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Green-space preservation and allocation for sustainable greening of compact cities

C.Y. Jim*

Department of Geography, University of Hong Kong, Pokfulam Road, Hong Kong, People's Republic of China

Including greenery in human settlements is a tradition deeply rooted in antiquity, with diverse expressions. Realization of the green city ideal has changed with prevailing social–economic–political regimes and landscape styles. Variations in land use and development mode have generated green spaces of different geometry, distribution and composition. The compact city incurs inherent physical and institutional obstacles, restricting the quantity and quality of amenity vegetation. Recent research findings in arboriculture, urban forestry, urban ecology, urban planning and urban geography suggest alternative strategies for both existing and new green sites. A multidisciplinary interpretation distils relevant principles and practices to facilitate greening in packed neighborhoods and overcome major constraints. Measures are proposed to guard green spaces from intrusion, intensification and infilling to preserve both sites and conditions for plants, wildlife and ecological functions. New developments and redevelopments, with suitable encouragement and incentives, can earmark enough new green areas with appropriate location and design. Natural enclaves, especially woodlands, with high biodiversity and complex biomass should be incorporated into the future built environment. Partnership among government, developers and citizens should nurture the community's determination and capability to augment greening. A coordinating body to mobilize initiatives and efforts could gel disparate stakeholders and bring concerted actions.

Keywords: Green city, Compact city, Sustainable city, Green space, Green site, Green plan, Urban tree, Urban forest

Introduction

The green city is an ideal of universal appeal that transcends temporal, spatial and cultural divides (Hestmark, 2000). Greening is realized to different extents in cities, often subject to fluctuating contemporaneous societal attitudes and political climate (Mumford, 1961; Attorre *et al*., 2000). A city with high-quality and generous green spaces epitomizes good planning and management, a healthy environment for humans, vegetation and wildlife populations (Adams and Leedy, 1987; Johnston, 1990; Godefroid, 2001), and bestows pride on its citizenry and government. It is human nature to harbor psychological attachment to beautiful natural objects such as meritorious amenity vegetation (Kaplan, 1984; Ulrich, 1986). Different socio-economic strata develop similar appreciations and preferences for urban nature (Kuo *et al*., 1998). The multiple functions and benefits of urban vegetation are widely known (Mole and Young, 1992; Petit *et al*., 1995) and expressed in tangible monetary terms (McPherson *et al*., 1997; Nowak and Dwyer, 2000), yet they can be sidetracked, if not suppressed, by political expediency and bureaucracy (Foster, 1977; Duvernoy, 1995). Regardless of existing green endowments, many enlightened and informed politicians, administrators, planners and citizens aspire to create green cities (Hough, 1994; Bradley, 1995) that echo the garden-city ideal (Howard, 1902). Many cities earnestly provide greenery in new developments and preserve existing greenery in redevelopments and expansions (Gordon, 1990; Beatley, 2000). Urban sustainability increasingly requires the abatement of pollution, plus the addition of positive features, notably trees, to

*Tel.: +852-2859-7020; fax: +852-2559-8994; e-mail: hragjcy@hkucc.hku.hk

ameliorate the new scarcity of healthy environments (Finco and Nijkamp, 2003).

Compact urban areas are characterized by the close juxtaposition of buildings and roads with limited interstitial space to insert greenery; mixed land use; and a union of form and function (Jenks *et al*., 1996). The compact city here encompasses the high-density built form (Burton, 2002) with a high proportion of the land surface covered by buildings and other artificial structures and surfaces. The ratio of impervious to pervious areas is very high (Arnold and Gibbons, 1996), and conditions for plant and animal life are usually trying. The advantages and disadvantages of compactness have been well expounded. Many cities contain areas with exceptionally high development density in the inner city or the old urban core, formed by organic accretions. Some cities develop new compact areas or infill existing areas to a higher density (Williams, 1999). Whether old, modified or new, such compactness needs more attention to green-space provision and environmental well-being, which could be overlooked or sacrificed (Jim, 1990). If green space is deprived, a compact city becomes the antithesis of a green city. The destruction of existing vegetation and inadequate plantable spaces (Jim, 2000) degrade the environmental quality, quality of life and human health (Jackson, 2003).

The case of cities in developing countries in particular is worrying because of the urge to take the myopic path of developing first and making amends later (Olembo and de Rham, 1987), and failing to benefit from other cities' experience. The exigencies of meeting basic needs and development aspirations may overshadow greenery and other environmental concerns (Marcotullio, 2001). Rapid urbanization and intensification, especially in some developing cities, could compromise environmental planning. Whereas individual cities have unique problems and limitations in implementing the greening imperative, most physical and physiological constraints that beset vegetation growth tend to be generic (Grey and Deneke, 1986; Bradshaw *et al*., 1995; Jim and Liu, 2001a). The constraints, however, are manifested at an increasing magnitude and pervasiveness in areas with condensed development. An understanding of the tangible and intangible limitations (Grey, 1996; Miller, 1997) could provide hints to maximize opportunities for green space and greenery in the sustainable city quest.

Urban greening, a common if not universal environmental issue, deserves more attention and resource support, with strengthening of both policies and practices. Comparing to spacious developments, green spaces for compact city areas encounter more restrictions and stresses, and are more amenable to degradation and losses (Jim, 2002a). Their green-space planning and management require more dedicated and coordinated efforts. This paper, adopting a problem-based approach, surveys the pertinent limitations to greening in packed city precincts, proposes precautions and preventive measures to forestall greenery degradation, and identifies practical alternatives, solutions and opportunities for greenery. With planning and foresight, compact areas could provide a reasonable quantity and quality of amenity vegetation to ameliorate the harsh milieu.

The first-hand experience on urban greening in compact cities, which epitomizes some of the extremely packed urban form, in conjunction with observations in other cities, provides information and insight for the ensuing analysis. By modifying existing approaches or adopting innovative ones, whether successful or otherwise, cities offer empirical examples from the standpoint of both researchers and practitioners. Urban greening is inherently a multivariate venture that demands the union of knowledge from disparate expertise and disciplines, and that the experience of a city could often be useful to others. Many fine cases, good practices and object lessons, however, remain obscure or fail to propagate and be applied outside their original realms. The gap between research and application and between science and practice, in the field of urban greening, needs to be closed by a more effective amalgamation of ideas and communication.

