Environmental Conservation 25 (2): 146–159 © 1998 Foundation for Environmental Conservation

Impacts of intensive urbanization on trees in Hong Kong

CHI YUNG JIM*
Department of Geography and Geology, University of Hong Kong, Pokfulam Road, Hong Kong
Date submitted: 18 August 1997 Date accepted: 6 March 1998

Summary

Trees in cities face a severe limitation of plantable space and an exceptionally stressful growing environment. In Hong Kong, shortage of developable land has relegated trees to a lower priority and intensified urban impacts on them, relative to other cities. The vicissitudes of urban growth and trees since the founding of Hong Kong are reviewed, and eleven specific conflicts between urbanization and trees in Hong Kong are described. Redevelopment of existing buildings has raised site coverage by impervious surface and taken away ground-level planting space within and around affected lots. Infilling of relatively low-density areas mainly for government and institutional land-uses has increased development density and removed existing greenery and planting spaces. Road construction and improvement has widely damaged roadside trees and removed valuable and conspicuous greenery. Proliferation of underground utilities has fuelled the contest for usable space and precluded planting in many places. Widespread and frequent roadside trenching, associated with utilities and the laying of cable television and telecommunication networks has incurred massive root damage at roadsides. Poor soil quality commonly beset by chemical and physical constraints has caused chronic poor tree performance. Intrusion into urban parks and other green enclaves by buildings and roads has usurped the limited stock of green spaces. Encroachment into peri-urban woodlands has deprived the city of fringing mature greenery with conservation, landscape and amenity worth. Plantable space in reclaimed lands has been intensively used with inadequate allocation for trees. Protection and preservation of champion specimens has lacked statutory means and a coordinated policy. Reinforcement and demolition of stone walls has destroyed many large trees on unique mural habitats. Quality of arboricultural practice is poor, particularly in the private sector. Possible solutions to these limitations in Hong Kong are suggested, and have implications for other cities facing similar problems.

Keywords: urban trees, urban forestry, urban ecology, tree management, tree preservation

* Correspondence: Professor Chi Yung Jim Tel: +852 2859 7020 Fax: +852 2559 8994 e-mail: hragjcy@hkucc.hku.hk

Introduction and historical backdrop

The phrase ‘urban tree’ is apparently a contradiction in terms. ‘Urban’ connotes artificiality and trying conditions for life, yet ‘tree’ conjures up an image of nature and serenity which is commonly wanting in the city milieu. Trees and cities, nevertheless, have coexisted for many years. It has been a customary practice in different cultures to plant trees as companions of settlements. The art and science of urban planting flourished in the seventeenth century in some European cities (Schmid 1975; Lawrence 1988). The urban greening practice was subsequently disseminated with the migration of Europeans and their cultural influence to different corners of the world. With more of the world’s population living in cities, the environmental quality of urban centres will to a large extent determine the well-being of many people. Trees in cities can play a pivotal role in ameliorating the harshness of urban living, and their multiple functions and benefits have been extensively reviewed (e.g. Schmid 1975; Grey & Deneke 1986; Miller 1988). Urban tree management, as an integral component of urban environmental management, is increasingly a concern of municipal authorities world-

Table 1 Some indicators of high-intensity urban development in Hong Kong (Data sources: compiled from various Hong Kong Government statistics)

Attribute	*State*
Land area	
total	1095 km^2
>100 m elevation (% total)	approx. 870 km^2 (79.5%)
reclaimed (% total)	60 km^2 (5.5%)
developed (% total)	175 km^2 (16.0%)
Population	
total	6.5 million persons
average density	5938 persons/km^2
average urban density	26 611 persons/km^2
maximum urban district density	53 610 persons/km^2
maximum urban spot density	116 531 persons/km^2
Road length	
total	1717 km
per unit area	1.57 km/km^2
per person	0.26 km/1000 persons
Vehicle	
total	466 068 nos.
per unit road length	271.4/km
per person	71.1/1000 persons
Open-green space	
urban formal (% total)	16 km^2 (1.5%)
country park (% total)	413.5 km^2 (37.8%)

https://doi.org/10.1017/S0376892998000198 Published online by Cambridge University Press

Figure 1 Urban areas in Hong Kong are characterized by a maximum use of developable land, often with 100% impervious site coverage and absence of setback at road frontage, thus precluding the planting of intra- and peri-site trees.

wide in a quest to make it cost-effective. There is a common desire to reduce the pressure on urban trees and provide them with a better tenure.

Hong Kong, a city on the subtropical coast of China founded some 150 years ago, has served well as a synergistic confluence of eastern and western civilizations. Ideas from distant lands were earnestly adopted, including the insertion of amenity trees in the then Victorian township. Tree species from various tropical lands were introduced through formal and informal channels (Jim 1991, 1992*a*), and historical photographs (Warner 1979; Hong Kong Museum of History 1982) attest to the assimilation of this fine tradition. Despite the shortage of space for the growth of the city since Hong Kong's inception, the pressure for land development did not preclude trees (Jim 1992*b*), and every effort was made to permit their coexistence with artificial structures.

The halcyon days for amenity vegetation have gradually succumbed to the relentless pressure to accommodate the rapidly-increasing population. Wars and turmoil in China pushed refugees into Hong Kong in droves, raising the population from a little less than one million before the Second World War to 3.13 million in 1961 (Lo 1992) and 6.5 million in 1998. The great expansion in human numbers necessitated land-use intensification, relegating the less exigent greening need to a low priority. The rapid urbanization fuelled consumption of land which is increasingly at a premium. Population density was raised to a level which is the world's highest, with an urban average of 26 611 person/km^2 and a maximum 116 531 person/km^2 (Census and Statistics Department 1997*a*).

Problems associated with urban-tree planting and management in Hong Kong are in many ways similar to those encountered in other cities (Bernatzky 1978; Gilbertson & Bradshaw 1985; Bradshaw *et al.* 1995). The difference between Hong Kong and other cities is more in degree than in kind. The vicissitudes of trees in urban Hong Kong reflect the universal phenomenon of intensive conflicts between artificial and natural components in cities, the associated landscape planning and management problems, and the possible solutions. However, the magnitude and pervasiveness of these problems due to the exceptional development density are much greater in Hong Kong. A main feature of this development intensity is the spatially-prevalent high-density and high-rise mode of development, extending all the way from the city centre to its peripheries (Table 1). There is a lack of gradational reduction in density along a centre-to-

https://doi.org/10.1017/S0376892998000198 Published online by Cambridge University Press

Table 2 Frequency of 47 common tree species at roadside habitats in Hong Kong (# denotes native species) (Data source: author's own census conducted in 1995 of the entire population of 19 154 roadside trees in the main urban areas of Hong Kong)

