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Landscape ecological assessment of green space fragmentation in Hong Kong

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ABSTRACT

A large body of the literature has assessed the complicated process of landscape fragmentation, while few studies have tackled urban green space (UGS) systems in the urban context, especially in compact cities like Hong Kong. The fragmentation index was modeled using landscape metrics to assess green space fragmentation in Hong Kong. Our results indicate that the set of parameters that can be used to analyze the fragmentation of UGS includes: AREA_MN, PD, SHAPE_MN, ENND_MN, CONNECT, DIVISION, MESH and SPLIT. According to the fragmentation index, five fragmentation levels were identified in the study area. The built-up areas in Kowloon and along the coast of Hong Kong Island exhibited the highest fragmentation level of green spaces, while the countryside of the New Territories had the lowest. The uneven distribution of green cover results in an uneven distribution of UGS fragmentation levels. The eight metrics and the PCA technique employed were validated with respect to their applicability to analyzing green space fragmentation in this study. The results of this study could contribute to our understanding of fragmentation from a landscape ecological perspective. They will also be useful in the appropriate, future planning of urban green spaces to increase connectivity, form green networks and realize sustainability in compact cities.

Introduction

Urban green spaces (UGSs) should not be considered as isolated entities. They are spatially interacting, functional components of landscape ecosystems (Noss, 1987). The benefits of UGS can be summarized as follows: (1) environmental services, such as purifying air and water and improving urban micro-climates (e.g., Chiesura, 2004); (2) psychological functions, such as reducing stress, enhancing contemplativeness, rejuvenating city dwellers and providing a sense of peacefulness and tranquility (Ulrich, 1981); (3) physical health improvement, such as extending the lifespan of elderly people (Takano et al., 2002); (4) social benefits, such as encouraging the use of outdoor spaces, increasing social integration and interaction among neighbors (Coley et al., 1997); and (5) economic benefits, such as reducing the cost of pollution abatement, preventing and reducing the incidence of diseases, attracting visitors, promoting a city as a tourism destination, and generating revenue and employment (Chiesura, 2004). Thus, in a natural landscape, green spaces provide habitats for numerous species. In the urban environment, they provide food and habitats for wildlife species (Attwell, 2000). They are crucial elements of all cities and play key roles in improving the quality of urban life not only because of their ecological functions but also due to their relevance with respect to human health, societal well-being, economic benefits and the central role that they perform in sustainability (Costa et al., 2007).

Landscape fragmentation is an anthropogenic process that consists of breaking up a continuous habitat, land use type, biota or ecosystem (Carvalho et al., 2009). In the urban context, urbanization is the main factor leading to an environment with a fragmented and heterogeneous composition, representing probably the most complex type of green cover mosaic (Anderson, 2006). The fragmentation process directly influences the development and the restoration of ecosystems. It may result in the elimination, displacement, or enhancement of populations of species (Li et al., 2009). Habitat fragmentation has been considered by many researchers as the single greatest threat to biodiversity (Noss, 1991). It may also provide opportunities for biological invaders (e.g., Flory and Clay, 2009; Jørgensen and Kollmann, 2009). Fragmentation of UGS not only reduces the health of urbanized ecosystems (Zeng and Wu, 2005), but it also deteriorates the quality of living and working environments of the residents of these areas and strengthens the difficulties involved in realizing sustainability, especially in congested cities (Jaeger et al., 2008).

The factors involved in the fragmentation process are complicated, and a single parameter is not adequate to explain them (Davidson, 1998). Landscape metrics are often used to examine

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landscape fragmentation (e.g., Stenhouse, 2004; Carvalho et al., 2009). In this type of investigation, the mean patch size (AREA_MN), mean patch shape index (SHAPE_MN), path density (PD) and mean nearest-neighbor distance (ENND_MN) have generally been considered as the basic metrics (Keyghobadi et al., 2005; Munroe et al., 2007; Carvalho et al., 2009). Furthermore, three metrics, the landscape division (DIVISION), splitting index (SPLIT) and effective mesh index (MESH), have been considered superior to other traditional metrics in assessing fragmentation processes, as reported by Jaeger (2000), because of their insensitivity to the omission or addition of tiny residual patches. Connectivity, quantified by the connectance index (CONNECT), has usually been used as a strategy to counter the problem of fragmentation (e.g., Noss, 1991; Tischendorf and Fahrig, 2000). However, previous studies always used one or several metrics to analyze the fragmentation process without considering its complicated characteristics. Furthermore, most studies of landscape fragmentation have been applied to natural or rural landscapes and were related to metapopulations or the dynamics of special animals (Davidson, 1998; Li et al., 2009, 2010a). Some studies have touched on landscape fragmentation or habitat fragmentation of birds (Nichol et al., 2010), arthropods (Gibb and Hochuli, 2002), and other species (Tigas et al., 2002) in urban environments. Few studies have examined the fragmentation of vegetation in urban landscapes and the potential influence of vegetation fragmentation on urban life, especially in the most compact cities in the world, such as Hong Kong. In the present study, we were motivated by related studies to use landscape indices representing different landscape characteristics to model the fragmentation index of green spaces in Hong Kong. Then, the validation of the model and its application and measures to decrease green space fragmentation were further explored. This analysis was expected to produce a general picture of the uneven distribution and alarming state of green cover (Kupfer, 2006) in Hong Kong and its fragmentation by districts. These results could contribute to our understanding of fragmentation from a landscape ecological perspective, and they will also be useful in the appropriate, future planning of UGS to increase connectivity, form green networks and realize sustainability in compact cities.