Recent research findings in a group of cognate disciplines, including arboriculture, urban forestry, urban ecology, urban planning and urban geography, have nurtured an interdisciplinary confluence that could be translated into policies and practices. A comprehensive review can serve to integrate the latest findings in the field from a planning perspective. With a longer life span, larger biomass and more notable environmental functions, trees are used as the surrogate of urban vegetation in the discussion. Relevant issues will be explored from the viewpoint of two fundamental entities in the urban greening equation, namely existing and new green sites. Existing sites have to be preserved against development pressure, and new ones adequately designated in new developments. The analysis is structured around five basic questions, namely what, where, when, how and who? The principles are expounded first, followed by their translation into practices to implement greening endeavors. Where appropriate, actual examples will be used to support or illustrate the exposition.

Existing green sites

What could be accomplished? This category includes all existing green spaces principally situated at the ground or street level, provided by the government and private sector, with or without

access to the public. It covers formal green spaces and remnant green pockets left by default due to topographical, geotechnical and other physical constraints (Jim, 1989). The planner could guard such "gap sites" against conversion to preserve the high degree of naturalness and wildlife habitats, and to enhance their essential contribution to urban environmental and scenic qualities (Parsons and Daniel, 2002) or outdoor recreation (Tartaglia-Kershaw, 1982). The planning authority needs to conduct a comprehensive survey to identify the city wilds, such as the treatises on London (Fitter, 1945) and on Portland, Oregon (Houck and Cody, 2000), and zone them as conservation areas. These sites can fulfill the increasing needs of many people who harbor the ecocentric form of environmental value and prefer informal and wild sites that provide solitude and escape from city existence (Kaltenborn and Bjerke, 2002; Thompson, 2002). It is especially pertinent to protect natural sites situated near homes and that are easily accessible from built-up areas, as they tend to be more frequently used for passive recreation (Müller-Perband, 1979; Burgess *et al*., 1988). Where green spokes or fingers penetrate at the urban fringe, with interpenetration between city and nature, they should be preserved to maximize their conservation and environmental functions, as illustrated by the example of Stuttgart in Germany (Schabel, 1983) and the proposed green plan for Nanjing in China (Jim and Chen, 2003).

Some sites are fully occupied by trees, especially natural woodland pockets occluded within the built-up areas. Sites with plantable spaces yet to be enlisted for trees should be targeted to raise the tree cover. Prepared sites in general have lower ecological value than inherited natural sites, due to synthetic design with simple composition and biomass structure, limited vegetation coverage, isolated configuration, low habitat and species diversities, and lack of attraction to wildlife (Fernández-Juricic, 2000; Hess and King, 2002). Planners could aim at converting at least parts of such conventionally designed and well-manicured parks into natural areas following ecological design principles (Henke and Sukopp, 1986). The creation of a diversity of wild habitats in a naturalistic setting to be filled with native species would be welcomed by urban residents (Johnston, 1990). Even small pockets, such as the Camley Street Natural Park in the Camden Borough of London, the small Russell Square Garden in central London, and the university Botanical Garden in Prague, could create interesting ecological diversities and attract both wildlife and human visitors. It will be necessary to enlist the expert inputs of ecologists in the design team. Measures could be taken to forestall the multiple problems encountered by tree growth that are specific to compact urban areas, such as cramped above-ground environment, intrusions of structures into tree-growth space, poor air quality, vandalism and inadvertent damages, epitomized by the extreme manifestation of tree-city conflicts in Hong Kong. Roadside amenity trees in particular need to be protected against the most acute stresses (Chevallerie, 1986; Hauer *et al*., 1994). Infilling of relatively low density and low site-coverage plots has widely eliminated such green spaces.

The planner can grasp the extent of the profusion of buried utilities underneath pavements that often usurps space for tree roots and precludes tree planting. Attempts could be made to minimize the damages to roots and confinement of future root growth due to frequent excavation and trenching (Urban *et al*., 1988). Trench routing and trenching would benefit from some control or regimentation to avoid injuring tree roots, especially those of outstanding heritage trees (National Joint Utilities Group, 1995; Jim, 2003). Otherwise, routine trenching practice can weaken trees, which are predisposed to other stresses and diseases, increase the maintenance burden and induce premature decline. The planner can give proper attention to the importance of soils as a green-site attribute, one which has been widely neglected or misunderstood (Bullock and Gregory, 1991; Craul, 1992). Understanding common urban soil problems will usher in attempts to improve or replace the site soil: excessively stony and sandy materials with limited rooting volume (depth and lateral spread) (Perry, 1994; Jim and Ng, 2000); heavy compaction (Jim, 1998a); and contamination by construction rubble with undesirable alkaline reaction and other soil pollutants (Craul, 1980; Jim, 1998b).

Where should it occur? Different types of ground-level green spaces can be identified: roadside, road-median, lot-frontage, intra-lot, trans-lot, formal venue (public parks and gardens), and remnant enclaves. Due to the intensive competition to use land, green spaces in compact areas tend to be small, isolated and unevenly distributed, and are precious due to their scarcity. Formal green spaces such as public parks and gardens are usually well protected and managed (Jim, 2002b). Semi-natural and natural pockets, embedded within the city fabric or located at the city fringe, are often subject to intrusion and damage. As a city intensifies its land use and expands outwards, such no-man's land face being sacrificed (Swenson and Franklin, 2000). In some quarters, such "residual" pockets are considered to be wasted resources or impediments to development. The natural tropical rain forest pocket in the Botanic Gardens of Singapore, although small, is a rare example of preservation of nature against urban sprawl. Due to property right issues, protection of private land with high conservation value needs special policies (Bowers, 1999). A spatial planning strategy should be adopted to provide the best green-space configuration, aiming

at a green network that links patches by greenway corridors or stepping-stone sites in order to maximize connectivity (Langevelde *et al*., 2002; Vuilleumier and Prelaz-Droux, 2002). Cases in point are the Capital Area Greenway in Raleigh, NC, the Williamette River Greenway System of Portland, OR, and the Park Connector Network Plan that is in progress in Singapore. Conversely, habitat fragmentation and associated landscape degradation should be minimized, as exemplified by Phoenix, AZ (Cook, 2002) and the Delta Metropolis of the Netherlands (Valk, 2002), in order to reduce biodiversity pauperization and invasion by weeds and alien species (Smale and Gardner, 1999; Godefroid and Koedam, 2003). The massive green belts around cities such as Berlin and Seoul could serve their ecological and recreational functions better by creating links to intra-urban greenways and green spaces. The size and shape of patches and their edge structure at the city-nature interface (matrix-patch and matrix-corridor), based on landscape ecology principles, should foster ecological functions and diversities (Dramstad *et al*., 1996; Jim and Chen, 2003).

