Introduction to Landscape Ecology

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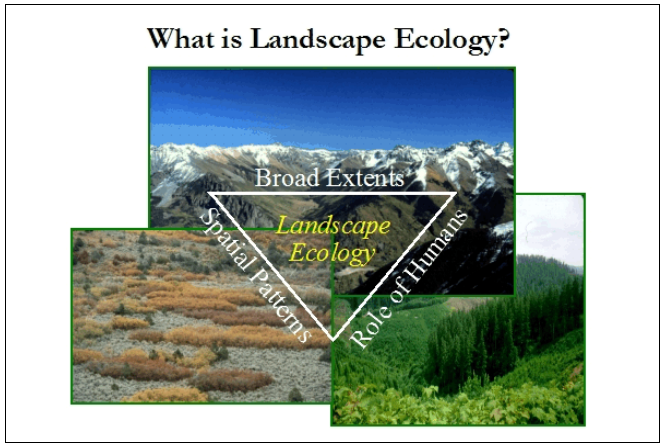
Disclaimer: Some of the material in this document was borrowed from Turner et al. (2001) and Dean Urban's Landscape Ecology course notes, Duke University.

What is Landscape Ecology?

Landscape ecology, as the name implies, is the study of landscapes; specifically, the composition, structure and function of landscapes. But what's a 'landscape'? Although there are myriad ways to define 'landscape' depending on the phenomenon under consideration, suffice it to say that a landscape is not necessarily defined by its size; rather, it is defined by an interacting mosaic of elements (e.g., ecosystems) relevant to some phenomenon under consideration (at any scale). Thus, a landscape is simply an area of land (at any scale) containing an interesting pattern that affects and is affected by an ecological process of interest. Landscape ecology, then, involves the study of these landscape patterns, the interactions among the elements of this pattern, and how these patterns and interactions change over time. In addition, landscape ecology involves the application of these principles in the formulation and solving of real-world problems.

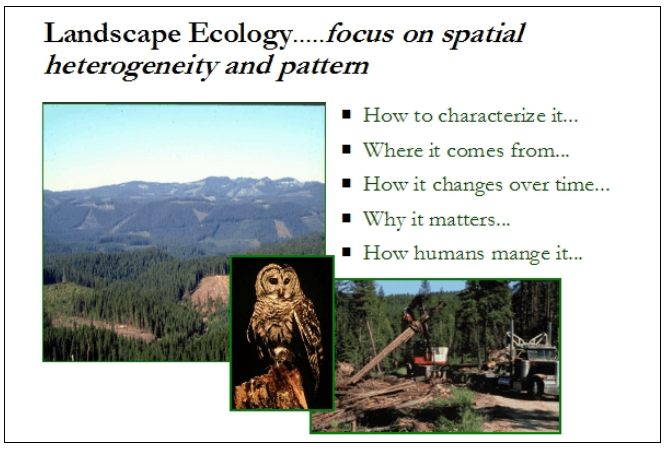


Landscape ecology is perhaps best distinguished by its focus on: 1) spatial heterogeneity, 2) broader spatial extents than those traditionally studied in ecology, and 3) the role of humans in creating and affecting landscape patterns and process.

- **Spatial Heterogeneity**

Landscape ecology might be defined best by its focus on spatial heterogeneity and pattern: how to characterize it, where it comes from, how it changes through time, why it matters, and how humans manage it. As such, landscape ecology has five central themes:

- Detecting pattern and the scale at which it is expressed, and summarizing it quantitatively.
- Identifying and describing the agents of pattern formation, which include the

