
Dealing with Scale in Landscape Analysis: An Overview

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I. SCALE AND SCALING

Scale is an essential concept in both natural and social sciences, and has been defined in several different ways (Gibson et al. [4], van Gardingen [19], Peterson and Parker [16], Marceau [12], Withers and Meentemeyer [21], Jenerette and Wu [6]). In landscape ecology, scale refers primarily to grain (or resolution) and extent in space or/and time. Scale may be absolute (measured in spatial or time units) or relative (denoted as a ratio). Scale may be the observer's measuring stick or viewing window size, a spatial or temporal characteristic of an ecological pattern or process, or a fundamental framework in which diverse ecological phenomena can be more effectively studied and understood individually and collectively. Scaling, on the other hand, is usually defined as the process of extrapolating or translating information from one scale to another, including scaling up and scaling down (Caldwell et al. [3], King [8], Wu [24]). Scale and scaling have become buzzwords in ecology in recent years as the research emphasis of the field has shifted from local to increasingly broader scales. This research emphasis shift is inevitable for at least two reasons. First, it has become evident that most if not all environmental and resource management problems can only be dealt with effectively at broad scales. The second and more profound reason is that ecologists are now acutely aware that, in order to unravel how nature works, we must understand broad-scale patterns and processes and relate them to those at fine scales with which we are most familiar. In both cases, transferring information between scales is indispensable.

II. LANDSCAPE AND LANDSCAPE ECOLOGY

Landscapes are spatially heterogeneous areas and often manifest themselves as mosaics of patches with varying size, shape, composition, and history. They may be as large as thousands of square kilometers or as small as tens of square meters if landscapes are defined according to organisms or ecological processes under consideration. However, human-scale landscapes that span over tens or hundreds of square ki-

lometers are more familiar and convenient to us, and often are relevant geographic domains for dealing with many ecological and environmental issues. But, many have argued that fixing the spatial dimension of landscape at a particular size is arbitrary, and may impede rather than facilitate the development of landscape ecology as a science (see Allen and Hoestra [2], Wiens and Moss [20]). Although landscape ecologists still can not agree on the spatial dimension of the very object they study, they do converge on the most essential feature of a landscape: spatial heterogeneity. They also tend to agree that spatial heterogeneity exhibits different patterns at different scales, and that organisms and ecological processes with distinctive characteristic scales respond to spatial heterogeneity at different scales. This means that the same landscape is heterogeneous to certain organisms or ecological processes, but not to others because of their distinctive abilities to perceive and filter spatial information.

Landscape ecology is simply the study of relationship between spatial pattern and ecological processes over a range of spatial scales (Pickett and Cadenasso [17]). Because of the scale multiplicity in spatial pattern and ecological processes, scale holds the key to understanding the pattern-process interactions and, indeed, becomes one of the corner-stone concepts in landscape ecology. The existence of scale multiplicity in patterns and processes in landscapes has naturally resulted in the hierarchical perspective in landscape ecology (Urban et al. [18], O'Neill et al. [14], Wu and Levin [22]). Hierarchy theory provides a conceptual framework for investigating and explaining the multiple-scale patterns and processes, and has contributed substantially to our understanding of ecological scale (O'Neill [15]). Because a landscape usually is composed of smaller "landscapes nested in larger landscapes" (Allen and Hoestra [2]), or a hierarchical patch dynamic mosaic (Wu and Loucks [23]), scale and hierarchy are inevitably related in landscape ecological studies.