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'Ecological land-use complementation' for building resilience in urban ecosystems

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Abstract

Few scientific analyses exist on how different land uses can be configured for greater support of biodiversity and ecosystem services. Based on ecological premises, and through a synthesis of information derived from the literature related to urban ecology, this paper elaborates on the potential biodiversity benefits of 'ecological land-use complementation' (ELC). The approach builds on the idea that land uses in urban green areas could synergistically interact to support biodiversity when clustered together in different combinations. As proposed, ELC may not only provide for increased habitat availability for species, but also promote landscape complementation/supplementation functions and other critical ecosystem processes; hence, realize 'emergent' ecological functions of land use. Planners and urban designers could adopt ELC to promote ecosystem resilience when planning new urban areas, such as in the support of 'response diversity' among functional species groups, and in the support of ecosystem services. ELC-structures in urban landscapes could also be used as arenas to promote participatory management approaches and Local Agenda 21. The paper concludes by summarizing some guiding principles for urban planning and design.

Keywords: Land use; Biodiversity management; Complementation/supplementation; Ecological land-use complementation; Resilience; Urban ecosystems

1. Introduction

Urban ecosystems are the most complex mosaics of vegetative land cover and multiple land uses of any landscape (Foresman et al., 1997). Urban land uses are in a state of continuous flux, where change is the norm rather than the exception. Although decisions governing land-use change almost exclusively occur at the local level (Theobald et al., 2000), such change may be driven by non-local drivers that cannot be anticipated in advance (Altieri et al., 1999). Throughout the dynamic transformation of land use, less desirable, unwanted states may be witnessed in urban areas, such as when the biota increasingly is lost due to habitat degradation, fragmentation and loss, with the subsequent loss and thinning out of ecosystem services. Such 'benefits that people obtain from ecosystems' include provisioning services (the products obtained from ecosystems); regulating services (the benefits obtained from the regulation of ecosystem processes); cultural services (the nonmaterial benefits people obtain from ecosystems through spiritual enrichment, cognitive development, reflection, recreation, and aesthetic experiences); and the supporting services (those that are necessary for the production of all other ecosystem services) (MA, 2005).

The loss of such services also leads to loss of ecosystem resilience and options for future generations (Folke et al., 2004). Although the concept of resilience holds different meanings to scientists (Folke, in press), it is used here as the capacity of an ecosystem to absorb disturbance and reorganize while undergoing change so as to retain essentially the same function, structure, identity and feedbacks (Berkes et al., 2003; Carpenter and Folke, 2006; Holling, 1973). This also includes an ecosystem's capacity to recover from management mistakes (Fischer et al., 2006).

Resilience building should be part of the agenda of urban spatial planning and design. To date, urban development generates some of the greatest local extinction rates of species and frequently eradicates a large proportion of native flora and fauna (McKinney, 2002). Land use in urban areas has also a particularly strong influence on biodiversity, and will likely have the largest effect on terrestrial ecosystems in the coming century (Sala et al., 2000). As recent studies of satellite data indicate (Hansen et al., 2004), land use continues to intensify in formerly

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occupied areas (e.g., urban areas) often with an overlap of location of areas rich in biodiversity (Ricketts and Imhoff, 2003). Humans tend to settle in areas with high ecosystem productivity with people most dense on lands suitable for agriculture or in low elevation and coastal areas that also support high levels of biodiversity (Hansen et al., 2004; Ricketts and Imhoff, 2003).

There is much to be gained from building in ecological functions in the accommodation of land uses in the future growth of cities. This, however, requires a much stronger partnership among ecologists, urban designers, landscape architects, and urban residents than has hitherto been the case and more knowledge about the functioning of urban ecosystems needs to be developed (Felson and Pickett, 2005). While much is known about the interactions between land-use change and biodiversity at the global level, little analysis exists on how varying landscape designs influence landscape functions in specific contexts (e.g., Hobbs, 1993, 1997), and on the synergistic effects that different land uses may have in terms of supporting processes essential for biodiversity. The aim of this paper is therefore to synthesize information on land-use configurations that more optimally support ecosystem processes and promote resilience in urban settings, and to elucidate some guiding principles for urban planning and design.

