

The Effects of Grazing on Abiotic and Biotic Parameters in a Semiarid Ecosystem: A Case Study from the Northern Negev Desert, Israel

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Livestock grazing is considered a disturbance of both biotic and abiotic parameters that may lead to degradation of rangelands and desertification. We report a case in which grazing was used as a management tool in a rehabilitation project. The aim of this study was to quantify the effects of grazing on a managed ecological system. To do so, we monitored the diversity and composition of the plant community, herbaceous biomass, soil moisture, soil organic matter, habitat structure and quality

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of the vegetation for grazers (protein content and digestion). These parameters were monitored on the south and the north slopes, because of the differences in the radiation, which affect the water regime and the vegetation. Monitoring was in grazed plots and in plots ungrazed for three years. Our results showed that grazing had immediate effects on the plant community and habitat structure. The densities of plant species decreased (~20%), vegetation community composition was affected (~50–61%) and exposed soil surface increased (~50%). A significant decrease was found in total protein content in plants over time: from 17–19% in beginning of the grazing season to 5–6% at the peak of the season. Digestible material was significantly more at the peak of the growing season in the grazed plots (63.7%) compared to the ungrazed plots (57.4%) in the north-facing slope, but not in the south-facing slope. When plant diversity, soil fertility, and soil moisture were considered, no correlation was found in relation to grazing. The significance of the research was that it demonstrated that livestock grazing can be effective as a management tool while imposing limited damage to the ecosystem.

Keywords biomass, diversity, management, organic matter, productivity, soil moisture

In arid and semiarid landscapes, essential resources such as water, organic matter and nutrients, which limit plant growth, are distributed patchily in the landscape (Noy-Meir, 1985). The patches characteristic of the landscape are macrophytic patches composed of dwarf shrubs with loose soil and annual plants underneath, and microphytic patches comprised of the intercanopy soil crust with its biogenic community. These patches cause the partitioning of resources into two zones: one which sheds resources (microphytic) and the other which receives these resources (macrophytic). This partitioning results in the formation of “islands of fertility” (Garner and Steinberger, 1989; Schlesinger et al., 1990; Tongway and Ludwig, 1994), with nutrient- and soil-rich patches supporting higher amounts of plant growth and biomass, and enhancing species diversity (Boeken and Shachak, 1994; Boeken et al., 1995; Weinstein, 1975). In this system, after a rainfall event, microphytic crusts create runoff water which is redistributed to, and infiltrated into, the macrophytic patches (Eldridge et al., 2000; Schlesinger et al., 1990; Shachak, Sachs, and Moshe, 1998) thus supporting the shrubs that comprise the vascular plant community. The system is sustainable due to the flow of resources between the various patches (Shachak et al., 1998). Microphytic crusts also play a major role in seedling emergence and establishment (Eldridge et al., 1995; Harper and Marble, 1988; Zaady, Gutterman, and Boeken, 1997), and protect the soil against wind (Williams, Dobrowolski, and West, 1995) and water (Eldridge and Kinnell, 1997) erosion.

The Savannization Project attempts to turn long-term heavily grazed rangeland into a savanna-like park. This is a rehabilitation project conducted at the semiarid northern Negev of Israel. The project is based on water-harvesting techniques by means of which runoff developed on the loessic microphytic crust, is used to support planted trees (Shachak et al., 1998). The harvested water flows on the slopes to human-made contour banks where the water infiltrates near the planted trees. The introduction of livestock grazing to the park during the grazing season was done in order to decrease annual vegetation biomass on the contour banks and on the microphytic crusts, to allow runoff water to support the planted trees.

The aim of this study was to quantify the effects of grazing on the ecological system at Sayeret Shaked Long Term Ecological Research (LTER, Gosz, French, and Spratt, 2000) station. We compared the diversity and composition of plant community, herbaceous biomass, soil moisture, soil organic matter, habitat structure, and quality of the vegetation for grazers (protein content and digestion). These measurements were done in grazed plots and plots ungrazed for three years. The results should help in determining proper management techniques for effective runoff

cultivation and minimum loss in soil erosion, as well as for minimum disturbance in plant diversity and productivity.

Study Site

The research site is located in Sayeret Shaked LTER near Beer Sheva in the northern Negev of Israel ($31^{\circ}17'N$, $34^{\circ}37'E$). It is comprised of a 2 km^2 hilly area closed off from livestock grazing since 1987, six years prior to this study. The long-term annual rainfall average of 200 mm occurs only in winter (November–March). Average daily winter temperature is $6\text{--}8^{\circ}\text{C}$, and average daily maximum summer temperatures are $32\text{--}34^{\circ}\text{C}$ (Stern et al. 1986). The 200 mm isohyet forms the transition zone between the arid and semiarid deserts in Israel (Bruins, 1990). The soil surface is covered with microphytic soil crust, consisting of bacteria, cyanobacteria, algae, mosses, and lichens (Zaady, Groffman, and Shachak, 1996), and with scattered patches of perennial shrubs. Soil, covered with a well-developed microphytic crust, has a tightly structured surface (Fletcher and Martin, 1948). The dominant perennials in the research areas were *Asphodelus ramosus* (Liliaceae), *Thymelaea hirsuta* (Thymelaeaceae), *Noaea mucronata* (Chenopodiaceae), *Atractylis serratuloides* (Asteraceae) and *Pituranthos tortuosus* (Apiaceae) (Feinbrun-Dothan and Danin 1991) (Table 1). In contrast, the soil of macrophytic patches lacks a well-developed microphytic crust, and its surface is covered with loose soil particles.

The soil is loessial, about 1 m thick, with 14% clay, 27% silt, and 59% sand [USA classification: loess soil with sandy loam texture—Calcixerollic, Xerochrepts (Dan et al. 1977)] on Eocene bedrock. Salt content of the 0–25 cm soil layer is low, with electrolytic conductivity of 0.04 S m^{-1} (Teomim, 1990).

Inside the park there are two research locations, one at the eastern side and the other at the western side of the park (Figure 1). Each of them was divided into two groups of plots, one on a north-facing slope and the other on a south-facing slope. The south and the north slopes were selected because of the differences in the radiation, which affect the water regime and the vegetation. The slopes are in an angle of about 7–15%. The western research location was set up in the contour banks system. In this location, on each of the slopes, six squares ($4 \times 4\text{ m}$) plots, three fenced and three open to grazing were denoted. For the eastern research location due to topography, the size of the plots was $2 \times 8\text{ m}$. On the north-facing slope, three were fenced and three plots were left open for grazing, and at the south-facing slope, two were fenced and two left open.

