^2) lies about 40 km south-west of Jodhpur in the Luni tehsil of

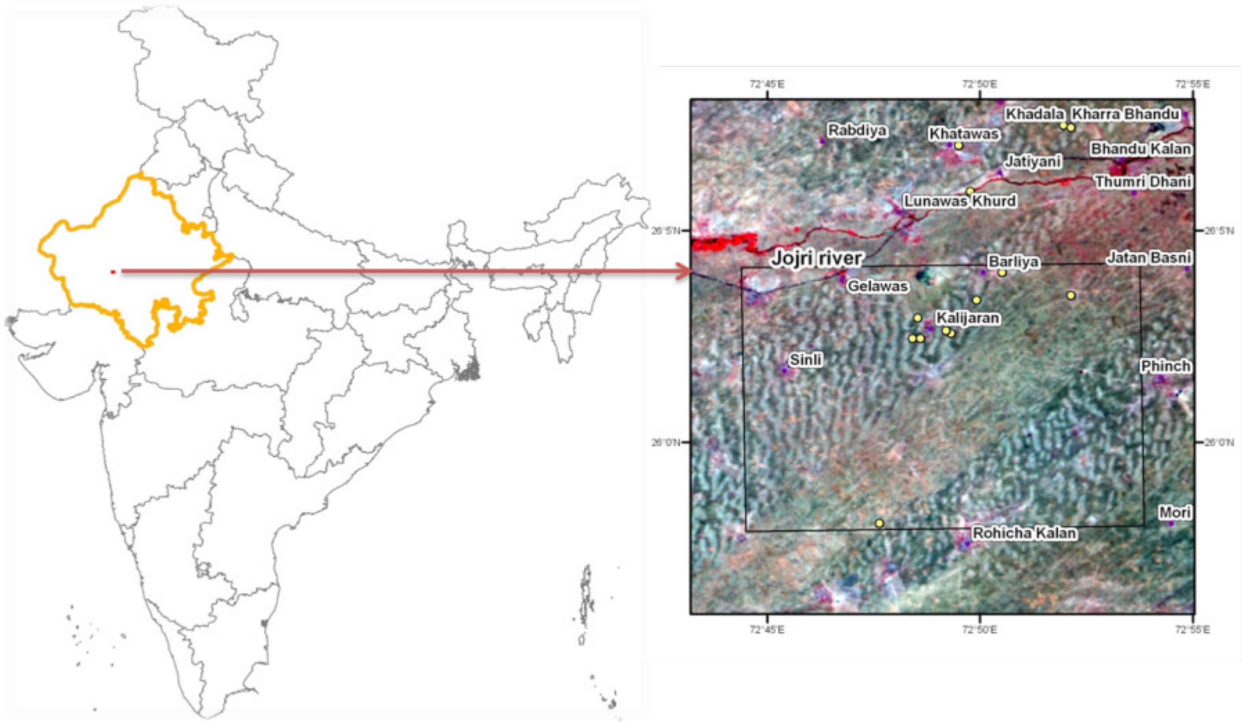


Fig. 1. Location map with sample location on satellite image (AWiFS) showing the zibar landscape.

Jodhpur district, and within the interfluves of the Jojri and the Luni River (Fig. 1). The zibars occur as closely-spaced, 2-4 m high, broadly convex sand mounds, oriented roughly in N-S to NNW-SSE direction, on a sandy alluvial plain that slopes from NE to SW. The dominant wind is from SW during the summer months. Because of their low amplitude of relief, the zibars are hardly identifiable in field, but they become visible on satellite images due to perhaps the contrasting reflectance properties of the sediments in the zibars and the sandy plains.

Materials and Methods

The following satellite data of various spectral and spatial resolutions were used for the analysis. Standard False Color Composites (FCC) of AWiFS & LISS IV satellite sensors were used for identification of the bright and dark patterns of zibar bedform (Table 1). CartoDEM (10 m resolution) helped in depiction of the terrain. A radiometrically-corrected hyperspectral image data (in watts/(sr-micron-m^2) x 100) from Hyperion (EO1H1490422003039110PZ. L1R; path 149, row 042; 8th February 2003) was used for detailed spectral analysis. Microwave data from RADARSAT-2 ('C' band, Fine beam-8 m, Incident angle 32.56°, orbit 34-178A; date of pass 07/04/2012) was analyzed for soil moisture.

