Spatial distribution of overland flow and sediment yield in semi-arid rangelands

P. Sarah, H. Lavee

Laboratory of Soil and Geomorphology, Department of Geography and Environment, Bar-Ilan University, Ramat-Gan 52900, Israel. Email: pariens@mail.biu.ac.il

INTODUCTION

Feedbacks and mutual links exist among soil, vegetation and water; they enable co-evolution of these features within eco-geomorphic systems. These relations are fragile, especially in semi-arid areas where grazing is the main land use. The simplest subdivision of the surface of many semi-arid rangelands is into a two-component mosaic pattern comprising shrub patches interspersed with open spaces, with the former acting as sinks for water and other resources, and the latter as sources. However close observations in areas under grazing in the northern Negev region of Israel suggested that the spatial pattern of surface components is more complicated, and that the open space between shrubs consists of two components: herbaceous areas, separated by trampling routes that support no vegetation. It is suggested that the apparent trampling routes function differently from the remainder of the intershrub area, with regard to pedo-hydrological characteristics.

This study aims: 1) to determine the differences between the soil properties in the three different types of cover (shrub patches, trampling routes, and the remainder of the intershrub area; 2) to assess the actual overland flow and sediment yield in the above types of cover, i.e., to characterize the flows of resources within the hillside; and 3) to study the impact of livestock on soil properties, and on runoff and sediment yield.

STUDY AREA

The research was conducted at the Lehavim Bedouin Demonstration Farm, located in the northern Negev region of Israel (31°20' N, 34°46' E). This is a hilly, semi-arid area, 350-500 m above sea level, with mean annual precipitation of about 300 mm that falls between October and May. Average daily temperatures in the hottest and coldest months (July and January, respectively) are 25 and 11°C, respectively. Relative humidity ranges between 51% in May and 68% in January. The lithology is chalk of the Eocene. The soil type is Brown Rendzina. The soil is shallow, generally not deeper than 20 cm in open spaces between shrubs and 40 cm under shrubs, except in rock fissures. The color is dark brown (7.5YR4/3) and the texture is clay-loamy in which the primary particle size distribution is 30% clay, 40% silt and 30% sand. The clay size fraction is dominated by calcite and montmorillonite, and the stone content is about 15-30%.

The study region, like many other semi-arid areas of the Old World, has been grazed by flocks of sheep and goats for centuries. A 800-ha experimental farm was established in 1980, and has since been managed under the auspices of the Ministry of Agriculture and Rural Development; it is grazed by flocks of sheep and goats, totaling about 800 head of breeding stock.

METHODS

Surface cover survey

A survey of the surface cover components of the study site was conducted in January 2005. Three plots of 4 × 4.5 m were randomly selected on each of an opposing north- and south-facing hillside of slope 15° and 13°, respectively, in an area frequented by the flocks and subjected to intense grazing pressure. A metal frame of 2.0 × 1.3 m was constructed with metal wires stretched across it to create a grid of 260 cells of 0.1 × 0.1 m. The frame was supported by four telescopic legs which enabled it to be leveled horizontally. The area of each plot (excluding two central access strips of 0.3 m width) was mapped using six placements of the frame. For each cell the cover component with the largest surface area was recorded.

Soil- field and laboratory work

Soil sampling was conducted on north- and south-facing hillsides, in the peak of the growing season (March) and at the end of the hot, dry season (September).

On each hillside three sampling areas, located at the middle of the slope, were delineated. Each sampling area comprised of one non-grazed control exclosure (established in 1994) and an adjacent intense grazing area (a total of 12 experimental plots). Soil was sampled from each of the three types of cover which were chosen on the basis of their dominance in the surface cover survey: shrub (SH) (represented by *S. spinosum*, which had a high cover on both aspects); flock trampling route (RU); and the rest of the intershrub area (IS). For each type of cover, soil was sampled from seven randomly selected points within each of the 12 experimental plots. At each point soil samples were collected from a depth of 0-2 cm and 5-10 cm.

For each soil sample soil moisture content, organic carbon content, bulk density, calcium carbonate content, and aggregate size distribution were determined.