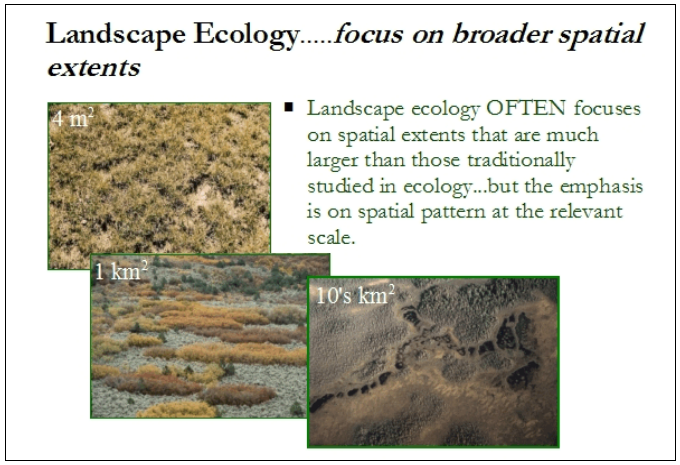


physical abiotic template, demographic responses to this template, and disturbance regimes overlaid on these.

- Characterizing the changes in pattern and process over space and time; that is, the dynamics of the landscape, and summarizing it quantitatively. An interest in landscape dynamics necessarily invokes models of some sort--because landscape are large and they change (usually!) over time scales that are difficult to embrace empirically.
- Understanding the ecological implications of pattern; that is, why it matters to populations, communities, and ecosystems – and this is the stuff of conservation biology and ecosystem management.
- Managing landscapes to achieve human objectives.

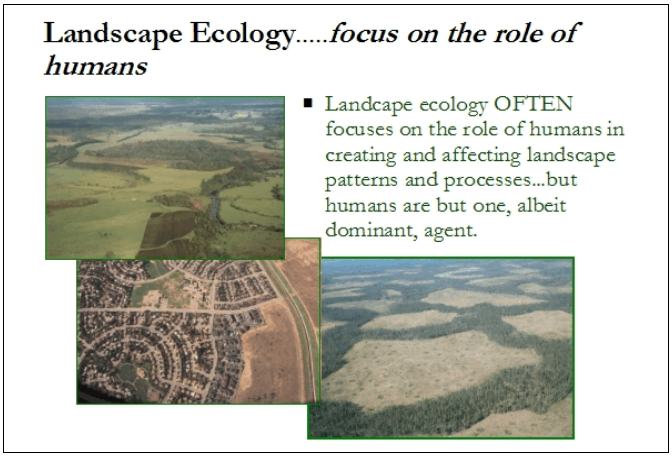
■ Broad Spatial Extents

Landscape ecology is distinguished by its focus on broader spatial extents than those traditionally studied in ecology. This stems from the anthropocentric origins of the discipline (see below). Initial impetus for the discipline came from the geographers aerial view of the environment, for example, the patterns in the environment visible from an aerial photograph. The focus on large geographic areas is consistent with how humans typically see the world–through a coarse lens. However, modern landscape ecology does not define, a priori, specific scales that may be universally applied; rather, the emphasis is to identify scales that best characterize relationships between spatial heterogeneity and the process of interest.



■ The Role of Humans

Landscape ecology is often defined by it focus on the role of humans in creating and affecting landscape patterns and process. Indeed, landscape ecology is sometimes considered to be an interdisciplinary science dealing with the interrelation between human society and its living environment. Hence, a great deal of landscape ecology deals with 'built' environments, where humans are the dominant force of landscape change. However, modern landscape ecology, with



