Spectral reflectance of biogenic crust developed on desert dune sand along the Israel-Egypt border

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Abstract. The effect of biogenic crust on imagery acquired by spaceborne sensors is demonstrated. The crust consists mostly of microphytes such as cyanobacteria. The macrophytes (higher vegetation) on the sand dunes are sparse and have a relatively low spectral reflectance response. However, since a considerable portion of the ground is covered by this biogenic crust, (which has a different spectral reflectance from that of the mobile sands), a sharp brightness contrast is created between the two areas. It can be concluded that the well-known contrast between Sinai (Egypt) and the Negev (Israel), that has long drawn the attention of many observers, is not a direct result of vegetation cover but is caused by an almost complete cover of biogenic crust in the Negev, and a lack of this crust in Sinai, due largely to man’s activities.

1. Introduction

Arid and semi-arid regions are characterized by sparse vegetation cover. Vegetation located in areas between 100 and 300 mm of mean annual rainfall diffusely covers the surface, whereas in areas with less rainfall, the vegetation is concentrated along the ephemeral channels (Danin et al. 1975). The soil background contributes a different reflected signal than areas of dense vegetation which usually have relatively higher components. It was noted by several researchers (e.g., Hutchinson 1982, Tueller 1987, Smith et al. 1990) that it is difficult to extract vegetation information when the vegetation cover is less than 30–40 per cent. This is due to the spectral dominance of the background soil and rocks.

Most observers perceive desert and desertified landscapes as having scarce plant life with sparseness of vegetation (West 1990). However, a closer examination of the desert landscapes provides a different view of the plant cover. In the absence of a dense distribution of macrophytes (higher plants), much of the arid and semi-arid surfaces are covered by microphytic communities of small non-vascular plants. These microphytic communities, containing mosses, lichens, algae, fungi, cyanobacteria (blue-green algae), and bacteria, in various combinations, form microphytic crusts over and within a wide range of soil and rock substrates.

Cyanobacteria are usually the primary components of soil crust (Booth 1941). They are often accompanied by soil algae, mosses and lichens. Cyanobacteria crust
is dominant in regions of less than 100 mm of rain, whereas lichens are dominant in regions of 100 to 200 mm, and mosses in regions of 200 to 300 mm of rain. Since cyanobacteria colonize the soil faster than the other microphytic communities, they usually represent an early stage in the soil crust succession.

The Israel–Egypt political border is crossed by linear sand dunes of the same lithological unit. The border line is characterized by a sharp contrast between the bright reflectance values from the Egyptian (Sinai) side and the dark reflectance values from the Israeli (Negev) side (figure 1). This contrast has been discussed in various papers over the last twenty years (Otterman 1974, 1977, 1981, Otterman et al. 1975, Otterman and Fraser 1976, Muchlberger and Wilmarth 1977, Alison et al. 1978, Adams et al. 1978, Noy-Meier and Seligman 1979, Otterman 1981, Danin 1983, Warren and Harrison 1984, Otterman and Tucker 1985, Waisel 1986; Tsoar and Möller 1986, Danin 1987, 1989, Otterman et al. 1990, Danin 1991). The relative higher reflectance value on the Egyptian side of the border has been interpreted as

Figure 1. The Israel–Egypt border (upper left corner) as shown by Landsat-TM image for band number 4.
being caused by the severe anthropogenic impact of the Sinai Bedouin—especially overgrazing by their black goat and sheep herds, as well as by gathering the plants for firewood (Tsoar and Møller 1986). On the other hand, the Israeli side has been under a strict conservation policy.

Otterman (1974) observed the contrast at the Sinai/Negev boundary in the first Landsat image of the area taken in 1972 and pointed out that semi-dormant desert fringe plants strongly reduce the albedo of sandy terrain. The contrast reported in that study was about the same in all spectral bands of the MSS, which included two visible (500–700 nm) and two NIR (700–1100 nm) bands. It was claimed that the plant cover on the vegetated side of the Negev does not exhibit characteristics common to green vegetation of non-arid regions. It was further stated that green plants would have produced a Sinai/Negev contrast ratio much higher in the visible bands and in particular in the MSS red band from 600 to 700 nm, where plant chlorophyll strongly absorbs radiation. The contrast was therefore interpreted as effects of the dark plant debris littering the surface and shadowing (Otterman et al. 1990).

2. Analysis and discussion

Field measurements were carried out in situ using the Li-Cor LI-1800 portable spectrometer (LI-CORE, 1989). The instrument was fixed to 2 nm wavelength spectral resolution increments between 400 and 1100 nm, and 15° field of view (FOV). The spectrometer was hand-held at about 1-m heights, at nadir. The spectral reflectance was calculated by relating the target radiances to the downwelling irradiation as measured by a cosine-corrected receptor.

