23
Dynamic Terrestrial Ecosystem Patterns and Processes

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23.1 Introduction

Ecological assessments often begin with the inventory of a site’s biological resources and culminate in the generation of a static, two-dimensional map or other fixed report of present site conditions. Using this approach, we may fail to appreciate the short- and long-term dynamics of the populations and ecosystems that we are assessing. Spatial and temporal dynamics of patterns and processes are important to consider for at least three reasons. First, the very resources we assess may be changing, with consequences for the conclusions of the assessment itself. Second, the dynamics have implications for whether and under what conditions the populations and ecosystems are sustainable on the site of interest. Finally, key processes may occur at broader spatial scales or on longer temporal scales than we would otherwise consider in the assessment; that is, the populations and communities at one site may be attributed in part to the spatial context surrounding that site or the occurrence of rare past events. In essence, the processes responsible for the biological resources on the site may themselves not be contained within the site being assessed, and the resources may not be in balance with current site processes. Overlooking the effects of dynamic patterns and processes can therefore lead to misinterpretations of observations and erroneous conclusions concerning a given site’s condition and functional nature.

Ecosystem dynamics can encompass a broad spectrum of phenomena, including global climate change, succession, exotic invasions, and episodic disturbances. These phenomena can be classified into three general categories. Gradual changes in the environment, such as climate change or long-term geomorphic and soil development, occur at broad scales and over very long time periods. Disturbances are relatively discrete, disruptive events and may include fires, floods, storms, wind, ice, droughts, freezes, and disease. Natural periodicities, such as seasonal variations and semiperiodic environmental fluctuations like those caused by the Southern Oscillation, include annual hydrologic cycles and regular temperature- and solar radiation-dependent fluctuations (DeAngelis and White, 1994) (Figure 23.1). These three classes of ecosystem dynamics readily interact with one another; global warming, for example, may alter the hydrologic cycle, and seasonal wet or dry periods influence the probability of droughts, floods, or fire events. Often, the immediate effects of both gradual environmental change and natural periodicities (e.g., changes in precipitation caused by the Southern Oscillation) are disturbances to the existing ecosystem. In this chapter, we focus on disturbances as the prime agents of change in dynamic pattern; natural periodicities and gradual changes occur on such a broad scale that they are beyond the scope of most assessment efforts.

Disturbance regimes are part of a more general group of agents of pattern formation that also includes the biophysical template (e.g., physical landform constraints, precipitation patterns, and substrate conditions) and biotic processes (e.g., dispersal, colonization, extinction and other demographic processes) (Urban et al., 1987; Bourgeron and Jensen, 1994). By altering the availability of space and resources and creating patchy environments, disturbances play a particularly critical role in the determination of landscape pattern and in the development of ecosystem composition, structure, and function.

Disturbances are also important in maintaining biological diversity. A site’s ecological attributes result from the way disturbances interact with environmental gradients, substrates, and topography.
23.2 Definition of Terrestrial Dynamic Pattern

Terrestrial dynamic pattern refers to the arrangement and distribution of biotic and abiotic phenomena. The two major components of landscape pattern include composition (the variety of patch types) and configuration (position and orientation of patches). The myriad pattern descriptors include size, shape, orientation, and edge-to-area ratio (or patch shape index) of individual patches; distance between patches; and patch density, patch diversity, patch connectivity, and patch contiguity (Forman, 1995). Pattern in the landscape is generated by various biotic and abiotic processes operating at various scales (Urban et al., 1987). The driving forces behind pattern are complex. They include not only the formative processes themselves, but also interactions among processes and a feedback effect of pattern on process, wherein pattern itself may act as an environmental constraint to disturbance events and biotic processes. It is this dynamic nature of pattern that we are attempting to characterize and understand in assessing landscape dynamics.

Terrestrial patterns with which we are familiar include the distribution of vegetation communities, such as the distinct transition from mixed hardwood