A Case Study of Energy, Water and Soil Flow Chains in an Arid Ecosystem

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Abstract. Little attention has been directed to the study of soil flow and the complex relationships among energy water and soil flow in terrestrial ecosystems. Soil plays an important role in arid ecosystems. After water soil is the second key factor in the development of an arid ecosystem, since soil is the only part of the system capable of absorbing and storing water and nutrients during the hot and long summer period. The present work presents a case study of an ecological soil flow chain in an arid environment and analyses the relationship between this chain and the energy and water flow chains. The study was conducted at the Sde Boqer experiment site located in the northern Negev of Israel where average annual rainfall is 92 mm. Data collected during five consecutive years show that the soil movement process within the ecosystem studied cannot be considered as a purely physical phenomenon, but rather as a part of a complex system in which the burrowing and digging activity of Isopods and Porcupines plays an important role by providing disaggregated soil particles easy to remove by shallow flows. Although controlled by the spatial distribution of soil moisture the biological activity acts as a regulator of soil depth and thus of soil moisture. If this regulating role is deleted from the system a new ecosystem, more arid, can be expected to develop. It is therefore concluded that the study of state and flow variables of an arid ecosystem should consider altogether the water, soil, energy and mineral chains.

1 Introduction

Numerous recent studies deal with flow of energy and of minerals in ecosystems. The study of energy flow (Lindeman 1942; Odum 1957; Golley 1960) deals with the conversion of solar energy to organic matter by the producers and the transformation of the energy to the consumers and decomposers. The mineral flow studies are concerned with the movement of minerals from the abiotic elements to the biotic and vice versa (Cole et al. 1967; Likens and Bormann 1972; Burton and Likens 1975; Gosz et al. 1976). Except for some notable exceptions (Abaturov 1972; Lofty 1974; Russek 1975), little attention has been directed to the study of soil flow and the complex relationships among energy, water and soil flow in terrestrial ecosystems. The inclusion of soil flow in the study of ecosystems is of great importance, especially in arid areas. After water, soil is the second key factor in the development of an arid ecosystem, since soil is the only part of the system capable of absorbing and storing water and nutrients for long periods. In the absence of sufficient soil, few higher plants can become established. Therefore, the input, output and the flow of the soil through processes of soil erosion and deposition must be considered as part of ecological flow chains. (In this study an ecological flow chain is defined as the flow of matter and/or energy controlled by biotic and abiotic elements.) Of particular interest are the spatial distribution of soil, its depth and its salt content. The latter indirectly influences the water holding capacity of the soils which, in an arid environment, controls the spatial distribution of plants and burrowing animals (Yair 1978). The activity of burrowing and digging animals contributes to the soil turnover within the physical structure of the ecosystem. Therefore, the study of the soil flow chain may contribute to current research on the role of consumer populations as regulators in the total ecosystem function (Kitchell et al. 1979).

The main purpose of the present paper is to present a case study of an ecological soil flow chain in an arid environment and to analyze the relationships between this chain and the energy and water flow chains. Special attention will be accorded to the spatial variability over limited areas of rainfall, runoff, soil moisture and their influence on the spatial distribution of soil turnover by animal activity, namely isopods and porcupines. The assumed relationships between the abiotic and biotic factors in the soil flow chain in the ecosystem under study are presented in Fig. 1.

![Fig. 1. Assumed relationships among abiotic and biotic variables in the soil flow chain in the Northern Negev Desert ecosystem](image-url)
2 The Study Area

2.1 Climate

The study area is located in the northern Negev, some 40 km south of Beer Sheva (Fig. 2), at an altitude of 510 m. Average annual rainfall recorded over 30 years is 92 mm, with extreme values of 34 mm and 167 mm. Mean monthly temperatures vary from 9°C in January to 25°C in August. Average daily relative humidity attains 60-70% in winter-time and 40-50% during the hot summer months.

2.2 Topography, Geology and Soil Cover

The study area was limited to the north-facing hillside of a first order drainage basin, extending on one side of the channel (Fig. 2). The relative relief is 30 m. Length of slopes varies from 55 m to 76 m and mean slope gradient varies from 12% to 29.5%. The site extends over an area of 11,325 m². The local stratigraphy is Turonian, represented by the Drorim, Shivta and Netzer formations. Although the three formations are mainly composed of limestone rock (Arkin and Braun 1965), they create completely different environments. Rock strata of the Drorim formation are 10-30 cm thick and very densely jointed. The rock weathers into cobbles and boulders which cover most of the surface. The middle and lower parts of the slopes are covered by an extensive stony colluvial soil whose thickness at the slope base exceeds 250 cm. It is a desert brown loessial serozem (Dan et al. 1972). Repetitive wetting and drying cycles have produced a compacted topsoil crust. Vegetation covers 5-10% of the area and is quite uniformly spread. The characteristic plant association is that of Artemisia herba alba-Gymnocarpos decander (Danin 1972; Yair and Danin 1980).

The Shivta formation is a massive crystalline limestone. Stratum thickness is 30-80 cm forming a stepped topography. Jointing is spaced and bedrock is exposed over 60-80% of the surface. Soil material is found in two different adjoining environments (Fig. 3): (1) non-contiguous soil strips located at the base of bedrock steps; (2) joints and bedding planes of the surficial rock strata. The vegetation...