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Properties and spatial distribution of microbiotic crusts in the Negev Desert, Israel

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ABSTRACT

Playing a cardinal role in surface stabilization and in carbon and nitrogen fixation, microbiotic crusts play a crucial role in arid regions where they may serve as useful biomarkers for wind power and wetness duration. This is especially the case on relatively unstable and infertile sand dunes in the Negev Desert where high correlations between the crust chlorophyll content and the daytime wetness duration were found. Yet, only scarce data are available as to the possible link between the chlorophyll content and other physical (color, thickness, strength, crack density, surface roughness and infiltrability) and biological (protein, carbohydrate, organic matter and species composition) factors, which determine, in turn, the crust type and its effect upon geomorphological and ecological processes. No data are available on crust type distribution. These were the aims of the current research.

When a cluster analysis was performed, five types of microbiotic crusts were defined, four of which were cyanobacterial (A–D) and one moss-dominated crust (E). The crusts differed in their physical and biological properties. They showed an increase in chlorophyll content, protein, carbohydrates and organic matter from A to E, with concomitant increase in species diversity, thickness, roughness and strength, but with some variables (crack density and infiltrability) showing a reversed trend at the moss-dominated crust. The increase in the biomass components of the crust and the gradual change of the physical properties are explained by the improved physical conditions (primarily wetness duration), which facilitates longer hours of photosynthetic activity and consequently the introduction of additional, more mesic species such as green algae, lichens and mosses. Extended wetness duration was found to shift the crust type from cyanobacterial to moss-dominated crust. The spatial distribution of the crusts, as verified by crust mapping, coincided with the daylight surface duration, which in turn was controlled by topography (aspect, angle and slope position). It implies that whereas initial physical conditions dictates species composition and thus crust type, the crust type in turn is responsible for characterizing the physical properties of the surface, which may largely affect ecological and geomorphological processes.

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1. Introduction

As a result of the low cover of higher plants in arid regions, microbiotic crusts often fulfill similar functions such as surface stabilization (van den Ancker et al., 1985; McKenna Neuman et al., 1996) or organic carbon (Lange et al., 1992) and nitrogen (Mayland and McIntosh, 1966; Evans and Lange, 2001) fixation. Additionally, the crusts may significantly alter the hydrological properties of the surface (Booth, 1941; Kidron and Yair, 1997; Belnap, 2006), and affect plant germination and establishment (St. Clair et al., 1984; Prasse and Bornkamm, 2000). All the above functions may be largely dependent upon the crust biomass, its species composition and its physical properties, all of which may show a gradual increase, which may be difficult to sort into distinct categories. Nonetheless, these categories, namely, the definition of distinct crust types, are essential for ecologists and geomorphologist aiming to study abiotic–biotic relationships.

In a previous study (Kidron et al., 2009) carried out at the Nizzana research station, at the Hallamish dune field, western Negev Desert (mean annual precipitation of 95 mm), a high correlation was found between crust cover and wind power and between the crusts chlorophyll content and the surface wetness duration. This study was conducted along a 12 point transect (hereafter stations, each having a pair of plots) that extended between two crests of active dunes, crossing a stabilized low dune and two interdunes (Figs. 1 and 2). While stations 1 and 12 were demarcated at the mobile dune crests (and therefore lacked crusts) and stations 2 and 11 were established on the semi-stable midslopes (having therefore a patchy and