Rank	*Species*	*Frequency*	*Per cent*	*Cumulative per cent*	*Final height (m)*	*Final crown spread (m)*
1	*Aleurites moluccana*	2474	12.92	12.92	>15	
2	*Melaleuca quinquenervia*	1444	7.54	20.46	>15	
3	*Phoenix roebelenii*	1337	6.98	27.44	<5	
4	*Livistona chinensis*	1325	6.92	34.36	10–15	
5	*Caryota ochlandra*	1018	5.31	39.67	>15	
6	*Archontophoenix alexandrae*	688	3.59	43.26	10–15	
7	*#Bombax malabaricum*	648	3.38	46.65	>15	
8	*Delonix regia*	647	3.38	50.02	>15	>15
9	*Cassia siamea*	573	2.99	53.02	>15	>15
10	*Cassia surattensis*	520	2.71	55.73	<5	
11	*#Ficus microcarpa*	476	2.49	58.22	>15	>15
12	*Washingtonia robusta*	473	2.47	60.69	10–15	
13	*Ficus benjamina*	445	2.32	63.01	>15	>15
14	*#Hibiscus tiliaceus*	437	2.28	65.29	5–10	
15	*Crateva religiosa*	429	2.24	67.53	>15	
16	*Thevetia peruviana*	421	2.20	69.73	<5	
17	*Acacia confusa*	415	2.17	71.89	5–10	
18	*#Bauhinia blakeana*	382	1.99	73.89	5–10	
19	*Roystonea regia*	363	1.90	75.78	>15	
20	*#Albizia lebbeck*	312	1.63	77.41	>15	>15
21	*Casuarina equisetifolia*	272	1.42	78.83	>15	>15
22	*Peltophorum pterocarpum*	265	1.38	80.22	10–15	
23	*Spathodea campanulata*	236	1.23	81.45	10–15	>15
24	*Cycas revoluta*	195	1.02	82.47	<5	
25	*Grevillea robusta*	146	0.76	83.23	10–15	
26	*#Ailanthus fordii*	144	0.75	83.98	5–10	
27	*Eucalyptus citriodora*	141	0.74	84.72	>15	
28	*Eucalyptus robusta*	139	0.73	85.44	10–15	
29	*#Celtis sinensis*	133	0.69	86.14	>15	>15
30	*Juniperus chinensis*	131	0.68	86.82	<5	
31	*#Bischofia javanica*	122	0.64	87.46	10–15	
32	*#Macaranga tanarius*	120	0.63	88.08	5–10	
33	*#Cinnamomum camphora*	114	0.60	88.68	>15	>15
34	*Tristania conferta*	109	0.57	89.25	10–15	
35	*Syzygium jambos*	98	0.51	89.76	5–10	
36	*#Cinnamomum burmanii*	91	0.48	90.24	<5	
37	*Syagrus romanzoffiana*	88	0.46	90.69	5–10	
38	*#Schefflera octophylla*	79	0.41	91.11	<5	
39	*#Ficus virens*	78	0.41	91.51	>15	>15
40	*Michelia alba*	77	0.40	91.92	>15	>15
41	*Lagerstroemia speciosa*	76	0.40	92.31	5–10	
42	*Pterocarpus indicus*	70	0.37	92.68	>15	>15
43	*Araucaria heterophylla*	62	0.32	93.00	10–15	
44	*Khaya senegalensis*	62	0.32	93.33	>15	>15
45	*Melia azedarach*	61	0.32	93.64	10–15	
46	*Bauhinia variegata*	57	0.30	93.94	5–10	
47	*Erythrina variegata*	51	0.27	94.21	5–10	
	Total	18 044	94.22			

edge gradient that is common in many cities. Most urban lots have been used to their maximum potential, often with 100% impervious site coverage at the ground level with no setback from the frontage and no within-lot openings. The intervening roads often have inadequate space for roadside amenity planting (Fig. 1). Whereas new trees are being planted, the old ones face tremendous pressure and degeneration (Olembo & de Rham 1987). The so-called inner-city type of environment is therefore found in the bulk of the metropolis, cramped into a small 1095 km^2 of land of which about three-

https://doi.org/10.1017/S0376892998000198 Published online by Cambridge University Press

Figure 2 The high-rise and high-density urban fabric in Hong Kong is occasionally punctuated by low-density and low-rise government, institutional and community (GIC) plots which allow tree existence. Redevelopment of such sites often results in the loss of valuable greenery spaces.

quarters are not easily developable due to difficult terrain. Hong Kong is a phenomenal congregation of buildings and roads with little intervening open spaces. Amenity trees are meagre and exist in confined growth space (Table 2). Opportunity for greenery is inherently and severely constrained (Jim 1987*a*).

By comprehensively assessing the varied and intensive pressures of urbanization on trees in Hong Kong through an analysis of tree-dampening factors and processes at the macro- and micro-scales, this study aimed to determine how urban tree-care might be improved so that long-term improvement in the quantity and quality of city greenery might be effected.

Redevelopment of existing buildings

Due to inadequacies in building design, construction method, material and maintenance, vis-à-vis the aggressive humid-tropical weather, most buildings in Hong Kong tend to deteriorate substantially within a matter of several decades (Bristow 1984). The cycle of urban renewal here is thus exceptionally short in comparison with temperate cities.

The transient state of the city's structures should provide many opportunities to revamp the town plan, but redevelopment at a much higher intensity (Jim 1994*d*) is more often than not the case in many urban-renewal schemes due to an ever-increasing demand for building space and world-record real-estate values (Wong *et al.* 1996). Moreover, the renewal frequently occurs in a piecemeal and uncoordinated manner (Bristow 1984) and the opportunity to rectify past excesses and negligence in terms of urban landscaping and environmental quality is rarely taken.

In the course of redevelopment, within-lot trees are often removed completely, resulting in significant reduction in the urban tree cover in recent years (Jim 1989*a*, 1990*a*). Few trees are preserved *in situ* (Jim 1988). The small and cramped building lots, commonly sandwiched between adjacent buildings, do not leave much latitude for engineering manoeuvre. Where trees are occasionally kept, the ensuing demolition and subsequent construction activities often leave them in a dismal state. Roadside trees abutting lot boundaries usually cannot escape a similar ill fate. The common practice of building up to lot boundaries, and erecting awnings above the narrow pavement, do not augur well for peripheral roadside vegetation.

The poor-quality tree-care on construction sites (Jim 1987*a*) can be improved if contractors adhere to arboricultural standards (British Standards Institution 1991; NHBC 1992); for example, stressful site conditions can be improved by measures such as soil improvement and replacement (Dudle 1986). High-calibre existing trees affected by construction should be carefully evaluated and preserved in situ by a sympathetic building plan, failing which, transplanting should be recommended. Statutory planning measures are needed to preserve growing space (Profous *et al.* 1988) and to institute a coordinated setback of buildings by zoning to supply more roadside amenity strips. A long-term greening strategy should aim at providing good-quality planting sites (Kelcey 1978) to be disseminated throughout the city in a matrix enmeshing built-up areas.

