Investigating the backscatter contrast anomaly in synthetic aperture radar (SAR) imagery of the dunes along the Israel–Egypt border

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A B S T R A C T
The dune field intersected by the Israel–Egypt borderline has attracted many remote sensing studies over the years because it exhibits unique optical phenomena in several domains, from the visual to the thermal infrared. These phenomena are the result of land–use policies implemented by the two countries, which have differing effects on the two ecosystems. This study explores the surface properties that affect radar backscatter, namely the surface roughness and dielectric properties, in order to determine the cause for the variation across the border. The backscatter contrast was demonstrated for SIR-C, the first synthetic aperture radar (SAR) sensor to capture this phenomenon, as well as ASAR imagery that coincides with complementary ground observations. These field observations along the border, together with an aerial image from the same year as the SIR-C acquisition were used to analyze differences in vegetation patterns that can affect the surface roughness. The dielectric permittivity of two kinds of topsoil (sand, biocrust) was measured in the field and in the laboratory. The results suggest that the vegetation structure and spatial distribution differ between the two sides of the border in a manner that is consistent with the radar observations. The dielectric permittivity of sand and biocrust was found to be similar, although they are not constant across the radar spectral region (50 MHz–20 GHz). These findings support the hypothesis that changes to the vegetation, as a consequence of the different land–use practices in Israel and Egypt, are the cause for the radar backscatter contrast across the border.

1. Introduction

Remote sensing imagery is one of the most powerful tools for studying the surface of the Earth because it is an efficient way to study vast areas, and areas to which access is restricted or difficult. Thus, the mosaic of land use and land cover that make up the different ecosystems on the Earth’s surface can be mapped using remote sensing imagery (Rozenstein and Karnieli, 2011; Levin, 2015).

An interesting example for such use of remote sensing can be found in the continuous study of the dune field intersected by the Israel–Egypt border (Fig. 1A) (e.g., Otterman, 1974; Schmidt and Karnieli, 2000; Roskin et al., 2012). While ground access to this study site has been restricted at times due to geopolitical circumstances, this area attracted many remote sensing scientists due to a contrast along the two sides of the political border. The first remote sensing study of the area showed a difference in spectral reflectance between the relatively dark Negev dunes in Israel, and the very bright Sinai dunes in Egypt, based on a Landsat-MSS image from 1972 (Otterman, 1974). This phenomenon was considered to be the result of overgrazing of the vegetation in Sinai, and simultaneous recovery of the vegetation in the Negev (Otterman, 1981). However, two decades after the origin of this interpretation, it was rejected, and an alternative explanation was postulated; the lower reflectance in the Negev was determined to be associated with the wide-spread cover of the surface by cyanobacteria-dominated biocrusts rather than with higher vegetation, which was considered too sparse to cause this effect on brightness (Karnieli and Tsoar, 1995; Tsoar and Karnieli, 1996). The high reflectance of the Sinai dunes was attributed to the absence of biocrusts due to continuous trampling of the surface by pastoralist activities, preventing biocrust establishment (Meir and Tsoar, 1996). Hence, the high reflectance in Sinai was associated with the bright sands of the relatively bare dunes (Karnieli and Tsoar, 1995; Tsoar and Karnieli, 1996). Moreover, a thermal variation across the border occurs and is also attributed to the same land-use and land-cover differences (Qin et al., 2001; Qin et al., 2002). The relatively dark biocrusts

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absorb more solar irradiance than the bright sands, which results in higher land surface temperatures in the Negev than in Sinai during daytime. In addition to the land surface temperature contrast between exposed and biocrusted dunes, it was shown that because biocrusts are characterized by higher thermal emissivity (Qin et al., 2005), the land surface emissivity of the Negev dunes is higher than the Sinai dunes (Rozenstein and Karniel, 2015). Recently, space-borne observations of the fluctuations in the surface emissivity as a result of water vapor adsorption by the topsoil at night, and their subsequent evaporation during the day were also shown to differ between the two environments (Rozenstein et al., 2015).