How could it be achieved? A database of actual and potential green spaces graded according to landscape and ecological values would help when developing a management plan. Conservation should aim at both physical land area and site quality for plant growth and human enjoyment. Protected sites should be guarded, against on-site and nearby off-site events, by working proactively with developers at the earliest opportunity, as illustrated by the modus operandi established recently in Seattle, WA (Ames and Dewald, 2003). Sites unavoidably or inadvertently damaged during the construction phase can be restored. Rather than adopting a resigned attitude that treats the damages as irreversible, the science of ecological restoration could be more frequently enlisted for this purpose. Protection should cover both above-ground space for continued tree growth, and soil quality and volume in the often-neglected below-ground realm (Evans *et al*., 1990; Goldstein *et al*., 1991; Lindsey and Bassuk, 1991). Intrusions into tree crowns by buildings and their appurtenances, advertisement signs, lampposts, traffic signs, and other street paraphernalia, vividly manifested in cramped urban Hong Kong (Jim, 1997) and Guangzhou, China (Jim and Liu, 2001b), should be minimized. The spirit and practice of tree protection should be enshrined in tree laws that give power to the urban tree authority and to require it to fulfill certain objectives, as exemplified by the case of Guangzhou, China (Jim and Liu, 2000).

Green spaces designated for preservation in construction sites need special attention because the protected vegetation commonly lacks proper care (Matheny and Clark, 1998; Watson and Neely, 1995). Excessive shading and venting of hot and polluted exhaust air from buildings situated near green sites can damage trees. Similarly, buried utility lines and associated installations should not intrude into the rooting room. Unusual habitats and their vegetation, such as old stonewalls embedded in urban Hong Kong (Jim, 1998c) and relict native communities, should receive special care. For natural sites, conservation zoning without proactive management measures may not protect them from degradation. A conservation plan should be prepared to protect the green enclaves from intrusion by other uses and to ensure that the natural ingredients of flora, fauna, landform, soil and water will continue to flourish. If necessary, the plan could include ecological enhancements such as selective planting of native species, or selective removal of aggressive alien species, such as the case of Mount Eden Bush in New Zealand (Smale and Gardner, 1999).

Conflicts between development and trees (Morell, 1992) could compromise attempts to minimize infilling. Upon redevelopment, setting back from lot boundaries can reduce new building footprints. Even with higher development intensity, a taller building with a smaller footprint permits more open space. Instead of excessive paving with artificial materials, pervious soil and vegetation should be preserved to allow infiltration, groundwater replenishment, flood alleviation, and unimpeded evapotranspiration to bring summer cooling (Svensson and Eliasson, 2002). Trenching should be routed away from green spaces with outstanding trees, and if that is not feasible, a suitable boring or micro-tunneling technique could be selected from the package of well-developed trenchless or no-dig methods to minimize root injury (Thompson and Rumsey, 1997; Jim, 2003). Soil conditions could be evaluated before planting with a view to amelioration or replacement with a prepared soil mix. The attempts to replace the poor site soil with specially composed soil mixes in Amsterdam (Couenberg, 1994) and in Ithaca and New York City, NY (Grabosky and Bassuk, 1995), could be monitored for their efficacy in the long term.

When should it be realized? Site preservation has to be planned in good time (Watson and Neely, 1995; Matheny and Clark, 1998). A comprehensive database of heritage trees and tree conservation areas is indispensable for effective and timely tree protection. It may be a truism to stress that a field visit of the development site must be conducted by relevant professionals before any plan is drafted. Especially for sites ripe for redevelopment, measures to retain existing green spaces have to be introduced before planning and building authorities approve developments. For roadwork, widening or re-alignment proposals that affect green spaces should be scrutinized at the earliest opportunity. By anticipating well in advance the impacts of development projects, more green sites could be

preserved by sympathetic design. If an entire green space cannot be kept, the best portion could be selected according to objective criteria (Council of Tree and Landscape Appraisers, 2000). Input of landscape professionals should be enlisted at the earliest opportunity at the project incubation stage. They should not be solicited after development plans are finalized; even so, it is still worthwhile to argue for eleventh-hour changes.

Who should implement it? The planning authority and its planning officers are the custodian of green spaces. The opinions of landscape professionals (especially arborists, landscape architects and urban foresters) must not be drowned by development-related demands. They should be treated as equal partners in the development team to provide inputs from the incipient stage of development planning (Ames and Dewald, 2003). Government land users should take measures to keep green spaces in their allocated lots. Developers should fulfill civic responsibilities to preserve green spaces and provide alternatives or substitutes for losses. City councilors, in conjunction with green groups and concerned citizens, have traditionally taken a confined watchdog role to monitor developments and propose alternatives and solutions. The increasing urge in the community to participate in local events, including local environmental improvement projects, has been echoed by the decentralized thinking and actions of many municipal authorities.

