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Research Paper

Assessing the landscape and ecological quality of urban green spaces in a compact city

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HIGHLIGHTS

- The landscape patterns of UGS were analyzed for their ecological quality.
- The landscape patterns of UGS have not improved with town renewal and developments.
- Some old districts have relatively low-quality landscape attributes.
- Vegetation-dominated land uses often have more interfacial benefits.
- UGS in land uses with less human disturbance tend to be larger and more homogeneous.

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ABSTRACT

The interrelated nature of landscape metrics calls for their joint application in analyzing complicated landscape patterns and associated ecological processes. Using geographic information system, remote-sensing and factor-analysis techniques, the landscape patterns of urban green spaces (UGS) in the compact city of Hong Kong were analyzed for their landscape-ecological quality in different land uses and districts. Using the Fragstat software, some key indices were selected to characterize the landscape mosaic with reference to patch size, patch shape, proximity relationship and edge configuration. Some old districts have smaller and more heterogeneous UGS than newer ones due to relatively low-quality landscape attributes. The landscape patterns of UGS have not improved with old-town renewal and new-town developments. In land uses with less human disturbance, UGS tend to be larger, and more homogeneous to enhance ecosystem services, and are closer to each other with more green cover to enhance connectivity and facilitate movements of organisms and people between proximal patches. Furthermore, vegetation-dominated land uses often have more complicated and hence longer UGS edges than other land uses to augment interfacial benefits. Of the 11 land uses, Government, institution and community and open space have more complicated UGS edges than more human-dominated types. The findings could inform the landscape-pattern design of UGS in compact cities to optimize their ecological qualities and benefits to both nature and residents, and to reinforce urban nature conservation.

1. Introduction

Urban green spaces (UGS) are important natural and cultural entities of cities. They shoulder significant roles in sustainable urban development and urban ecology by virtue of multiple environmental, social and economic benefits (Chiesura, 2004; Zhou & Wang, 2011). Due to biogeographical barriers and limited habitat diversities, islands often have fewer species than similar areas on the mainland, and larger islands could accommodate more species (Johnson & Winquist, 2011; Krohne, 2001; MacArthur & Wilson, 1967). Most UGS and more so in compact cities are limited in size, occluded within the built-up matrix, and separated from each other by harsh and often inhospitable developed areas. In effect, UGS behave as small island habitats with restricted biodiversity and pauperized wildlife components. The islands situated close to the mainland, with a higher probability of net migration, tend to have more species (MacArthur & Wilson, 1967; Ndubisi, 2002). Similarly, the UGS located near the countryside or urban fringe have better chances to acquire biodiversity from nearby natural habitats.

Different urban land uses could impose a wide range of impacts on the natural environment and the ability to support nature. The land cover attributes of different land uses could regulate the amount, ecological quality and biodiversity of constituent

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UGS. Land use zoning and associated human activities could induce undesirable landscape patterns such as fragmentation (e.g., Andersson, 2006; Tian, Jim, Tao, & Shi, 2011) and degradation of habitat conditions and ecosystem services. The type and magnitude of the human disturbance regimes constitute the key determinants of UGS landscape characteristics.

Landscape ecology is an integrating subject synergizing the principles and methods of ecology, economics and geography. Landscape ecology assessment could enhance the urban planning and development process to address the deteriorating environmental quality, and highlight the need to adopt a synoptic and spatial viewpoint in landscape protection and improvement (Buyantuyev, Wu, & Gries, 2010; Wu, Jenerette, Buyantuyev, & Redman, 2011).

Many studies have expounded the significant functions of UGS in urban life (Uy & Nakagoshi, 2008). Landscape pattern assessment could infer potential ecological processes (Leitão & Ahern, 2002; Turner, Gardner, & O'Neill, 2001). Relevant attributes such as size, shape and distribution of UGS play a decisive role in defining their ecological and landscape functions (Gilbert, 1989; Kong, Yin, & Nakagoshi, 2007). These factors express the ecological quality of UGS from different aspects, such as biodiversity, physical and mental health, and visual and amenity benefits (Harper et al., 2005; Fuller, Irvine, Devine-Wright, & Gaston, 2007; Gonzalez et al., 2010). This study analyzed the landscape patterns such size, shape, edge effect and proximity of different UGS types in Hong Kong. The results could clarify the relative contributions of UGS types in improving the ecological quality of urban areas by districts and land uses.