So far, the exploration of the anthropogenic anomaly created by the contrasting land use practices in Sinai and the Negev utilized different spectral regions along the optical spectrum. A backscatter contrast in synthetic aperture radar (SAR) imagery of the border was previously suspected to be caused by differences in vegetation across the border, but this was not established (Blumberg, 1998). Considering that radar backscatter is affected by very different surface properties than those affecting optical remote sensing images, the contrast appearing in SAR images points to additional differences between the processes occurring in Sinai and the Negev. Radar backscatter is mainly influenced by the surface topography, roughness, and dielectric properties, in combination with the beam incidence angle, wavelength, and polarization (Blumberg and Greeley, 1993). Yet, the topography of the linear dunes does not change significantly across the border, and therefore it is not the cause for the differences in backscatter between Sinai and the Negev. In light of this, the aim of this paper is to explore the factors affecting surface roughness (e.g., the vegetation spatial patterns, and composition) and dielectric properties of the dune surface to determine the cause for variation in radar backscatter across the border.

2. Methodology

2.1. Study area

The study area in the Negev–Sinai erg (sand sea) is characterized by linear dunes arbitrarily intersected by the Israel–Egypt political border. This borderline that runs in an almost straight line from the Mediterranean to the Red Sea is based on the 1906 agreement between the British and Ottoman empires, which later on laid the foundation for a number of agreements between Israel and Egypt. In spite of their appearance from space, the dunes on both sides of the border are of the same pedological unit (Roskin et al., 2011). Since this border was last demarked in 1982 following the peace agreements between Israel and Egypt, this has restricted pastoralist activities to Sinai, as conservation policies were...
enforced by Israel in the Negev dunes (Meir and Tsoar, 1996; Tsoar et al., 2008). The minimal disturbance of the Negev surface during these decades resulted in a stabilization process of the dunes (Karnieli and Tsoar, 1995) due to the development of biocrusts composed of cyanobacteria, lichens, mosses, green algae, microfungi, and bacteria (Belnap and Lange, 2001; Pointing and Belnap, 2012). In parallel to the development of biocrusts, the perennial vegetation cover in the Negev has increased compared to Sinai (Qin et al., 2006; Seifan, 2009). The rainfall in the area is sporadic and occurs mainly during the winter season. Since the mid 1990’s until 2009, mortality of perennials was recorded in the Negev due to a prolonged drought (Siegal et al., 2013); the corresponding changes in Sinai were not studied. The biocrusted dune surface contain significantly larger proportions of fine clay and silt particles compared to the underlying sand (Danin and Ganor, 1991; Rozenstein et al., 2014), and as a result they differ in mineralogical composition. The sand moisture in the area is very low, between 0 and 2% (Roskin et al., 2012).

2.2. SAR imagery

Synthetic aperture radar (SAR) imagery from the third shuttle imaging radar (SIR-C) deployed from the space shuttle on 3 October 1994 was the first radar images to clearly show a contrast in backscatter across the border (Fig. 1B). The SIR-C instrument was unique since it acquired data for both C-band (5.7 cm) and L-band (24 cm) in quad-polarization configuration (Evans et al., 1997). As each frequency-polarization combination is sensitive to different landscape features, the availability of a multi-band, multipolarization SAR data is advantageous for interpretation of different ground features (Hess et al., 1995). In addition, a series of 15 co-polarized C-band (5.6 cm) images acquired by the advanced synthetic aperture radar (ASAR) on-board Envisat during 2011–2012 were used to demonstrate the persistence of the radar backscatter contrast across the border. The images were calibrated, terrain corrected and co-registered. The backscatter from equal area polygons of 5.5 km on each side of the border was compared.

2.3. Dielectric permittivity measurements

2.3.1. Dielectric permittivity measurements in the field

The temperature corrected real dielectric permittivity of sand and crust was measured in the field on the afternoon of 24 August 2013 using a POGO Portable Soil Sensor (Stevens Water Monitoring Systems Inc., Portland, Oregon, USA) with an absolute accuracy of 0.2. This sensor operates at a single frequency of 50 MHz.