Infilling of relatively low-density sites

Development of occasional low-density sites earmarked for government, institutional and community (GIC) uses, such as schools, churches, and hospitals, allows less impervious site coverage (e.g. <50%) at the ground level; space not occupied by buildings is often filled with trees and other greenery (Jim 1987*b*; Nowak 1994). Urban morphology as a determinant of tree-cover structure (Sanders 1984) is strongly expressed. This is a deliberate configuration in the urban design of Hong Kong which breaks the otherwise close packing of tall buildings with relieving gaps; together with formal open spaces, such vegetation plays an essential role in environmental amelioration (Fig. 2).

Urban rejuvenation has recently begun to consume GIC sites which are well placed and have good transport linkages. A low-rise and low-density (such as schools or churches) urban morphology can give way to high-rise office or residential blocks, with permanent loss of ground-level open space and greenery. The more massive new buildings generate more traffic, which in turn necessitates higher capacity roads and less roadside space for amenity planting, in a snowballing effect which reduces the green cover (Jim 1990*a*) and degrades the urban landscape.

The population is highly polarized in terms of tree ownership; a few rich people can afford houses with gardens in core city areas, but the rest must do without or share a tiny pool of communal trees. This tree-ownership dichotomy deviates from the close socio-economic association between tree characteristics and income-group neighbourhood found in other cities (Schmid 1975; Talarchek 1990), and the gap is widening due to rising property prices and infilling.

Infilling contradicts the purported policy of reducing population density in the older neighbourhoods (Planning Department 1993) and defeats the important objective of improving quality of life. A high proportion of impervious surface cover in a city has been used as an indicator of poor environmental well-being and quality of life (Arnold & Gibbons 1996). There is a need to guard against indiscriminate infilling through statutory zoning. Low-density sites playing an important role in diluting the negative environmental aspects of high-density areas should be identified by a comprehensive study and be designated as special areas for cityscape conservation. A clear official message should be sent to developers that infilling is detrimental to environmental quality and will not normally be approved. In new developments, the tradition of breaking densely-packed areas with more spacious and green GIC sites should continue, with due regard to spatial spreading of such benefits.

Road construction and improvement

Of the different habitats for urban trees, the roadside is the most inimical (Barlett Tree Expert Company 1968; Richards & Stevens 1979; Chevallerie 1986), and this is particularly so in core urban Hong Kong (Jim 1997*a*, *b*; Figs. 3 & 4) where inherently difficult site conditions are aggravated by frequent roadwork imposing severe damage and injury on existing trees. In hilly districts, the narrow and winding old roads largely follow the contour (Tregear & Berry 1959). Increasing development density necessitates upgrading to meet traffic needs and modern road design and safety standards. Widening and straightening, gradient adjustments, drainage installations and roadside cut slope stabilization are most destructive to roadside vegetation.

Recent disastrous slope failures have accentuated concern for the stability of roadside engineered slopes and therefore shotcrete (concrete diluted with water and pump-sprayed onto the bare soil surface reinforced with steel-wire mesh) has been extensively applied to seal unstable slopes. The resulting surfaces are sterile and roadside slopes scars are left instead of living green cover. The stripping of sylvan roads has drastically degraded landscape quality, leaving roads barren and harsh.

In densely built-up parts of the city, frequent road improvement work, such as realignment and widening, requires adjusting the road-lot interface. This adjustment often results in removal of roadside trees. Specific types of harm include grade change, truncation or burial of soil and roots, injury and lopping of branches. Only rarely can trees be preserved, but this usually entails severe confinement in incongruous niches, such as shifting from roadside to median positions and entrapment in tiny island plots. Traffic-volume increase after road improvement raises air pollution loading, both gaseous and particulate, which exacerbates stresses to remnant trees.

Roadwork affecting trees should be preceded by a comprehensive tree survey identifying target specimens for preservation or transplanting (Jim 1996*a*, *b*), and most importantly providing a basis to modify the alignment to minimize damages on greenery. New or refurbished roads should seize every opportunity to furnish roadside planting spaces (Evans *et al.* 1990; Goldstein *et al.* 1991). Rather than being treated as dispensable adjuncts, trees should be recognized as an integral component of a road. A change in the ingrained attitude of relevant professionals, to be encouraged

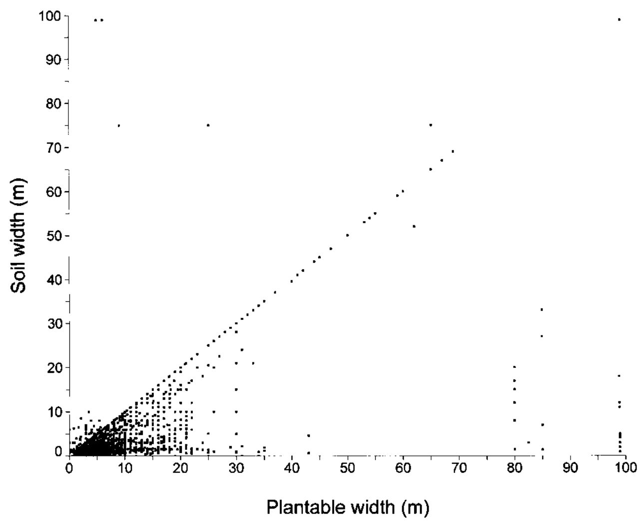

Figure 3 Plot of soil width (room for root expansion) against plantable width (room for crown expansion) for urban trees in Hong Kong (n = 19 154 trees) (Data source: author's own census conducted in 1995 of the entire population of roadside trees in the main urban areas of Hong Kong).

by a forceful government policy, may bring relief in the long term.

Proliferation of underground utilities

All utility lines are buried underground in Hong Kong. Cable television brings the latest onslaught, mainly routed through pavements, which has aroused alarm in other cities (Pearce 1994) and precludes many roadside sites from future planting. With limited roadside space, utilities are restricted to subterranean corridors, with extremely keen competition for usable space. The unregulated disposition has usurped tree-rooting room under pavements and obstructed root growth.