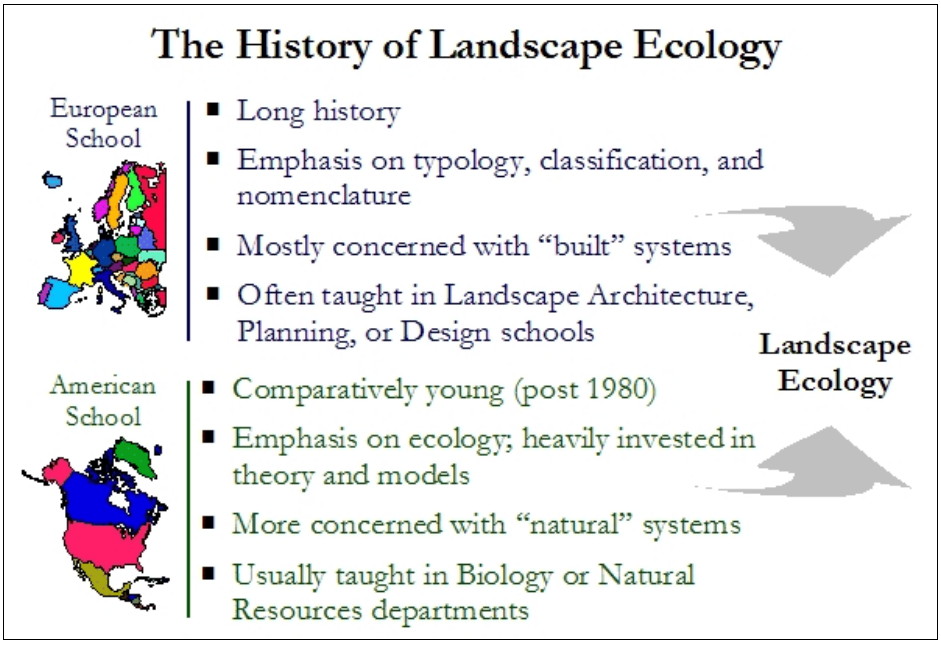
its emphasis on the interplay between spatial heterogeneity and ecological process, considers humans as one of many important agents affecting landscapes, and emphasizes both natural, semi-natural, and built landscapes.

History of Landscape Ecology

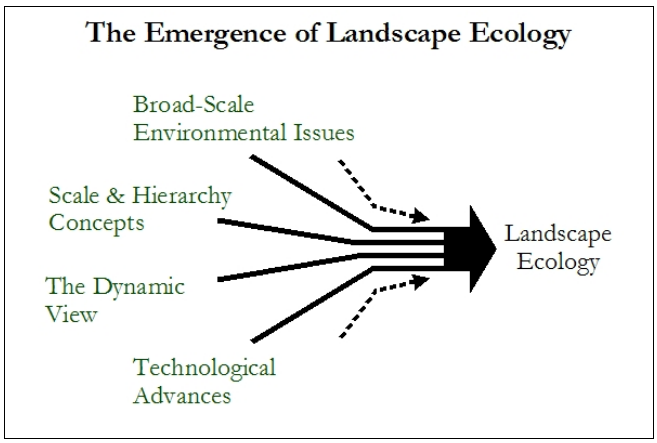
Landscape Ecology as a discipline has two evolutionary lines, which might be caricatured as the "European School" (which is also strongly represented in the United States and elsewhere), and the "American School" (which is also common in Australia and elsewhere).

- **The European school**
  - Very long history (as long as ecology itself, almost).
  - Emphasis on typology and classification and mostly is concerned with "built" systems.
  - In the U.S., it is found more often in Landscape Architecture, Planning, or Design schools than in Biology departments.

- **The American school**
  - Comparatively young, gaining a high profile in the U.S. only after the early 1980's.
  - Launched, for practical purposes, by a workshop at Allerton Park (Risser et al. 1984). This was a pivotal meeting because the meeting decided what landscape ecology was about: its intellectual domain (what would be considered "interesting") and the tools of the trade (officially sanctioned approaches).
  - In contrast to the European school, much more of a focus on natural systems (or at least, semi-natural ones such National Parks).
  - Is much more invested in theory and models, including some extremely abstract ones.