Fig. 2. (A) Backscatter in the Negev and in Sinai as measured by SIR-C on 3 October 1994; (B) daily precipitation distribution throughout the winter season of 1993–1994 in Nizzana, Israel, at the southern end of the dune field (Kidron and Yair, 1997). Precipitation measurements show that the next rainy season did not start until October 8, 1994, a few days after the SAR image acquisition, and therefore the soil water content is assumed to be minimal during the space shuttle overpass; (C) backscatter in the Negev and in Sinai in 15 Envisat-ASAR co-polarized images (top), and daily precipitation for January 2011 to April 2012 in Kadesh-Barnea, Israel (bottom); the backscatter coefficients in A and C are calculated for equal area polygons on each side of the border.
Two modes of measurement were performed: (1) the sensor was inserted directly into the dune crest, where sand is exposed at the surface, to the encrusted surface of the dune slopes, and to the same spots on the slope following the removal of the biocrusts covering the top few mm of the dune surface; (2) sand from the dune crest and crumbled biocrusts from the dune slopes were measured in a 1 L glass jar.

2.3.2. Spectral dielectric permittivity measurements

The same sediments that were measured in the field were oven dried at 105 °C for two days. One kilogram of each sediment was measured in a glass jar using a commercial open end coaxial probe kit (Agilent, Model 85070E, USA) connected to a network analyzer (Hewlett Packard, Model 8720C, USA). The dielectric permittivity was measured at 1600 points along the entire frequency range of the Network Analyzer (50 MHz–20 GHz). Following that, 10 mg of distilled water were added to the sediments to constitute an addition of 1% of the weight, and the measurement was repeated.

2.4. Aerial image

2.4.1. Pre-processing

To evaluate the state of the vegetation across the Israel–Egypt border at the time of the SIR-C SAR mission, we used an aerial image from the same year (1994). The negative of the panchromatic aerial image area taken over the research site on 30 April 1994 at 3pm was scanned at the highest resolution available (10 μm). The image was geometrically rectified, which resulted in a pixel size of about 29 cm. A subset of the image, encompassing sections of four linear dunes on both sides of the border was chosen for further analysis of vegetation patterns (Fig. 1C). In order to remove non-uniform illumination effects, a cross-track illumination correction was applied using ENVI software (ITT Visual Information Solutions, Boulder, Colorado, USA), but no topographic correction was applied because it was not shown to improve the classification accuracy (as in Carmel and Kadmon, 1998).

2.4.2. Binary vegetation classification

Vegetation patches appear as dark spots in the image. Therefore, an iterative-threshold segmentation approach was applied to classify the vegetation, whereby the image is segmented into areas of connected pixels by iterating the maximal DN (digital number) value considered as vegetation. The minimum size for each segment was defined as two pixels, and connectivity was considered for 8 neighboring pixels. Each of the segmentation products was examined by two independent expert image interpreters who are intimately familiar with the research area. The consensus between the interpreters was that a maximum DN threshold of 130 best separates vegetation patches from the surrounding background. Two subsets of equal areas of 744,356 m² were defined on each side of the border (Fig. 1C). In order to evaluate the vegetation classification, an accuracy assessment was performed for a set of 1000 randomly sampled points, 500 on each side of the border. The land cover at these validation points was visually interpreted and each point was assigned as “vegetation” or “non-vegetation”. A confusion matrix was created, and overall accuracy, kappa statistic, the user's accuracy, and producer's accuracy were calculated (Congalton and Green, 2008).

