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Perspectives on five decades of the urban greening of Singapore

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ABSTRACT

For about five decades since the onset of rapid urbanization and industrialization, Singapore has placed significant emphasis on urban greening as a key component of its development approach, setting the foundation for its development as a "Garden City". Much of the original forest cover that had been lost due to urbanization and agriculture had been replaced by managed vegetation in the form of urban green spaces. This article assessed the distribution of urban green spaces in Singapore at the aggregate level and between the designated planning areas. It showed a high level of heterogeneity in the distribution of urban green spaces. Increasing population density is a key driver of lower per capita green cover and park provision ratio as reported for other cities. In particular, the park provision ratio had consistently stayed below the planning target for the past decade despite increasing land area dedicated for parks. Comparative assessment of Singapore's urban green space provision indicates that it is not significantly differentiated from other high-density cities, indicating that the physical distribution of vegetation in the urban fabric is more important than the absolute quantum of vegetation to create a perception of pervasive greenery. Given the downward pressure created by the increasing built-up area and population density, broad strategies are suggested for how Singapore can continue to upkeep its high level of urban greening.

Introduction

The increasing emphasis on urban greening is a recent trend in the planning and development of cities. Such an emphasis manifests in the long-term strategic and sustainable development plans of a number of global cities, which almost invariably incorporate the promotion of urban greening to help achieve a high quality of life and of the built environment. For instance, the London Plan incorporates policies and programmes to safeguard and renew existing green open spaces and water bodies, and create new green spaces and biodiversity habitats over a 30–50-year time frame (GLA, 2011). New York City's strategic development plan, PlaNYC (NYC, 2011) includes dedicated programmes to create and upgrade destination parks and enliven the streetscape, and create ecological connectivity within the city. The Seoul 2020 vision aims to make Seoul a "human-oriented green city with as many public green spaces as cities in advanced nations", where nature and people thrive (Ra, 2006). China has also developed national standards on "National Garden City" and "National Ecological City", which incorporate criteria of per capita park space and green area coverage to integrate greening into the urban development model of its cities (Zhao, 2011). Sydney (City of Sydney, 2011), Hong Kong (HKSAR Government, 2010) and several European cities (Beatley, 2000) have also put in place policies and programmes to conserve existing greenery, and introduce more greenery in new developments and urban renewal programmes.

The introduction of greenery in different forms within a city environment, such as street planting verges, parks and open spaces, forecourts, courtyards, sky terraces, rooftop gardens, and vertical greenery on building walls is therefore gaining prominence in scientific studies and urban planning. This has also, in part been driven by the fact that living in cities has become, and will increasingly be the predominant choice of humans. A high quality of the built environment made possible through the functional benefits of urban greenery has therefore emerged as an important goal of urban development to create healthy and liveable cities. One key focus of functional benefits is the health-promoting effects of parks and green spaces (Grahn & Stigsdotter, 2003; van den Berg, Maas, Verheij, & Groenewegen, 2010; Ward Thompson & Aspinall, 2011). Other functional benefits include ameliorating the effects of urbanization through the phytoremediative properties of greenery (Bolund & Hunhammar, 1999), meeting the social, recreational and cultural needs of urban dwellers (Matsuoka & Kaplan, 2008; Ward Thompson, 2002), and provision of habitats for urban biodiversity (Dearborn & Kark, 2010; Rosenzweig, 2003). Urban green spaces have also been identified to be an important measure to reduce heat storage and mitigate the phenomenon of urban heat island effect in cities (Roth, 2007). There is also some evidence that a green environment with a diversity of landscapes is attractive to the

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creative class (Ling & Dale, 2011), and the creative class is in turn a driver in the competitiveness of knowledge-based economies (Florida, 2004).

Singapore presents an interesting case as a city-state in which urban greening received strong emphasis early in its urban development approach at the onset of the city's rapid urbanization and industrialization almost five decades ago. This occurred before the concepts of sustainable development, and the emphasis on liveability of cities have taken roots. Commencing with the first tree planting campaign in 1963 (Lee & Chua, 1992), five decades of greening have created a distinctive green ambience in the island city-state. This occurred amidst a relatively short period of urban development from its independence in 1965 to the present day. Singapore was transformed from a post-colonial, entrepôt port beset with housing, overcrowding, sanitation and social integration problems described in Hassan (1969), to a cosmopolitan global city-state often considered among the likes of New York City, London, Hong Kong, and Seoul. As a small city-state, its urban development is often cited as an example of a compact, high-rise, and high-density city with a high level of infrastructural and industrial development. These include a well-developed transportation network, a public housing programme that houses 85% of the population in a high-rise environment, and a port that is one of the busiest in the world. However, rapid and extensive urbanization, particularly for industrial, commercial and infrastructural purposes (Neville, 1993), has necessitated massive clearance of native vegetation in the development process, a phenomenon that is similarly reflected in the low percentage of remaining native vegetation in many cities (Hahs et al., 2009).