To avoid conflicts, utilities are given priority and trees are eschewed, leaving many roads treeless. Few roads are endowed with a dedicated tree strip free from the entanglements of buried utilities. Existing amenity corridors often cannot be kept due to conversion into additional carriageways to meet traffic requirements. Repeated excavations are needed to repair, overhaul, upgrade and cut utilities. Roots are massively severed, weakening trees and

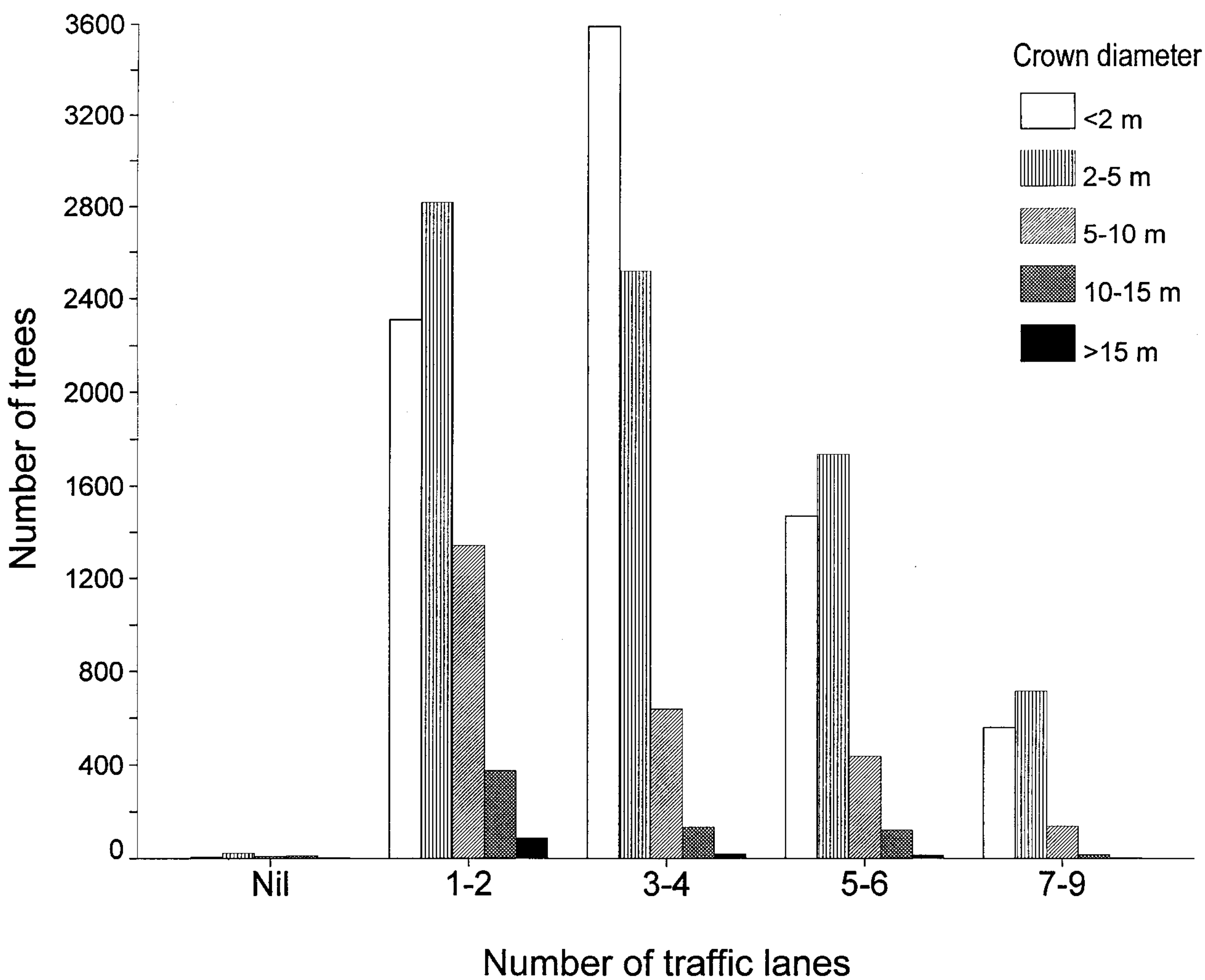

Figure 4 Frequency of trees (n= 19 154) in urban Hong Kong growing along roads with varying width (number of traffic lanes) (Data source: author's own census conducted in 1995 of the entire population of roadside trees in the main urban areas of Hong Kong).

https://doi.org/10.1017/S0376892998000198 Published online by Cambridge University Press

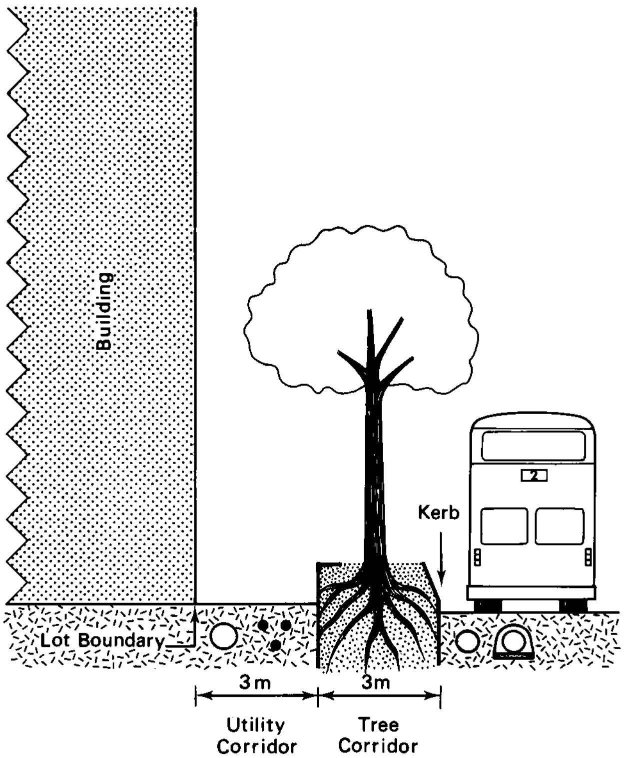

Figure 5 To forestall the intense conflicts between underground utilities and tree roots, a clear separation of the tree corridor (to be filled with good-quality soil) from the utility corridor can be adopted in new development areas.

predestining them to a below-par performance and premature decline.

That unregimented buried services will bring havoc to roadside trees should be brought home to utility and construction companies (Morell 1992). Conflicting users require spatial separation within the subterranean space. To secure rooting room, the tree-planting corridor should be protected by a permanent division from the utility corridor (Fig. 5). Improving communication between urban foresters and concerned industries can work towards a mutually-acceptable code of practice (National Joint Utilities Group 1995). A higher standard of material and workmanship should reduce the need for too frequent repairs.

Widespread and frequent roadside trenching

Repairing and laying utility lines, including the recent installation of territorywide networks for cable television and communication has demanded extensive trenching along pavements. The widespread root injuries and severance, and the poor quality of workmanship with respect to tree care may have triggered a long-term tree decline. Similar damage (Baines 1994; Gardening Which 1996) is happening in Hong Kong. Full-scale excavation under the canopy of large trees is widely practised, as is digging next to the trunk base. Straight-line least-distance and least-effort routing is routinely practised.

There is little evidence of professional arboricultural guidance on how to minimize impacts of root cutting and shock on trees. The fact that most tree roots are concentrated in the top one metre or so of the soil (Perry 1982, 1994; Cutler *et al.* 1990; Gasson & Cutler 1990), and that they spread out well beyond the area defined by the crown's dripline (Gilman 1988, 1989), have been ignored in road opening practices. Hardly any measure is taken to contain root injury and to protect exposed roots. Trenching aggravates the common problem of confined rooting volume, and may introduce foreign materials into urban soils, disturb soil structure, compact the soil, and expose injured roots to pathogenic incursion. These deleterious impacts are the major cause of widespread poor performance of roadside trees.