2.4.3. Spatial statistical analysis

The FRAGSTATS spatial pattern analysis program (McGarigal et al., 2012) was used to analyze differences in vegetation patches between the Negev and Sinai subsets. First, the vegetation cover fraction was calculated as the ratio between the total vegetation cover to the total landscape area. Next, the patch density was determined as the ratio between the number of patches and the total landscape area; it is a basic metric for landscape pattern and subdivision. However, it has been criticized for its insensitivity and inconsistent behavior across a wide range of subdivision patterns (Jaeger, 2000). Therefore, several other measures were used to complement it and provide a comprehensive description of differences in spatial patterns of vegetation across the border. One such indicator is the patch cohesion index (Schumaker, 1996), which is proportional to the standardized patch perimeter-area ratio and ranges from 0 to 1. Two additional indices that quantify the degree of fragmentation were computed from a patch adjacency matrix, which shows the frequency with which different pairs of patch types appear side-by-side on the map: the aggregation index (He et al., 2000) and the clumpiness index (McGarigal et al., 2012).

Additionally, vegetation pixels were converted into polygons and an average nearest neighbor analysis was performed for each side of the border (Clark and Evans, 1954; Scott and Janikas, 2010) using ArcGIS 10.2.2 (ESRI, Redlands, California, USA). This method is based on the distance between each polygon feature and its closest neighbor. To overcome a possible bias of the average statistic, the entire distribution of nearest neighbor distances was examined in comparison to a hypothetical expected distances distribution of an equal number of randomly distributed patches over an equal area. A Z-test was conducted to determine whether the observed nearest neighbor distance distribution is different from the expected distribution. A nearest neighbor ratio was calculated between the observed average distance and the expected average distance. When this ratio is less than 1, the pattern exhibits clustering, and when it is greater than 1, the distribution leans toward a dispersed pattern (Mitchell, 2005). All of the metrics described thus far use only one value to represent each area of interest (i.e., a subset of Sinai or the Negev). In order to plot the differences between the two areas of interest across the border in the form of a spatial map, the vegetation polygons were converted into points representing their centroids and the density of points was calculated for a circle of the default size suggested by the program (25.27 m in radius) around every point.

2.5. Ground photography

In the absence of ground observations concurrent with the space and aerial coverages of 1994, more recent ground reconnaissance from the same year as the ASAR imagery were used to provide insight into differences in the vegetation communities between the two ecosystems. In addition to repeated visits to the field, digital still images from high observation points along the Israel–Egypt border were photographed around noon on 3 February 2011 using a 200 mm Nikon lens. On that day, visibility was excellent, biocrusts were green and annuals had started to emerge. These conditions made it easier to interpret which types of vegetation appear in the photos. At each location, the camera was pointed toward both Sinai and the Negev. The interpretation of these images emphasized the differences in vegetation composition between the two sides of the border. Since specific species were identified with high certainty mostly for larger plants, the analysis focused on describing the prevalence of perennial shrubs, annual herbaceous vegetation and biocrusts in different habitats of the dune (i.e., crest, slopes, and interdune areas).

3. Results and discussion

3.1. SAR backscatter

The Negev only appears brighter than Sinai in the SIR-C co-polarized C-band image (C-HH), while the cross-polarized C-band image (C-HV) and the L-band images show a similar backscatter
across the border (Fig. 2A). The VV polarization was not available for this image. No significant rain events occurred prior to the SIR-C image acquisition, and therefore the soil water content is assumed to be minimal during the space shuttle overpass. The same contrast as the SIR-C co-polarized image is consistently demonstrated by the ASAR time-series, in a manner independent of the time of year and proximity to rain events (Fig. 2C).