Yet, Singapore is also known as a "Garden City" in various popular and scholarly literature, for example in Yuen (1996), Warren (2000) and Kingsbury (2012). This recognition has also seemingly permeated into the public realm, as captured in perception studies of both local residents (Lui, 2012) and visitors (Hui & Wan, 2003) on their view of Singapore as a Garden City. In fact, parks and greenery were deemed to be one of top five most important elements to the quality of life in Singapore, and is the top-ranked feature that makes Singapore special according to Singapore residents (URA, 2010). Singapore residents also appear to have accorded a high level of satisfaction (81% in 2007) with the overall level of greenery in their environment (MOF, 2010). These observations reflect the presence of a high level of greenery in the city, and when considered against the backdrop of considerable deforestation as well as competing social and economic developmental needs over the past five decades, points to a deliberate and systematic programme in urban greening. Several factors have been suggested to be important in this greening process. These include a clear vision backed by effective urban planning policies and supporting legal framework (Koh, 1995; Lin, 2007; Yuen, 1996), and effective governance and development of institutions to operationalize greening policies (Neo, Gwee, & Mak, 2012). Collectively, they reflect a strong government commitment and the allocation of resources, both in terms of land and financial resources towards the greening movement. For instance, on a per capita basis, the total expenditure in public parks and greenery development and management in Singapore has steadily increased from SGD$27.47 in 2000 to SGD$78.10 in 2010, and total expenditure represented about 0.85% of total government expenditure in 2010, more than doubling from 0.4% over a 10-year period.[1]

However, given the pressures of space constraints that it is already experiencing (PMO, 2009), would resource commitment alone be adequate to enable Singapore to continue its high state of urban greening into the future? The built-up area of Singapore was projected in 1993 to reach 60% by 2030 (Neville, 1993), but this has seemingly been attained by 2012 (Cheam, 2012). Further increase in built-up area is to be expected as more land is needed for social and economic developmental needs as population growth continues. In addition, a key driver of reducing green space that has been noted in both low and high-density cities is population density (McConnachie, Shackleton, & McGregor, 2008; Tian, Jim, & Tao, 2011; Venn & Niemala, 2004; Yang & Zhou, 2009). Given the exponential increase in the population density already experienced in Singapore from the late 1900s to now,[2] and an expected further increase in population density with growing population, would this become a driver of decreasing green spaces in the city? What would be the strategic directions it needs to adopt, given the importance accorded to green spaces by Singaporeans? How could insights on these issues be developed? This paper examines these questions. The specific objectives are: (1) to analyze the historical trends in the urban greening of Singapore centered on the physical provision and spatial distribution of green spaces, and (2) thereby suggest key strategies for the city to maintain a high level of urban greening in view of the twin drivers of increasing built-up area and population density. The approach taken is a longitudinal study of the quantum and distribution of urban green spaces (UGS), juxtaposed against key urban development patterns and green space indicators of comparable cities, using primary and secondary data sources. This line of enquiry seeks to identify the key contributory factors leading to a high level of greening in Singapore, and possible strategies going forward that will also be relevant for developing cities of the region. UGS in the paper refers to the managed green spaces in the form of greenery in public and private open spaces, parks, greenery on buildings such as on walls, roofs and podiums, as well as roadside greenery. This is in contrast to unmanaged greenery, which refers to secondary and primary forests, including those in nature reserves and undeveloped land. The rest of the paper is organized as follows: an analysis of the current distribution of greenery in Singapore, including changes in different aspects of UGS over the past decade, followed by an analysis of key urban developmental factors that will shape future provision of UGS, and how UGS planning could respond to the challenges.

Physical patterns of green spaces in Singapore

Vegetation and tree cover

The scale of the greening efforts in Singapore has to be viewed in the context of rapid urbanization and other land use pressures that compete with limited land resource for a small city-state. For a relatively young city, Singapore's original land cover had undergone rapid and massive transformation from its primeval conditions, as described in Corlett (1992). Sustained deforestation for cash crops plantations within the first century of its founding in 1819, followed by urbanization driven by population growth and economic developments, has drastically removed the original forest and secondary forest covers. To-date, only about 200 ha of its original land cover, or about 0.28% of its total land area, remains intact. It can therefore be inferred that a substantial component of the overall greenery in Singapore has been recreated as UGS.

[1] Total expenditure is the sum of operating expenditure (including manpower expenditure) and development expenditure. Per capita expenditure on parks and greenery management programme was SGD$1.48 in 1970, SGD$10.98 in 1980, SGD$17.24 in 1990, SGD$27.47 in 2000, SGD$78.10 in 2010. Total expenditure on parks and greenery management expressed as a percentage of total government expenditure, increased from 0.4% in 2000, to 0.52% in 2005 and 0.85% in 2010. *Source*: expenditure data from MOF (multiple years); population data from DOS (2012).

[2] Both population density and population of Singapore increased exponentially from early 1900s to current period. For instance, between 1970 and 2011, population density increased by about 105%. *Source of data*: DOS (2012).

