MEASURING LANDSCAPES

A Planner's Handbook

André Botequilha Leitão, Joseph Miller,
Jack Ahern, and Kevin McGarigal

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André Botequilha Leitão dedicates this book to
Fernando H.D.O. Muge, Associate Professor with Aggregation
of Instituto Superior Técnico (IST), Technical University of Lisbon
who had a decisive influence in his academic career,
and for his friendship over many years.

Foreword

Land planning often resembles a multi-legged stool, with each leg a major goal and its thickness determined by the planner's expertise and perspective. A three-legged stool is also common, for instance, reflecting economics, social pattern, and environment. Alas, too often such approaches are strongly anthropocentric with natural systems receiving superficial attention. In contrast, consider mimicking a seesaw on the playground. Too much weight on either side brings unhappiness. The only stable point balances both sides . . . effectively integrating land and people, nature and humans, or culture and ecology.

Consider the vision: mold the land so nature and people both thrive long-term. Frederick Law Olmsted and other planning pioneers brilliantly knit people and nature together in large visible solutions that achieved top grades in the test of time. Not surprisingly, attempting to substitute short-term economics or public policy for the longer-term ecology produces results that fail the test.

Planning and design are normally considered "good," and done by optimists to help society. Objects are arranged at any scale, from continent or region to backyard or vase. Lack of planning generally leads to unsuitable spaces, such as fishing spots that become polluted, building sites that flood, and wildlife reserves cut off by busy highways. But a completely designed place seems sterile, controlled, boring. So, how much of the land should be planned, or designed? I'd say: "Plan most of the land at a broad scale, then design key places within it, and let the interplay of nature and people create the rest in ways that they both thrive."

The gaping lacuna in wise planning is not more knowledge, but rather the scarcity of accessible, informative and (especially) compelling syntheses and handbooks. The authors, from ecology, landscape architecture, and land-use planning, are experts in spatial pattern and landscape metrics, and have blended their expertise into this handy, readable book. Hopefully analogous collaborations will proliferate, with the land around us being the big beneficiary.

The authors highlight the importance of absorbing landscape ecology principles and then applying them in spatial planning. That has been, and is, exactly the growing success story in strengthening forestry (e.g., watershed management), biological conservation (rare species protection), transportation (road ecology), and wildlife management.

Landscape metrics, the measures of spatial pattern, are indicators of many human and natural conditions on land, from built-area patterns and built-system flows to the big three habitat issues: loss, degradation, and fragmentation. The pages ahead lucidly portray landscape metrics and their application, effectively sorting a large number in the literature down to a core set of ten. Both opportunities and caveats are explained. For the first time this scientific area is made available and readable.

Landscape structure is a key indicator of how the land works for people and for nature. Thus, changing landscape pattern emerges as a convenient "handle" for planners, and for each of us, to improve the planet. Over years, scholars will study the effects of landscape structure on function. But, over minutes and weeks, planners can and must help guide society by highlighting specific salutary changes in landscape structure. In effect, landscape metrics represent a "pre-handle," or primer, for the planners' handle for change.

Finally, what would you say if asked to develop a long-range plan that strengthens both natural systems and their human uses for the region around a growing major city? Give me funds and a couple of years to collect much-needed information? The Chief Architect/Planner for the Mayor of Barcelona visited me and posed the basic question at our first encounter. He said the work should be based on the book, *Land Mosaics: The Ecology of Landscapes and Regions*,[1] and added powerfully: "We're wasting land!" I suspected that no comprehensive model or case study existed for the task, and knew that "the bulldozers are running," as my students often hear. After emphasizing that I was a scientist, not a planner, had barely been to Spain, and never in the Greater Barcelona Region, the only response was, "I can do that. I've never done such a plan but, based on landscape ecology, I can envision what it might look like." The project took fifteen months and opened many doors. Unique solutions resulted from meshing stated principles with spatial patterns on the land.[2]

The experience also made me see cities as the key expanding powerhouses across the land, affecting everything, and that the ecology and planning of urban regions is ready to emerge as one of the great challenges of history. For most people the urban region is beyond understanding and defies optimism. Yet outlining a spatial vision, where both

[1]Forman, R. T. T. 1995, Cambridge University Press, New York.

[2]Forman, R. T. T. 2004, *Mosaico territorial para la region metropolitana de Barcelona*, Editorial Gustavo Gili, Barcelona.

nature and people thrive long-term, may provide a promising, tractable trajectory for cities. Landscape ecology is the only central paradigm I can find for such a vision.

The pages in your hand reveal a rich array of insights and an important big-picture perspective. Planners and ecologists, and indeed all who think about changing the land, will be enriched by the exploration ahead.

