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E&S HOME > VOL. 11, NO. 1 > ART. 34

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Synthesis, part of Special Feature on Urban Sprawl

Urban Landscapes and Sustainable Cities

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ABSTRACT

Ecological research targeting sustainable urban landscapes needs to include findings and methods from many lines of ecological research, such as the link between biodiversity and ecosystem function, the role of humans in ecosystems, landscape connectivity, and resilience. This paper reviews and highlights the importance of these issues for sustainable use of ecosystem services, which is argued to be one aspect of sustainable cities. The paper stresses the need to include social and economic factors when analyzing urban landscapes. Spatially explicit data can be used to assess the roles different green areas have in providing people with ecosystem services, and whether people actually have access to the services. Such data can also be used to assess connectivity and heterogeneity, both argued to be central for continuous, long-term provision of these services, and to determine the role urban form has for sustainability.

Key words: ecosystem function; landscape scale; sustainable development; urban ecology

INTRODUCTION

The rapid and worldwide urbanization of the human population raises concerns about the sustainability of cities. Sustainable development is a broad term generally thought to include equity, and economic and environmental concerns. As the Brundtland report states, sustainable development "...seeks to meet the needs and aspirations of the present without compromising the ability to meet those of the future" (United Nations World Commission on Environment and Development 1987). The issue is obviously subjective as it debates the way things ought to be and how we ought to live. Yet even so, there are some elements that should be included in any sustainability discourse, and the focus of this article is on one of them: functioning ecosystems. The article reviews and discusses the importance of ecosystems within cities and how cities can be analyzed as landscapes.

The word urban has a number of meanings related to a variety of conditions, such as population density, land cover, or cultural practices, with most authors using their own definition, or none (reviewed in McIntyre et al. 2000). Still, urbanization is something tangible that influences the environment, e.g., through increased air temperature and changed water cycles, and by altering ecological processes. In terms of shape rather than processes, urbanization results in an environment that is compositionally more heterogeneous, geometrically more complex, and ecologically more fragmented (Zhang et al. 2004), and may represent the most complex mosaic of vegetative land cover and multiple land uses of any landscape (Foresman et al. 1997). The roles of spatial heterogeneity and spatial/temporal scale are increasingly understood as essential for an understanding of ecological processes (e.g., Wiens 1989, Levin 1992, Drayton and Primack 1996, Watson 2002). Cities are interesting as they are dominated by one species, humans, and social and cultural factors are strongly involved in the shaping of system identity (Grimm et al. 2000, Pickett et al. 2001, Elmqvist et al. 2004). Yet our knowledge and understanding of the effects of these traits on urban landscapes and their ecology is far from complete.

From a self-sufficiency point of view there is no such thing as a sustainable city. Cities have always been dependent on their hinterlands for food and other ecosystem goods and services (e.g., Folke et al. 1997, Rees 1997, 2003). The regional or even global impact cities thus have stresses the important pedagogical role of functioning ecosystems in cities, especially as urbanization is increasingly disconnecting people from the nature that supports them (Pyle 1978, 1993, Miller 2005). To gain the much needed, broad-based public support for ecosystem preservation as well as more sustainable consumer demands, the places where people live and work need to be designed so as to offer opportunities for meaningful interactions with the natural world (Miller 2005). Apart from the educational value, urban systems also provide their inhabitants with a number of ecosystem services, some recognized and others unacknowledged. These ecosystem services are products of ecosystem processes and functions (Daily 1997) and include supporting (e.g., increased biodiversity, habitat, soil formation, ecological memory, seed dispersal, pollination, and storage and cycling of nutrients), cultural (recreation, enhancement of property value, community cohesion, source of knowledge), provisioning (e.g., food, water, fuel), and regulating (noise reduction, modulation of temperature, removal of air pollution, protection of water quality, etc.) services (Flores et al. 1998, Bolund and Hunhammar 1999, Jansson and Nohrstedt 2001, Millennium Ecosystem Assessment 2005). Many of these services are essential for human well-being (Chiesura 2004, and references therein) and thus an important aspect of liveable cities. The capacity, however, of a city to provide these services depends on the configuration of its ecosystems, and cannot be taken for granted. Nor are the services evenly distributed in space, and urban landscapes must be planned to ensure the citizens' access to important services. Ecological research targeting sustainable management of urban environments should include findings and methods from many lines of ecological research, such as the link between biodiversity and ecosystem function, the role of humans in ecosystems, landscape ecology, and resilience.