The grazing in the study site was done by a Bedouin herd of 200 Awasi sheep. The grazing season is usually from mid-February to mid-August. During this season, the flock visited each of the plots five times. This study summarizes the results of grazing effect for three years.

Materials and Methods

Field Measurements

Monitoring vegetation biomass. This was carried out by harvesting the natural vegetation in five squares ($25 \times 25\text{ cm}$) distributed randomly in each of the plots, once a month. The vegetation was cleared to 5 cm above the soil surface (simulating removal of vegetation by grazing activity). The samples were oven-dried (80°C) for 72 hours, then weighed for dry biomass.

Vegetation cover and habitat structure. Surveys were conducted to study the changes in vegetation cover and habitat structure through the growth season. Two parallel cross sections were delineated by meter rulers, along each plot. Every 10 cm, the readings under the ruler were recorded. The vegetation was documented by four

TABLE 1 Species richness in the western research location at Sayeret Shaked LTER Station (A- north-facing slope with grazing, B- north-facing slope without grazing, C- south-facing slope with grazing, and D- south-facing slope without grazing)

Species name	Family	A	B	C	D
Annuals					
<i>Aegilops kotschyi</i> Boiss.	Poaceae	✓	✓	✓	
<i>Aegilops longissima</i> Schweinf. et Muschler emerd. Eig	Poaceae	✓			
<i>Ammochloa palaestina</i> Boiss.	Poaceae			✓	✓
<i>Anagallis arvensis</i> L.	Primulaceae			✓	✓
<i>Anthemis pseudocotula</i> Boiss.	Asteraceae	✓	✓	✓	✓
<i>Arnebia decumbens</i> (Vent.) Cosson et Kralik	Boraginaceae	✓	✓		
<i>Astragalus callichrous</i> Boiss.	Fabaceae		✓		
<i>Astragalus hamosus</i> L.	Fabaceae			✓	✓
<i>Astragalus tribuloides</i> Delile	Fabaceae			✓	
<i>Avena barbata</i> Link	Poaceae	✓	✓	✓	✓
<i>Bellevalia eigii</i> Feinbrun	Liliaceae			✓	
<i>Bromus fasciculatus</i> C. Presl	Poaceae	✓	✓	✓	
<i>Bromus rubens</i> L.	Poaceae				✓
<i>Calendula arvensis</i> L.	Asteraceae	✓	✓	✓	✓
<i>Carthamus tenuis</i> (Boiss. Et Blanche) Bornm.	Asteraceae	✓	✓	✓	✓
<i>Centaurea hyalolepis</i> Boiss.	Asteraceae	✓	✓	✓	✓
<i>Crepis aspera</i> L.	Asteraceae		✓		
<i>Crucianella herbacea</i> Forssk.	Rubiaceae	✓	✓		
<i>Cutandia memphitica</i> (Sprengel) K. Richter	Poaceae			✓	
<i>Filago contracta</i> (Boiss.) Chrtaket Holub	Asteraceae	✓		✓	
<i>Hedypnois cretica</i> (L.) Dum.-Courset	Asteraceae	✓	✓	✓	✓
<i>Hippocrepis unisiliquosa</i> L.	Fabaceae	✓	✓	✓	✓
<i>Linaria haelava</i> (Forssk.) Delile	Scrophulariaceae	✓	✓		✓
<i>Lotus peregrinus</i> L.	Fabaceae			✓	✓
<i>Malva aegyptia</i> L.	Malvaceae			✓	✓
<i>Matthiola livida</i> (Delile) PC	Brassicaceae	✓	✓		
<i>Minuartia picta</i> (Sibth. Et Sm.) Bornm.	Caryophyllaceae		✓	✓	
<i>Onobrychis squarrosa</i> Viv.	Fabaceae	✓	✓	✓	✓
<i>Ononis variegata</i> L.	Fabaceae	✓	✓	✓	
<i>Plantago albicans</i> L.	Plantaginaceae	✓	✓		
<i>Plantago coronopus</i> L. subsp. <i>Commutata</i> (Guss.) Pilger	Plantaginaceae	✓			
<i>Pterocephalus brevis</i> Coulter	Dipsaceae				✓
<i>Reboudia pinnata</i> (Viv.) O. E. Schulz	Brassicaceae	✓	✓		
<i>Reseda alba</i> L.	Resedaceae				✓
<i>Rostraria cristata</i> (L.) Tzvelev	Poaceae		✓	✓	✓
<i>Salvia lanigera</i> Poiret	Lamiaceae				✓
<i>Senecio glaucus</i> L.	Asteraceae	✓	✓	✓	✓
<i>Stipa capensis</i> Thunb.	Poaceae	✓	✓	✓	✓
<i>Trifolium campestre</i> Schreber	Fabaceae	✓	✓		
<i>Trifolium tomentosum</i> L.	Fabaceae	✓	✓		
<i>Trigonella arabica</i> Delile	Fabaceae	✓	✓	✓	✓
<i>Trigonella stellata</i> Forssk	Fabaceae	✓	✓	✓	✓
Perennials					
<i>Allium stamineum</i> Boiss.	Liliaceae			✓	✓
<i>Asphodelus tenuifolius</i> Cav.	Liliaceae		✓	✓	
<i>Atractylis carduus</i> (Forssk.) C. Chr.	Asteraceae		✓		
<i>Atractylis serratuloides</i> Cass.	Asteraceae		✓	✓	✓
<i>Noaea mucronata</i> (Forssk.) Ascherson et Schweinf.	Chenopodiaceae	✓	✓		✓