The community forestry programmes implemented by various cities can actively involve local people and interest groups, largely as volunteers, in a synergistic partnership (Jennings and Adams, 1976; Bishop, 1991). With increasing environmental awareness and literacy, some residents have taken the initiative to organize themselves to take up more proactive roles in urban greening in their own neighborhoods (Weiner, 1992; Flink and Searns, 1993). Local people desire to be given a share in the decision process, and would be less inclined for decisions to be dictated by government officers, national level organizations or special interest groups. Such sentiments are met by enlightened mechanisms that ensure that residents' concerns and ideas are heard and realized (Shindler and Neburka, 1997). A spectrum of partnership arrangements exists (Johnston, 1990), ranging from the government-dominated, to the equal status, and to the citizen-dominated. Some cities have formal institutional setups to involve citizens and interest groups, such as the Community Forestry Committee or City Tree Board in the US that are stipulated in the local urban tree laws (Abbey, 1998). Others have citizen groups playing important roles in identifying, planning, designing, planting, maintaining and protecting green sites and greeneries, including the construction of community gardens. The activities of the Friends of the Urban Forest (2003) and the San Francisco Tree Council (2003) in San Francisco, and the Green Guerrillas (2003) in New York City, are notable cases in point. Residents who planted their own public trees (investing in money, time and effort) were more satisfied with the outcome than residents whose trees were planted by the government or an outside agency (Sommer *et al*., 1994).

New green sites

What could be accomplished? New developments and redevelopments should assign green spaces following the spatial and conservation planning guidelines (Dramstad *et al*., 1996) discussed above. Rather than a biased preoccupation with green-space acreage and tree counts, planners could also emphasize the geometry of the green network and quality of the greenery. New sites should preferably have the potential to nurture high-quality amenity vegetation, especially overstory trees with sizeable biomass for substantial visual and environmental benefits. In places earmarked for future development, areas with high-grade existing vegetation, notably mature woodlands, should be preserved as gap sites to blend sympathetically with future buildings and roads (Löfvenhaft *et al*., 2002). To create interesting and diverse urban vegetation, both green coverage and contents are important. The anachronistic 19th-century idea of containing, controlling and conquering urban green spaces (Jorgensen *et al*., 2002), still widely adopted, needs to be overhauled to meet modern aspirations. Instead, informal and somewhat wild green sites could be provided to complement manicured ones (Thompson, 2002). For instance, in London, the semi-wild woodland-like state of Holland Park is in demand, as it is the case for the fine and elaborate horticultural layout of Regents Park. Factors that militate against green spaces are a tree-unfriendly development mode, excessive density, high site-coverage, lack of setback, and inertia that retards change (Jim, 2000).

Where should it occur? Spatial permeation and connectivity of green spaces is desired along new roads (amenity strips on roadsides and medians), amenity parcels in roundabouts, and incidental plots. Within lots, green spaces should be allocated in the grounds of residential, office, government, institutional and community land uses. Remnant natural areas within new developments especially should be salvaged. Planting opportunities could be maximized at linear greenway sites (Flink and Searns, 1993), such as promenades and riverbanks. More streets in city centers, and locations where vehicular traffic is light and has alternative routes, could be pedestrianized to provide green shopping and recreational venues. Vegetation could serve as

a buffer between non-complementary land uses. As far as possible, green spaces should be configured to form a landscape structure that links patches with corridors to penetrate and envelop compact urban areas. Landscape ecology concepts related to the size, shape and connectivity could be applied with imagination to green-space planning (Cook, 2002; Leitão and Ahern, 2002). Ideally, every residential area should be within walking distance of green spaces, as most people are unwilling to walk over 400 m (or 10 min) from home to reach them (Burgess *et al*., 1988).

How could it be achieved? To knit together disparate greening endeavors, a comprehensive green plan is needed with specific recommendations on locations, dimensions, ingredients and functions of green spaces, to be tailor-made for different land uses and urban habitats (Jim, 1999). Combining high-density and high-rise residential development with adequate provision of fine green spaces is feasible, as exemplified by the Tampines new town in Singapore (Foo, 2001). Residual plantable sites, which are often omitted in formal but piecemeal greening projects, could be systematically enlisted into the green network. Amenity corridors and wedges are especially valuable in a green-space web (Schabel, 1983; Valk, 2002). To avoid conflicts between trees and utilities, a dedicated tree strip protected from above- and below-ground intrusions should be separated from a utility zone. Where feasible, a utility tunnel can be built to substantially reduce the need to open trenches in the long term. Landscape projects should check soil quality and recommend amelioration. Actual planting site design, especially in confined roadside strips, needs innovative approaches to overcome the severe physical constraints (Kuhns *et al*., 1985; Evans *et al*., 1990). The successful insertion of trees along many narrow pavements in Tokyo and other Japanese cities provides some hints for other compact cities.

Trees should be mandated as an essential urban infrastructure of developments, and a statutory green-space zone can enhance provision at the land-use zoning stage. A green building code that stipulates intra-lot and lot-frontage green-space standards can trigger widespread and coordinated private-sector participation in urban greening. Requiring a proportion of a lot to be designated as green space could open up the tight town plan in new developments and renewal areas. Incentives such as bonus plot ratios, reduced land premiums, relaxation in building height, and additional flexibility in project and building design should encourage participation. To position green spaces at strategic locations, development rights could be transferred elsewhere. A road code could similarly be developed, such as the one adopted in Singapore, to ensure that trees will dress up new and overhauled roads. Where justifiable in the interest of the community, land could be regained by a land trust or with public funds for conversion to green spaces, which has been realized in Shanghai, China. The collective contributions of individual lots, which tend to be finely divided in compact areas, will in time bring significant townscape improvements, including added value and prestige to properties.

The principle of nature-in-the-city urban design (Cole, 1986; Henke and Sukopp, 1986) could be more earnestly translated into practice. For new developments that extend into well-vegetated natural areas, portions with high ecological value should be demarcated for sympathetic incorporation into the future built environment. Whereas countryside fringing a city is precious, countryside occluded by a built-up area is a gem. Assessment of the naturalness of areas designated for new developments (Mazzotti and Morgenstern, 1997) could be made mandatory, so that important sites will not be inadvertently damaged. Peri-urban woodlands with a high diversity of habitats, communities of flora and fauna, soil–water conservation functions, fresh air sources (Schabel, 1983) and passive recreational and nature-educational potential, constitute a natural heritage in the vicinity of beneficiaries. That such natural areas in cities can play these key roles, which cannot be emulated by manicured urban parks, should be emphatically brought home. Natural areas situated close at hand, particularly intra-urban woodland enclaves, as islands of nature, constitute a prized possession. As much as possible of the original organic structure, associations and constituents should be preserved intact; future activities and management should respect the integrity and continuity of natural features and processes.