Arboricultural standards associated with trenching near trees (National Joint Utilities Group 1995) should be followed by contractors, to be supported by penalties for poor practice. Recommendations are that: (1) qualified arboriculturists should be employed by utility companies to train the construction staff and monitor their work; (2) trenching should be diverted away from valuable specimen trees; and (3) minimum digging or non-digging technique, such as micro-tunnelling by mechanical or hydraulic drilling, should be adopted for high-calibre trees.

Poor soil quality

The urban-tree programme in Hong Kong, similar to other cities, tends to focus on the above-ground space and subaerial portion of trees (Shigo 1989; Harris 1992). Actions on urban soils and tree roots are often indirect and minimal, such as adding amendments at the time of planting (Harris *et al.* 1977; Chaney *et al.* 1992), correcting girdling roots which occur at the soil level (Shaw 1977; Watson *et al.* 1990), and repairing hard pavings cracked or heaved by roots (Barker 1994; Kopinga 1994). Poor soil quality is a significant cause of depressed aesthetic and other environmental benefits of trees (Grey & Deneke 1986; Miller 1988).

Most soil at roadside and offroad sites is drastically disturbed (Bullock & Gregory 1991; Craul 1992; Watson & Neely 1994), with loss of natural soil horizons and contamination by heterogeneous and haphazardly-deposited fill materials. Urban tree growth is dampened by soil constraints including rooting volume and physical and chemical composition. Occasional soil replacement (Watson *et al.* 1996) is limited to a small volume within a soil pit or a narrow channel.

Urban soils in Hong Kong show pervasive severe soil compaction (Jim 1993*c*), leading to low porosity, restricted aeration, sluggish infiltration and drainage, inadequate storage capacity for plant-available moisture (Whitlow *et al.* 1992), and physical obstruction to root growth. Chemical problems are equally common (Jim 1998*a*, *b*), such as macro- and micro-nutrient deficiencies, limited nutrient-holding capability, contamination by pollutants inherited from fill materials and alkalinity due to ubiquitous use of cement and concrete in the built environment (Messenger 1986; Ware 1990). Other less common but vexing problems include high soil temperature (Halverson & Heisler 1981) and natural gas leakage from buried pipes (Gilman *et al.* 1982).

Despite these problems, site soils are accepted in bulk with little questioning about their suitability for plants. Existing work, mainly focusing on extrapolation of general soil science concepts to applications in urban forestry, should be reinforced by comprehensive empirical research in different urban habitats and climatic regimes. Urban soil science should be nurtured as a subdiscipline with a view to developing specific ameliorative measures for poor soil properties. Specific problems that need attention are compaction, restricted rooting volume, textural discontinuity, degraded structure, moisture deficit, alkaline reaction, low organic matter, low nutrient content and exchange capacity, and soil pollution. An urban-soil specification for landscape planting should be designed taking into account local soil conditions and availability of materials. A long-term soil management regime for different habitats should also be adopted. It is necessary to rectify the current bias of caring for young plants within the establishment period whilst neglecting the long-term health of mature trees. This calls for nurturing a soil-management ethos amongst urban foresters and arboriculturists.

Intrusion into urban parks and other green enclaves

Hong Kong city is short of open spaces in comparison to the population base. Private gardens are rare except in the few high-income group neighbourhoods with single-family houses (Jim 1993*b*). The main urban areas have a mere 4000 house-type residential units, accommodating 4% of the population (Census and Statistics Department 1997*b*). Most residents live in high-rise flats, communal open-space provision is inadequate, resulting in very heavily patronized urban parks. Due to transport needs, public parks and gardens are often intruded upon, with a steady loss of public open spaces and erosion of their amenity worth.

An alternative configuration increasingly being adopted recently is to lift green space up to rooftop, i.e. the podium level, and put roads and commercial uses underneath. This arrangement has been practised in private housing developments where the communal recreational facilities and gardens are usually placed on the top of a podium. The imminent extension of railways into the city requires the loss of several highly-popular parks and gardens to accommodate mass-transit stations (KCR 1997). Open-space plots are often utilized as temporary storage or work areas for nearby construction projects, causing vegetation damages.

The city has several barracks which originally occupied fringe or rural lands when they were commissioned more than a century ago. In the last few decades, several intra-city barracks had been converted into urban parks to relieve open-space shortfall, and are endowed with many mature trees (Jim 1990*e*). Before land-use conversion, these green enclaves contrasted vividly with the surrounding heavily built-up areas, with rich green ingredients to serve as ready-made urban parks. With central locations, however, parts of the former barracks had been earmarked for office and residential blocks. Such a legacy of historical accident will not be repeated in the future.

The preservation of the limited total acreage of open green spaces in urban Hong Kong should receive wide support. Ready-made green spaces such as barracks should be converted into urban parks as a matter of official policy rather than as a response to vociferous public outcry. An evaluation of such suitable sites should be included in a city-wide landscape master plan. Where building incursion cannot be avoided, compensatory land provision should be made mandatory with full replacement of tree losses.

Encroachment into peri-urban woodlands

Two modes of urban growth, namely reclamation from the sea and terracing hillslopes, are practised in Hong Kong (Jim 1990*a*). Whereas reclamation generates new land initially devoid of plants, encroachment into the hills can bring havoc to existing woodlands of high amenity value. The steep city-fringe hillslopes are enveloped by a rather continuous stretch of mature woodlands, a product of decades of assiduous afforestation initiated in the late nineteenth century. Urbanization thus had the dualistic effect of increasing the tree cover at the city's edge, whilst reducing it within the city proper (Andresen 1978). In other cities, urbanization can decrease tree cover at the edge (e.g. cities in forests) and increase it in the city proper (e.g. cities in deserts). The peri-urban woodlands (Jim 1989*a*) are valuable due to diversified composition and physiognomy, containing some of the largest mature trees in the territory. They are also ecologically important as the repository of some rare and unusual species of flora and fauna (Thrower 1975).

Woodlands in a spoke-like configuration extending into the developed areas are particularly valuable as green corridors. Such tongues of hillslope woodlands at the urban edge (Jim 1989*a*, *b*) provide a desirable interpenetration of city and nature. They denote a much higher-order of greenery that cannot possibly be replicated or emulated in the bland roadside or urban-park settings (Tregay 1979). The countryside fingers also serve as easily-accessible passive recreational outlets which can be reached within minutes from the city's heart. As such, they have high amenity as well as conservation values. Such city-fringe woodlands, not uncommonly found in other big cities, are often subject to development threats (Goldsmith 1988).