Overland flow and sediment yield measurements

Overland flow and sediment yield on each of the three cover types were measured inside and outside the exclosures, on a north- and a south-facing hillside, by means of small runoff plots (0.25-1.5 m^2). Five types of plots (shrub, intershrub, route, route + shrub, intershrub + shrub) were constructed, each in 3-4 replicates, resulting in 76 plots in total.

Overland flow and sediments were collected during two consecutive winters: 2007/8 and 2008/9.

RESULTS

Ground surface cover

The dominant shrub species on both aspects was *Sarcopoterium spinosum*, which is a moderately palatable cushion-like shrub, 20-60 cm in height, and with width ranging from 30 cm for small individuals to more than 100 cm for older, well-developed patches. The shrub *Coridothymus capitatus* – an unpalatable cushion-like shrub, 30-40 cm in height, 30-50 cm in width – occurred on the south-facing aspect only. A litter layer of about 1 cm was found underneath the canopy of both shrub species. The most dominant component of the intershrub area was herbaceous vegetation (primarily annual grasses and forbs), which had a very similar cover to that of *S. spinosum*. The next most dominant component of the intershrub area comprised flock trampling routes of almost bare, compacted soil which traversed the hillsides with a predominantly horizontal orientation, and were visually recognizable because of their mechanically formed crusts and the very sparse herbaceous cover. The cover of these was similar on both aspects and accounted for an average of 21% of the area.

Soil properties

The soil moisture and organic carbon contents were highest under the shrubs and lowest under the trampling routes, and had intermediate values under the intershrub areas. Bulk density and calcium carbonate content were lowest under the shrubs and highest under the trampling routes, with intermediate values under the intershrub areas (Figure 1).

In the grazed areas, soil moisture and organic matter contents under the shrubs and in the intershrub areas were higher than those in the control. The trampling routes showed an opposite trend.

In the grazed area, bulk density under the routes was significantly higher than that in the control.

In the grazed area calcium carbonate was significantly higher than that in the control (Figure 1).

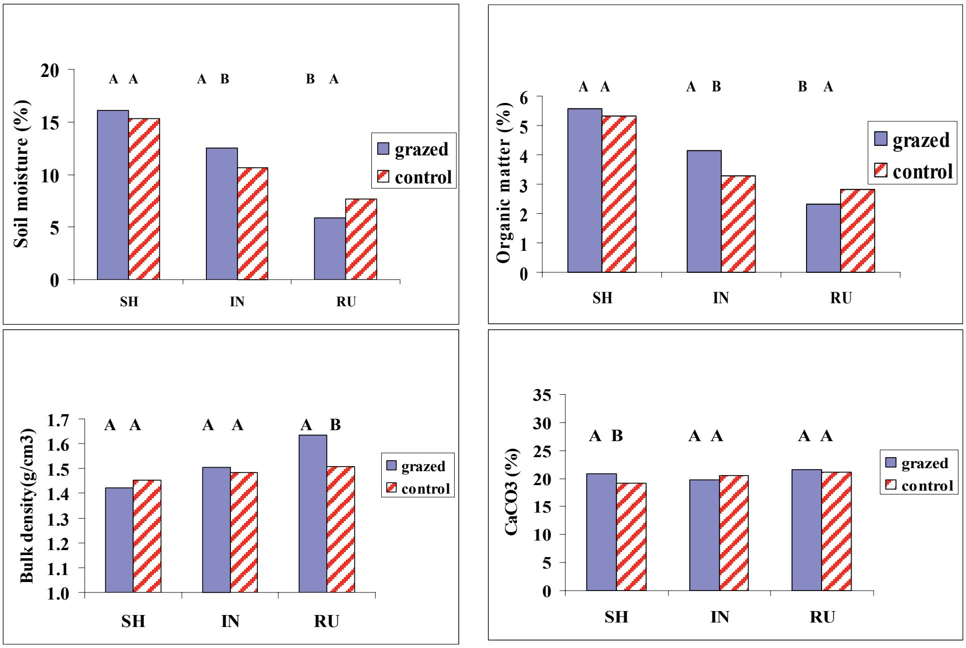

Figure 1: Soil properties in grazed and control areas for the different surface cover types, in 0-2 cm depth. The values represent both the northern and southern hillsides. For each surface cover type different letters indicate significant differences between the grazed and control areas at a 0.05 probability level.