A single landscape index is inadequate to characterize UGS landscape and ecological quality. Redundant information should be abridged and related indices should be jointly considered for a comprehensive explanation (Li & Wu, 2004). Recent studies evaluated the most effective combination of indices for particular situations (e.g., Corry & Nassauer, 2005; Li, Du, Ling, Wu, & Feng, 2011; Wu et al., 2011). The chosen indices to quantify spatial pattern and ecological quality should be relatively simple and encompass key factors (O'Neill et al., 1997). The broad analysis of relevant factors should reflect the critical issues in a given landscape pattern (Giles & Trani, 1999). Furthermore, the indices representing the artificial pattern should be carefully selected to match their counterparts (Tischendorf, 2001).

Few studies cover landscape ecology assessment of UGS quality in compact cities and in the tropics. The relevant works focused on theoretical analysis or a subset of UGS such as greenway (Baschak & Brown, 1995) and green network (Kong, Yin, Nakagoshi, & Zong, 2010), or a specific landscape pattern such as UGS fragmentation or connectivity (Tian et al., 2011). This study selected landscape metrics to analyze UGS pattern in the compact city of Hong Kong at the scales of districts and land uses. The landscape mosaic is composed of an admixture of human-dominated landscape with limited green spaces in the city, and the vegetation-dominated landscape with development intrusion in the countryside. Comparing their landscape patterns could highlight the ecological quality of the intensively developed urban landscape, and offer practical hints for UGS planning and management in the compact city. The interpretation of landscape pattern and quality with the help of appropriate indices could inform similar studies on nature conservation in the urban context.

2. Study area

Hong Kong is composed of three main administrative parts, namely Hong Kong Island, Kowloon, and the New Territories together with some small islands. The humid subtropical climate is dominated by the Asian monsoon system. It is characterized by a long and hot summer with abundant rainfall, and a short, cool and dry winter. The transitional spring and autumn seasons are mild and relatively short. The rugged hilly topography and grave shortage of easily developable land has dictated the urban form.

Since its inception in the 1840s, urban development has adopted consistently the high-density and multiple intensive land-use mode, which has become exceptionally high-rise after the 1960s. The 7.1 million population is accommodated in merely 21% of the total land area of 1104 km^2 (Census and Statistics Department, 2012). It is an extreme case of a congested and compact city with meager ground-level UGS. The public UGS provision in built-up areas stands at only 3.5 m^2 per capita, which is one of the lowest in the world for cities of a comparable size (Planning Department, 2012). The tightly squeezed UGS supply has left imprints on their spatial pattern and ecological traits. In contrast, 40% of the land lying outside urban areas has been designated as country parks. These extensive protected areas serve as the pertinent green lung and nature-conservation companion of the city, and they contribute significantly to its livability.

In 170 years of urban development, the districts in Hong Kong have kept imprints of organic growth in their urban fabrics in relation to the built-up matrix and open spaces. Using district in conjunction with land use as the analytical framework could help to decipher the UGS development factors and patterns. Thirteen districts have been selected to represent three kinds of towns: old towns, mature new towns, and developing new towns (Table 1). The districts in Hong Kong Island and Kowloon are old towns. Tsuen Wan and Kwai Tsing are first generation and mature new towns in the New Territories. Tai Po denotes another mature new town of the second generation with better design of green spaces than other parts of Hong Kong. Tseung Kwan O represents a developing new town of the latest generation.

Nearly half of the study area is covered by green spaces which include those lying outside built-up areas in the urban fringe and the countryside. The built-up areas provide only one third of the per-capita green cover of the study area. Hong Kong Island has the highest and Kowloon the lowest green cover. Of the 13 districts, only two (Southern and Tai Po) have >40% green cover (Table 1).

3. Methods

High quality digital maps with a resolution of 0.5 m × 0.5 m were purchased from the government (Lands Department, 2010). The green space layer was digitized manually piece by piece from the orthophoto maps with the Able software R2V for Windows and NT. The subsequent field trips provided information to validate the interpretations. The approximate size of the shadowed or covered green spaces were investigated and drawn proportionally by hand to improve the quality of green space demarcation.

The land use types adopted the standard classification used in government outline zoning plans (OZP) (Town Planning Board, 2013). It contains two main land-cover groups: built-up area, and non-built-up area including urban fringe, rural area and countryside, which were further divided into 14 classes: C, commercial; CDA: comprehensive development area; C/R, commercial-residential; G/IC, government institution and community; R, residential, including High density, median-density and low-rise and low density residential developments, and phasing out of existing industrial uses through redevelopment (or conversion) for residential use in built-up areas; RD, road; I, industrial; OP, open spaces; POS, private open spaces; OU, other land uses; U, undeveloped area; V, village (rural area); UF, urban fringe, including amenity area and green belt; CS, countryside (protection area).

The boundaries of different land uses were digitized from OZP paper maps and were labeled by different attribute ID in the