In fact, recent analysis of vegetation cover of the island indicates that UGS constitutes about half of all green spaces in Singapore, with the remaining half comprising unmanaged vegetation of secondary forests, young secondary forests on reclaimed land yet to be developed, as well as small remnant patches of primary forest and mangrove areas (Table 1). Together, these two types of green spaces contribute to an overall vegetation cover of 56%. The vegetation cover includes shrubs and other forms of ground cover including scrubland and turfed areas, and is distinguished from tree canopy, which is a more commonly used metric for extent of urban greening in cities (Berland, 2012). The tree canopy cover is conservatively estimated to be at around 31% (Table 2). This is marginally higher among the cities from which tree canopy cover information is available. For instance, the average tree canopy cover among 20 US cities is around 27.8% (from Nowak & Greenfield, 2012). For Melbourne, a city which has dedicated a relatively high percentage of its city area for parks, the tree cover is 22% (City of Melbourne, 2011). Singapore is therefore not significantly differentiated from other cities in its tree cover, especially considering that the large portion of its tree cover is attributed to forest cover of the central and western catchments.

As a city-state which needs to cater for diverse land functions of a city (residential, commercial, recreation, etc.) as well as those of a state (nature reserves, water catchment, heavy industries, etc.), it is expected that there is significant spatial heterogeneity in vegetation cover. This is shown in the distribution of vegetation cover among selected planning areas[3] in Singapore (Table 3). For instance, even after excluding the planning areas of Western Catchment, Central Catchment, Lim Chu Kang and Mandai which have vegetation cover as high as 93% as they encompass large parts of the forested areas of the Central Nature Reserve and western water catchment, the difference in vegetation cover between the highest in Bukit Panjang (62.6%) and the lowest in Pioneer (9.6%) was 53%. The planning areas of Tuas and Pioneer, which are zoned for heavy industries, have the lowest vegetation cover. The older regions of Singapore, i.e., areas of early settlements, such as Rochor, Downtown Core, Singapore River, also have comparatively low vegetation covers. These are approximately half of those of newer housing estates, such as Punggol and Seng Kang.

However, there is no discernible relationship between vegetation cover and population density among the different planning areas (Fig. 1a). This contrasts with observations in a similarly compact city like Hong Kong in which higher population density and building density correlate with lower green cover (Tian et al., 2011). However, as in the case of Hong Kong, per capita green space, which is approximated from per capita vegetation cover, decreased with increasing population density. In Singapore, the sharp decrease occurred until a population density of 4000–6000 per square kilometer, when the decrease becomes more gradual (Fig. 1b). A logarithmic function fitted to the data points showed a significant negative relationship between the two variables ($R^2 = 0.798$, $p < 0.001$, df = 32). Planning areas with relatively high vegetation cover per capita of 1% per 1000 residents or more are dominated by those with a high level of mixed land uses, particularly for commercial uses and private residential housing. These include the planning areas with low vegetation cover, such as Rochor, Singapore River and Downtown, and as well as predominantly private residential estates in River Valley, Tanglin and Novena. Public housing estates, which house more than 85% of the population, tend to have moderate to low levels of vegetation cover per capita. Population is the dominant factor among the three variables of population, area of planning area, and overall vegetation cover, which determine the relative levels of vegetation cover per capita. In other words, planning areas such as Tampines and Yishun have lower per capita vegetation cover, not due to lower overall vegetation cover, but because of higher population sizes.

[3] Singapore is divided into 55 planning areas. The demarcation of the planning areas are available in URA (2008).

Table 1
Distribution of vegetation cover (per cent of land) in Singapore. The vegetation cover of parks and roadside is estimated as the amount of land dedicated to roadside greenery and public parks (managed by the National Parks Board). The vegetation cover of "other public and private estates" (such as urban green spaces in housing, commercial, business and industrial estates) is estimated as total managed vegetation cover less those of parks and roadside greenery. *Source*: amount of land area dedicated to roadside greenery and public parks in 2010 (NParks, multiple years); all other figures (Yee, Corlett, Liew, & Tan, 2011).

Vegetation cover	Percentage (%)
Managed vegetation (urban green spaces)	**27.5**
Public parks	3.2
Roadside greenery	3.7
Green spaces in other public and private estates	20.6
Unmanaged vegetation	**28.5**
Scrubland	5.92
Young secondary forest	19.6
Old secondary forest	1.37
Primary forest	0.16
Mangrove forest	0.91
Freshwater marsh	0.11
Freshwater swamp forest	0.39
Total vegetation cover	**56.0**

Urban parks

During the two to three decades leading to its independence, rapid population growth and poor infrastructure had led to generally grim urban living conditions. According to Yuen (1996), Singapore in the early 1960s had one of the largest slum areas in South-Asia. It is therefore to be expected that parks and open spaces provision then will not rank high compared to other basic housing and infrastructural needs, and which are provided as an afterthought on left over spaces. Neo et al. (2012) also described park development efforts in the early 1960s as "mostly unplanned and cosmetic". In 1971, the Concept Plan stipulated a recreational open space standard of 0.13 ha per 1000 residents (Neo et al., 2012). From the 1970s to 1980s, parks and open spaces, through a hierarchy system of parks such as precinct garden, neighborhood park and town parks, were systematically introduced as integral spaces of new township developments (Yuen, 1996). Public park area continued to increase over the past decade (Fig. 2a), and took up about 3.2% of Singapore's land area in 2010 (Fig. 2b). The park provision ratio (PPR), which is park area per 1000 residents, was 0.75 ha per 1000 residents. This is a low to moderate level compared to other cities in Asia-Pacific, north America and Europe (Table 4). While comparatively high among Asian cities, Singapore's PPR is significantly lower compared to cities with lower population densities such as Melbourne and Stockholm. It is also more than three times lower than the average PPR of 13 high-density cities in north-America. Mainly driven by a higher population growth, PPR had remained constant after 2004, despite the gradual increase in park area. The PPR was lower than the target of 0.8 ha per 1000 residents for more than a decade (Fig. 2b), which has been set as a land use planning parameter since the 1980s (Tan, 2006). Both PPR and park area as a percentage of city area are clearly influenced not just by park area, but also by population and city area, and how city boundaries are defined. Cities with high population, such as New York City and Chicago, need not necessarily have low PPR. However, as population density increases, as in the case of Singapore, it will become increasingly challenging to increase or maintain its PPR. This is consistent with the evidence that up to an