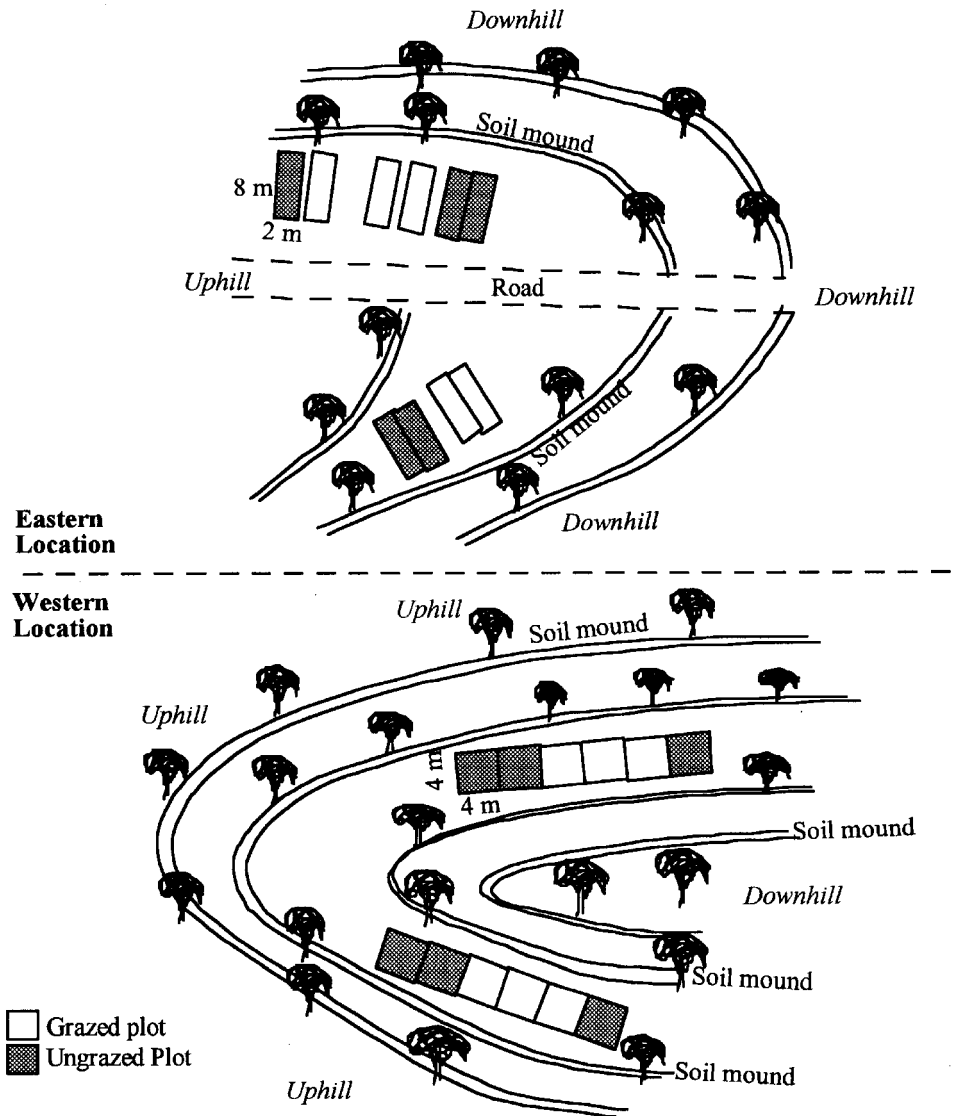


FIGURE 1 Conceptual diagram of the grazing locations and plots at the Sayeret Shaked LTER Station.

groups: annuals such as Poaceae and Fabaceae, which are most favored by the grazers and others, and the perennial vegetation. Spots under the ruler in which bare soil and stones were found, were also recorded.

Soil moisture. Soil moisture was measured with Tektronix 1502C Metallic Time Domain Reflectometer (TDR) (Topp and Davis, 1985). Soil moisture was determined at the peak of the growing season (March) and in the middle of the dry season (August). Two 15-cm long probes were used in the estimation of average volumetric soil water content in the 0–15 cm soil layer. The 15-cm long probes were used in order to reach the root depth of the most of the annuals. Volumetric soil content is proportional to the dielectric constant of the medium, which is measured as the time at which the reflection of an electrical pulse sent down the probe is minimal. In order

to calibrate this method, soil samples were brought from the field and were weighed before and after oven drying (105°C).

Plant species diversity and community composition. Once a month, a species diversity survey was made in three permanent squares (40 × 40 cm) in each plot. There were 36 squares in the 12 plots of the western location. In this survey each plant that germinated and grew during the growth period (February to June) in these squares was counted and identified.

Laboratory Measurements

Organic matter content. Soil samples were collected randomly from each plot (5–10 cm deep) and mixed together. Each sample was sieved (2-mm sieve) and a sample of 3 g of it was oven dried (72°C for 3 h) and weighed. It was then burned in a furnace (650°C for 2 h) (Ben-Dor and Banin, 1989). Organic matter content was calculated from the weight before and after the drying process. The results are the mean of the soil samples that were collected on 23/11/1993, 1/5/1994, 22/12/1994, and 6/7/1995.

Protein content and digestibility. Five samples of the vegetation from the same sampling date were combined after being oven dried (72°C, 48 h). The samples were weighed for their biomass and sieved to the 1-mm particle size class. A total of 30 samples, from three different dates: 26/1/1995, 27/2/1995, and 22/3/1995, from both ungrazed and grazed plots were tested. Protein content was determined by the Kjeldahl-N method (Sparks and Page, 1996) and digestibility of dry biomass was determined after incubation with rumen fluid employing the two-stage of Tilley and Terry technique (Tilley and Terry, 1963).

Statistical Analysis

Data were analyzed using analysis of variance with the SuperANOVA statistical package. One-way ANOVA, with Duncan Multiple Range Tests and Scheffe F-tests (Sokal and Rohlf, 1995) were used to test for differences in dependent variables: the organic matter, soil moisture, protein content, digestibility, plant species densities, diversity and richness, dry biomass, and soil surface cover. Habitats, grazing status, season, and dates were the independent variables.

Results

Soil organic matter (Table 2) showed no statistical differences between grazed and plots ungrazed for three years for each of the sites. Differences were found between

TABLE 2 Changes in soil organic matter (% of soil weight)

Plot and treatment	21 Nov 1993	1 June 1994	22 Dec 1994	6 July 1995
Western location:				
south-facing slope, ungrazed plots	3.6a*	3.5a	3.2a	3.2a
south-facing slope, grazed plots	3.7a	3.4a	2.8a	3.3a
north-facing slope, ungrazed plots	4.0a	4.2b	3.2a	3.3a
north-facing slope, grazed plots	4.2a	3.7ab	3.1a	3.3a
Eastern location:				
south-facing slope, ungrazed plots	5.0b	4.9c	4.7b	4.7b
south-facing slope, grazed plots	5.1b	5.0cd	4.2b	4.8b
north-facing slope, ungrazed plots	5.2b	5.4cd	4.4b	4.9b
north-facing slope, grazed plots	6.0c	5.5d	4.6b	4.9b

* Values with different letters in the same column are significant ($P < 0.05$).