Green-space design can aim at maximizing biodiversity and connectivity by networking preserved woodlands (Swenson and Franklin, 2000) with other formal and informal green sites. A site survey could identify appropriate conservation targets. The group value of tree clusters and woodlands should take precedence over the narrow focus on species rarity as a conservation yardstick. Meritorious natural areas could be designated as future parks and passive recreation venues, as illustrated by the projects initiated by the London Ecology Unit (Johnston, 1990), to be incorporated into an intra-urban green-space system linked to urban-fringe and extra-urban natural areas. In the development of several new towns in Hong Kong, small islands and knolls with natural vegetation were preserved amidst high-density and high-rise areas. Where suitable sites are unavailable, new urban woodlands could be created with innovative afforestation techniques that use a diversified assemblage of native species and sensitive site preparation (Harmer, 1999; Baines and Smart, 1991). Brown fields and derelict sites can be trans-

formed into green areas, such as the projects in Toronto (Sousa, 2003), in a reverse land conversion process. A pertinent measure of success is the attraction of indigenous wildlife into the wooded enclaves (Fernández-Juricic, 2000; Livingston *et al*., 2003). The city–countryside synergy could be fully tapped by designing for their mutual interpenetration and interfingering. The cardinal principles of nature-reserve design, based on island biogeography theory—namely large size, contiguity, proximity and connectivity—can enhance the quality of green sites (Davey, 1998).

When should it be realized? At the germinal stage of a new development plan, the possibilities of allocating green spaces should be explored to dovetail with a city-wide green plan (Jim, 1999). Better still, future green spaces could be marked on statutory zoning plans as reserved green sites in new developments or redevelopments. Planting verges should be earmarked as a component of all new roads at the blue-print stage. In open space zones and urban renewal areas, an early decision has to be made on the proportion of space to be assigned for greenery. Always plan a priori for green spaces, so as not to take the messy and ineffectual a posteriori approach. As land is the most fundamental factor for urban greening, it is imperative to include trees as an integral component of a town plan rather than as an afterthought (Petit *et al*., 1995). Conversion of developed lands into green spaces is a painful, protracted and extremely expensive exercise (Mumford, 1961).

Who should implement it? Besides the stakeholders listed under existing green sites, developers have to be convinced to contribute generously to fulfill the green plan. They can allocate sufficient land in development sites at the right locations for greening, and sufficient resources for planting and long-term maintenance of the green spaces. Urban greening has to be a public–private partnership, and the resources and resourcefulness of the private sector should be fully mobilized in a joint endeavor. In this regard, government, and especially the planning authority, can act as the umpire and the facilitator to encourage and ensure that both public and private developments will conform to the green plan, and to a high standard of design and management. It will be essential to recruit an urban forester to take a pivotal role in the planning, implementation and management of the green plan. The pertinent contributions of citizens and community groups, discussed above, are also applicable to new green sites.

Conclusions

The institution of the city has been extolled as the epitome of human cultural achievement, and the crucible of recent scientific–technological innovations. The long history of urban development has generated a diversity of forms and functions due to organic growth or conceived plans. Admitting nature as a companion to the built environment is rooted in antiquity and had been earnestly revived over several centuries ago in some cities (Lawrence, 1988). The phenomenal city expansion and intensification in recent decades have somewhat diluted the greening tradition. While some cities manage to retain or even extend their green spaces, others experience degradation and destruction. Compact cities tended to encounter more inherent restrictions to greening, and many cities in developing countries have inherited the old compact form. In the course of environmental transition, cities could attempt to keep as many as possible of the environmental-sustainability ingredients, including green spaces (Marcotullio, 2001). With more people moving into cities in the developing nations, the need to maintain the quality of growth has become all the more pertinent (Thomas *et al*., 1999). The urban renaissance conducted in some developed cities could pay tribute to the need to enhance greenery as a means for environmental and economic revival (Hughes, 1991). The recent trend to adopt the compact city policy in some developed countries (Burton, 2002) also calls for a different approach to greening. As some of their development paths might begin to converge, cities in both the developed and developing worlds could learn the art and science of urban greening from each other. The innate desire to be close to nature can hardly be extinguished, and it tends to be kindled earnestly in the increasingly cramped and stressful compact city milieu.

The ideas of the livable city (Lennard and Lennard, 1987) and the ecological city (Platt *et al*., 1994) have blossomed into the sustainable city (Roseland, 1998; Newman, 1999) conception, which should give a direction rather than a target to future urban developments. Many municipal authorities would strive to bring the elegant theoretical considerations down to earth. It will be a multidimensional and multivariate endeavor, which by necessity needs to involve various government and non-government efforts. Greening cities, especially upgrading compact urban areas with greenery, is widely advocated as a key feature of a livable and sustainable city. By itself, greening could serve as a necessary but not sufficient condition towards urban sustainability; at best, it could only afford a partial answer. It is, however, an important piece of the bewildering jigsaw puzzle as humanity attempts to find an alternative and elusive urban-growth paradigm that departs from those that have been used for millennia. Whereas it is well known that socio-economic benefits carry environmental costs, it is high time to accept the reciprocal reasoning, that is, that environmental benefits have to incur socio-economic costs. The

reversal will be more costly and less agreeable, for we need to repair the past ills as well as augmenting the benefits. It is a transgenerational time warp, in that the greening deficits of the previous generations have to be made good by the present and future generations. The notion of bestowing cities with trees has been well received for their utilitarian environmental and ornamental functions. To usher green sites and to fill them with meritorious vegetation require the assiduous contributions of many parties working closely together and breaking barriers in mindset and practice. Physical and institutional obstacles would have to be overcome. A survey of the relevant recent advances, from a multidisciplinary viewpoint, can provide useful insights, possibilities and opportunities. The necessary knowledge to effect fine greenery in compact cities exists disparately in a cluster of cognate fields, and they need to be knitted together into an implementable package.

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References

Abbey, B (1998) *U.S. Landscape Ordinances: An Annotated Reference Handbook*. John Wiley and Sons, New York, NY.