Overland flow and sediment yield

Overland flow and sediment yield were higher on the southern than on the northern hillside. Whereas the shrub area exhibited the lowest overland flow (Figure 2) and sediment yield (Figure 3), the trampling routes were usually at the other end of the scale. In the remainder of the intershrub areas, intermediate values were found. Grazing significantly increased overland flow and sediment yield on the southern hillside.

In both grazed and control areas sediment yield was the lowest under the shrubs.

In grazed areas, for each surface cover type, sediment yield was greater than that in the control.

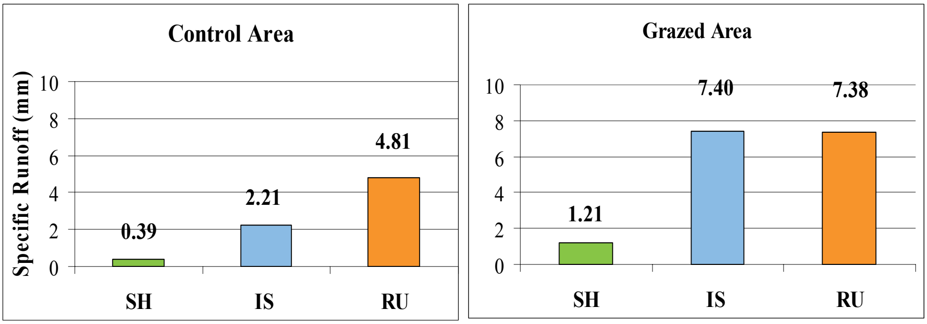

Figure 2: Runoff yield in the different surface cover types in grazed and control areas. Southern hillside, winter 2007/8.

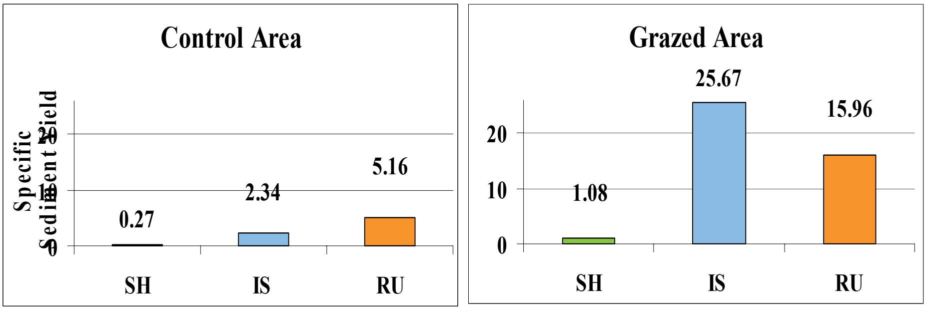

Figure 3: Sediment yield in the different surface cover types in grazed and control areas. Southern hillside, winter 2007/8.

CONCLUSIONS

A hierarchical structure exists in semi-arid eco-geomorphic systems: the soil properties (first layer) are associated with the vegetation cover types (second layer), and these affect runoff and sediment yield (third layer). In rangelands this "web" pattern encourages regulation of the redistribution of resources on the hillside by changing the surface cover type.

The presence of livestock creates a network of trampling routes. The soil characteristics and hydrological response of these routes differ from those of the remainder of the intershrub area. This means that the trampling routes play an important role in ecosystem functioning.

Grazing increases the spatial heterogeneity and amounts of overland flow and sediment yield, and intensifies source-sink relations. Such non-trophic effects are readily subsumed within the definition of an ecosystem engineer: an organism that regulates the productivity of other organisms by controlling their resource supply or by modifying their habitat.

As the impact of grazing, through its creation of source areas, overland flow and erosion, is higher on the southern than on the northern aspect, the former hillsides are more fragile than the latter.