Unfortunately, city expansion has intruded into peri-urban woodlands, particularly the green corridors, resulting in destruction of vegetation cover, wildlife, ecology, soil, landform, and landscape. Past hill-terracing operations mainly cleared small isolated enclaves, leaving intervening woodland strips occluded within the urban matrix. Recent hill terracing tends to clear large areas to create large building platforms, leaving huge and ugly scars of cut slopes. In new towns developed since the 1970s, some attempts have been made to preserve good-quality woodlands within their boundaries. They are, however, fragmented remnants of the original more continuous covers (Hill 1985). Some pockets have degenerated into woodland slums (Holtam 1980) due to continual damage and neglect.

Where urban intrusion cannot be avoided, impacts can be reduced by preserving pockets of original wooded hillslopes, to be sympathetically blended with future development (Dorney *et al.* 1986). Such quasi-wilderness and wild enclaves (Manning 1979) are particularly precious near or better still within urbanized areas. Moreover, new intra-urban and peri-urban woodlands can be created by appropriate site allocation, preparation and selection of species assemblage. Small pockets of remnant precinct woodlands (Izumi 1983) can be nurtured in the midst of high-density areas. Preferably, the vegetation cover should form a connected network enveloping built-up areas to maximize their benefits in the city environment (Henke & Sukopp 1986). To protect against intrusions, they could be designated as green belts, or better still conservation areas, in statutory land-use zoning (Planning Department 1996).

Plantable space in reclaimed lands

As much as 60 km^2 of built-up areas around the harbour, about a quarter of the total urbanized areas, were reclaimed from the sea. The initially vacant land could have provided excellent opportunities for comprehensively green-space planning, with due regard to quantity and more importantly to quality and connectivity aspects. Unfortunately, the high cost of land production and the grave shortage of developable land have nurtured a policy of excessive development intensity especially in the 1960s and 1970s (Tregear & Berry 1959; Bristow 1984). With few site constraints, there was the temptation in the past to maximize building density.

The legacy of frenetic city growth in the last few decades is evidenced by large tracts completely filled by buildings and roads, devoid of greenery (Jim 1987*b*). The older reclaimed lands have some isolated and dispersed amenity plots, mainly created recently by demolition of old buildings. The roadsides are too narrow for planting strips or tree pits (Jim 1993*a*), with restrictive conditions for tree growth, and existing trees have to struggle to survive in poorly prepared sites.

Recently, a more enlightened attitude towards land-use and environmental quality has been adopted. The new-town programme has since the 1970s transferred some two million people to the hitherto rural New Territories. More open spaces have been designated (Bristow 1989) to allow a more heterogeneous urban form. With large-scale land reclamation planned and land to be released by the decommissioning of the existing intra-city airport, a green city within the old city can be created. At the macro level, the chance to implement the desirable green matrix concept (Scott *et al.* 1986) should not be missed. Linear roadside tree corridors could link nodes of larger green spaces such as gardens and parks, so as to maximize visual and environmental benefits. At the detailed level, proper sites should be earmarked for trees in the nascent urban land in terms of underground and above-ground growth dimensions, quality of the growth medium, and particularly good-quality soil with adequate drainage and aeration.

Protection and preservation of champion specimens

A tiny proportion of trees, despite inimical site conditions, have managed to attain the champion or elite rank (Randall & Clepper 1977; Mitchell *et al.* 1990) by a fortuitous combination of circumstances. Meritorious genetic make-up, dwelling in a genial environment with freedom from damages, injuries, pests, diseases and typhoon destruction, have permitted them to mature into outstanding specimens in terms of size, form, health and vigour. The main urban areas of Hong Kong, with some 25 000 roadside and 35 000 park trees, have merely 365 trees rated as champions (Jim 1994*a*). The detailed information gleaned in a recent study has been published by the municipal council (Jim 1994*b*) as an unofficial register of the most prominent sylvan members.

With the current growth environments, it is difficult to nurture elite-grade trees. In fact, few trees planted in the post-Second World War years manage to attain or have the hope of attaining outstanding quality (Jim 1994*a*). The inherited champions are especially valuable in view of their relict nature, as a rarity that is being threatened and gradually eroded. They deserve a special protection status, preferably bestowed by statutory measures, which are not currently provided in Hong Kong. The protection accorded by a tree protection clause included in some land-lease documents, and the Summary Offence Ordinance is construed as ineffectual. Whereas such trees in government lands are given attention if they are threatened by public development, those in private lots need augmented legal protection (Coughlin *et al.* 1988).

There is a general lack of awareness and recognition that champion trees should be preserved as the community's inheritance. They receive inadequate care and continue to be damaged even after the publication of the unofficial inventory (Jim 1994*b*). The carefree attitude of the community towards the exemplary trees should be revamped. In particular, the professionals associated with developers should learn to respect them and take concrete action to preserve the city's diminishing living heritage (Jim 1995). To convey forcefully the relevant message, plaques could be erected near the trees. A programme of inspection and care can be instituted to ensure timely and long-term attention. A legal instrument, analogous to a tree preservation order, as adopted in other countries (Batho 1990; Profous & Loeb 1990) should be enacted.

Reinforcement and demolition of stone walls

Many cities have patches of remnant nature or unique habitats, harbouring special assemblages of biota and deserving protection from intrusions (Johnston 1990). Hong Kong has a large urban portion built on hillslope terraces created by expensive engineering endeavours. In the past, the traditional

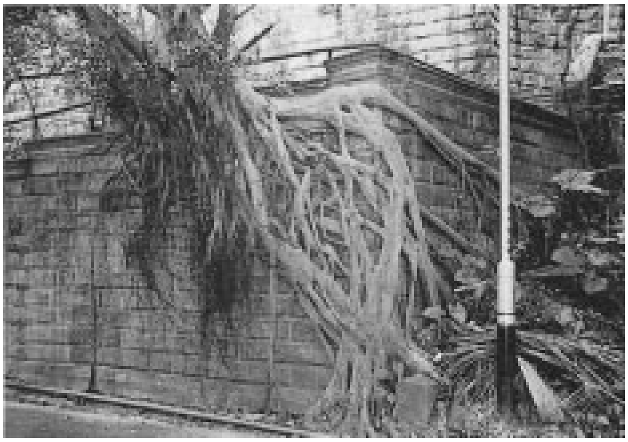

Figure 6 Old stone walls in the sloping parts of urban Hong Kong permit spontaneous colonization by a host of plant life, including large trees such as this *Ficus microcarpa* (Chinese Banyan) which sends out a profuse amount of roots gripping securely on the stone facade, furnishing a unique natural-cum-cultural heritage that deserves preservation.

stone retaining walls were used. The oldest walls have open gaps between individual stones, furnishing ample opportunities for propagules to lodge, germinate and mature into plants of varying sizes and habits. Similar vertical or mural habitats accommodate mainly herbaceous vegetation in temperate latitudes (Darlington 1981; Gilbert 1992).