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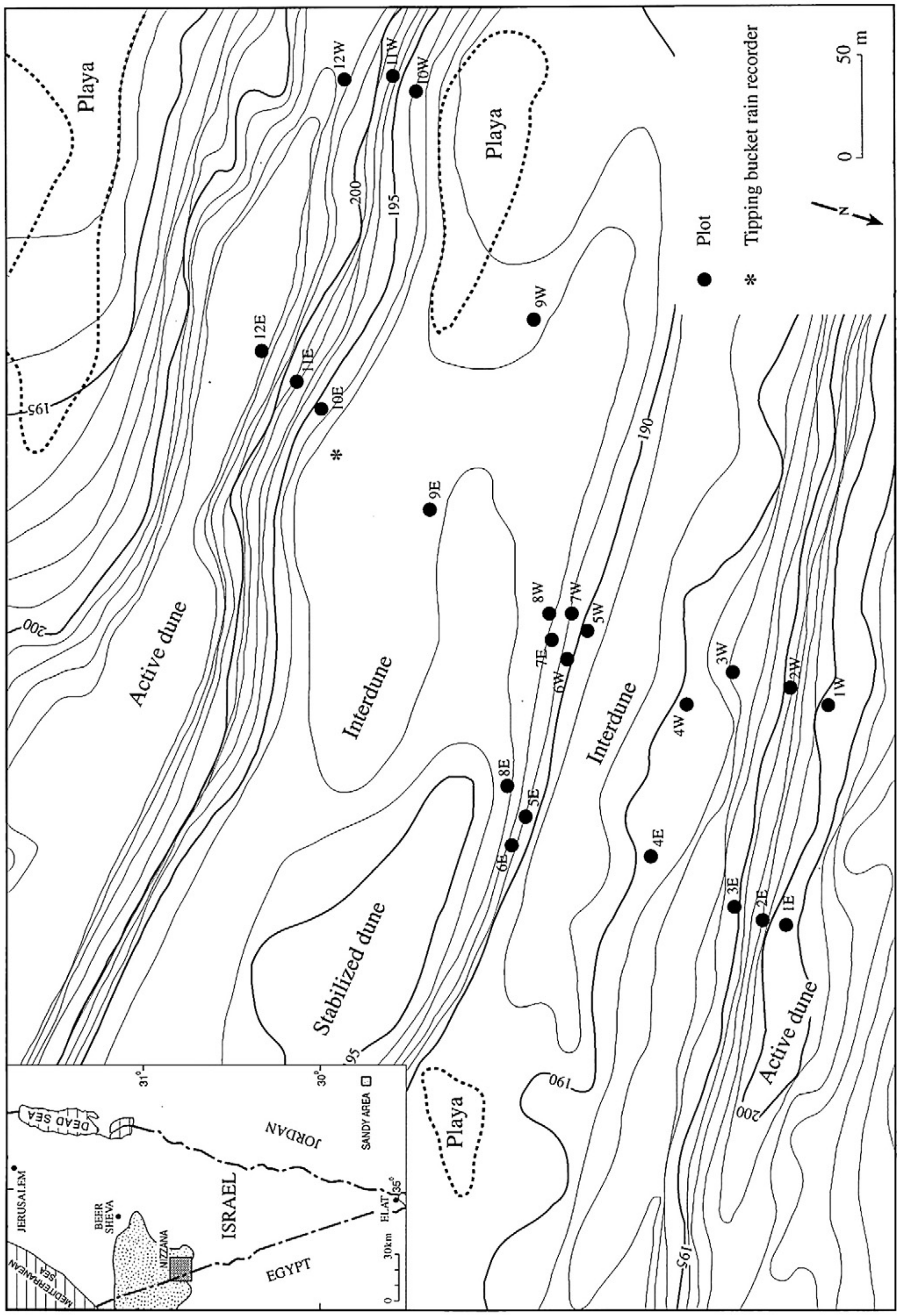

Fig. 1. Location and the experimental layout at the Nizzana research site.

fragmented crust cover), low wind power characterized the remaining stations (stations 3–10) where the crusts appeared homogeneous and where a clear topographically-induced zonation in the chlorophyll content was noted (Fig. 3). At these stations, a high correlation was obtained between the crust chlorophyll content and surface wetness duration (Kidron et al., 2009).

Unlike disturbed habitats that are characterized by immature crusts that exhibit different stages of development (Belnap et al., 2008; Kidron et al., 2008), this research was conducted on surfaces or crusts found to be in a quasi equilibrium with the abiotic conditions. While high wind power at the dune crest and the upper dune slopes was regarded as a negative factor that can cause crust death following its burial, extended wetness duration was seen as a positive factor responsible for the crusts' chlorophyll content, thus facilitating net photosynthetic carbon gain.

The chlorophyll content is however only one of the biological properties of the crust. Wetness duration may well affect other crust properties. Furthermore, while a large-range continuum, ranging from several milligrams to almost 100 mg of chlorophyll *a* per square meter was monitored, any practical evaluation of the crust role will necessitate a relatively clear distinction of the crust types. Knowledge regarding the types of the crust may assist in highlighting the crust

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