3.2. Dielectric permittivity of sand and biocrust

The results of in-situ dielectric permittivity on a typical summer day are presented in Fig. 3. No differences were observed between the dielectric permittivity of exposed sand and biocrusted sands (Fig. 3A). This may occur since the biocrusts are only a few mm thick. However, even when crumbled biocrusts were amassared and compared to sand, only a minute difference in their dielectric permittivity was found (3.2 for sand and 3.31 for biocrusts as shown in Fig. 3B). The typical dielectric permittivity of water is 80 and it ranges from 3 to 8 for non-vegetated dry soil or rock (Blumberg and Greeley, 1993). While higher surface dielectric permittivity is usually associated with higher backscatter, it appears that dielectric permittivity differences between the Sinai and Negev dunes are too small to likely be the cause for the contrast that appears in SIR-C imagery. This conclusion is in agreement with that of a previous study (Blumberg, 1998), which used a laboratory time domain reflectometer to measure sand and biocrust. While the TDR frequency used in this study is not specified, our in-situ measurements are performed in 50 MHz, and C-band radar frequency is at about 5.3 GHz. In order to determine the potential for backscatter differences in different bands, spectral measurements of dielectric properties for sand and biocrusts was performed (Fig. 4). The results of this measurement showed that the dielectric permittivity is not constant throughout this spectral range. The dielectric permittivity of both sand and biocrust is higher in L-band compared to C-band. However, the differences between sand and biocrust are very small. The addition of 1% gravimetric moisture to the samples resulted in a similar increase in the dielectric permittivity of both sand and biocrust. Therefore, the spectral measurement of dielectric permittivity reaffirms the conclusion that this property is probably not the cause for the spectral backscatter differences across the border. This type of spectral measurement, however, can be useful to other cases, where the dielectric properties of the surface in different bands are of interest.

3.3. Vegetation patterns across the border

Our 2011 ground observations along the border showed markedly different vegetation patterns in Sinai and the Negev (Fig. 5). According to these observations, in Sinai, the dune crests were characterized by active sands, and much of it was bare, unvegetated sands. The Negev dune crests were partially active; however, they presented more vegetated patches than in Sinai. Biocrusts appeared in Sinai in small, non-continuous patches, on the lower dune slopes and interdune areas, while in the Negev they covered vast, continuous surfaces, even on some dune crests (in the northern parts of the dune field). Annual herbaceous vegetation and plant litter appeared mostly on crusted surfaces, and was therefore more common in the Negev. These findings are in agreement with observations made in previous studies: Dune stability in the Negev positively influences annual plant germination and growth on stabilized sands by preventing root exposure and seedling burial by sand movements, as well as increasing soil nutrients and fertility through carbon and nitrogen fixation by the biocrusts (Kidron, 2014). While annual herbaceous vegetation generally tends to occupy encrusted surfaces, perennial shrubs tend to prefer the non-crusted semi-stable dune crest (Li et al., 2002; Kidron, 2015). It appears that grazing in Sinai reduces the cover of annuals not only by predation, but also by trampling the biocrusts, and thus decreasing the area of the habitat where annuals are typically found. The distribution of perennial shrubs in the Negev was relatively homogenous, while in Sinai it had a patchier appearance. Furthermore, large Calligonum comosum L’Her shrubs and Tamarix aphylla (L.) Karsten trees were concentrated in patches on the dune crests only in Sinai. Therefore, naked-eye and telescopic observations on the ground give the impression that the spatial vegetation patterns are notably different across the border.

These ground observations are supported by quantitative analysis of the 1994 aerial photograph. The classification of vegetation patches was found to be 98.9% accurate. The confusion matrix and additional accuracy measures are presented in Table 1. Vegetation patch metrics are presented in Table 2. There were more vegetation patches in the Negev than in Sinai. Additionally, vegetation in the Negev covered more area, and the patch density was greater than in Sinai. The vegetation cover was estimated at 16% for the Negev, which is higher than the 7% cover previously found for the same area in 1994 (Segal et al., 2013). However, since that study only included perennial shrubs in their analysis, and our analysis included patches that contain both annuallys and perennials, and may contain herbaceous vegetation and dry vegetative material, it makes sense for our estimation of vegetation cover to be higher.