Issues of management and sustainable use of urban landscapes require some kind of theoretical framework to set goals and evaluate results. Resilience theory is arguably one of the most suitable in urban environments because it allows integration of ecosystem function with social dynamics. The definition of ecological resilience used here is given by Folke et al. (2004): it is the capacity of a system to absorb disturbance and reorganize while undergoing change so as to retain essentially the same function, structure, identity, and feedbacks. Urban landscapes are best described as socioecological systems where natural and social processes together shape the ecosystems. Such systems are self-aware, and non-genetic information plays an important role in system dynamics, which adds to resilience the dimensions of learning, anticipation, and potential for active transformation (Berkes et al. 2003, Olsson et al. 2004). However, this paper will focus on the spatial aspects of resilience.

ISSUES IN URBAN ECOLOGY

Biological Diversity and Ecosystem Functions

Little has been written on the importance of the species present in the city for the provision of ecosystem services or resilience. Changing the species diversity, abundance, and community composition may have functional consequences because the number and kinds of species present determine the efficacy of many ecological consequences because the number and kinds of species present determine the efficacy of many ecological functions (see, e.g., Holling 1973, Chapin et al. 1998, Rosenfeld 2002, Norberg 2004). High numbers of species with similar ecological roles increase the number of potential community organizations that can uphold similar ecosystem functions, which makes the system resilient. Which species are found in urban green areas has to do with both internal factors and landscape context (Flores et al. 1998). Several urban bird communities are rescued by their surroundings, evidenced by strong correlations between certain species and landscape forest cover and parks (Melles et al. 2003). The individual patch may also have an influence on its surroundings, e.g., by providing ecosystem services to areas that are much larger than the patch itself (Bodin et al. 2006). The urban landscape mosaic is quite complex, with residential, commercial, industrial, government–institutional, cultural–educational land uses, patches of remnant vegetation, secondary green areas such as parks or cemeteries, and other land uses; all of them more or less suited as habitat for different species.

Ecological Processes and Social Drivers

Cities are subjected to a strong human influence, and management decisions have profound implications for ecosystem function. One of the central tenets in landscape ecology is that processes can be inferred from geographical patterns, but it may not be that straightforward in urban landscapes where human activities both transcend habitat boundaries and differ between patches of the same habitat. Instead, urban landscapes may be conceived of as composites of many different types of influence, all expressed on a single surface plane. Some natural processes are rarely allowed to run their courses, and then only to a limited extent in restricted areas or under limited time periods (Dow 2000). Others are, at least to some extent, replaced by anthropogenic processes; e.g., all socioecological systems are exposed to two different selective forces at the same time, i.e., natural and cultural selection, the latter guided by human ideas and preferences. These two may work in concert, but they may also work in opposite directions. When human land-use intensity reaches a certain point, the system moves from being controlled by biotic and abiotic factors toward being controlled by human preferences, and the limiting factor will then be the financial means to realize these preferences (Hope et al. 2003). It is important to identify the processes controlled or strongly influenced by human activities because these are likely to cause deviating system behavior, such as arrested successions or changed seasonality. For example, early successional stages are common, and the number of possible successional pathways is extremely high (Alberti et al. 2003). Although arrested successional stages have their own stability, it is dependent on the occurrence of the arresting factor. However, the farther from a "natural" state the system is kept, the more resource demanding and dependent on continuous management will it be.

Much of the heterogeneity present in cities is probably a result of a wide range of different management objectives and practices (Grimm and Redman 2004, Barthel et al. 2005). Land management decisions themselves occur at multiple spatial scales driven by the scale of influence of the decision maker (Conroy et al. 2003), whose decisions can be expected to influence very different processes and ecosystem functions. For example, the activities of the single homeowner will have a direct impact on individuals of smaller, less vagile species and local soil processes, whereas it is the collective actions of a whole neighborhood that will affect larger species or population dynamics (e.g., Lepczyk et al. 2004). Some of the management routines are adjusted on a daily basis while others are restricted in practice by legislation and regulation (Dow 2000). Legacies from historical land uses have been shown to be pervasive (e.g., Foster et al. 2003) and urban green areas, especially in old cities, may have a quite varied land-use history, which could potentially help explain the high biodiversity found in old parks.