A field spectro-radiometer (SV-HR-1024), which has three spectral resolution at 3.5, 9.5, and 6.5 nm in 350-1000, 1000-1890 and 1890-2500 nm ranges for three sensors, was used for ground measurement of reflectance from different features in the area. It was also used to find out the reflectance from different end-members suspected within a pixel from the digital interpretation of satellite data. Hyperion data were classified using Spectral Angle Mapper (SAM) classification technique and Grain Size Index (GSI) was calculated as (R-B)/(R+B+G), which basically differentiates between vegetated/water surface and fine sand (Xiao *et al*., 2006). Both the calculations were performed using the band math operation in ENVI 4.7 image processing software. Sediment samples were collected from representative bright and dark objects in field and analyzed for physico-chemical properties. The broad size characteristics were related with spectral response of both satellite data and field spectro-radiometer observations.

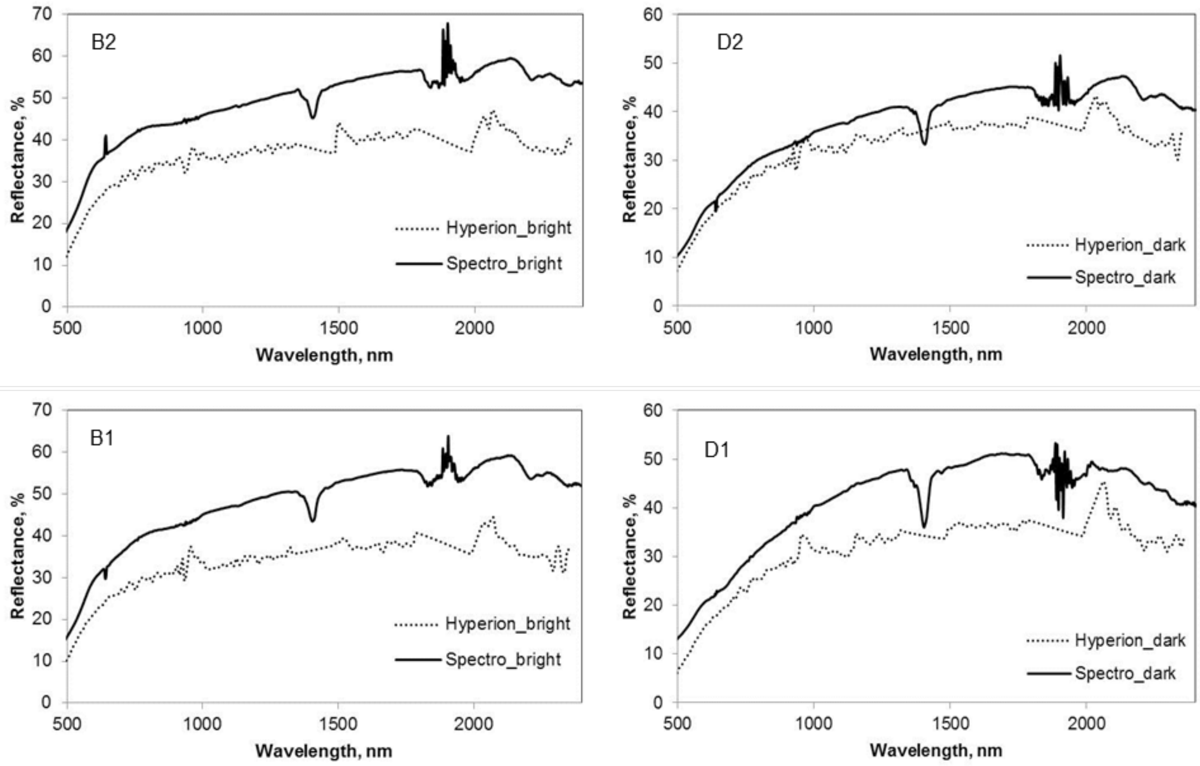
Table 1. Specifications of the satellite sensors used for FCC