Additionally, clumpiness index, cohesion index, and aggregation index were all higher in the Negev, supporting the field observations of greater subdivision and less physical connection in Sinai. The nearest neighbor analysis (Table 3) revealed similar results, as

### Table 1
Confusion matrix and derived accuracy measures for the vegetation classification in Sinai and the Negev.

<table>
<thead>
<tr>
<th></th>
<th>Vegetation</th>
<th>Non-vegetation</th>
<th>Sum</th>
<th>User's accuracy</th>
</tr>
</thead>
<tbody>
<tr>
<td>Vegetation</td>
<td>116</td>
<td>4</td>
<td>120</td>
<td>96.67%</td>
</tr>
<tr>
<td>Non-vegetation</td>
<td>7</td>
<td>873</td>
<td>880</td>
<td>99.20%</td>
</tr>
<tr>
<td>Sum</td>
<td>123</td>
<td>877</td>
<td>1000</td>
<td></td>
</tr>
<tr>
<td>Producer's accuracy</td>
<td>94.31%</td>
<td>99.54%</td>
<td></td>
<td></td>
</tr>
</tbody>
</table>

Overall classification accuracy = 98.9%; overall kappa statistic = 0.95.

### Table 2
Vegetation patch metrics.

<table>
<thead>
<tr>
<th></th>
<th>Number of patches</th>
<th>Vegetation cover (%)</th>
<th>Patch density [patches/hectare]</th>
<th>Clumpiness index</th>
<th>Cohesion index</th>
<th>Aggregation index</th>
</tr>
</thead>
<tbody>
<tr>
<td>Negev</td>
<td>39,712</td>
<td>16</td>
<td>532.9%</td>
<td>0.76</td>
<td>93.1</td>
<td>79.82</td>
</tr>
<tr>
<td>Sinai</td>
<td>27,906</td>
<td>7</td>
<td>374.51</td>
<td>0.73</td>
<td>88.79</td>
<td>74.6</td>
</tr>
</tbody>
</table>

### Table 3
Results of the nearest neighbor analysis.

<table>
<thead>
<tr>
<th></th>
<th>Observed mean distance</th>
<th>Expected mean distance</th>
<th>Nearest neighbor ratio</th>
<th>z Score</th>
</tr>
</thead>
<tbody>
<tr>
<td>Negev</td>
<td>2.154</td>
<td>1.963</td>
<td>1.098 (dispersed)</td>
<td>41.042</td>
</tr>
<tr>
<td>Sinai</td>
<td>2.063</td>
<td>2.302</td>
<td>0.896 (clustered)</td>
<td>−37.237</td>
</tr>
</tbody>
</table>
the nearest neighbor ratio was found to be 1.098 for the Negev and 0.896 for Sinai. The deviation of these values from 1 (random distribution) suggests that the vegetation pattern exhibits dispersion in the Negev, and clustering in Sinai (Mitchell, 2005). These differences in spatial patterns are presented in Fig. 6, which demonstrates the greater spatial variability of vegetation density in Sinai compared to the Negev. Therefore, it appears that the vegetation structure and pattern differ significantly between Sinai and the Negev and that this variation changes the surface roughness. These differences in surface roughness are imaged as a radar backscatter contrast between the two ecosystems.

The intensity of the returned signal is sensitive primarily to the roughness on a scale comparable to the radar wavelength (Blumberg and Greeley, 1993). When vegetation is present at the surface, its effect on backscatter varies as a function of wavelength (Das and Paul, 2015). Senescent vegetation and dry plant litter can also influence the backscatter (Li and Guo, 2015). The vegetation in the research area is relatively low lying, and therefore, it is reasonable for the contrast in backscatter to appear in the C-band (\(\lambda = 5.7\) cm) that interacts with small branches, as opposed to the L-band (\(\lambda = 24\) cm), which is known to interact with larger vegetation components, such as tree trunks (Mougin et al., 1999). Hence, if the surface roughness estimation from radar data is desired (e.g., Genis et al., 2013), the presence of vegetation at the surface must also be accounted for. Contrary to previous studies that found that cross-polarized C-band data best discriminates between active and fixed dunes as a result of multiple scattering from vegetation (Blom and Elachi, 1981; Lancaster et al., 1992), in the SIR-C case the copolarized C-band data showed a greater contrast across the border.