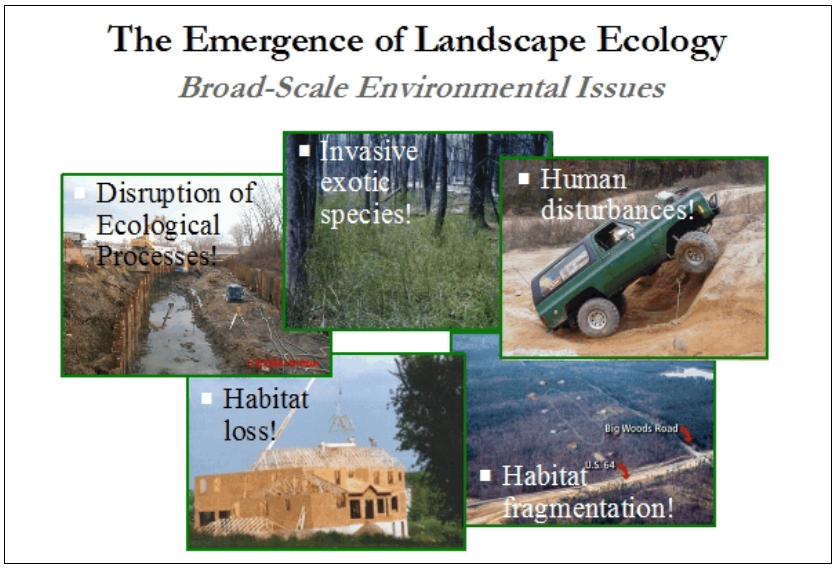


The emergence of landscape ecology as a prominent subdiscipline of ecology in the early 1980's can be traced to a number of factors: 1) growing awareness of broad-scale environmental issues requiring a landscape perspective, 2) increasing recognition of the importance of scale in studying and managing pattern-process relationships, 3) emergence of the dynamic view of ecosystems/landscapes, and 4) technological advances in remote sensing, computer hardware and software.



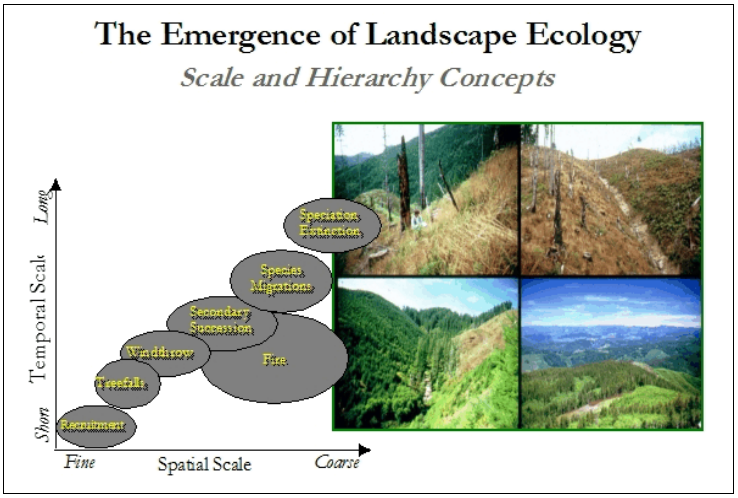
- **Broad-scale environmental issues**

Unrelenting demand for more and more commodities and services from global ecosystems has led to numerous ecological crises. Staggering losses of topsoil each year from many of America's farmlands demonstrate that these ecosystems are being exploited. Failure of certain tropical humid forests to rebound after clearcutting dramatically illustrates their vulnerability to radical disturbance. Equally compelling evidence of ecosystem limits is seen in the altered flooding regimes, increased suspended loads, chemical contamination, and community structure changes in virtually every temperate river in the world. The degradation of Earth's ecosystems is further signaled by the unprecedented decline of thousands of species, many of which have become extinct. Many of these crises are the result of cumulative impacts of land use changes occurring over broad spatial scales (i.e., landscapes). Questions of how to manage populations of native plants and animals over large areas as land use or climate changes, how to mediate the effects of habitat fragmentation or loss, how to plan for human settlement in areas that experience a particular natural disturbance regime, and how to reduce the deleterious effects of nonpoint source pollution in aquatic ecosystems all demand basic understanding and management solutions at landscape scales.



