24
Conceptual Frameworks: Plan for a Half-Built House

Gary M. Lovett, Clive G. Jones, Monica G. Turner, and Kathleen C. Weathers

Abstract

The consideration of spatial heterogeneity in ecosystem science is a challenging problem both empirically and conceptually. Although conceptual frameworks have been developed for some aspects of the problem, there is as yet no overarching framework that links them together. In this paper, we review many of the conceptual frameworks used in the chapters of this book. We discuss how the ecosystem concept can be extended to the "landscape system." Like the ecosystem, the landscape system must have defined boundaries so that inputs and outputs can be distinguished from internal circulation. Given the delineation of the landscape system and its component ecosystems, a series of questions is posed that allow the investigator to determine what aspects of heterogeneity are likely to be important and what kind of model (homogeneous, mosaic, or interactive) most appropriately captures the behavior of the system.

Conceptual Frameworks

One of the principal goals of this book is to advance the development of conceptual frameworks for consideration of spatial heterogeneity in ecosystem science. In science, conceptual frameworks provide an intellectual structure on which to hang empirical observations and hypotheses, and within which to design empirical studies (Pickett et al. 1994). Like the joists and rafters of a wood-frame house, the conceptual framework provides the bounds and constraints for the structure within. The construction of a house usually starts with an architectural plan, but science rarely proceeds that way because the form of the completed structure is not known when the building begins. It appears that the house for spatial heterogeneity and ecosystem processes has some well constructed rooms, almost ready to live in; a few rooms with bare framing where the wind still whistles through; and some empty spaces where no structure is yet apparent. Our purpose in this

chapter is to provide a plan that will at least show how the rooms fit together and to begin constructing a roof that will encompass them all.

With many types of entities (e.g., mass, energy, information, organisms) moving simultaneously within and between ecosystems, and many different ecosystems juxtaposed in a landscape, incorporating spatial heterogeneity into an understanding of ecosystem function can get exceedingly complex. One way to simplify is to search for pattern in the spatial heterogeneity that can inform us about important processes. This approach is discussed by White and Brown (Chapter 3), Pastor (Chapter 4), Tongway and Ludwig (Chapter 10), and Meinders and van Breemen (Chapter 11), among others. This approach is particularly appealing to the mathematically inclined, because pattern lends itself to mathematical description. But not all spatial heterogeneity generates recognizable patterns, so this approach, while valuable, has limitations. Another simplifying approach is the use of probabilistic models, where heterogeneity is expressed as a statistical distribution (see Tague, Chapter 7; Band et al., Chapter 13). This is a useful shortcut for some applications but does not allow explicit spatial interactions between ecosystems within a landscape, so it cannot shed any light on the potential importance of configurational heterogeneity. Our instincts as ecologists often tell us that much of the heterogeneity we observe is noise that is not important to the overall functioning of the ecosystem. Parsimony tells us that we should use simple models until they are proven inadequate, and economy tells us we cannot afford to measure all the heterogeneity in every property of an ecosystem (Smith, Chapter 8; Strayer, Chapter 20). So, the central question is, when do we need to deal with all this heterogeneity and when can we safely ignore it?

Strayer (Chapter 20) answers this question directly by proposing four situations in which it might be acceptable, or even wise, to ignore spatial heterogeneity: when the heterogeneity is unimportant functionally, when it is at too small a scale to be appropriate for the analysis, when it is not parsimonious scientifically (i.e., a simpler model yields adequate accuracy), or when it is not cost-effective (i.e., even if a simpler model doesn't work as well, it is all you can afford). Other chapters of this book and other recent publications provide conceptual models that can help ecologists understand how heterogeneity might be important in their study systems and how to deal with it if it is. For instance, the simple scheme proposed by Shugart (1998) to divide spatial models into homogeneous, mosaic, and interactive approaches has been very useful (see Turner and Chapin, Chapter 2; Lovett et al., Chapter 1). Turner and Chapin (Chapter 2) describe an important distinction between what they term "point" processes, for which horizontal fluxes among ecosystems on a landscape are unimportant, and "lateral" processes, for which they are important. Reiners (Chapter 5) discusses a related conceptual framework that has been extensively developed—the factors that regulate transport within heterogeneous environmental space. He analyzes the factors that control the rate and extent of propagation of mass, energy, and information in the environment. Steinman and Denning (Chapter 18) discuss a framework in which the service or function desired of the ecosystem determines what aspects of heterogeneity are likely to