January 2006
Richard T. T. Forman
Harvard University

Preface
The Need for Sustainable Planning

Sustainability is a powerful but hard-to-define concept that is addressed by many disciplines, including planning. Sustainable planning is a multidimensional activity, which aims to assure the viability of ecological, social, and economic systems. Many scientists believe that planning for conservation and the protection and appropriate use of land and natural resources is the overarching goal of landscape planning (Forman 1995). According to Van Lier (1998a, 81), "the notion to create more sustainable systems in the countryside has become a leading principle for all those scientists that are involved in planning future land uses." To some, sustainability is the major objective of any planning (Grossman and Bellot 1999).

From an ecological point of view, sustainability can be defined as the capacity of the earth to maintain and support life and to persist as a system (Franklin 1997). This concept is relevant globally as well as for smaller ecosystems (Jongman 1999). Sustainability involves the maintenance of spatial patterns of land cover types that are ecologically beneficial. The spatial dimension of planning for sustainability is strongly related to the interdependence of land uses, and to spatial processes such as fragmentation (Bryden 1994 cited in Van Lier 1998, 79).

Sustainability also recognizes the interdependencies between ecosystems and human culture. Therefore, sound planning cannot be achieved without due consideration of ecology. Ecology and planning share many common characteristics. Ecology is concerned with the functioning of systems and resources, and planning focuses on their use for human benefit. However, planning has only recently accepted ecological principles, and ecology has traditionally focused on the biophysical dimension where humans were viewed as separate from natural systems.

To plan an ecologically sound human habitat, it is essential for ecology to provide clear linkages to planning by explicitly addressing the spatial dimension and adopting a more anthropocentric perspective. Planning a landscape is inherently a spatial problem. Plans for watershed management, wildlife conservation, housing development, and public recreation all share a fundamental concern for the spatial component. Plans attempt to influence specific changes in the pattern of landscapes with particular consequences for ecosystem structure and function. For example, when new housing is built in a forested landscape, water flows and wildlife movements may be interrupted, and important habitats may be displaced.

Landscape as an Appropriate Unit to Plan for Sustainability

Due to the interdependencies of ecosystems, a planning approach is needed that examines a broad context: the landscape. An ecosystem's external linkages with the landscape are as important to proper functioning as the internal ecosystem environment (Odum 1989). Some even argue that landscape context is more important than content (Dramstad et al. 1996). This recognition of the importance of context supports a hierarchical or systems view in which landscapes are nested within larger regions and are themselves composed of lower-order ecosystems.

Landscape is arguably the optimal scale for sustainable land planning for two reasons. First, landscapes are usually large enough to contain many different ecosystems with enough redundancy in ecosystem composition, structure, and function to accommodate natural variability in the system while maintaining the flow of ecosystem goods and services. Second, landscape is consistent with the scale of human perception, decision making, and physical management (Forman 1995; Ahern 2002). Many conservation and land management organizations, both public and private, now view a landscape perspective as essential for sound resource management (Wallinger 1995; Wigley and Sweeney 1993 cited in Gustafson 1998, 144).

Landscape Ecology as an Integrative Science

Science needs to inform planning in a more effective way. Science is evolving to help society move towards a more sustainable condition (Lubchenco 1998 cited in Nassauer 1999, 131). The relatively new interdisciplinary science of landscape ecology is particularly well poised to address this challenge. In landscape ecology, human activities are considered an integral part of ecosystems, not a separate component. Landscape ecology addresses issues related to the understanding, analysis, planning, design and management of natural systems at the landscape and regional levels. A transdisciplinary perspective considers the principal landscape dimensions—spatial, temporal—as the nexus of nature and culture, and as a complex system (Tress and Tress 2001). New methods have been proposed to apply landscape ecological knowledge to landscape planning. Across the world, landscape ecology is beginning to provide a scientific basis for landscape and natural resource planning and management.

The Role of Landscape Metrics in Planning

Landscape ecology focuses on three main characteristics: structure, function, and change. Landscape ecology-based metrics quantify landscape structure or pattern. Structure relates to the composition and spatial distribution patterns of landscape elements: ecosystems, or, at a coarser level, land cover types (LCTs). For example, picture a map representing agricultural fields, forests, urban areas, roads, wetlands, lakes, ponds, and rivers. Structure has two dimensions. One dimension is composition: the number, type and extent of these elements without explicit consideration of their spatial distribution. For example, the number of LCTs and the proportion of each type are measures of landscape composition. The other dimension is configuration, which is the spatial character, arrangement, position, or orientation of landscape elements. For example, the distance from one pond to another, the shape and complexity of forest patches, and the clumpiness of landscape elements are measures of landscape configuration.

Some ecologists view landscape functions as the flows of animals, plants, energy, mineral nutrients, and water between landscape elements (Forman and Godron 1986; Forman 1995). For example, a river transporting dissolved nutrients from its headwaters downstream across a diverse landscape, a young animal dispersing across a landscape from its natal site, and the spread of wildfire disturbance across a landscape are all considered landscape functions. Besides the flow of water, rivers and streams serve as a transport media for dissolved nutrients and soil particles.