Stone walls in Hong Kong, with a humid-tropical environment, are colonized by a surprisingly diversified collection of flora with many woody components (Jim 1996*c*). Some walls have abundant green cover, ranging from mosses, lichens and algae to grasses, herbs, vines and ferns, and to shrubs and large trees (Fig. 6). The largest organisms growing on stone walls are Ficus trees or Banyans (Jim 1990*b*). *Ficus microcarpa*, *F. virens* and *F. superba* are common species which can attain 20 m tall with 1 m trunk diameter, including some champion specimens (Jim 1994*a*). Masses of roots are sent out to grip the wall face and to penetrate crevices between stones and weep-holes, allowing steadfast anchorage on an apparently precarious substratum. Direct typhoon attack with wind velocity exceeding 100 km/h rarely dislodges them. They do not occupy significant ground space, and grow spontaneously with little human intervention or care. As many stone walls abut narrow roads in the hilly neighbourhoods, they present a special habitat with a rich complement of flora, adding significantly to the otherwise treeless streetscape.

Recent building redevelopment and road improvement, particularly the heightened concern about terrace wall stability (Geotechnical Control Office 1981), have brought large-scale wall demolition. Where reinforcement work was adopted in lieu of wholesale removal, the adding of a reinforced-concrete veneer often requires tree felling or causes severe damage to existing trees and other vegetation.

An ecologically-sound technique should be developed to salvage the genuinely unstable walls. Whenever feasible, natural regeneration should be allowed to run its own course. Overzealous tampering with old stone walls in the name of safety should be resisted. A register of stone walls of exceptionally high amenity value will help the protection cause (Jim 1996*c*). They should be subsumed under the Antiquities and Monuments Ordinance as listed structures to be provided assured preservation for posterity. New stone walls can be designed by mimicking old ones with a view to enhancing spontaneous colonization by vegetation.

Quality of arboricultural practice

Inadequate, substandard or untimely tree-care erodes tree performance (Insley & Buckley 1986) and increases management burden and cost. The close juxtaposition of trees and urban structures in Hong Kong makes tree care difficult (Urban *et al.* 1988). Research findings (Jim 1986, 1997*b*) suggest a need to raise the standard of arboricultural practice. Arboricultural knowledge and skill are mastered mainly by government amenity officers trained overseas via diploma-standard dedicated courses; the technical staff and labourers are trained locally. The 'tree team' has the background to do routine tree-care jobs (Jim 1994*c*), but lacks a senior-grade officer with high-level training and experience. Creating an urban forester or municipal arboriculturist post as the repository of expertise knowledge will reinforce the tree-management team.

For research, local universities can team up with government departments to study urban-tree themes such as: (1) genetic make-up of the local tree population; (2) identification and development of superior cultivars (Moll 1987); (3) screening and introduction of good-quality species and varieties from other countries (Jim 1990*c*, *d*); (4) long-term trials in experimental arboretum; (5) improvement in nursery practice with a view to producing higher-quality planting materials; (6) development of local tree planting and maintenance standards; (7) diseases and pests of local trees and related issues on plant protection. There is a need to raise an awareness that trees in human settlements, especially in densely-packed urban Hong Kong, require active maintenance. The widespread belief that trees will fare for themselves, and the inertia amongst people outside the government about caring for trees, can be dispelled through educational programmes.

Conclusions

Due to geographical reality, the opportunity for tree growth in Hong Kong is inherently limited. The constraints are more akin to those of the developed rather than developing countries (Olembo & de Rham 1987). The fundamental scarcity of land for everything – buildings, roads, open space, greenery – has engendered an untypical built form where everything is telescoped together. It is as much a vertical city as a horizontal one in terms of space utilization. The community is conscious of the grave deficiency of developable land and the extremely expensive real estate. The concept that urban land which is not built upon and used for roads is wasted is commonly held. The general attitude is to accord a low priority to amenity tree planting, being less so in public projects but strongly expressed in most private ones.

The resulting exceedingly keen contest for space (Urban *et al.* 1988) engenders an oppressive growing environment, makes tree insertion in the compact urban matrix difficult, renders vigorous tree growth unlikely, and results in frequent tree damage. Such a bleak scenario is believed to have conditioned professionals and lay-persons subconsciously to accept less healthy trees and tree loss. This societal acceptance is not easy to reverse, but educational and publicity programmes can help to dissipate the misconceptions. Exemplary development projects illustrating the synergistic coexistence of trees and buildings should help to change attitudes towards an important urban infrastructure.

The tree population which is disproportionately limited in relation to the human population should be increased, yet the tremendous pressure on existing trees is working against this objective. Additionally, pressure on the provision of potential space for amenity vegetation can trap people in a vicious circle as planting sites are usurped for other purportedly greater needs. Thus every tree and every plantable site is important, and they should not be given up or allowed to be degraded. Hong Kong should make the best use of the available habitats to aim at high-quality greenery. With a confined urban area and a phenomenal population density, the city does not require many trees to impose a significant impact on the cityscape. The high-density development enhances not only the human dimension (Hughes 1996) but also the sylvan scale of the city. In other words, each tree can serve a large number of people, hence they are highly cost-effective, and it should not be difficult to justify planting more trees. The city's tree manager needs to have a comprehensive understanding of the negative as well as positive forces which mould the past, present and future structure of the urban forest. An optimal tree-cover configuration can be designed accordingly to maximize the functions and benefits of the urban forest (Nowak 1993) in the local context.

As Hong Kong is striving to become an international city, it has to upgrade its environmental image. Other fast-growing cities are facing a similar situation. It will be paradoxical if a first-world economy is incongruously accompanied by a degraded third-world environment. Increasingly, the attractiveness of a city to residents, investors, business and related people from different lands will hinge upon the quality of the environment and the quality of human life. Greening the city on a moderate scale is an effective way to keep the place healthy, productive and competitive. It is very necessary to preserve and introduce more natural ingredients into the city (Cole 1986; Henke & Sukopp 1986). The multiple functions and values of urban trees can be objectively quantified and explained (McPherson *et al.* 1997) to justify an adequate level of funding to sustain a long-term programme. A thorough overhaul of the current attitude and procedures for green space planning and management is earnestly needed.

Acknowledgements

The research grant support provided by the Environment and Conservation Fund and Woo Wheelock Green Fund is gratefully acknowledged. Deep appreciation is due for the help generously given by Alfred Cheung, Alan Cheung, Lawrence Cheung, L. C. Choi, W. H. Leung, P. Mok and K. C. Wong of the Urban Services Department, Mr. S. T. Chan of the Botany Department of the University of Hong Kong, and Grace Jim.

References

Andresen, J.W. (1978) The greening of urban America. *American Forests* 84(1): 10–12, 56-61.

Arnold, C.L., Jr. & Gibbons, C.J. (1996) Impervious surface coverage: the emergence of a key environmental indicator. *Journal of the American Planning Association* 62(2): 243–58.

Baines, C. (1994) Trenching and street trees. *Arboricultural Journal* 18: 231–6.