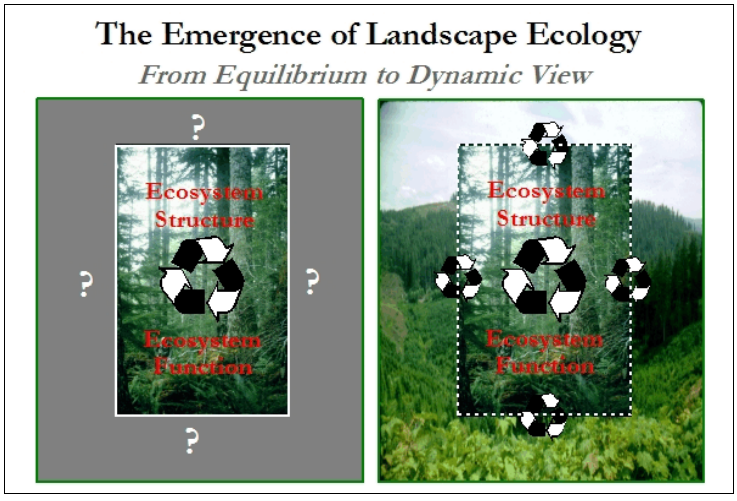
- **Concepts of scale**

Despite early attention to the effects of sample area on measurements, such as species-area relationships, the importance of scale was not widely recognized until the 1980's. Recognition that pattern-process relationships vary with scale demanded that ecologist give explicit consideration to scale in designing experiments and interpreting results. It became evident that different problems require different scales of study, and that most problems require multiple scales of study. The theory of scale and hierarchy emerged as a framework for dealing with scale. The emergence of scale and hierarchy theory provided a partial theoretical framework for understanding pattern-process relationships, which became the basis for the emergence of landscape ecology as a discipline.



- **Dynamic ecosystem view**

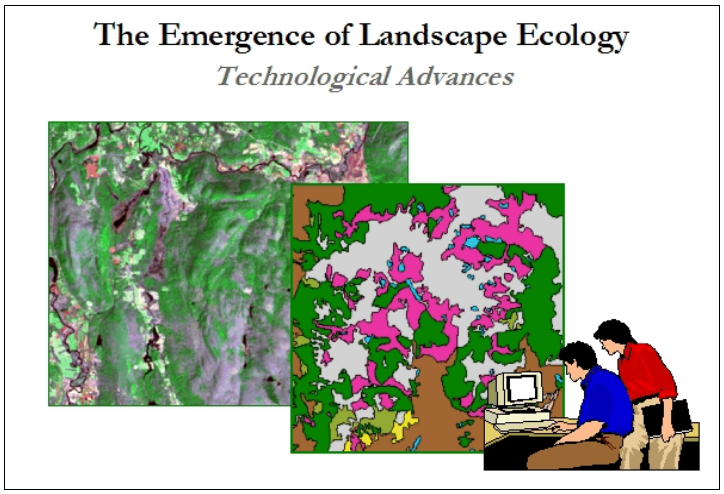
A major paradigm shift in ecology from the “equilibrium” view of ecosystems to a “dynamic” view occurred in the 1980's. Coupled with the view that ecosystems are dynamic, characterized more by their dynamics than by their tendency towards a stable equilibrium, is the notion that ecosystems are not isolated systems and cannot be understood without considering the flow of energy and material across ecosystem boundaries. This view of ecosystems as “open” systems required an understanding of how mosaics of ecosystems interact to effect ecosystem processes, and this led to the emergence of landscape ecology.



- **Technological advances**

Technological advances, in particular, rapid advances in computing power, availability of remotely sensed data such as satellite images, and development of powerful computer software packages called geographic information systems (GIS) for storing, manipulating, and displaying

spatial data, provided the tools for studying spatial patterns over broad spatial scales. Indeed, because landscapes are often large in extent, the use of computers and computer models are essential to studying their behavior. Technological advances since the 1980's has made possible the study of landscapes. The American school of landscape ecology, in particular, is heavily invested in the use of these technologies.