Table 2
Tree cover of cities.

City	Tree canopy cover as percentage of city area	Notes and sources of information
Singapore	31	Yee et al. (2011) estimated the overall vegetation cover to be 57%, which includes area covered by grass (e.g. amenity lawns, sports field, and golf courses) and other ground cover, other than trees and shrubs. Based on the sum of estimated forested canopy cover (22.1%) and assuming that about a third of managed vegetation cover (27.5%) is treed (including roadside trees, trees in parks, public and private estates, and institutions), overall tree canopy cover is conservatively estimated to be about 31%
Average of 20 US cities	27.8	Figure refers to tree and shrub vegetation cover, ranging from a low of 9.6% in Denver to a high of 51.6% in Atlanta. *Source*: Nowak and Greenfield (2012)
Melbourne	22.0	City of Melbourne (2011)
Los Angeles	20.6	Figure refers to tree and shrub vegetation cover. *Source*: Nowak and Greenfield (2012)
Toronto	19.9	City of Toronto (n.d.)
New York City	19.3	Figure refers to tree and shrub vegetation cover. *Source*: Nowak and Greenfield (2012)
Beijing	19.1	Figure refers to tree and shrub vegetation cover. *Source*: Yang and Zhou (2009)
Chicago	18.0	Figure refers to tree and shrub vegetation cover. *Source*: Nowak and Greenfield (2012)
Sydney	15.5	City of Sydney (2011)
Shanghai	10.2	Figure refers to tree and shrub vegetation cover. *Source*: Yang and Zhou (2009)

Table 3
Vegetation cover of and population density of planning areas, arranged in decreasing per capita vegetation cover. Note that planning areas with high vegetation cover typical of forested areas, namely Central Water Catchment, Lim Chu Kang, Mandai, Marina East, Simpang, Straits View, Tengah, and Western Water Catchment and offshore islands have been excluded. Similarly, planning areas with very low population such as business (industrial) areas, civic and shopping districts, namely Pioneer, Tuas, Boon Lay, Orchard, Museum, Sungei Kadut, Changi Bay, Seletar, Paya Lebar and Marina South, have been excluded. *Source*: vegetation cover information (Hahs et al., 2011); population (DOS, 2012); planning area and dominant land use (URA, 2008).

Planning area	Vegetation cover (%)	Per capita vegetation cover (% per 1000 resident)	Dominant land use
Changi	57.3	22.92	Port/airport, reserve site
Newton	52.3	8.05	Residential, civic and community institution
Singapore River	12.7	5.52	Business, commercial, commercial and residential
Downtown core	19.7	5.32	Business, white, reserve site
River Valley	33.7	3.92	Residential
Tanglin	55.7	3.13	Residential, park
Outram	28.5	1.30	Commercial, commercial with residential
Novena	52.4	1.11	Residential
Rochor	16.9	1.11	Business, residential
Marine Parade	41.8	0.86	Residential, reserve site
Bukit Timah	48.2	0.67	Residential
Punggol	45.3	0.61	Residential
Bukit Panjang	62.6	0.48	Residential, open space
Sembawang	33.9	0.46	Residential, business
Bishan	40.0	0.43	Residential, business
Bukit Batok	56.2	0.39	Residential, park, special use
Queenstown	37.1	0.38	Residential, port/airport, educational institution
Clementi	30.8	0.34	Residential, business
Pasir Ris	40.8	0.30	Residential, business
Toa Payoh	37.2	0.29	Residential
Ang Mo kio	51.9	0.29	Residential, reserve site
SengKang	48.2	0.27	Residential
Jurong East	23.4	0.27	Business, reserve site, residential
Yishun	50.5	0.27	Residential, special use, reserve site
Kallang	26.6	0.26	Residential, business, sports and recreation, reserve site
Bukit Merah	38.2	0.24	Residential, business, park
Choa Chu Kang	35.6	0.20	Residential
Tampines	45.7	0.18	Residential, reserve site sports and recreation
Geylang	19.9	0.17	Business, residential, institution
Serangoon	19.7	0.16	Residential
Woodlands	35.9	0.14	Residential
Hougang	27.7	0.13	Residential, business
Jurong West	33.3	0.12	Residential, residential with commercial
Bedok	32.3	0.11	Residential

upper limit, per capita green space tends to decrease with increasing population densities in a study of 386 European cities (Fuller and Gaston (2009). Similarly, the relationship between PPR and population density of cities listed in Table 4 showed a decreasing relationship between PPR and population density (Fig. 3), although the relationship is not statistically significant ($R^2 = 0.20$, $p < 0.168$, df = 9). Particularly for compact cities with small land area, such as Singapore, population density is expected to be a key driver of future changes in cities' PPR.