Connectivity and Spatial Resilience

Connectivity is defined here as the degree to which habitat for a species is continuous or traversable across a spatial extent. No landscape is inherently fragmented or connected, and can only be assessed in the context of an organism's ability or willingness (Harris and Reed 2002) to move between patches and the scale at which the organism interacts with the landscape (e.g., D'Eon et al. 2002). There are two aspects of connectivity, the continuity of a certain habitat (structural connectivity) and the possibility for organisms to move within or between patches (functional connectivity). Landscapes are often described as consisting of patch and matrix habitat, the latter defined as the most extensive and connected habitat of a landscape (Forman 1995), and as such, the matrix can potentially have a great influence on the species dynamics in the landscape (Rodewald 2003). There is a growing appreciation among landscape modelers that the configuration of the matrix can be of great importance for landscape connectivity, species dispersal, and habitat use, and that the matrix is rarely homogeneous (e.g., Gustafson and Gardner 1996, Ricketts 2001, Verbeylen et al. 2003, Revilla et al. 2004). The permeability and overall landscape composition will be perceived differently by different organisms (e.g., MacArthur and Levins 1964, Johnson et al. 1992, Hostetler and Holling 2001), which is why it is problematic to apply a binary matrix model to real urban landscapes. The effective distance between patches is a result of landscape permeability (i.e., how suitable a habitat is or how permeable it is to movement) as well as geographical distance, and dispersal across continuous landscapes is more frequent and faster than across binary landscapes (Malanson 2003). Effective distance has been shown to offer a better explanation for population dynamics than geographical distance alone (Verbeylen et al. 2003).

Spatial resilience deals with the ability of interconnected ecosystems to persist on a regional level (Nyström and Folke 2001). The capacity to reorganize after a disturbance event is related to a patch's connections with its surroundings as well as internal factors and has been called ecological memory (Nyström and Folke 2001, Bengtsson et al. 2003). The ecological memory is the network of species, their interactions in space and time, and includes the life-history experience with environmental fluctuations. Long-range dispersal has a positive effect on persistence in dynamic landscapes as it increases the number of couplings between patches. The trajectory of a disturbed patch undergoing reorganization is influenced by the access to different source areas and the dispersal ability of different organisms. However, no degree of connectivity between green areas will suffice to overcome critical deficiencies in their combined ecological content. Landscape heterogeneity, created by, e.g., multiple, contemporaneous successional stages, is a prerequisite for ecological memory (Berkes and Folke 2002) and provides insurance against uncertainty (Folke et al. 1996). There is a seeming paradox one has to deal with when discussing connectivity: on the one hand, connectivity facilitates movement between systems and is a prerequisite for spatial resilience and ecological memory; on the other, isolation or modularity prevents synchronicity over large scales and buffers against cascades of disaster and disease epidemics (Levin 1998).

DISCUSSION

The Cityscape, Urban Ecology from a Landscape Perspective

To comprehend and manage cityscapes, processes and functions must be understood and linked to their spatial, ecological, and social origin (Grimm and Redman 2004). The relation between ecological characteristics (e.g., the presence of different functional groups) and the ecosystems services people enjoy in cities is incompletely understood, and, because urban development is guided by human values, there is a need to inform people about the ecological requirements for the ecosystem services that increase human well-being. Many of these services depend on the species present in different green areas, and the presence of these species is, in turn, a result of a number of factors, socioeconomical as well as ecological. Consequently, different green areas will have different ecological functions and thus offer different ecosystem services. To ensure that the flow and access to ecosystem services is not interrupted, at least at the citywide scale, representative successional stages and different kinds of green areas in different urban contexts should be planned and managed for (Flores et al. 1998, see also Nyström and Folke 2001, Bengtsson et al. 2003). Many of the ecosystem services that have been described as important are by their nature highly subjective and likely to change. This, I argue, is just another strong reason to maintain resilient cityscapes with the ability to adapt to future needs. Heterogeneity has been argued to increase resilience in ecosystems, and it might be that this tenet holds true also for other aspects of socioecological systems. For example, an area with a diverse set of management practices based on different values might be better prepared to cope with changes in the environment or in the perception of desired ecosystem services among the human users.

It has been claimed that the ecological character of cityscapes can be described by adding layers of social and economical information to land cover maps (e.g., Redman et al. 2004). The resultant multi-layered information on the ecology of every patch in the city can then be used to assess their different roles in providing people with ecosystem services. The proximity to other similar areas is crucial for the maintenance of ecological properties within a patch, especially for smaller patches that are more likely to lose species over time (Drayton and Primack 1996). Analogously to reorganization after disturbance, the success of restoration projects is strongly influenced by the connections to existing green areas (Robinson and Handel 1993, 2000). Analyses of more comprehensive data sets may also help us understand the role of urban form; there has, for example, been a long-standing debate on whether compact cities or urban sprawl are most sustainable (see, e.g., Wiersinga 1997). However, as shown in a review by Neuman (2005), it is not the form itself that is sustainable or not, but the processes that create and are in turn shaped by the form. The combination of ecological and social information should be able to capture important processes in the landscape and determine their origin and implications for sustainability, e.g., how citizens' access to different ecosystem services affects their choices and actions.

RESPONSES TO THIS ARTICLE

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