Satellite and sensors	Path/row	Date of pass	Spectral resolution (in meter)	No. of band and bandwidth (in nano-meters)	
Resourcesat-2, AWiFS	90/55	06/03/2012	56	G	: 520-590
				R	: 620-680
Resourcesat-2, LISS-IV (FX)	92/53	21/02/2012	5.8	NIR	: 770-860
				SWIR	: 1550-1700 (SWIR band is available only in AWiFS)

Results and Discussion

Orientation and morphometry of the zibar bedforms could be identified through multi-spectral data. AWiFS data highlighted the broad bright and dark features, while LISS IV data was useful for comparison with finer resolution images, particularly microwave. CartoDEM was able to highlight the height difference between different major landforms, e.g., hills, parabolic dunes and zibars. Field spectro-radiometer observations helped to identify twenty end member locations. A maximum GSI value of 0.32 was obtained from the interpretation of Hyperion data.

Higher amplitudes of spectral response were found for both bright and dark features in the Hyperion and spectro-radiometer data, but variations were more apparent in the samples of dark features (Fig. 2). In the visible region of the spectral curves a sharp change in slope for both bright and dark features was also noticed (Fig. 3a). Since the samples have apparently similar mineralogical composition, i.e., "mixed type" (Shyampura and Sehgal, 1995), not much variation was also expected in the reflectance patterns of the features. However, grain size varies between the bright and the dark features (Table 2), which gets highlighted in the absorption feature at 1410-1420 nm of the



(a) (b)

Fig. 2. Spectral response of the Hyperion image and field spectro-radiometer for (a) bright features, and (b) dark features at four different sites on zibar bedform.