TABLE 3 Soil water content at the research site ($\text{g H}_2\text{O g}^{-1}$ soil)

Plot and treatment	Summer	Winter
Western location:		
south-facing slope, ungrazed plots	0.1a*	23.5cd
south-facing slope, open plots	0.11a	19.5bc
north-facing slope, ungrazed plots	0.11a	17.7b
north-facing slope, open plots	0.11a	25.4d
Eastern location:		
south-facing slope, ungrazed plots	2.1d	7.3a
south-facing slope, open plots	1.8b	8.5a
north-facing slope, ungrazed plots	1.9c	10.4a
north-facing slope, open plots	2.0cd	10.5a

* Values with different letters in the same column are significant ($P < 0.05$).

the locations (western and eastern locations). In the eastern sites there was 25–35% more soil organic matter than in the western sites (6.0% on average on the north-facing slope at the eastern location sites as compared to 4.2% at the western sites in the grazed plots, in 1993). The amount of organic matter decreased with time, from 6.0% in 1993 to 4.9% in 1995 on the north-facing slope of the eastern sites and from 4.2% to 3.3% on the north-facing slope of the western sites, in the grazed plots.

The results of the soil moisture analysis showed almost no changes among treatments and plots in the summer but significant differences found between the sites (Table 3). During the winter, in contrast to the summer, soil moisture in the western sites was higher in the grazed plots on the north-facing slope (25.4%), as compared to the soil moisture in the grazed plots of the eastern sites (10.5%). Differences were also found in winter between the sites within the western location. On the south-facing slope there was more soil moisture in the ungrazed plots compared to the plots on the north-facing slope where the soil moisture was higher. In the grazed plots the picture was reversed; soil in the north-facing slope is more moist than that in the south-facing slope. In the eastern plots, soil moisture was higher on the south-facing slope in the grazed plots than in the plots without grazing. At the north-facing slope there was no meaningful difference between the grazed and ungrazed plots. In general, north-facing slopes were wetter than south-facing slopes in the eastern location while there seemed to be no difference in the western location.

A significant decrease ($P < 0.05$) was found, as expected, in total protein content in plants over time from 17–19% in January to 5–6% in March (Table 4). On the south-facing slope, the initial protein content was equal in both the grazed and the ungrazed plots. On the north-facing slope, in January protein content was higher in

TABLE 4 Percent of protein content in the vegetation of the eastern research location

Plot and treatment	26 Jan 1995	27 Feb 1995	22 Mar 1995
south-facing slope, grazed plots	17.5a*	11.2a	5.0a
south-facing slope, ungrazed plots	17.5a	13.1a	5.6a
north-facing slope, grazed plots	19.3a	12.5a	6.2b
north-facing slope, ungrazed plots	16.8a	13.7a	5.6a

* Values with different letters in the same column are significant ($P < 0.05$).

TABLE 5 The digestibility of the vegetation (% that can be digested) in the eastern research location

Plot and treatment	26 Jan 1995	27 Feb 1995	22 Mar 1995
south-facing slope, ungrazed plots	77.2a*	71.9a	59.5ab
south-facing slope, grazed plots	75.8a	75.1b	59.5ab
north-facing slope, ungrazed plots	77.1a	72.7a	57.4a
north-facing slope, grazed plots	78.0a	74.9b	63.7b

* Values with different letters in the same column are significant ($P < 0.05$).

grazed (19.3%) compared to ungrazed plots (16.8%), but these differences diminished with time and were not significant. High and statistically significant differences ($P < 0.05$) were found with protein content in March within the grazed plots in north-facing slope in comparison to the ungrazed plots (Table 4).

Digestibility decreased, as expected with time (corresponding to the decrease in protein and increase in fiber) (Table 5). At the beginning of the season, digestibility was similar in the ungrazed and the grazed plots on both slopes. In February, statistical differences were obtained for grazed and ungrazed plots, on both north- and south-facing slopes. At the peak of the growing season there was significantly ($P < 0.05$) more digestible material in the grazed plots (63.7%) compared to the ungrazed plots (57.4%) in the north-facing slope but not in the south-facing slope.

Anthemis pseudocotula, *Avena barbata* and *Trigonella arabica* were among the plant species presented in all plots (Table 1). *Crucianella herbacea* and *Trifolium campestre*, on the other hand, appeared only on north-facing slopes while *Allium stamineum* appeared only on south-facing slope. The number of species on south-facing slope after three years of grazing was similar in the grazed plots (28) and the ungrazed plots (27), while on north-facing slope there were more plant species in the grazed plots (31) than in the ungrazed plots (27).

In the western location, at the ungrazed plots of the north-facing slope, density of *Bromus fasciculatus* was the highest at the peak of the growing season in March compared to other plants (3611 individuals m^{-2}). The presence of most annual plants (e.g., *Anthemis pseudocotula* and *Senecio glaucus*) decreased in April and disappeared in June. Eight families were identified in the plots: Asteraceae (7 species), Fabaceae (7 species), Poaceae (5 species), Brassicaceae (3 species), Plantaginaceae (2 species) and Scrophulariaceae, Chenopodiaceae, and Rubiaceae with one species each. The peak of most Fabaceae commenced in February with a decline towards May. In the grazed plots, also *Bromus fasciculatus* was the dominant species. At the peak of the growing season in March, its density (2986 individuals m^{-2}) was lower than in the ungrazed plots. Density of the Fabaceae decreased drastically under grazing, even in February, compared to closed plots. Representatives of 10 families were encountered in the grazed plots: Asteraceae (8 species), Fabaceae (9 species), Poaceae (5 species), Brassicaceae (2 species), Plantaginaceae and Boraginaceae, Liliaceae, Chenopodiaceae, and Rubiaceae with one species each.

In the western location, in ungrazed plots on the south-facing slope, density of *Stipa capensis* was found to be higher compared to other plants at the peak of the growing season (March – 1340 individuals m^{-2}). As with Fabaceae, their peak growth was in February and only a few were left in May. Seven families were found in these plots: Asteraceae (8 species), Fabaceae (6 species), Poaceae (7 species), Liliaceae (3 species), Primulaceae, Malvaceae, and Caryophyllaceae having one species each.

