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Urban landscape pattern design from the viewpoint of networks: A case study of Changzhou city in Southeast China

Hsiaofei Chang [a,b], Feng Li [a,*], Zhengguo Li [c], Rusong Wang [a], Yanglin Wang [b,d]

[a] State Key Laboratory of Urban and Regional Ecology, Research Center for Eco-Environmental Sciences, Chinese Academy of Sciences, Shuangqing Road 18, Beijing 100085, China
[b] Key Laboratory for Environmental and Urban Sciences, Shenzhen Graduate School, Peking University, Shenzhen 518055, Guangdong, China
[c] Key Laboratory of Resources Remote Sensing and Digital Agriculture of Ministry of Agriculture (MOA), Beijing 100081, China
[d] College of Environmental Sciences, Peking University, Beijing 100871, China

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ABSTRACT

Urban landscape pattern (ULP) is becoming increasingly important for the sustainable development of regions and the whole world. Knowing the ULP status is crucial for making decisions to avoid ecological disasters, reducing environmental problems and industrial pollution, and harmonizing urban development and natural conservation. To link and harmonize various landscape elements and flows in the ULP, this study developed a theoretical scheme from a network viewpoint to explain the spatial interactions among landscape elements and flows. Using a case study of Changzhou city located in southeastern China, this paper tried to integrate ecological factors and socioeconomic conditions using landscape functions modeling and network analysis to establish strategies for ULP design. Because an urban landscape is highly complex with various social, economic, and natural elements, urban landscapes were classified into four subtypes, each with its own specific appearance. Then the paths of socioeconomic and ecological flows were determined using a least-cost distance model. The overall pattern of linkage paths among the ecologically fragile areas could help identify the areas with high ecological risk in Changzhou. For ecologically sustainable, economically sound, and socially just development, a scheme for ecological rehabilitation and security-pattern design was proposed to reduce ecological risks. Finally, this study discussed how to balance economic and ecological needs from the viewpoint of network theory and how to optimize landscape patterns through enhancing functional linkage and strengthening structural connectivity.

1. Introduction

Global ecological security is becoming increasingly important because of severe pollution and ecosystem degradation, including air pollution, water pollution, soil loss and degradation, desertification, decrease in forest cover, the greenhouse effect, destruction of the ozone layer, and decrease in species diversity (Zhao and Yang, 2007; Fu et al., 2010). Ecological security functions are highly influenced by various human activities, and in return, the efficiency of human activities will also be affected by the state of regional ecological security (Zhou et al., 2010). In the 1990s, China began to pay attention to ecological security problems. The 2000 Compendium of National Environmental Conservation, published by the State Council of China (2000), established the objectives of improving environmental quality and maintaining national eco-environmental security and specified the latter as the principal mission of national environmental conservation activities.

The definitions and emphasis of the ecological-security concept vary with different authors, including improvement of ecosystem services (Costanza, 1997; Zhu et al., 2003); maintenance of ecosystem health (Schaeffer et al., 1998; Kong et al., 2002), and remaining within environmental carrying capacity limits. Another, more specific definition focuses on the security of natural and semi-natural ecosystems, that is, the overall integrity and health of ecosystems (Xiao and Chen, 2002; Yang and Lu, 2002; Ma et al., 2004). It has been generally accepted that the ecological security concept comprises the security of nature and of human beings, including nature conservation, economic and social growth, and human life, health, rights, safety, and adaptive abilities with respect to ecological risks (Xiao and Chen, 2002).

Typical urban landscape is a kind of complex social-economic-natural ecosystem. Natural and physical elements are its primary components, economic activities and metabolic processes continue and evolve, and human needs drive its succession and evolution (Wang, 1991; Burkhard et al., 2010). A city does not exist independently and is composed of many subsystems with specific structures and functions. The ideal urban landscape is harmonic, efficient, continuous (Dong, 2002), and with a reasonable set of

* Corresponding author. Tel.: +86 10 62849103; fax: +86 10 62849103.
E-mail address: lifeng@rcees.ac.cn (F. Li).

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structures and relationships (Li and Xie, 2005). Therefore, safe urban landscape is able to maintain its organization, configuration, and flexibility in the face of risks at a specific spatiotemporal scale (Guo, 2002; Xie and Li, 2004). Urban ecological security means environmental and developmental safety in the future and could also be understood to mean the health and balance of the urban ecosystem (Wang and Ouyang, 2007). The carrying capacity of an urban ecosystem is limited, so when optimizing the urban landscape, it is necessary to maintain adaptation, cooperation, and symbiosis among landscape elements (Zhang et al., 2007).

