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Development potential of sky gardens in the compact city of Hong Kong

Yuhong Tian[a], C.Y. Jim[b,*]

[a] State Key Laboratory of Earth Surface Processes and Resource Ecology, Beijing Normal University, Beijing 100875, China
[b] Department of Geography, University of Hong Kong, Pokfulam Road, Hong Kong, China

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ABSTRACT

Sky gardens have been actively studied and installed in different cities. Their development potential in compact developing cities has received little attention. Using remote sensing and GIS techniques, this study evaluates the vegetation configuration and development potential of sky gardens in urban Hong Kong, their underlying location, land use and building factors, and future planning and implementation concerns. Existing sky garden area is limited with sparse vegetation cover and low biomass. Existing podium gardens exceed roof gardens by about nine times. District development age has little effect on existing and potential sky gardens. Old towns have higher potential roof and podium gardens than new towns in most land uses. The effect of land use on potential sky gardens varies greatly by districts. Buildings with 10–20 floors have higher potential roof gardens in most districts. Building area is the main determinant of potential roof garden, and population density of potential podium gardens. Three scenarios of realization, namely minimum (20%), medium (50%) and maximum (80%), are adopted to project sky garden provision in individual districts. The projection extends to the contribution of new sky gardens to urban greening in terms of green cover and greening rate in districts. The challenges include susceptibility to typhoon damage in high-rise exposed sites, aggressive weed invasion, lack of roof-slab loading data in old buildings, and poor building maintenance. The opportunities include affordability of the new technology, enabling government policy, and establishment of scientific and research foundation in the local context. The development strategy could aim squarely at stringent technical standards and contractor skill requirement, and programme prioritization based on research findings. The study provides useful hints, approaches and recommendations for a systematic sky-garden action plan in Hong Kong and other similar compact cities.

Introduction

Sky garden has been actively studied and applied in cities in recent years. It is defined as the green spaces in the intermediate floors of high-rise buildings (podium garden or elevated garden) or on the rooftops (roof garden) (Ong, 2003). They serve a wide range of formal ecological functions of urban green spaces (UGS), including lowering air and surface temperature, suppressing the urban heat island effect (DeNardo et al., 2005), furnishing the urban cool island effect (Chang et al., 2007), absorbing pollutants (Yang et al., 2008; Rowe, 2011), abating noise, reducing dust and smog levels (Van Renterghem and Botteldooren, 2009), and providing natural habitats and stepping stone sites for plants and animals plant species selection (Wong et al., 2003; Dunnett and Kingsbury, 2004). Green roof contributes to sequestering of carbon (Nagase and Dunnett, 2011); on average an extensive green roof planted with Sedum could sequester 375 g C m^{-2} in the aboveground and belowground biomass and soil organic matter in two growing seasons (Getter et al., 2009).

For the enveloped building and indoor space, sky gardens help to extend the usable life span of the roof waterproofing membrane (Kosareo and Ries, 2007), save money on energy consumption for indoor cooling or heating (Sailor, 2008), and make good use of unused spaces on the roofs and podiums for leisure and recreation. The on-site benefits can bring upstream reduction in greenhouse gas and air pollutant emission at the power plants. The soil in sky gardens can retain up to 50% of the rain, substantially reducing and delaying the release of stormwater, and improving the quality of discharge (Osmundson, 1999; Berndtsson et al., 2006; Carter and Jackson, 2007).

Sky gardens also serve as important links in the green-space network of a city. The well-connected and pleasant open spaces can bring relief to people living in high-rise buildings in congested neighborhoods beset by meager green spaces and stressful urban living. Biodiversity in the sky gardens may not be as high as that in ground-level venues because of physical isolation from the ground creating a barrier for biotic encounters and interactions. However, the provision of more and varied habitats would help to enhance

* Corresponding author. Tel.: +852 2859 7020; fax: +852 2559 8994.
E-mail address: hragjcy@hku.hk (C.Y. Jim).

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urban biodiversity to contribute to the aggregate biodiversity of a region.

For many compact cities with inadequate ground-level land for UGS, sky gardens offer an alternative with notable potentials. Not occupying ground-level spaces, they provide multiple ecological, environmental and amenity benefits that are analogous to UGS. Hong Kong, as one of the world's most compact cities, is characterized by exceptionally high development and population density, reflected as high plot ratio, high site coverage, highly impermeable land surface, mixed land use, close juxtaposition of different land uses, efficient public transit system (Burgess, 2000; Ganesan and Lau, 2000; Zaman et al., 2000), and highly fragmented UGS (Tian et al., 2011, in press). Sky gardens offer an alternative strategy to improve the outdoor living environment, and solutions to the grave shortage of UGS in Hong Kong. Data on the relative proportions of urban land covered by trees, shrubs and other growth forms (i.e., vegetation configuration) provide an indicator of UGS-deficient areas, and the horizontal and vertical vegetation structure in UGS. The findings could facilitate future green-space planning (Attwell, 2000).