In the grazed plots density of *Stipa capensis* was also found to be higher at the peak of the growing season in April, but its value was lower than in protected plots (938 individuals m^{-2}). Representatives of 11 families were found in these plots:

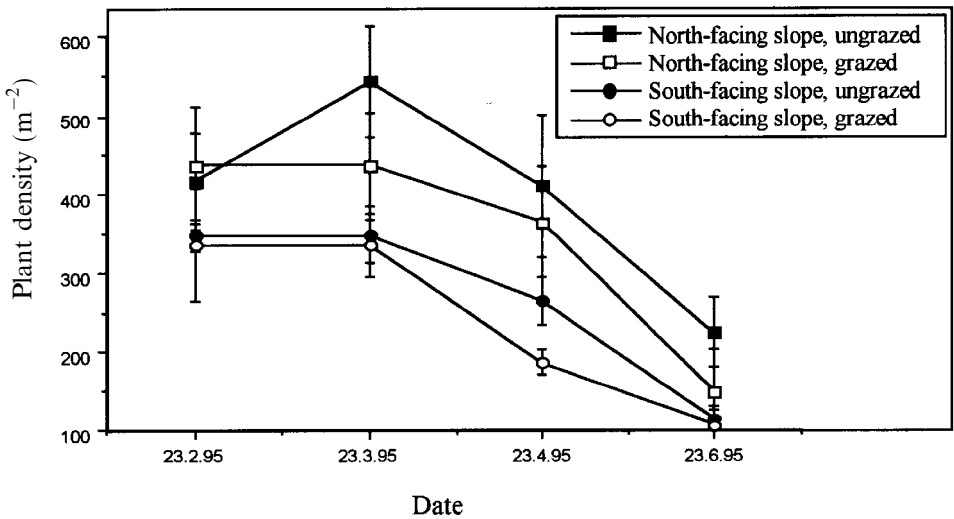


FIGURE 2 Comparison of total plant species densities among the four habitats during the grazing period. Values are Mean \pm SE of plant density vs. each of the habitats.

Asteraceae (7 species), Fabaceae (6 species), Poaceae (6 species), and Primulaceae, Boraginaceae, Malvaceae, Liliaceae, Lamiaceae, Dipsacae, Scrophulariaceae, and Chenopodiaceae had one species each.

Comparison of total plant species densities among the four habitats showed that plant density in north-facing slope is higher than south-facing slope (Figure 2). Plant density of ungrazed plots in north-facing slope was higher, as expected. In south-facing slope no differences were found between grazed and ungrazed plots (except for 23 April 1995). Grazing showed no effect on species richness (Figure 3) and plant diversity.

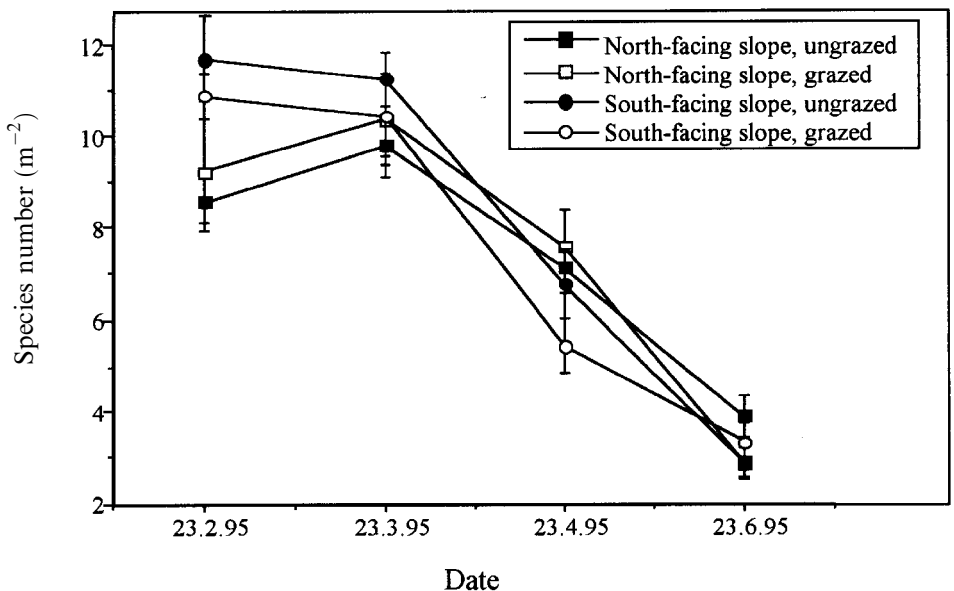


FIGURE 3 Comparison of plant species richness among the four habitats during the grazing period. Values are Mean \pm SE of plant richness vs. each of the habitats.

There were almost no differences in dry biomass of vegetation of ungrazed and grazed plots until sheep were introduced in mid-February. In both north- and south-facing slopes, although vegetation peak was in March, amount of dry biomass was higher in ungrazed plots, as expected (Figure 4a, b).

During winter 1993, the amount of rainfall was 200 mm. In winter 1994, there was only 74 mm rainfall and in winter 1995 there was 282 mm, which is more than the annual average (200 mm) (Table 6). In the eastern site, at the north-facing slope, differences in dry biomass, at the peak growth season, reached 74% (120 g m^{-2}) on average, compared to the south-facing slope plots (without grazing). Mean maxima were in north-facing slope plots, 163 g m^{-2} in 1993, 110 g m^{-2} in 1994, and 283 g m^{-2} in 1995. In the eastern site, differences, at the peak of the season, between north- and south-facing plots reached 162 g m^{-2} in 1993, 70 g m^{-2} in 1994, and about 90 g m^{-2} in 1995.