Many landscape metrics are used in environmental assessments (Jones et al., 2001; Wade et al., 2003) and to help landscape planning and decision making (Hobbers, 1997; de Groot et al., 2010). In this context, the network is an appropriate concept which provides a viewpoint and a method to break down a complex landscape system, linking and harmonizing landscape functions across multiple scales (Green and Sadedin, 2005). A network can be seen as an entity composed of nodes and corridors, and conceptions of network have therefore often been used to reflect the spatial relationships and configurations of landscapes. In ecology, the concept of networks has been used to describe interactions such as competition and symbiosis among various organisms and communities (Zong, 1999). In addition, in landscape planning and biodiversity protection, the ecological network is a widely accepted framework for it can help maintain or strengthen landscape eco-functions through reorganizing the spatial arrangement of landscape elements (Opdam et al., 2006). Furthermore, the connectivity of landscape patterns can also have an effect on the spatial diffusion of landscape functions. Greenways, waterways, and transportation networks can affect the movement and flow of organisms, minerals, nutrients, and information (Antrop, 2004; Arendt, 2004), and landscape connectivity and patch size are related to various ecological processes (McGariga and McComb, 1995; Li et al., 2005).

For the gradient of urbanization, changes in ecosystem characteristics can reflect the intensity of human influence on the environment (Weng, 2007). To examine the spatial effects of urban landscape patterns and functions, this study targets the questions of cost-distance and least-cost paths in the ULP. Cost-distance is similar to Euclidean distance, but instead of the actual distance from one point to another, it represents the shortest weighted distance (or accumulated travel cost) from each cell to the nearest cell in the set of source cells. Another minor difference is that cost-distance measures distance, not in geographic units, but in cost units. These costs may be travel time, dollars, preferences, or other costs. Cost-distance analysis could help to define the area of influence of an economic center (Hare, 2004), improve the results of landscape optimization (Niu et al., 2002), identify suitable paths for traffic (Chen et al., 2004) or species migration (Schadt et al., 2002), and quantify the degree of landscape-function connectivity on different types of cost surfaces.

Landscape is a spatial structure formed by contiguous corridors and patches. Interactions of flow, energy, and materials in a landscape depend on landscape network structure. To optimize ULP, this work included the construction of a landscape network based on least-cost modeling which is capable of reconfiguring landscape patterns to avoid or buffer incompatible interactions, thus providing a new research framework for ULP design.

2. Theoretical framework of landscape networks

A landscape network is comprised of nodes, subnodes, and connective units that may be large patches, patches, or corridors (Fig. 1). Classifications of landscape networks depend on the viewpoint used. A landscape network could be classified into corridors and patches according to the shape of its landscape elements (Fu et al., 2001). With respect to landscape function, a landscape network also includes ecological and economic networks. The ecological network comprises urban parks, green corridors, forest belts, and other natural conservation areas which could protect biodiversity and enhance eco-functions (Cook, 2002; Jongman et al., 2004; Schuller et al., 2000; Kühn, 2003). The economic network concept developed out of computerization and is composed of traffic infrastructure and socioeconomic centers.

2.1. Ecological landscape networks

The ecological network concept was already developed in urban planning by the beginning of the 20th century (Jongman et al., 2004). Based on the division of territory between the urban area and the natural environment (Antrop, 2004), the construction of an ecological landscape network could protect diversity and enhance the exchange of materials and energy (Schrijnen, 2000) through connecting conservation areas, areas of limited development, and greenways, parks, and other ecological "stepping stones" within cities.

The ecological network is a famous concept as well as a strategy for biodiversity protection and environmental optimization (Yan and Tan, 1998) at various scales. The basic function of an ecological network is to provide paths for wildlife, energy, and other materials to move and exchange in a fragmented landscape. Its configuration can be summarized at the regional, landscape, and patch scales based on related research (Table 1).

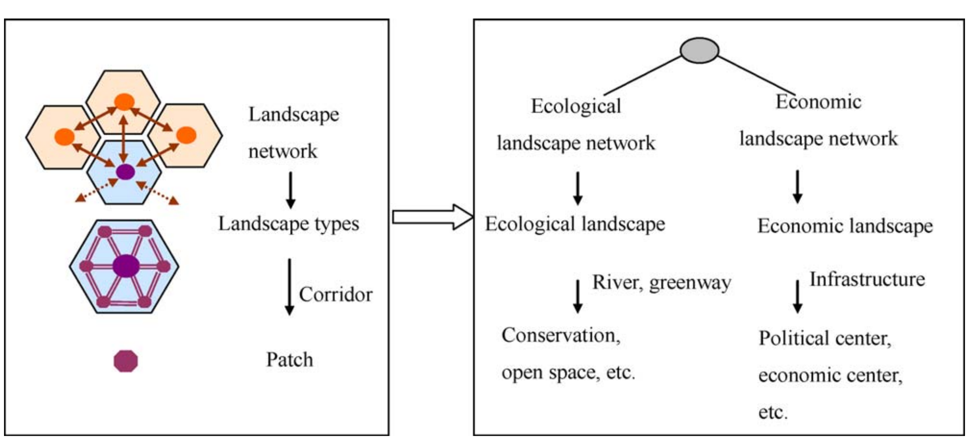

Fig. 1. Conceptual framework and principal composition of landscape networks.