Adams, L W, Leedy, D L, (Eds.) (1987). *Integrating Man and Nature in the Metropolitan Environment*. National Institute for Urban Wildlife, Columbia MD.

Ames, B and Dewald, S (2003) Working proactively with developers to preserve urban trees. *Cities* **20**, 95–100.

Arnold, Jr C L and Gibbons, C J (1996) Impervious surface coverage, the emergence of a key environmental indicator. *Journal of the American Planning Association* **62**, 243–258.

Attorre, F, Bruno, M, Francesconi, F, Valenti, R and Bruno, F (2000) Landscape changes of Rome through tree-lined roads. *Landscape and Urban Planning* **49**, 115–128.

Baines, C and Smart, J (1991) *A Guide to Habitat Creation*. London Ecology Unit, London.

Beatley, T (2000) *Green Urbanism: Learning from European Cities*. Island Press, Washington, DC.

Bishop, K (1991) Community forests: implementing the concept. *The Planner* **77**(18), 6–10.

Bradley, G A, (Eds) (1995). *Urban Forest Landscapes: Integrating Multidisciplinary Perspectives*. University of Washington Press, Seattle, WA.

Bowers, J (1999) Policy instruments for the conservation of remnant vegetation on private land. *Biological Conservation* **87**, 327–339.

Bradshaw, A D, Hunt, B and Walmsley, T (1995) *Trees in the Urban Landscape: Principles and Practice*. Spon, London.

Bullock, P, Gregory, P J, 1991. (Eds.) *Soils in the Urban Environment*. Blackwell, Oxford.

Burgess, J, Harrison, C M and Limb, M (1988) People, parks and the urban green: a study of popular meanings and value for open spaces in the city. *Urban Studies* **25**, 455–473.

Burton, E (2002) Measuring urban compactness in UK towns and cities. *Environment and Planning B Planning and Design* **29**, 219–250.

Chevallerie, H (1986) The ecology and preservation of street trees. In *Ecology and Design in Landscape*. (Eds.) A D Bradshaw, D A Goode, E H P Thorp, pp. 383–397. Blackwell, Oxford.

Cole, L (1986) Urban opportunities for a more natural approach. In *Ecology and Design in Landscape*. (Eds.) A D Goode, D A Goode, EHP Thorp, pp. 417–431. Blackwell, Oxford.

Cook, E (2002) Landscape structure indices for assessing urban ecological networks. *Landscape and Urban Planning* **58**, 269–280.

Couenberg, E A M (1994) Amsterdam tree soil. In *The Landscape Below Ground*. (Eds.) G A Watson, D Neely, pp. 24–33. International Society of Arboriculture, Savoy, IL.

Council of Tree and Landscape Appraisers (2000) *Guide for Plant Appraisal*. 9th ed. International Society of Arboriculture, Champaign, IL.

Craul, P J (1980) Characterization of streetside soils in Syracuse, New York. *Metropolitan Tree Improvement Alliance (METRIA) Proceedings* **3**, 88–101.

Craul, P J (1992) *Urban Soil in Landscape Design*. John Wiley and Sons, New York, NY.

Davey, A G (1998) *National System Planning for Protected Areas*. World Conservation Union, Gland, Switzerland.

Dramstad, W E, Olsen, J D and Forman, R T T (1996) *Landscape Ecology Principles in Landscape Architecture and Land-use Planning*. Island Press, Washington, DC.

Duvernoy, G (1995) Keeping it green, political and administrative issues in the preservation of the urban forest. In *Urban Forest Landscapes: Integrating Multidisciplinary Perspectives*. (Eds.) G A Bradley, pp. 78–87. University of Washington Press, Seattle, WA.

Evans, M, Bassuk, N and Trowbridge, P (1990) Sidewalk design. *Landscape Architecture* **80**, 102–103.

Fernández-Juricic, E (2000) Avifaunal use of wooded streets in an urban landscape. *Conservation Biology* **14**, 512–521.

Finco, A and Nijkamp, P (2003) Pathways to urban sustainability. *Journal of Environmental Policy and Planning* **3**, 289–302.

Fitter, R S R (1945) *London's Natural History*. Collins, London.

Flink, C A and Searns, R M (1993) *Greenways: A Guide to Planning, Design, and Development*. Island Press, Washington, DC.

Foo, T S (2001) Planning and design of Tampines, an award-winning high-rise, high-density township in Singapore. *Cities* **18**, 33–42.

Foster, R S (1977) Roots: caring for city trees. *Technology Review* **July/August**, 29–34.

Friends of the Urban Forest (2003) *Neighborhood Organizers Manual*. (Available from http://www.fuf.net accessed on October 12, 2003.)

Godefroid, S (2001) Temporal analysis of the Brussels flora as indicator for changing environmental quality. *Landscape and Urban Planning* **52**, 203–224.

Godefroid, S and Koedam, N (2003) How important are large vs. small forest remnants for the conservation of the woodland flora in an urban context? *Global Ecology and Biodiversity* **12**, 287–298.

Goldstein, J, Bassuk, N, Lindsey, P and Urban, J (1991) From the ground down. *Landscape Architecture* **81**, 66–68.

Gordon, D, (Eds) (1990). *Green Cities: Ecologically Sound Approaches to Urban Space*. Black Rose, Montreal.

Grabosky, J and Bassuk, N (1995) New urban tree soil to safely increase rooting volume under sidewalks. *Journal of Arboriculture* **21**(4), 197–201.

Green Guerrillas (2003) *What we do*. (Available from http://www.greenguerillas.org/ accessed on 10 October 2003.)

Grey, G W (1996) *The Urban Forest: Comprehensive Management*. John Wiley and Sons, New York, NY.

Grey, G W and Deneke, F J (1986) *Urban Forestry*. 2nd ed. John Wiley and Sons, New York, NY.

Harmer, R (1999) Creating new native woodlands: turning ideas into reality. In *Forestry Commission Information Note 15,* p. 6. *Edinburg, UK.*

Hauer, R J, Miller, R W and Ouimet, D M (1994) Street tree decline and construction damage. *Arboricultural Journal* **20**, 94–97.