Strategies for maintaining a high level of greenery

The trends in and the spatial distribution of urban green spaces highlight several learning points that form important considerations for how the city could continue to maintain a high level of green. Firstly, population density is a consistent driver of low vegetation cover per capita, which when used as an approximation of per capita green space, predicts a declining green space per person over the past development period of Singapore, as well as a likely

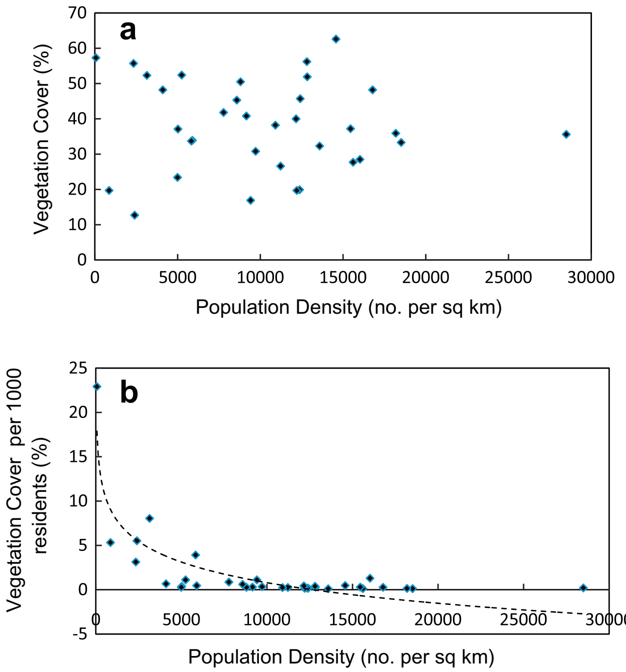

Fig. 1. Relationship between (a) green cover of planning areas versus population density, and (b) green cover per 1000 residents within planning area versus population density. *Source*: vegetation cover information (Hahs, McDonnell, Dobbs, Giljohann, & Holland, 2011); population density and population in each planning area (DOS, 2012).

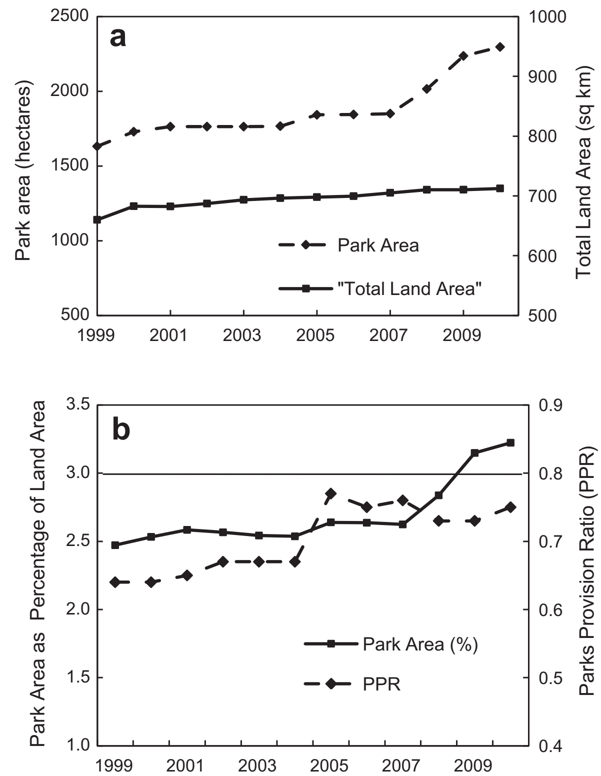

Fig. 2. (a) Changes in total area of public parks maintained by the National Parks Board (primary vertical axis) and Singapore's total land area (secondary vertical axis); (b) park area as percentage of total land area (primary vertical axis) and parks provision ratio (PPR) (secondary vertical axis). Singapore's target PPR is 0.8 ha per resident (horizontal line). Total park area excludes the Bukit Timah Nature Reserve, Central Catchment Nature Reserve, Sungei Buloh Wetland Reserve and Labrador Nature Reserve, and precinct gardens in public housing estates. *Source*: park area and PPR (MOF, multiple years; NParks, multiple years); population (DOS, 2012); Singapore's land area (SLA, n.d.).

reduction in the future with rising population density. The downward pressure is also expected for UGS in the form of usable recreational spaces measured as PPR. New directions need to be adopted to expand possibilities of incorporating UGS in the urban fabric, both for recreational and ecological considerations. Secondly, given that Singapore's PPR and tree canopy cover are not significantly differentiated from other cities despite its Garden City reputation, it appears that the visual presence of UGS, rather than its absolute quantum could have an important role that has not been recognized. An important strategy going forward could be to enhance the visibility and visual quality of UGS. Thirdly, the marked contrast between vegetation cover in older and newer planning areas suggests that even with urban renewal, areas with a history of low vegetation cover have limited opportunities for further increases in vegetation cover. This suggests that upfront urban planning is critical for adequate levels of UGS. These points are elaborated below.