Some pertinent research questions on sky gardens are yet to be explored, and they are critical to sky garden development especially in compact cities like Hong Kong: (1) What is the vegetation configuration (VC) of greenspaces on roofs and podiums? (2) What are the development potentials of sky gardens with reference to district, land use and building height, and the underlying factors? (3) What are the provisions of existing and potential roof and podium gardens? (4) What are the relative contributions of the existing and potential roof and podium gardens? (5) What are the main concerns in future planning and installation of sky gardens? In this study, we applied remote sensing and GIS techniques to establish relevant layers of spatial data in urban Hong Kong. Building upon recent research (Tian and Jim, 2011), we analyze the associations amongst the data layers to seek answers to the above research questions. From the results, we distill general hints, approaches and recommendations for future planning of sky gardens in Hong Kong with suggestions for knowledge transfer to cities with a similar urban form.

Study area

The Hong Kong Special Administrative Region of China (HKSAR) (abbreviated as Hong Kong) is located at 22°17′N, 114°09′E, on the eastern side of the Pearl River Estuary and borders Guangdong Province in south China. It has a land area of 1104 km^2 (Census and Statistics Department, 2010) with a highly rugged and hilly terrain. Its climate is strongly influenced by the Asian monsoon system, characterized by hot and humid summer, cool and dry winter, and notable rainfall of 2380 mm per annum mainly dropped in spring and summer. The humid-subtropical climate provides an enabling environment for high biotic diversity.

In the three regions of Hong Kong, namely Hong Kong Island (HKI), Kowloon (KL) and New Territories (NT), 13 districts with different development history and urban form were selected as the study area. The abbreviations, development history, land area and population density of the districts are displayed in Table 1. Of the districts, CW, WC, S, E in Hong Kong Island and KC, YTM, SSP, WTS, KT in Kowloon represent the old towns. In the New Territories, TW represents the first-generation new town and KT2 the second-generation new town, TP the third-generation new town, and TKO the latest fourth-generation new town. S has the largest area in 13 districts and WC the smallest. WTS has the highest population density and S the lowest.

Methods

Data collection and analysis

Orthophoto maps and B5000 (1:5000 scale) digital maps with 0.5 m × 0.5 m resolution and B1000 data with a 0.1 m × 0.1 m resolution were purchased from the Hong Kong Government and used to digitize the spatial information of green spaces and land uses. The results were verified by subsequent field investigations. Greenspaces were divided into five categories: UGS-1, trees with shrubs or grasses or both; UGS-2, shrubs with grasses or small trees, or shrubs with sparse small trees; UGS-3, only trees; UGS-4, herbs or turfs with sparse shrubs; UGS-5, bare or nearly bare open spaces with sparse grasses, which deserves to be improved by additional greenery. Based on official zoning plans, land uses were placed in five categories: commercial (C), comprehensive development area (CDA), government, institutional and commercial (GIC), residential (R) and other land uses (others).

The building information in B1000 digital maps (1:1000 scale) include podium line and podium line under elevated structure, which were used as the layers to define podiums. Podium refers to the first several floors of a high-rise building with high site coverage usually at 100% and mainly devoted to retailing and sometimes car parking uses; it is situated above the ground level and below the roof. High-rise buildings with podiums dominate the built-up cityscape in Hong Kong. The building block outline and building outline under elevated structure were used as the layer to define roofs. The definitions and calculations of building density and building floors were explained in Tian and Jim (2011). Field trips were conducted to verify and refine the results achieved in ArcGIS 9.2.

By matching the greenspace layer with the roof and podium layers in ArcGIS 9.2, the spaces for actual or potential roof gardens and podium gardens were obtained. A flow chart showing the data processing steps in the analysis of roof and podium gardens is given in Fig. 1.

Calculating potential areas of sky gardens

In this study, both old and new towns have roof and podium gardens with typical 20% or so green areas. The sky garden development in Hong Kong is still in the embryonic stage. Thus it was assumed that 20% should be the minimum area proportion for sky garden installation. Most cities in mainland China stipulate that green areas on roofs or podiums should exceed 50% to provide notable ecological and environmental benefits (Huang, 2007). Thus the longer-term objective of sky garden development in Hong Kong should aim at planting 50% of roof and podium areas.

Theoretically, any roof surfaces can be planted and even sloping or curved roofs can receive a layer of sod or wild flowers (Canada Office of Urban Agriculture, 1999). Generally, green roofs can be installed on surfaces up to 45°, but special soil barriers should be installed across the slope to prevent erosion. Maintenance access will be difficult on pitched roofs. As most rooftops in Hong Kong are flat, these gradient issues do not pose notable constraints. Considering existing load bearing capacity, roof angle, planting techniques and other related factors, in practice only a certain portion of the roofs and podiums can support greenery. Excluding areas allocated to required facilities and footpaths, the upper limit of green areas for roofs and podiums could attain 80%. Thus the minimum, medium and maximum potential areas for roof and podium gardens were calculated by subtracting the existing roof and podium gardens from 20%, 50% and 80% of site areas respectively.

Grey Relational Analysis (GRA) is a quantitative analysis to show the similarity and dissimilarity between the reference series and alternative series of the parameters (Hamzacebi and Pekkaya, 2011). It was employed to analyze the main factors such as