Henke, H and Sukopp, H (1986) A natural approach in cities. In *Ecology and Design in Landscape*. (Eds.) A D Bradshaw, D A Thorp, E H P Thorp, pp. 307–324. Blackwell, Oxford.

Hess, G R and King, T J (2002) Planning open spaces for wildlife. I. Selecting focal species using a Delphi survey approach. *Landscape and Urban Planning* **58**, 25–40.

Hestmark, G (2000) Temptations of the tree. *Nature* **408**, 911.

Houck, M C, Cody, M J, (Eds.) (2000). *Wild in the City: A Guide to Portland's Natural Areas*. Oregon Historical Society Press, Portland, OR.

Hough, M (1994) Design with city nature, an overview of some issues. In *The Ecological City: Preserving and Restoring Urban Biodiversity*. (Eds.) H P Rutherford, R A Rowntree, P C Muick, University of Massachusetts Press, Amherst, MA.

Howard, E (1902) *Garden Cities of Tomorrow*. Faber and Faber, London.

Hughes, R (1991) The role of urban forestry in environmental strategies and the economic regeneration of the post industrial town. *European Environment* **1**, 1–5.

Jackson, L E (2003) The relationship of urban design to human health and condition. *Landscape and Urban Planning* **64**, 191–200.

Jenks, M, Burton, E, Williams, K, (Eds.) (1996). *The Compact City: A Sustainable Urban Form*. Spon, London.

Jennings, N E and Adams, D M (1976) *Guide to Community Forestry Planning*. Cooperative Extension Service, Institute of Agriculture and Natural Resources, University of Nebraska-Lincoln, Lincoln, NE.

Jim, C Y (1989) The distribution and configuration of tree cover in urban Hong Kong. *GeoJournal* **18**, 175–188.

Jim, C Y (1990) Tree canopy characteristics and urban development in Hong Kong. *Geographical Review* **79**, 210–225.

Jim, C Y (1997) Roadside trees in urban Hong Kong: tree size and growth space. *Arboricultural Journal* **21**, 73–88.

Jim, C Y (1998a) Soil compaction at tree planting sites in urban Hong Kong. In *The Landscape Below Ground II*. (Eds.) G W Neely, D Neely, pp. 166–178. International Society of Arboriculture, Savoy, IL.

Jim, C Y (1998b) Urban soil characteristics and limitations for landscape planting in Hong Kong. *Landscape and Urban Planning* **40**, 235–249.

Jim, C Y (1998c) Old stone walls as an ecological habitat for urban trees in Hong Kong. *Landscape and Urban Planning* **42**, 29–43.

Jim, C Y (1999) A planning strategy to augment the diversity and biomass of roadside trees in urban Hong Kong. *Landscape and Urban Planning* **44**, 13–32.

Jim, C Y (2000) The urban forest programme in the heavily built-up milieu of Hong Kong. *Cities* **17**, 271–283.

Jim, C Y (2002a) Planning strategies to overcome constraints on greenspace provision in urban Hong Kong. *Town Planning Review* **73**, 127–152.

Jim, C Y (2002b) Heterogeneity and differentiation of the tree flora in three major land uses in Guangzhou city, China. *Annals of Forest Science* **59**, 107–118.

Jim, C Y (2003) Protection of urban trees from trenching damage in compact city environments. *Cities* **20**, 87–94.

Jim, C Y and Chen, S S (2003) Comprehensive greenspace planning based on landscape ecology principles in compact Nanjing city, China. *Landscape and Urban Planning* **65**, 95–116.

Jim, C Y and Liu, H T (2000) Statutory measures for the protection and enhancement of the urban forest in Guangzhou city, China. *Forestry* **73**, 311–329.

Jim, C Y and Liu, H T (2001a) Species diversity of three major urban forest types in Guangzhou city, China. *Forest Ecology and Management* **146**, 99–114.

Jim, C Y and Liu, H T (2001b) Patterns and dynamics of urban forests in relation to land use and development history in Guangzhou city, China. *The Geographical Journal* **167**, 358–375.

Jim, C Y and Ng, J Y Y (2000) Soil porosity and associated properties at roadside tree pits in urban Hong Kong. In *Soils of Urban, Industrial, Traffic and Mining Areas Volume III*. (Eds.) W Burghardt, C Dornauf, pp. 629–634. University of Essen, Essen, Germany.

Johnston, J (1990) Nature areas for city people. *Ecology Handbook 14*. London Ecology Unit, London.

Jorgensen, A, Hitchmough, J and Calvert, T (2002) Woodland spaces and edges, their impact on perception of safety and perception. *Landscape and Urban Planning* **60**, 135–150.

Kaltenborn, B P and Bjerke, T (2002) Associations between environmental value orientations and landscape preferences. *Landscape and Urban Planning* **59**, 1–11.

Kaplan, R (1984) Impact of urban nature: a theoretical analysis. *Urban Ecology* **8**, 189–197.

Kuhns, L J, Meyer, P W and Patterson, J (1985) Creative site preparation. *Agora* **5**, 7–10.

Kuo, F E, Bacaicoa, M and Sullivan, W C (1998) Transforming inner-city landscapes, trees, sense of safety, and preference. *Environment and Behavior* **30**, 28–59.

Langevelde, F, van Claassen, F and Schotman, A (2002) Two strategies for conservation planning in human-dominated landscapes. *Landscape and Urban Planning* **58**, 281–295.

Lawrence, H W (1988) Origins of the tree-lined boulevard. *Geographical Review* **78**, 355–374.

Leitão, A B and Ahern, J (2002) Applying landscape ecological concepts and metrics in sustainable landscape planning. *Landscape and Urban Planning* **59**, 65–93.

Lennard, S H C and Lennard, H L (1987) *Livable Cities: People and Places, Social and Design Principles for the Future of the City*. Gondolier Press, Southampton, NY.

Lindsey, P and Bassuk, N (1991) Specifying soil volumes to meet the water needs of mature urban trees and tees in containers. *Arboricultural Journal* **17**, 141–149.

Livingston, M, Shaw, W W and Harris, L K (2003) A model for assessing wildlife habitats in urban landscapes of eastern Pima County, Arizona (USA). *Landscape and Urban Planning* **64**, 131–144.