Landscape structure and function influence one another; when structure changes, functions change, and vice versa. Consider a stream located in an urban watershed. Imperviousness affects both the physical (channel stability and water quality) and biological (stream biodiversity) qualities of stream habitat (Center for Watershed Protection, 1998). In this case, the structure of the watershed, characterized by sizeable urban areas located upstream (size and location of urban areas), affects the downstream flow of water and nutrients (landscape function).

The need for flood control and navigational improvements in riverine systems also illustrates the relationship between landscape structure and function. Channelization causes drastic alteration and simplification of rivers, as opposed to the original, complex, meandrous, and remarkably self-organized structures of riparian corridors (Bell 1999, 156). River channelization causes serious disruptions of the natural functions of these hydrological systems by decreasing their capacity for storage, nutrient cycling, and riparian processes (Bell 1999).

When significant relationships between structural landscape features and ecological functions are established, landscape metrics-based approaches can constitute useful tools for planning. They can contribute to an understanding of ecological processes, allowing for the construction of models, and the comparative evaluation of planning alternatives. The establishment of relationships between landscape structure and function can help planners to predict the impacts of planned activities on ecological systems. By looking at landscape structure, planners can gain insights into landscape functioning in a holistic manner.

Landscape metrics measure the geometric properties of landscape elements, and their relative positions and distributions (composition and configuration). At this point one might ask, so what? How are metrics useful for planning? The answer lies at the core of landscape ecology in the fundamental relationships between landscape structure and function. Spatial structure influences ecological functions and processes, and is therefore highly relevant for landscape planning and management (Turner 1989; Ahern 1999). For example, there is strong empirical evidence that landscape structure has a close relationship with biodiversity (McGarigal and Marks 1995). These structure and function relationships help to anticipate the ecological consequences of plans and designs of the landscape, and ultimately help to make landscapes more sustainable.

A wide gap still exists between science and planning. Science in general, and ecology in particular, has developed much knowledge about the functioning of landscapes. However, only a small proportion of this information makes its way through the decision-making arenas where the future of landscapes is debated and decided (Rockwood 1995). Opdam et al. (2002) argue that planners do not use the current body of knowledge on species and landscapes and thus future landscape plans are not tested against criteria based on ecological processes. Planners simply do not have the knowledge or time required to put it into a form that they can apply (Meredith 1996 cited in Theobald et al. 2000, 36). In order for planners to use the existing science successfully, ecologists need to understand the goals of planners and design ecological research to produce both data and findings that are directly relevant to planning.

Planners should acquire an appropriate level of landscape ecological literacy and numeracy as a prerequisite to understanding the fundamental principles of landscape ecology (Ahern et al. 1999). This would provide planners with a conceptual basis for holistic, transdisciplinary planning of multifunctional landscapes of a total human ecosystem (Naveh 2001, Tress and Tress 2001). It is therefore crucial to improve the flow of information between science and planning. A way to help to bridge the gap is to develop tools for planning informed by landscape ecological principles that will help practitioners relate landscape patterns to both natural and cultural processes (Botequilha Leitão 2001).

Purpose and Organization of the Handbook

This handbook will introduce the ecological and spatial dimensions of sustainability and focus on a particular tool (landscape metrics) to support planning for sustainability. We provide linkages between the concepts and tools presented, which are derived from multidisciplinary literature and from professional practice.

This handbook aims to promote awareness, understanding, and application of landscape metrics by planners, and thus facilitate interdisciplinary communication and collaboration. This handbook is a primer designed to help planners acquaint themselves with landscape metrics and thus help promote more ecologically sustainable planning solutions. We emphasize the application of metrics by planners and managers of landscapes across a reasonable spectrum of resources. In any landscape we can recognize three principle types of resources: Abiotic, Biotic, and Cultural (ABC). These have been traditionally addressed in three discrete planning sectors: watershed planning and management, conservation planning, and urban and recreation planning. In the application examples provided in this handbook, we address each of these sectors from a holistic perspective.

Chapter one provides an introduction to landscape ecology and explains how to quantify landscape structure. Chapter two presents an overview of planning categories and stages, and describes how planning can relate to landscape ecology. It also identifies a core set of landscape metrics for planning, and introduces some technical issues and data models for mapping a landscape. Chapter three presents a selected set of ten metrics, each explained in terms of concept, metric equation and calculation, application(s), limitation(s), recommendations, related metrics, and selected references. Chapter four includes a broad application of landscape metrics to spatial planning, focusing on the three ABC resources: water (abiotic), biodiversity/wildlife (biotic), and human habitat (housing and recreation) (cultural). Chapter five provides a summary and conclusions.

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