To date, studies of the ecological change to the dune system were mostly conducted in the Negev ecosystem (Breckle et al., 2008), and comparative field studies between both sides of the

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**Fig. 3.** Real dielectric permittivity measurements: (A) dune crest, where sand is exposed at the surface (sand), encrusted surface of the dune slopes (crust), and the dune slopes following the removal of the biocrusts covering the top few mm of the dune surface (sand under crust); (B) sediment in a 1 L glass jar filled with either sand from the dune crest (sand), or crumbled biocrusts from the dune slopes (crust).

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**Fig. 4.** Laboratory real dielectric permittivity measurements across the radar spectral region.
border were not carried out, except by remote sensing tools (e.g., Qin et al., 2006; Seifan, 2009; Siegal et al., 2013; Rozenstein et al., 2015; Rozenstein and Karnieli, 2015). Some of these remote sensing observations show a higher proportion in perennial vegetation and microphytic cover in the Negev compared to the Sinai, but neglect to note the differences in spatial vegetation patterns (e.g., Qin et al., 2006; Seifan, 2009). This aspect was only emphasized in the current study, following the analysis of the SAR observations. Unlike coarse resolution optical remote sensing imagery that are not sensitive to the signal of the higher vegetation in this area (Karnieli and Tsoar, 1995), the SAR imagery is affected by the spatial patterns of this vegetation. The utilization of radar imagery complements those studies, as it emphasizes the differences in the spatial arrangement of the vegetation. Therefore it is shown that combining multiple observations, using different sensors, which are sensitive to different regions of the electromagnetic spectrum, can produce new insight into old observations. However, extracting the vegetation height from an aerial image is difficult, especially for low lying bushes. Future studies might benefit from the incorporation of Light Detection and Ranging (LiDAR) data over the area, which may provide the means to assess the surface roughness quantitatively (Sankey et al., 2010). LiDAR data, possibly in combination with aerial imagery, is expected to provide not only the spatial distribution of the vegetation, but also its height, and the dune topography (Schenk and Csathó, 2002). Such surface measurements may be desirable for modeling Aeolian erosion and deposition (Wang et al., 2015).
While our results support the consensus in the literature regarding the degradation of the Sinai ecosystem due to grazing (e.g., Otterman, 1974; Karnieli and Tsoar, 1995; Harrison et al., 1998), this degradation is only demonstrated by a decrease in biocrusts and vegetation cover, and by the Aeolian activity in the dunes. Since no detailed flora and fauna surveys have been carried out in the Sinai dunes, there is no information on biodiversity such as species richness and composition for that ecosystem. The resilience of the vegetation to anthropogenic pressures and its recovery following their removal, suggest that pessimistic views of desertification and overuse are not justified in this case, since the degradation in this ecosystem is reversible (Meir and Tsoar, 1996; Kidron et al., 2008). In fact, it was shown that moderate grazing in the Negev dunes increased vegetation species richness (Olsvig-Whittaker et al., 1993). Moreover, it was recently shown that when disturbance to biocrusts occur, and dune mobility is restored, the faunal communities’ response depends on the affinity of specific species to shifting sands (Columbus et al., 2012). Since some rare and endangered species (e.g., Cerastes cerastes) seem to prefer the disturbed sands, it seems that in terms of conservation, some disturbance may have a positive influence on faunal biodiversity, through maintaining habitat diversity. Therefore, conservation efforts should focus on ensuring representation of all niches (active, semi-stabilized, and stabilized sands) in the landscape, rather than allowing for the extremes: uncontrolled intensive grazing on the one hand, and complete removal of disturbance agents (e.g., trampling, grazing, and wood gathering) that lead to almost complete stabilization on the other hand.

4. Summary and conclusion

Different land-use practices in Israel and Egypt are the dominant cause for differences in the vegetation structure and pattern between Sinai and the Negev. This variation changes the surface roughness, leading to a difference in radar backscatter across the border. Dielectric permittivity differences between the two sides of the border are small, and are likely not contributing much to the difference in backscatter. Although this area was studied intensively using remote sensing means for many years, differences in the vegetation structure across the border were not discussed by previous studies. Therefore combining both SAR and optical imagery into ecological studies can stress features otherwise overlooked.

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