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Heterogeneity in Arid and Semiarid Lands

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Abstract

Spatial heterogeneity is a hallmark of vegetation patterns in arid and semiarid landscapes. First observed in terms of the spatial array of vegetation patches, spatial heterogeneity is now more broadly interpreted as the cumulative outcome of the processes affecting the spatial and temporal distribution of vital resources such as water, topsoil organic matter, and propagules individually and collectively. Spatial resource redistribution is shown to be important at a variety of scales varying from millimetres to hundreds of metres and beyond and can be conveniently studied as a nested spatial hierarchy. The processes by which heterogeneous resource distribution arises are a mixture of physical and biological and can be represented by an information-structuring conceptual framework, which is described. Heterogeneity is crucial to the functioning of arid and semiarid lands, and changes in the scale of heterogeneity can be used to study and understand the processes underlying desertification and rehabilitation. Models of heterogeneous landscapes in semiarid landscapes have had two broad themes: a pragmatic approach, describing ecosystem function in landscapes under management, and a curiosity-driven approach, speculating about the *de novo* development of landscape heterogeneity.

Introduction

The spatial heterogeneity of natural vegetation at broad scale in arid and semiarid lands began to be noted when people were able to view landscapes from aircraft (Gillett, 1941). Pattern had previously been difficult to identify on the ground in arid lands, due to the scale at which pattern elements were expressed and uncertainty as to whether heterogeneity was natural or due to adverse management. The great expansion of systematic aerial photographic surveys in the 1950s revealed the spatial extent, globally, of natural vegetation patterns of a distinctly geometric type (Macfayden 1950; Clos-Arceduc 1956; Greenwood 1957; Litchfield and Mabbutt 1962; Slatyer 1961;

Boaler and Hodge 1964; White 1969). These overtly patterned lands were a curiosity, and much of the early literature speculated about their origins and dynamics. Some writers saw these lands as the result of degradation from a formerly uniform cover of vegetation, due to adverse landscape use in historical times (Hemming 1965; Wickens and Collier 1971). Others suggested that the pattern was caused by climatic shifts during the Holocene (Clos-Arceduc 1956; Boaler and Hodge 1964). Biotic causes such as the slumping of termite mounds were suggested (Macfayden 1950). The most enduring proposals suggested geomorphic processes (Litchfield and Mabbutt 1962; Cornet et al. 1988).

Vegetation patchiness continues to have interest for ecologists in new locations and different spatial manifestations; for example, in the United States, Archer (1990); the Serengeti, Belsky (1995); in Mexico, Montana (1992); and Argentina, Aguiar and Sala (1999).

Functional Heterogeneity: Linking Heterogeneity to Differential Soil Water Availability

The early publications were entirely descriptive and largely focused on speculation about the reasons behind the spatial disposition of vascular plants. However, it was not long before the role of rainfall in arid and semiarid lands was recognized as the primary driver of the pattern. Slatyer (1961) studied the overall water economy of a patterned landscape in central Australia and showed that water accession and capture into *Acacia* groves from bare soil intergroves was very high and, several days after rainfall, evaporation from the soil in the grove ceased and water loss thereafter was purely from transpiration, indicating high water use efficiency. This work was probably the first to propose the concept of the role of the temporal and spatial dynamics of water supply to patterned lands with empirical data. Slatyer (1961) measured the capture of rainfall by foliage and the channeling of water into the soil at the foot of the tree as well as measuring water runoff from bare, crusted soils upslope of the tree grove. This work needs to be seen as the foundation of the adoption of runoff/run-on processes as the primary explanatory tool in understanding landscape function in arid lands. More recent key work by Valentin and Bresson (1992) on the nature and formation of a variety of soil physical crusts on the interpatch zone has been crucial in explaining water runoff and run-on characteristics.

Rainfall in arid and semiarid lands is low by definition but in addition is typically unpredictable in timing and amount. Table 10.1 shows how skewed the quantity of rain is per event in a typical semiarid landscape. There are many, very small rainfall events that are ineffective for vascular plant growth, so for the survival and persistence of plants in these landscapes, we