Table 4
Park provision ratio (PPR), and park area as a percentage of city area of cities in Asia-Pacific, North America, and Europe.

City	Park provision ratio (hectare of park area per 1000 resident)	Park area as percentage of city area (%)	Notes and sources of information
Stockholm	7.38	30	Derived from percentage of park area to city area, city area and population figures from City of Stockholm (2012)
Melbourne	4.77	12.5	Derived from park area, city area, and population figures from City of Melbourne (n.d.)
Los Angeles	2.51	7.9	Harnik (2010)
Average of 13 high-density north-American cites	2.44	11.6	Harnik (2010)
New York City	1.86	19.6	Harnik (2010)
Chicago	1.70	8.2	Harnik (2010)
Shanghai	1.06	2.3	Derived from park area, city and population figures from Shanghai Municipal Government (2009)
Singapore	0.75	3.2	PPR from MOF (2012); park area as percentage of city area from NParks (multiple years) and SLA (n.d.)
Hong Kong	0.35	2.3	Derived from park area (parks, playground and stadia), land area and population from HKSAR Government (n.d.)
Seoul	0.52	8.8	Derived from Choi (2007) for parks in urban areas
Barcelona	0.35	5.5	Derived from park area, city and population from Barcelona City Council (n.d.)
Bangkok	0.19	0.67	Derived from Thaiutsa et al. (2008) for publicly accessible parks, and excluding golf courses

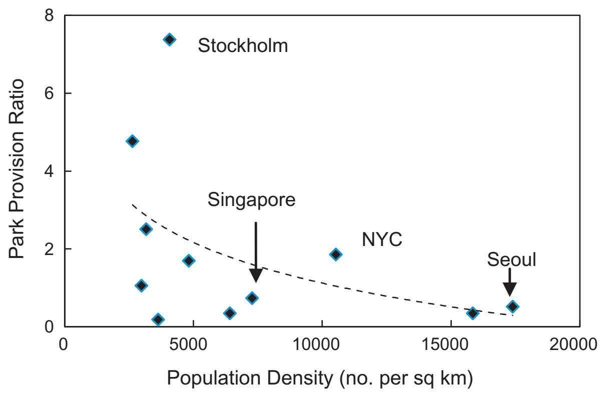

Fig. 3. Relationship between park provision ratio and population density of cities in Table 4.

Coping with rising population density through multi-functional spaces

The effect of declining per capita green space with increasing population density has been observed to be mainly an effect of more people within the urban areas. It nevertheless points out that the adequacy of, and therefore, access to green spaces on per person basis will be a concern with further population growth. There is currently no local assessment of what would be the threshold level of per capita green space below which the functional benefits of UGS will be drastically reduced. It has been reported that the World Health Organization recommends a minimum of 9 m^2 of per capita green space (for instance, as cited in Thaiutsa, Puangchit, Kjelgren, and Arunpraparut (2008)). However, as green space requirements are influenced by the unique social and cultural traits of cities and their communities, locally determined needs and thresholds will be more meaningful to inform planning policies relating to green space and open space provision. This is an area requiring further studies in Singapore. Nevertheless, to cope with increasing population density, it is also necessary to look at complementary spaces in the built environment that could deliver the benefits of UGS. For instance, particular attention has already been given to how Singapore can maximize the space in its high-rise environment to create a "Vertical Garden City" through active greening of the vertical space, such as in the form of rooftop gardens, vertical green walls, and sky terraces (Tan, 2012). However, although such green spaces continue to add to the overall greenery of Singapore, not all of such spaces are public spaces, and future policies will need to address the usability of such high-rise landscape spaces by the general public. For instance, while designed for access by occupants of the buildings, high-rise gardens on private residential, commercial buildings, and even some public residential buildings are typically not designated for open public uses. Policy innovations to require public access to privately-owned spaces may seem odd now, but could be a reality to confront in the future as Singapore, and similarly space-constrained cities examine ways to provide green open spaces so crucial to the liveability of cities. A telling indication is that Singapore for more than a decade has not met its PPR target despite increases in park area, pointing to the need for an examination of other open spaces that could also function as public recreational areas. Other than the greening of buildings, currently unused spaces, such as those under road flyovers, and open spaces in educational and other public institutions also offer opportunities to further expand the range of spaces suitable for recreational uses by looking beyond traditional site boundaries. This is in essence, adopting a stronger focus to achieve multi-functional land and infrastructure uses in high-density, compact cities as a means of optimizing land uses. This will also necessitate a review of how complementary green spaces should logically be included in the assessment of PPR.