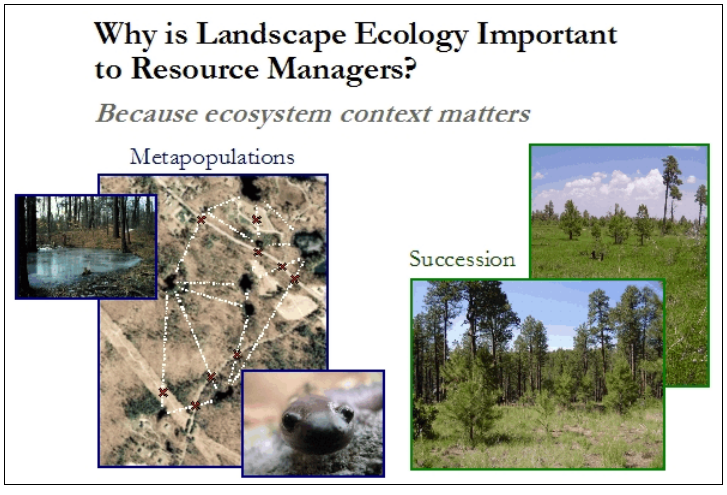


Why is landscape ecology important to resource managers?

Landscape ecology (or a landscape perspective) with its focus on spatial patterns is important to resource managers because: 1) ecosystem context matters, 2) ecosystem function depends on the interplay of pattern and process, and 3) because human activities can dramatically alter landscape context and the relationship between patterns and processes, resource managers have a stewardship responsibility to understand and manage these impacts – more pragmatically, resource managers have a policy and legal mandate to include a landscape perspective in resource management decisions.

- **Because ecosystem context matters**

Landscape ecology is founded on the principle that ecosystem composition, structure and function partially depend on the spatial (and temporal) context of the ecosystem (i.e., its landscape context); i.e., that what we observe ecologically at any particular location is affected by what is around that location. This shift in perspective from the site to the site embedded in a landscape context has profound implications for resource management. Let's consider a couple of examples:



- *Metapopulations*.–Metapopulations depend on the number and spatial arrangement of habitat patches – where the probability of a habitat patch being occupied at any time is at least partially dependent on its proximity to other habitat patches. Focusing

management on the individual site, in this case, without consideration of its landscape context, can have disastrous consequences for the population.

- *Forest succession*.–Neighborhood effects can play an important role in determining the successional response following a disturbance. For example, edge effects that modify the distribution of energy and water and the plant species composition of the immediate neighborhood (which can influence the relative abundance of propagules) can exert a strong influence on succession in forest gaps and in larger openings, e.g., via wave-form succession. Ignoring these effects can lead to undesirable outcomes, including an unwanted shift in species composition or an inadequate recovery of vegetation altogether.

■ **Because ecosystem function depends on the interplay of pattern and process**

Landscape ecology is also founded on the principle that spatial patterns affect ecological processes, which in turn affect spatial patterns. This interplay of spatial pattern and process is in fact the overarching focus of landscape ecology. While it can be argued that "ecology" has always sought to explain the relationship between pattern and process, it is safe to assert that "landscape" ecology has shifted the focus to pattern-process relationships over *broad spatial extents* and emphasized the *role of humans* in creating and affecting these relationships. This shift has profound implications for resource managers. Let's consider a couple of examples:

- *Habitat fragmentation*. –Disruption of habitat connectivity is a major impact of human activities on plant and animal populations and one of the leading causes of the biodiversity crisis. Anthropogenic landscape elements (e.g., roads, developed land, dams) can function as impediments to the movement of organisms across the landscape, and the cumulative impacts of these impediments over broad spatial extents can be devastating.

- *Alteration of disturbance regimes*.–Disruption of natural disturbance regimes has long-lasting ecological and socio-economic impacts. For example, disruption of fuel mass and continuity by human land use practices (e.g., livestock grazing) over broad spatial extents can dramatically alter fire regimes in fire-dependent ecosystems, leading to shifts species distributions and community structure and serious socio-economic consequences (e.g., catastrophic fires resulting in loss of life and property).

- **Because there is a policy and legal mandate to include a landscape perspective**

Lastly, and more pragmatically, there is a policy and legal mandate to include a landscape perspective into resource management decisions. All federal land management agencies have formally adopted "ecosystem management" as the overarching resource management paradigm, and a landscape perspective (and all that it subsumes) is one of the pillars of the ecosystem management approach. More specifically, and more tangibly, a landscape perspective plays a critical role in the 2005 Forest Service Planning Rule (36 CFR Part 219) and the subsequent regulations to implement that rule.

A Few Key References

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