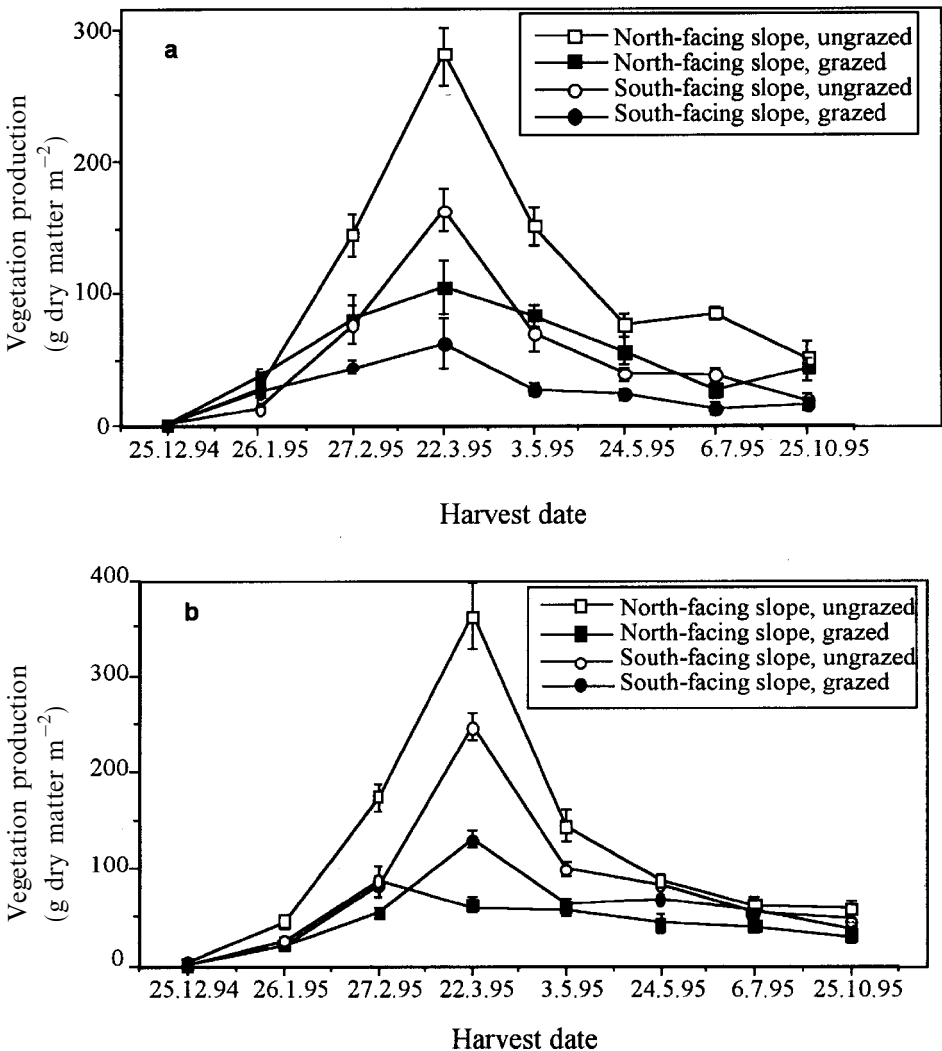


FIGURE 4 Comparison between dry biomass among the four habitats during the grazing period (a) in the eastern location, (b) in the western location. Values are Mean \pm SE of dry biomass vs. each of the habitats.

TABLE 6 The effect of annual precipitation on herbaceous dry biomass (mean maxima) obtained in Sayeret Shaked LTER

Year	1993	1994	1995
Annual precipitation (mm)	200	74	282
Eastern location (g m^{-2})	163	110	283
Western location (g m^{-2})	162	70	363

The cover of Poaceae, the dominant family, decreased significantly with grazing in comparison to ungrazed plots (Figure 5). A similar pattern was found with the Fabaceae, although their overall cover is too low to show clearly. On the other hand, grazing had no significant effect on forb cover, probably because they were less palatable.

Grazing had a negative effect on shrub cover and it decreased with time, mainly by direct foraging on *Noaea mucronata*, the dominant shrub in this system and one of the few palatable shrubs on this rangeland. *Pituranthos tortuosus*, *Atractylis serratuloides* and *Thymilea hirsuta* and the geophyte *Asphodelus tenuifolius* were not affected by grazing and their density remained almost the same during the grazing period.

Discussion

The goal of this study was to measure the grazing effects on the human managed ecosystem. Since we did not have previous knowledge about grazing impact in this area, we studied the grazing effects on a wide range of biotic and abiotic factors.

Introduction of livestock grazing to ecological systems is commonly considered a disturbance that affects ecological processes, especially if the grazing pressure is high (Noy-Meir, 1990). Grazing may affect the ecological system in many ways. Figure 6 demonstrates potential effects of grazing on ecological systems. Grazing may affect three components of the vegetation: plant density, plant chemical content and community structure. These changes may be of short-term nature, occurring right after the first grazing episode, or long-term effects that may be identified after years of grazing (Le Hou  rou, 1977; Perevolotsky, 1999).

In the short term, grazing affects the survival of some plant species (species sensitive to grazing) while other species are not affected at all (species resistant to grazing). As a result of this selection, part of the vegetation is removed while the other enjoys improved resources (light, water, etc.), which leads to changes in the vegetation community composition. This process leads to a change in species community composition (Noy-Meir, 1990).

In addition to the influence on species diversity, grazing could affect the chemical content of plants (protein content and digestion values). Livestock should prefer to feed on plants of high nutritional value such as legumes, rich in nitrogen content. Thus, the presence of these species should decrease as a result of selective grazing, leading to a decrease in quality of the pasture landscape. On the other hand, grazing may be keeping the vegetation in continuous growth, which increases its nutritional value (Naali, 1995).

Livestock grazing may also affect the biomass of herbaceous vegetation. In addition, the seed bank may be affected by long-term grazing. Resulting outcomes are a decrease in potential production of the area and related effects such as soil erosion. The phenomenon of decrease in potential primary production of the system is defined as overgrazing (Perevolotsky, 1991).