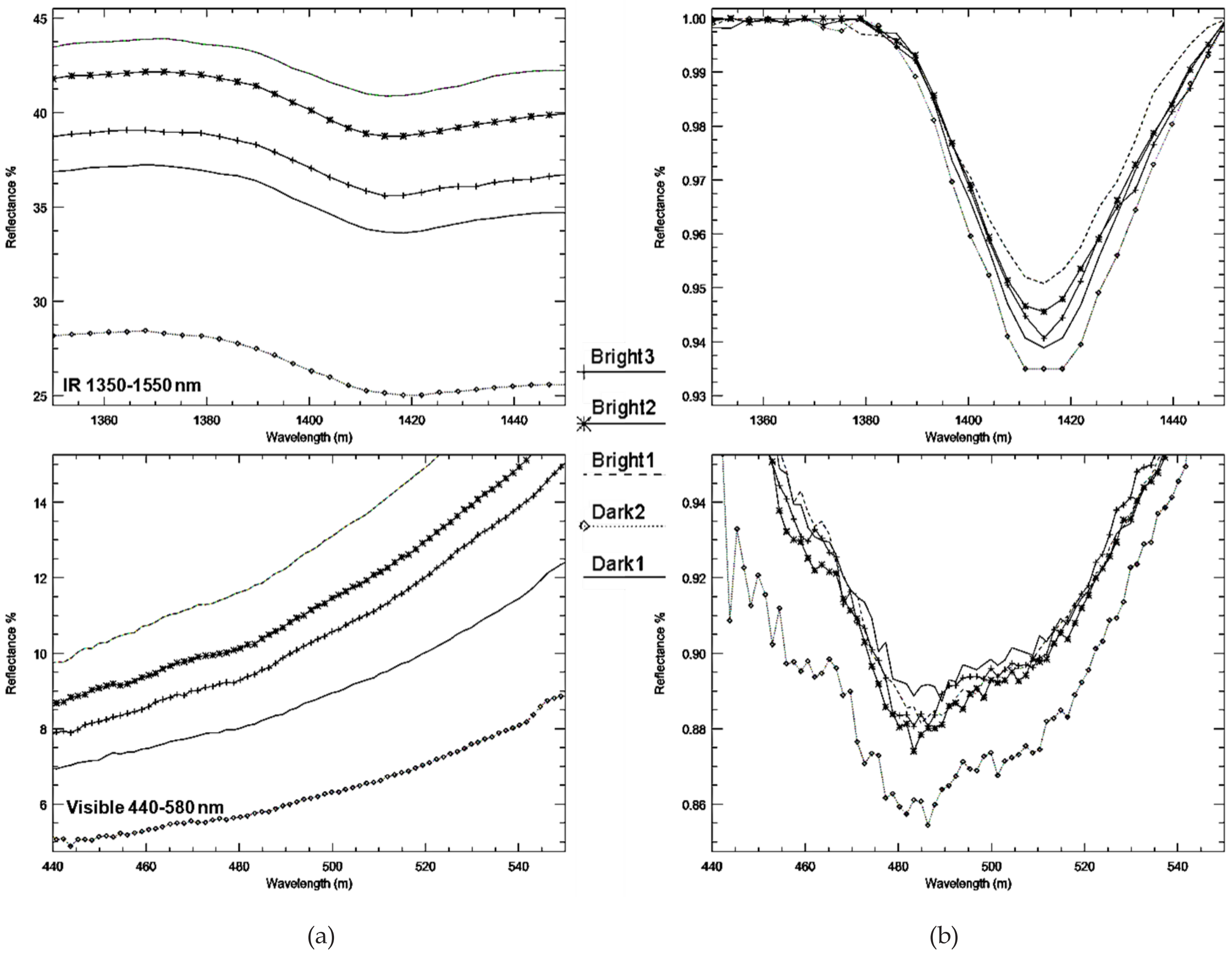


Fig. 3. (a) Normal spectra of bright and dark features in IR and visible region and (b) continuum removed spectra highlighting the absorption features at different sites

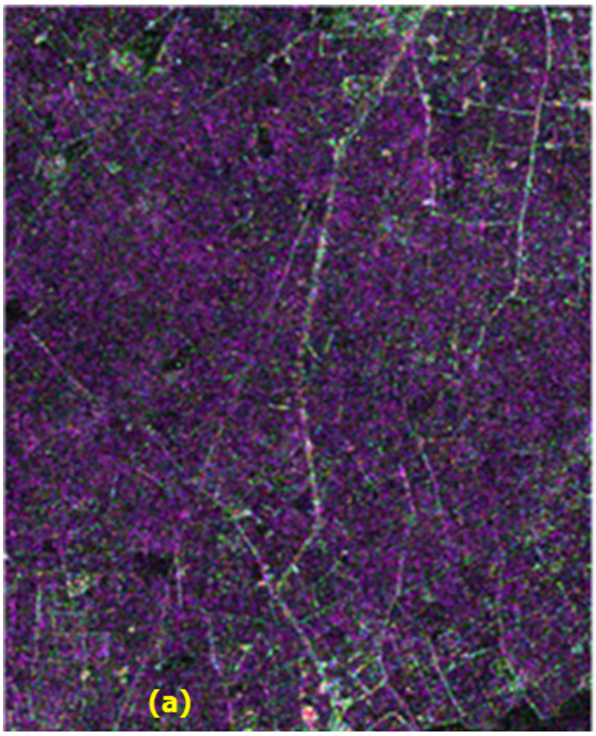
spectro-radiometer, but not in the Hyperion data due to elimination during atmospheric and noise corrections. Absorption in this region may result from either soil moisture or hygroscopic clay, but also due to difference in reflectance between coarser and finer sediments.

The absorption features at 1415 nm (IR region) and 490 nm (blue region) for different soil samples (dark area samples D1 and D2; bright area samples B1, B2 and B3) in the spectro-radiometer data become clear in the continuum-removed curves (Fig. 3b). In IR, the absorption maxima was noticed in the order D2>D1>B3>B1>B2, while in blue region it was in the order D2>B2>B3>B1>D1. This matches well with the finer soils in the dark-feature samples than in the bright-feature samples (Table 2). As particle size decreases, the reflectance in sandy soil increases because there are fewer voids in the soil to trap the impinging radiations.