Increasing the visibility and perception of UGS

The PPR and park area as a percentage of city area are at a low to moderate level compared to other cities. Tree canopy cover is also lower than those reported for several north-American cities. For Singapore to achieve the perception of a high level greenery throughout the island suggests that the overall land area that is dedicated for UGS, although important, is likely to be inadequate or act as the sole factor needed to achieve the perception of a green city. In fact, the gradual increase in built-up area in Singapore from the 1960s onwards, reaching about 60% in 2012, could have created an urban landscape that is visually dominated by an omnipresence of glass, concrete, steel and asphalt seen in cities with an equivalent level of built-up area. An example is Tokyo, which has a built-up area of 54.5% of the city's area (Tokyo Metropolitan Government, 2000), with the remaining nonbuilt-up areas in more suburban land uses such as country parks and forests, paddy fields, waste land, ponds and swamps. Within the urbanized zones, there is a general deficiency of green spaces (Tokyo Metropolitan Government, 2007; Yamamoto, 2010), pointing to an uneven distribution of green spaces over the whole metropolitan area. This has similarly been described of Genoa, which has a high overall vegetation cover but a low level of UGS in the urban core (Venn & Niemala, 2004). An uneven distribution in a city's vegetation cover will be manifested in the uneven distribution of its tree canopy cover (Yang, Zhao, McBride, & Gong, 2009), and will in turn affect the visual quality of UGS. The visual quality and visibility of greenery within the built environment has been suggested to be an important facet of the sensory function of greenery, and this has an immediate influence on the aesthetics of the urban landscape, appreciation of, and exposure to greenery in the day-to-day living of residents. This suggests that the spatial distribution of greenery, more than the amalgamated quantum of greenery is important for achieving a high perceived level of green within the city.

In this aspect, it is suggested here that two greening policies play a significant role in ensuring the visibility of greenery in Singapore. These are: the provision of dedicated planting verges along roads, and the requirement of green buffer to be set aside for developments facing roads. The planting of trees along roads is a regulatory requirement for a 2–4-m planting verge (depending on the category of road) to be provided as part of the standardized code of road construction.[4] The impact of this is that as the built-up areas in Singapore continued to expand, roadside greenery was systematically introduced into developed areas of Singapore from the 1970s onwards when the requirement was first imposed. A snapshot of this development showed that the roadside greenery area maintained increased by 15% between 1999 and 2010 (from NParks (multiple years)), whereas over the similar period, the length of paved roads in Singapore increased by 11%.[5] This suggests that at least over this period, roadside greenery was created at a similar pace as road construction, and which allowed greenery to be introduced in tandem with land development throughout Singapore.

The green buffer policy requires a 3–5-m verge to be set aside for tree planting on the sides of developments with boundaries that front a public road.[6] These green buffers are represented in

[4] A schematic representation of the planting verge requirement is available in Neo et al. (2012).

[5] Total length of paved road is 3038 km in 1999 (MITA, 1999), and 3377 km in 2010 (DOS, 2011).

[6] The green buffer, together with the physical buffer, constitutes the physical setback that is required between the building line and the road reserve line for developments with boundaries fronting a public road. Schematics of the buffer requirements can be viewed in (NParks, 2011a).

the category "green spaces in other public and private estates" in Table 1. The specific requirement varies with the types of development and the roads. There are two impacts of this requirement. Firstly, even within private land, there is a need to create a second layer of trees that runs parallel to roadside trees. This, together with the physical buffer space between the building line to the road reserve line, creates an increased visual depth of "borrowed greenery" for pedestrians and motorists. The second impact is that the physical setback provides important aerial space for trees to develop majestic canopies. This, as highlighted earlier, is a major constraint for tree planting in already built-up areas without adequate building setback from roads. The policies of tree planting along roads and green buffer within developments have in effect, created a consistent urban form that is extensively replicated throughout Singapore. So while publicly managed parks and roadside greenery maintained take up approximately the same land area at around 3.2% and 3.7%, respectively, due to the pervasiveness of roadside greenery, complemented by a second layer of privately managed greenery within the green buffer, the latter has a more critical role in the visual perception of green within Singapore beyond what its land uptake suggests. Clearly, a strategy going forward is to maintain a high level of roadside greening. This is especially important in view of the declining mature tree population in Singapore that has been observed for almost a decade from 2003 onwards, largely due to land developments and roads widening (NParks, 2011b). In addition, through leveraging on the movement in Singapore to introduce greenery to its buildings, in the same way as roadside greenery expanded with the road network, green spaces can similarly keep pace with the proliferation of buildings.