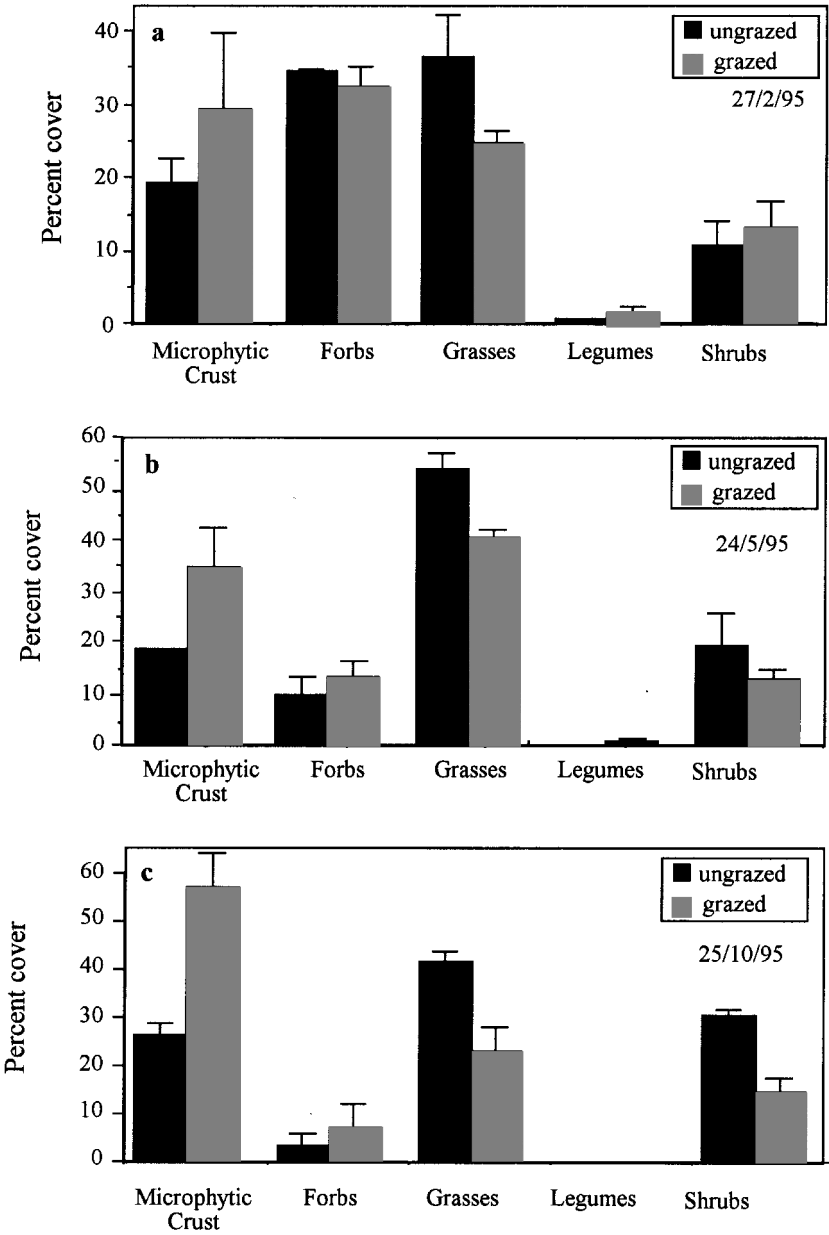


FIGURE 5 Soil surface cover within the four habitats during the grazing period (February, May and October). Values are Mean \pm SE of percents of the cover vs. each of the habitats.

The timing of introduction of the livestock into the area should also affect the vegetation (Figure 6). Introduction after seed germination will endanger plant development and growth. At the end of the season (after seed dispersion), the grazers will have a minor effect on the future vegetation (Seligman et al., 1959). The grazers may affect the abiotic components: soil erosion, nutrients and water flow. In grazed areas, trampling may cause physical destruction of the soil, crumbling and loosening of the soil surface, thus increasing water infiltration. In other soils, trampling may

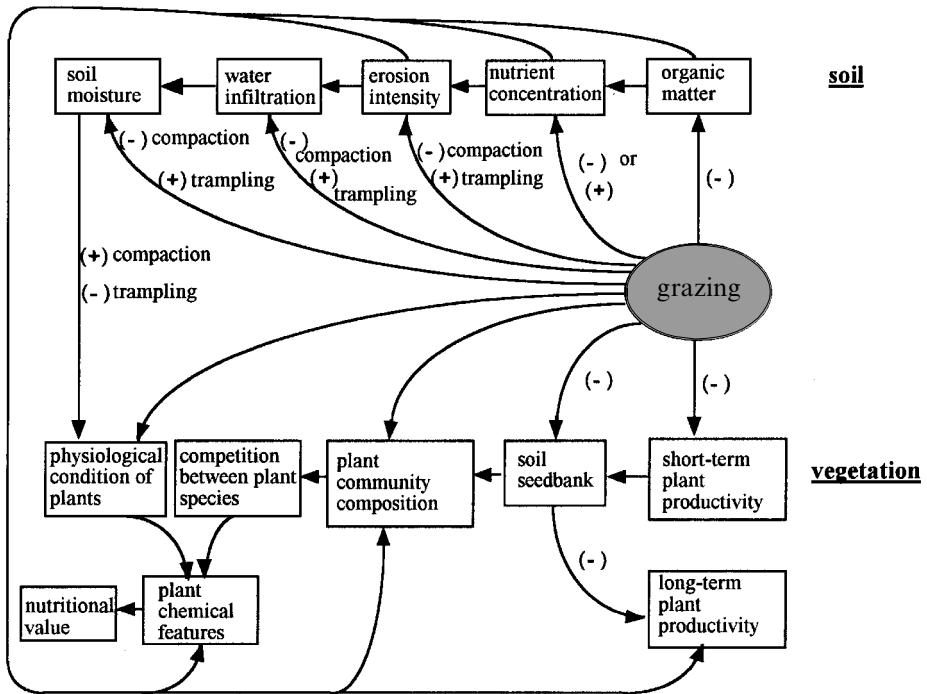


FIGURE 6 The potential effects of grazing on ecological systems.

cause soil compaction (Figure 6), thus increasing water runoff. When vegetation cover is low and the soil is loosened, soil erosion increases, and its fertility decreases. This phenomenon leads to degradation of the ecosystem through destruction of the soil structure. In dry regions overgrazing is one of the major factors of desertification (FAO, 1991; UNEP, 1991).

The direct effect of grazing on the vegetative community, in this study, could be observed soon after the introduction of the sheep into the area, especially at the peak of the season (in March). Grazing induced, as expected, a decrease in vegetation biomass and in the density of the dominant species. The plots in the western location on the north-facing slope were more strongly affected by the grazing. Over 60% of the plant material was removed by the sheep. The difference between the vegetation biomass in the ungrazed plots and the grazed ones implies the pressure. In the north-facing slope the animals removed 62% of the total dry biomass. In the south-facing slope, a similar amount, 61%, was removed. This shows that grazing was similar in the different habitats and relatively constant over the studied landscape.

As expected, grazing decreased vegetation biomass during the grazing season, but the principal question in any discussion of landscape degradation is whether grazing would have long-term effects on vegetation production. Our results (Figure 5), from the beginning of the production season (end of January, 1995), do not indicate any significant reduction in vegetation production in the plots that were grazed during the last three years compared to the ungrazed plots. From the management point of view, this finding shows that grazing can continue in the future since the potential of the seasonal vegetation production is maintained. Moreover, since we are interested in decreasing the annual vegetation in order to increase runoff water, we may even consider increasing grazing pressure. Although a significant amount of vegetation was removed every year by the livestock, there were

no differences in soil organic matter between the grazed and the ungrazed plots (Table 2). In other words, grazing had not caused damage to the soil fertility.