Study area

The Hong Kong Special Administrative Region (HKSAR), which is the protruding part of the Lingnan highlands, is located in eastern Asia on the eastern side of the Pearl River Delta and borders the Guangdong province (Fig. 1). It is within the subtropical climate zone, which is characterized by a high diversity of natural resources. Its geographical coordinates are 22°17′N, 114°09′E. Hong Kong is a typical congested city, with high-rise, high-density and multiple intensive land-use concepts (Zhang, 2000), and it possesses almost all of the attributes of a compact city (Zaman et al., 2000). It was selected in this study for its special characteristics related to urban congestion and urban form. Urbanization results in increasingly compact cities. Thus, the study of green spaces in Hong Kong may be a good reference for such spaces in other cities.

Because of the continuous increase of the population and urbanization, aggravated by deforestation and fires, most forests in Hong Kong were destroyed since the Second World War, with numerous species disappearing. To halt this fragmentation and preserve biodiversity, the Country Park Ordinance was enacted in August 1976 (Wong, 2002) to set up country parks and conservation areas. During the subsequent 25 years of development, approximately 40% of the lands in Hong Kong has become covered by forests with high green cover. The fragmentation processes caused by human interference accelerate the disappearance of some local species. Most plants in built-up areas are cultivated, and some are exotic species that threaten the habitat of local species, especially those species inhabiting the natural environment (Ng and Corlett, 2002). Increasing numbers of new species have been recorded, including birds like the *Gavia stellata* Pontoppidan (Red-throated Diver) (Tsim, 2002) and *Rostratula benghalensis* L. (Greater Painted Snipe) (Lam and Lee, 2002), and insects such as *Acraea issoria* Hübner (Yellow Coster) (Lo, 2002). Only a small number of natural pockets, including a few local species, have been preserved on stone walls. The extreme lack of UGS in the built-up areas in Hong Kong is a serious problem. However, the success of protecting biodiversity in country parks is prominent. The vicissitudes of UGS in Hong Kong reflect the universal phenomenon of intensive conflict between the natural and the artificial components of cities, which have both related landscape planning and management issues and possible solutions (Jim, 1998). A total of 13 districts were selected to represent different development stages of towns (Table 1).

Table 1
Abbreviations, town development stages and green cover of different districts.

District	Abbreviation	Town development stage	Green cover (%)
Hong Kong Island			
Central & Western	CW	Old town	24.89
Wan Chai	WC	Old town	23.50
Southern	S	Old town	44.27
Eastern	E	Old town	23.84
Kowloon			
Kowloon City	KC	Old town	15.83
Yau Tsim Mong	YTM	Old town	14.45
Sham Shui Po	SSP	Old town	14.99
Wong Tai Sin	WTS	Old town	26.37
Kwun Tong	KT	Old town	21.50
The New Territories			
Tsuen Wan	TW	First-generation new town	32.09
Kwai Tsing	KT2	First-generation new town	21.27
Tai Po	TP	Second-generation new town	41.60
Tseung Kwan O	TKO	Latest-generation new town	29.55

Methods

The original orthophoto maps and land use digital maps with 0.5 m resolution used in this study were purchased from the Hong Kong government. Green spaces and different land uses were extracted from the maps and transferred to raster maps, assisted by "*3S*" techniques. A resolution of 1 m × 1 m was selected for raster maps to calculate different landscape metrics in FRAGSTAT 3.3 at the landscape level.

Classifications of UGS and land uses

Based on the Hong Kong Planning Standards and Guidelines produced by the government (Planning Government, 2003), UGS are classified into five categories: open spaces, green belts, conservation areas, country parks and coastal protection areas. Open spaces include green spaces in parks, gardens, sports complexes or playgrounds, street playgrounds and plazas, clubs, beaches and waterfront promenades, residential areas, commercial centers and industrial estates. These areas are further divided into four classes: regional open spaces, district open spaces, local open spaces and amenity areas (Planning Government, 2003).