Three spectra are presented in figure 2: bare dune sand, cyanobacteria crust and vegetation. All were obtained almost simultaneously in the northern Negev (about 100 mm of mean annual rainfall). The typical dune vegetation spectral reflectance

![Figure 2. Spectral reflectance field measurements of active sand, biogenic crust, and typical vegetation in the study area. --- Sand dune; --- Biogenic crust; ••• Artemisia.](image)

response is represented here by *Artemisia monosperma* but is almost identical to the spectra of *Retama raetam*, *Lycium schweinfurthii*, *Stipagrostis scoparia* and others (Pinker and Karnieli 1995). Although it has a classic vegetation shape, it gives measurements much lower than the sand and crust spectra. The cyanobacteria crust consists mostly of *Microcoleus vaginatus* accompanied by *Scytonema*, *Schizothrix*, *Calothrix*, *Chroococcidiopsis*, *Nostoc*, and *Phormidium* (Danin et al. 1989, Danin 1991). Its spectral reflectance response is lower than that of the sand dune. Both have a typical soil shape, but one can notice the slight dip of the crust spectra from 600 to 700 nm on account of the biogenic activity. Furthermore, a field survey that had been conducted in the area reported that the vegetation cover is less than 14 per cent (10.5 per cent annual vegetation and 2.8 per cent perennial vegetation cover) (Abramsky 1989). This amount is obviously smaller than the 30 per cent threshold, as specified earlier, below which it is difficult to obtain vegetation in the satellite image using conventional image processing methods. The low altitude aerial photograph which is presented in figure 3 strengthens these results since the sparseness of the higher vegetation can be recognized. It can be concluded that the dune vegetation signal is masked by the soil signal both because of the relative sparseness of vegetation and its low spectral reflectance response.

The aerial photograph (figure 3) displays a closer view of the study area than in figure 1. The two routes are the Israeli (right) and the Egyptian (left) patrol roads. The brighter tones represent the active sand dunes, while the darker tones represent the cyanobacteria crusts. It can be seen that on the Israeli side, the active sand is limited only to the narrow strips of the dune crests, while most of the area is covered by the crust. On the contrary, on the Egyptian side the majority of the area is covered by active sands. Consequently, it can be concluded that in the absence of dense higher vegetation in the region, the contrast between Sinai and the Negev has been caused by the different distribution of active sand and biogenic crusts.

The following mechanism is suggested (Tsoar 1990, Danin 1991): As a result of limited human and animal activities in the Negev region, air-borne silt and clay, originating from adjacent deserts (Yaalon and Ganor, 1973, Yaalon and Dan 1974), have been deposited and trapped by the vegetation and accumulated mainly in the interdune areas where vegetation is denser. Cyanobacteria is also carried by the winds and once the fine material of the top layer exceeds 1.5–2 per cent, cyanobacteria communities may become established (Danin 1978). As a result of the gluye nature of the cyanobacteria, the biogenic crust spreads with time, causing aggregation of more fine-grained soil particles, covering areas larger than the interdune areas themselves. Finally, as in the Negev example, most of the area may be overlaid with cyanobacteria crust and the active dunes are turned into stable sand fields. In contrast, anthropogenic disturbance on the Egyptian side of the border prevents the crust from becoming established and the dust from being deposited.

Since the cyanobacteria has a lower spectral reflectance response than the pure sand (mostly above 600 nm) (figure 2), the entire area of the Negev appears darker than the adjacent area in Sinai. It is suggested, therefore, that the fact that human and animal activities prevent accumulation of crust or trample any existing crust, rather than the overgrazing mechanism itself, is the main reason for the sharp contrast between Sinai and the Negev.

3. **Summary**

Three types of evidence have been combined to verify the hypothesis explaining the difference in spectral reflectance on opposite sides of the border: (1) The higher
vegetation cover is less than 30 per cent and therefore the soil itself is believed to be the principal contributor to the overall spectral reflectance response of the region; (2) the spectral reflectance response of the dune vegetation is much lower than those of the active sand and biogenic crust. Consequently, the dune vegetation signal is masked by the soil signal; (3) The biogenic crust which covers most of the Israeli side contributes a darker tone to the image. Anthropogenic activities on the Egyptian side that prevent the establishment of this crust, contribute to the brighter tone. Hence, it is concluded that the well-known contrast between Sinai and the Negev, that has long drawn the attention of many scientists, is not a direct result of vegetation cover but is caused by almost complete cover of biogenic crust.

References