Grazing did not affect soil nutrients, nitrogen and phosphate (Zaady, Groffman, and Shachak, 1998). It was found that grazing induced an increase in soil moisture although its intensity depends on the habitat (Table 3). This is most probably related to the loosening of the soil surface and breaking of the soil microphytic crusts (Eldridge et al., 2000; Zaady et al., 1998) by trampling. These physical effects increase infiltration of water into the soil (Eldridge et al., 2000). The removal of vegetation by grazing lowers losses of water from the soil due to evapotranspiration. The increase in soil moisture, meaning less runoff water that will leak out from the system, was one of the aims of the managers interested in the planted trees, and also the reason that the sheep were brought into the area.

It is commonly claimed that heavy grazing brings about a decline in species richness and diversity (Nilchunas, Sala, and Lauenroth, 1988). In this study, it was found that grazing had no effect on species richness in the three years of the grazing experiment. For the plots where 60% of the vegetation was removed before the peak of the season, no differences were found between the number of species in the grazed area and in the plots where grazing was prevented for the experimental period (Figure 3). Species richness does not always indicate stability of the species composition. Comparisons among the dominant species in the plots helped to differentiate between the effect of the habitat and of grazing on species composition. Species diversity did not change with the years of grazing (Figure 7) implying stability of the plant community structure despite the grazing pressure (Table 7). Habitat orientation (south- against north-facing slope) had an effect on the species composition. *Bromus fasciculatus*, which dominated the north-facing slope, is not found on the south-facing slope. *Senecio glaucus* was less common in the south and *T. campestre* and *T. tomentosum* completely disappeared. On the south-facing slope the dominant species were *A. arvensis* and *R. cristata* which did not appear at all on the north-facing slope, while *A. barbata* and *Aegilops kotschy* became more common. We were

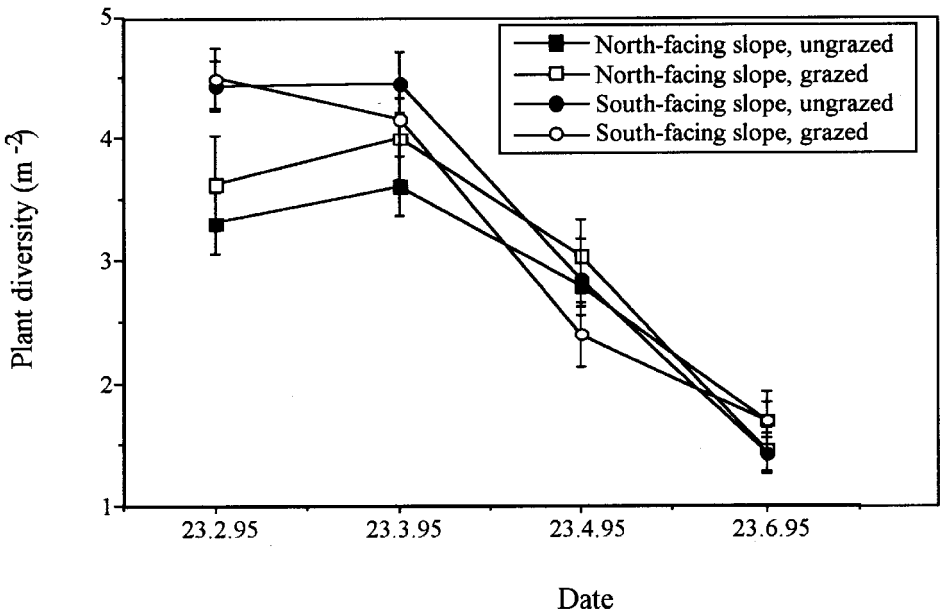


FIGURE 7 Comparison of plant diversity among the four habitats during the grazing period. Values are Mean \pm SE of plant diversity vs. each of the habitats.

TABLE 7 Plant community structure in the western site, on the two slopes (% of Fabaceae, Poacea and others), during 1995

	February			March			April			June		
	Fab.	Poa.	Others	Fab.	Poa.	Others	Fab.	Poa.	Others	Fab.	Poa.	Others
North-facing slope	16.7	73.4	9.9	18.1	74.5	7.4	15.1	80.1	4.8	13.1	81.6	5.3
—without grazing												
North-facing slope	15.8	54.3	29.9	8.3	77.8	13.9	4.0	89.2	6.8	0.5	97.2	2.3
—with grazing												
South-facing slope	10.2	50.5	14.3	7.3	67.6	25.1	3.0	85.8	11.2	0.6	90.8	8.6
—without grazing												
South-facing slope	16.6	38.2	56.5	8.4	55.7	35.9	0.4	85.1	14.5	0.0	90.7	9.3
—with grazing												

Fab. = Fabaceae, Poa. = Poaceae.

not able to determine the ecological factors explaining the differences in species composition, but it was clear that grazing was not one of them (same differences were found in the ungrazed plots). Most of the shrubs in the desert landscape have adaptations against grazing which make them unpalatable with strong defenses (thorns, aromatic compounds). This may explain why no significant differences were found between the grazed and the ungrazed plots in terms of shrub cover, except for *N. mucronata*, which is a palatable plant.

Study of the vegetation quality by protein content and digestibility (Tables 4 and 5) showed significant differences between the plots with and without grazing. This difference resulted from accelerated growth to rebuild the damage caused to the vegetation by grazing (Naali, 1995).

The amount of precipitation in the winter affected the amount of vegetation on the natural pasture (Table 6). The natural pasture biomass was foremost affected by the amount and the distribution of the precipitation and by the habitat (the vegetation on the north-facing slope was higher than that on the south-facing slope).

Grazing affected the habitat structure by lowering the vegetation cover. This was especially true for legumes and grasses, which exposed the soil microphytic crusts and hence increased its relative cover (Figure 5). The question whether this exposure affected soil erosion and water harvesting remains open. Accelerating soil erosion as a result of soil exposure is not a desirable action in dry landscapes where the build-up of soil cover and fertility is a very slow process. On the other hand, increasing runoff water is a desirable process in the management of Sayeret Shaked Park, because the tree planting is based on water harvesting. Further studies are needed to clarify the interactions between soil erosion and runoff water in relation to grazing and then to consider whether the benefit (more water) is higher than the cost (soil erosion).

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