Table 2. Mean value of samples collected from bright and dark features

Sample	Organic matter	% clay	% silt	% sand	Texture
Dark	0.345	4	10	86	Loamy sand
Bright	0.135	3	5	92	Sand (fine)

Micro-relief and soil moisture can be correlated with back scattering coefficient. Therefore, microwave data of summer season from RADARSAT-2 was analyzed for residual soil moisture study. It is known that soil moisture is a function of porosity and permeability of the soil. Finer soils store more moisture compared to the coarse ones.



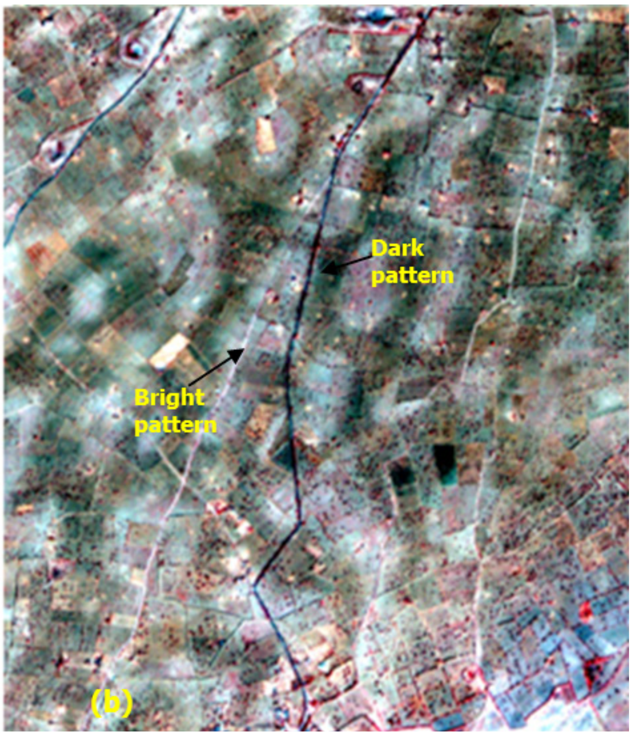


Fig. 4. Satellite images of the study area (a) RADARSAT-2 (R-HH, G-HV, B-VV) and (b) IRS-P6 LISS –IV (Standard FCC)

Although a standard FCC of visible bands (LISS-IV) depicted the variations in a zibar landscape better than in the FCC prepared from a RADARSAT-2 image (Fig. 4), digital analysis of the radar image provided new information. The radar image was first calibrated and the mean values for the polarization backscattering coefficients (σ^o in dB) were obtained for the bright and dark features (Table 3). Very low value of backscattering of the order of -30 dB is common in desert areas. Both bright and dark areas showed almost similar backscattering values in all the polarization bands, but slight differences were also noticed, which could be attributed to differences in soil moisture, vegetation and surface roughness. However, the difference being less than 0.5 dB in co-polarized data, it suggests that soil moisture values for both the areas were nearly the same.

Table 3. Mean backscattering coefficients (σ^o) for different polarization bands in dB

Type	HH	HV	VH	VV
Dark	-18.22	-28.98	-30.39	-18.08
Bright	-17.78	-30.97	-31.73	-17.61
Difference	-0.44	1.99	1.34	-0.47

Conclusion

The spectral response analysis of the zibar bedforms shows that the satellite remote sensing is capable of identifying features that are not readily discernable in field. Field-based spectro-radiometer observations were used to identify the end members and to understand the spectral response. Absorption spectra confirm that the pattern seen on the satellite data is largely due to changes in grain size than due to mineralogical composition or variation in organic carbon content. Spectral angle mapper classification was found better for separating bright and dark features of the zibar landscape than the density-sliced grain size index output. Multi-spectral data are too broad to highlight the minor variations in these features, whereas the hyperspectral data from Hyperion was found very useful in delineating the zibar bedforms.

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