UGS should be considered upstream in urban planning

Other than the industrial estates, the planning areas with the lowest vegetation cover are in the areas of early settlements and development in Singapore (eg. Singapore River, Downtown Core, Rochor). This is despite these areas having also undergone extensive urban renewals, suggesting that once developed, urban areas do not have significant opportunities for the introduction of green spaces, or that it will take several cycles of urban redevelopment for significant amount of greening to materialize. In fact, this could be the case in Hong Kong, which by the early 1950s already had a high proportion of built-up area (Hughes, 1951). Intensive high-rise and high-density developments during the subsequent two to three decades of economic and population growth further reduced the availability of open spaces within the city, which led to major impediments in inserting urban trees due to a lack of building-set back from public roads and congested below-ground spaces for adequate root growth (Jim, 1998, 2000). To-date this remains a persistent condition in the urban fabric of Hong Kong. The lack of at-grade planting spaces due to compact urban form with inadequate building set-back from the site boundary is a prevalent condition observed in the historical districts of Singapore. Efforts to introduce more green spaces could also be in conflict with the objective of conservation of the built heritage, which requires a certain level of historical authenticity in the conservation of buildings that will make it challenging to extensively integrate modern urban greening technologies of green walls and green roof onto the buildings without affecting the veracity of the conserved buildings. A possible solution is to convert portions of roads into at-grade planting areas, which will however compromise vehicular traffic movement. Clearly, heritage conservation objectives and urban greening objectives require trade-offs and affected communities will have to make collective decisions about the character of environment it desires. In the case of Singapore, urban heritage conservation areas amount to 751 ha (Yuen & Ng, 2001), or about 1% of Singapore's land area, suggesting that the problem is not extensive. Nevertheless, planning from a clean slate to cater for adequate UGS will offer more possibilities for adequate UGS to be safeguarded than subsequent urban renewal efforts, and should be a critical consideration in urban planning and design.

Both managed and unmanaged green spaces have to be considered

The discussion thus far has centered around managed vegetation (UGS), but it is obvious that unmanaged vegetation, most of which has developed from previously cleared forests, constitutes the other significant half of vegetation cover in Singapore. It will be necessary to consider these in the overall management of green spaces in Singapore. They have in fact, been the subject of recent debate on conservation of such spaces in view of impending developments (Chua, 2012). Such large spaces would logically have lower level of direct-use values for recreation, but could serve important ecological functions of biodiversity conservation and water catchment. They also form an important component of the emerging concept of ecosystem networks, or ecological networks (Opdam & Steingrover, 2008). This is particularly relevant to the recent effort to re-invent Singapore as a "City in a Garden" (NParks, 2012),[7] although the idea of a City in a Garden had been announced much earlier, with aims to create gardens in "all green spaces", make parks alive with programmes, and inject night life in parks (Lee, 1998). In particular, one of the announced initiatives is to enhance the urban biodiversity of Singapore. The patches of unmanaged vegetation dispersed in the urban matrix of Singapore form logical focal areas in an ecological network for biodiversity enhancement. However, the development of comprehensive urban ecological network requires an integration of multiple knowledge domains, for instance, in conservation biology to determine conservation value and needs of diverse species, in environmental biology to determine relationships between land use patterns and ecosystem processes, and in urban planning to understand how biodiversity conservation can dovetail with long term and strategic land use plans. Such an interdisciplinary approach is challenging to engender in an environment where science is seldom used in land use decision making processes (Opdam & Steingrover, 2008). In Singapore, it is still in its infancy stage undertaken in small scale studies in postgraduate research in the academia. However, it is a necessary step towards a holistic method of combining greening, conservation and other land use functions. It will also be useful as a means to address past criticisms of the loss of natural areas arising from extensive urban development. It has been suggested that Singapore could have taken a more sensitive approach to marry conservation of its natural spaces with land developments (Koh, 2000; Lin, 2007; Perry, Kong, & Yeoh, 1997), instead of adopting a typical pathway of clearing of vegetation, land development, followed by replanting of greenery. Given the public current interests in the protection of young secondary forests from developments, Singapore is at a point where innovative urban design and ecological ideas can be experimented to best meet conservation and developmental objectives of these sites.

Conclusions and Prospects for the future

Singapore embarked on an active urban greening programme early in its urban developmental history with an emphasis on creating a clean and green city, before issues of quality of the physical environment have come to the forefront of current discussions on cities' liveability and environmental sustainability. It has avoided a blighted urban landscape that typifies many rapidly urbanizing

[7] It is also interesting to note that Chicago, back in 1837 has adopted "Urbs in Horto" (City in a Garden) as the city's motto, and which appears in Chicago's corporate seal, although most Chicagoans probably do not pay much attention to it (Coclanis, 1992).

cities, in which efforts to re-introduce greenery will be now more challenging, and opportunities limited in having to grapple with already built-up spaces. However, assessment of both the internal distribution of per capita green space among planning areas, as well as comparison of UGS provision with other cities show that it is not immune to the downward pressure of rising population density on UGS. The observations of a declining mature population of trees and a PPR that has stayed below its planning target for the past decade suggest a need to look at strategies to upkeep both the quantum and visibility of UGS. In addition, it is also critical that as Singapore looks into the future, there is attention given to not just keeping it green, but also making it more ecological. Recent advances and synthesis of the knowledge in urban ecological studies are beginning to forge an understanding of how cities function as urban ecosystems (McDonnell, Hars, & Breuste, 2009; Pickett et al., 2011), and how within this ecosystem, green spaces, soil and water-bodies, interact to influence the overall flows of energy, water, nutrients, etc., and will affect the health and functioning of cities and their inhabitants. While urban ecosystem studies have yet to be effectively used in policy-making, useful frameworks have nevertheless been developed to improve our understanding of cities as complex systems, and the role of green spaces and biodiversity within the urban ecosystem. It is a field that can lead to an improved understanding of the ecology of Singapore (Tan & Abdul Hamid, 2012). Singapore, with its current high level of greenery as a foundation, will be in a good position to participate in the development of further knowledge in this frontier.

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