2. Framework of analysis

2.1. Scope of the paper

Through a review of the ecological literature (mainly urban ecology), this paper focuses on land-use combinations that ecological premises suggest promote biodiversity. Such combinations are here referred to as 'ecological land-use complementation' (ELC). This approach builds on the idea that constituent land uses synergistically interact to support biodiversity when clustered together relative to when they are interspersed in a heavily developed urban matrix.

While practitioners may not be implementing as many ecological design structures in landscape architecture as might be expected (Calkins, 2005), it is often the case that local governments are limited by knowledge for how to best maintain biodiversity in urban settings (Sandström et al., 2006). Insights generated in this paper may thus help planners and designers to better plan for biological conservation and management in urban development in congruence with other existing biodiversity management approaches (see, e.g., von Haaren and Reich, 2006).

One merit of ELC is its consideration of both the spatial structure and the fundamental role that ecosystem processes have for the maintenance of biodiversity (e.g., species movement, pollination, and seed dispersal). Normally, practitioners emphasize landscape structure and aesthetic values, but pay less attention to ecosystem processes in landscape designs (Hobbs, 1997; Kendle and Forbes, 1997).

While the ecological premises behind ELC have been described by ecologists as important determinants for biodiversity support in different landscape types, and some have been used in the designation of protected areas, little interest have been devoted to how those land use types that people use on a more regular basis can be spatially arranged to provide greater biodiversity support. In urban settings, these land types include areas for human habitation, work, education, recreation and amenity. Hence, this paper focuses on ecological land-use complementation that involves different types of urban green patches. In particular, it generates insights on how this approach can contribute to build resilience in urban ecosystems, such as for sustaining ecosystem services—a particularly relevant issue considering that ecosystem services are declining in many parts of the world (MA, 2005). Moreover, ELC can be used to promote 'response diversity' which is critical for the maintenance of ecosystem processes. Response diversity refers to the diversity of responses to environmental disturbance among species that contribute to the same ecosystem function (Elmqvist et al., 2003). In addition, because ELC takes into account the critical role of active land management for improving conditions for and qualitative attributes of species, the paper discusses how the approach could be used to promote a wider integration of urban residents in biodiversity management.

The paper begins by outlining the theoretical underpinnings behind ELC. Next, examples of land-use complementation are elaborated on, as synthesized from the ecological literature. These examples are further discussed in conjunction with the applicability of ELC in city-regions. The last section sums up the major insights generated in this paper and provides some general guidelines for urban planning and design.

2.2. Theoretical underpinnings of land-use complementation

Ecological land-use complementation (ELC) draws on the merging of some well-known theoretical concepts in ecology. One such premise is the landscape complementation/supplementation hypothesis developed by Dunning et al. (1992). Accordingly, in a landscape of different patch types, such as in heterogeneous, urban landscapes, a species needs to move between patches to obtain critical amounts of resources, i.e., for foraging, roosting and breeding; hence, an individual uses resources complementally to fulfill different life cycles (Pope et al., 2000). Landscape complementation involves a species requiring at least two different resources provided by habitats within the same season, and that resources are available in close proximity to each other (Eybert et al., 1995). Also, an organism may supplement its resource intake by the use of substitutable resources in different habitats (Quin et al., 2004), such as when birds use ruderal areas as seed sources to supplement those available in agricultural fields (Fuller et al., 2004) (Fig. 1). Hence, both habitat composition and configuration can variously affect the individuals, populations, and communities that inhabit a landscape (Guerry and Hunter, 2002) and patches used to complement/supplement resources can form ecologically functional units (Quin et al., 2004). It has been shown that these processes also occur among species confined to urban ecosystems (Blair, 1996; Melles et al., 2003).

In addition, ecological land-use complementation draws on the island biogeography theory (MacArthur and Wilson, 1967)