Löfvenhaft, K, Björn, C and Ihse, M (2002) Biotope patterns in urban areas: a conceptual model integrating biodiversity issues in spatial planning. *Landscape and Urban Planning* **58**, 223–240.

Marcotullio, P J (2001) Asian urban sustainability in the era of globalization. *Habitat International* **25**, 577–598.

Matheny, N and Clark, J R (1998) *Trees and Development: A Technical Guide to Preservation of Trees During Land Development*. International Society of Arboriculture, Champaign, IL.

Mazzotti, F J and Morgenstern, C S (1997) A scientific framework for managing urban natural areas. *Landscape and Urban Planning* **38**, 171–181.

McPherson, E G, Nowak, D, Heisler, G, Grimmond, S, Souch, C, Grant, R and Rowntree, R (1997) Quantifying urban forest structure, function, and value, the Chicago Urban Forest Climate Project. *Urban Ecosystems* **1**, 49–61.

Miller, R W (1997) *Urban Forestry: Planning and Managing Urban Green Spaces* (2nd ed.). Prentice Hall, Englewood Cliffs, NJ.

Mole, G and Young, S (1992) *Growing Greener Cities: A Tree Planting Handbook*. Living Planet Press, Los Angeles, CA.

Morell, J D (1992) Competition for space in the urban infrastructure. *Arboricultural Journal* **18**, 73–75.

Müller-Perband, E (1979) The modern town park in Germany. In *Nature in Cities*. (ed.) I C Laurie, pp. 297–326. John Wiley and Sons, New York, NY.

Mumford, L (1961) *The City in History: Its Origins, its Transformations, and its Prospects*. Secker and Warburg, London.

National Joint Utilities Group (1995) *Guidelines for Planning, Installation and Maintenance of Utility Services in Proximity to Trees*. NJUG, London (Publication Number 10).

Newman, P G W (1999) Sustainability and cities, extending the metabolism model. *Landscape and Urban Planning* **44**, 219–226.

Nowak, D J and Dwyer, J F (2000) Understanding the benefits and costs of urban forest ecosystems. In *Handbook of Urban*

and Community Forestry in the Northeast. (Eds.) J E Kuser, pp. 11–25. Kluwer Academic, New York, NY.
Olembo, R J and de Rham, P (1987) Urban forestry in two different worlds. *Unasylva* **39**, 26–35.
Parsons, R and Daniel, T C (2002) Good looking, in defense of scenic landscape aesthetics. *Landscape and Urban Planning* **60**, 43–56.
Perry, T O (1994) Size, management and design of tree planting sites. In *The Landscape Below Ground*. (Eds.) G W Watson, D Neely, pp. 3–15. International Society of Arboriculture, Savoy, IL.
Petit, J, Bassert, D L and Kollin, C (1995) *Building Greener Neighborhoods: Trees as Part of the Plan*. American Forestry Association, Washington, DC.
Platt, R H, Rowntree, R A and Muick, P C (1994) *The Ecological City: Preserving and Restoring Urban Biodiversity*. University of Massachusetts Press, Amherst, MA.
Roseland, M (1998) *Toward Sustainable Communities: Resources for Citizens and their Governments*. New Society, Gabriola Island, BC.
San Francisco Tree Council (2003) *Emergency Steps to Save Trees: When a Tree is in a Troubled Situation*. (Available from http://www.sftreecouncil.org/tensteps.htm accessed on October 2, 2003.)
Schabel, H G (1983) Urban forestry, some lessons from Germany. In: *Proceedings of the 1982 Annual Meeting of Society of American Foresters*, pp. 340–345. American Forestry Association, Washington, DC.
Shindler, B and Neburka, J (1997) Public participation in forest planning: eight attributes of success. *Journal of Forestry* **95**, 17–19.
Smale, M C and Gardner, R O (1999) Survival of Mount Eden Bush, an urban forest remnant in Auckland, New Zealand. *Pacific Conservation Biology* **5**, 83–95.
Sommer, R, Learey, F, Summit, J and Tirrell, M (1994) The social benefits of resident involvement in tree planting. *Journal of Arboriculture* **20**, 170–175.
De Sousa, C A (2003) Turning brownfields into green space in the city of Toronto. *Landscape and Urban Planning* **62**, 181–198.
Svensson, M K and Eliasson, I (2002) Diurnal air temperatures in built-up areas in relation to urban planning. *Landscape and Urban Planning* **61**, 37–54.
Swenson, J J and Franklin, J (2000) The effects of future urban development on habitat fragmentation in the Santa Monica Mountains. *Landscape Ecology* **15**, 713–730.
Tartaglia-Kershaw, M (1982) The recreational and aesthetic significance of urban woodland. *Landscape Research* **7**, 22–25.
Thomas, V, Dailami, M, Dhareshwar, A, Kaufmann, D, Kishor, N, Lopez, R E and Wang, Y (1999) The quality of growth. *Ekistics* **394**, 13–20.
Thompson, C W (2002) Urban open space in the 21st century. *Landscape and Urban Planning* **59**, 59–72.
Thompson, J and Rumsey, P (1997) Trenchless technology applications for utility installation. *Arboricultural Journal* **21**, 137–143.
Ulrich, R S (1986) Human response to vegetation and landscapes. *Landscape and Urban Planning* **13**, 29–44.
Urban, J, Sieveert, R and Patterson, J (1988) Trees and space: a blueprint for tomorrow. *American Forests* **94**, (7/8)58–74.
van der Valk, A (2002) The Dutch planning experience. *Landscape and Urban Planning* **58**, 201–210.
Vuilleumier, S and Prelaz-Droux, R (2002) Map of ecological networks for landscape planning. *Landscape and Urban Planning* **58**, 157–170.
Watson, G W, Neely, D, (Eds) 1995. *Trees and Building Sites*. International Society of Arboriculture Champaign, IL.
Weiner, M A (1992) *Planting a Tree: Choosing, Planting and Maintaining this Precious Resource*. John Wiley and Sons, New York, NY (Revised edition).
Williams, K (1999) Urban intensification policies in England, problems and contradictions. *Land Use Policy* **16**, 167–178.