Barker, P.A. (1994) Root barriers for controlling damage to sidewalks. In: *The Landscape Below Ground*, ed. G.W. Watson & D. Neely, pp. 179–85. Savoy, Illinois: International Society of Arboriculture.

Barlett Tree Expert Company (1968) *Street Tree Study for the District of Columbia Final Report*. Stamford, Connecticut: 246 pp.

Batho, W.J.S. (1990) *Review of Tree Preservation Policies and Legislation*. Report to the Secretary of State for the Environment. London: Department of the Environment: 53 pp.

Bernatzky, A. (1978) *Tree Ecology and Preservation*. Amsterdam: Elsevier: 357 pp.

Bradshaw, A.D., Hunt, B. & Walmsley, T. (1995) *Trees in the Urban Landscape: Principles and Practice*. London: Spon: 272 pp.

Bristow, R. (1984) *Land-use Planning in Hong Kong: History, Policies and Procedures*. Hong Kong: Oxford University Press: 328 pp.

Bristow, R. (1989) *Hong Kong's New Towns*. Hong Kong: Oxford University Press: 358 pp.

British Standards Institution (1991) *Guide for Trees in Relation to Construction*. BS 5837: 1991. London: BSI: 24 pp.

Bullock, P. & Gregory, P.J., eds. (1991) *Soils in the Urban Environment*. Oxford: Blackwell: 174 pp.

Census and Statistics Department (1997*a*) *1996 Population By-census Main Report*. Hong Kong: Hong Kong Government: 207 pp.

Census and Statistics Department (1997*b*) *1996 Population By-census Basic Tables for District Board Districts*. Hong Kong: Hong Kong Government: 87 pp.

Chaney, D.E., Drinkwater, L.E. & Pettygrove, C.S. (1992) *Organic Soil Amendments and Fertilizers*. Publication 21505. Oakland, California: Division of Agriculture and Natural Resources, University of California: 36 pp.

Chevallerie, H. de la (1986) The ecology and preservation of street trees. In: *Ecology and Design in Landscape*, ed. A.D. Bradshaw, D.A. Goode & E.H.P. Thorp, pp. 383–97. Oxford: Blackwell.

Cole, L. (1986) Urban opportunities for a more natural approach. In: *Ecology and Design in Landscape*, ed. A.D. Bradshaw, D.A. Goode & E.H.P. Thorp, pp. 417–31. Oxford: Blackwell.

Coughlin, R.E., Mendes, D.C. & Strong, A.L. (1988) Local programs in the United States for preventing the destruction of trees on private land. *Landscape and Urban Planning* 15: 165–71.

Craul, P.J. (1992) *Urban Soil in Landscape Design*. New York: John Wiley and Sons: 396 pp.

Cutler, D.F., Gasson, P.E. & Farmer, M.C. (1990) The wind blown tree survey: analysis of results. *Arboricultural Journal* 14: 265–86.

Darlington, A. (1981) *Ecology of Walls*. London: Heinemann: 138 pp.

Dorney, R.S., Evered, B. & Kitchen, C.M. (1986) Effects of tree conservation in the urban fringe of southern Ontario cities: 1970–1984. *Urban Ecology* 9: 289–308.

Dudle, P. (1986) Improving the living conditions for street trees in Zurich. *Anthos* 3/86: 28–30.

Evans, M.N, Bassuk, N. & Trowbridge, P. (1990) Sidewalk design. *Landscape Architecture* 80(3): 102–3.

Gardening Which (1996) Our trees need help: an investigation into the effects of trenching on Britain's tree heritage following the introduction of the NJUG voluntary guidelines in April 1995. *Arboricultural Journal* 20: 129–42.

Gasson, P.E. & Cutler, D.F. (1990) Tree root plate morphology. *Arboricultural Journal* 14: 193–264.

Geotechnical Control Office (1981) *Geotechnical Manual for Slopes*. Hong Kong: Public Works Department, Hong Kong Government: 228 pp.

Gilbert, O. (1992) *Rooted in Stone: The Natural Flora of Urban Walls*. Peterborough, UK: English Nature: 32 pp.

Gilbertson, P. & Bradshaw, A.D. (1985) Tree survival in cities: the extent and nature of the problem. *Arboricultural Journal* 9: 131–42.

Gilman, E.F. (1988) Tree root spread in relation to branch dripline and harvestable root ball. *HortScience* 23(2): 351–3.

Gilman, E.F. (1989) Predicting root spread from trunk diameter and branch spread. *Journal of Arboriculture* 14(4): 85–9.

Gilman, E.F., Leone, I.A. & Flower, F.B. (1982) Influence of soil gas contamination on tree root growth. *Plant and Soil* 65: 3–10.

Goldsmith, F.B. (1988) Threats to woodlands in an urban landscape: a case study in Greater London. *Landscape and Urban Planning* 16: 221–8.

Goldstein, J., Bassuk, N., Lindsay, P. & Urban, J. (1991) From the ground down. *Landscape Architecture* 81(1): 66–8.

Grey, G.W. & Deneke, F.J. (1986) *Urban Forestry*, 2nd edn. New York: John Wiley and Sons: 299 pp.

Halverson, H.G. & Heisler, G.M. (1981) Soil temperatures under urban trees and asphalt. Research Paper NE-481. Broomall, Pennsylvania: United States Department of Agriculture Forest Service, Northeastern Forest Experimental Station: 6 pp.

Harris, R.W. (1992) *Arboriculture: Integrated Management of Landscape Trees, Shrubs and Vines*, 2nd edn. Englewood Cliffs, New Jersey: Regents/Prentice Hall: 674 pp.

Harris, R.W., Paul, J.L. & Leiser, A.T. (1977) Fertilizing woody plants. Leaflet 2958. Berkeley, California: Cooperative Extension, Division of Agricultural Sciences, University of California: 23 pp.

Henke, H. & Sukopp, H. (1986) A natural approach in cities. In: *Ecology and Design in Landscape*, ed. A.D. Bradshaw, D.A. Goode & E.H.P. Thorp, pp. 307–24. Oxford: Blackwell.

Hill, D.B. (1985) Forest fragmentation and its implications in Central New York. *Forest Ecology and Management* 12: 113–28.

Holtam, B. (1980) Forestry in an urban environment. *Quarterly Journal of Forestry* 74: 141–52.

Hong Kong Museum of History (1982) *The Hong Kong Album: A Selection of the Museum's Historical Photographs*. Hong Kong: Urban Council: 99 pp.

Hughes, K.J. (1996) Hong Kong: making the most of a compact city. *Urban Design International* 1(1): 95–9.

Insley, H. & Buckley, G.P. (1986) Causes and prevention of establishment failure in amenity trees. In: *Ecology and Design in Landscape*, ed. A.D. Bradshaw, D.A. Goode & E.H.P. Thorp, pp. 127–41. Oxford: Blackwell.

Izumi, S. (1983) The urban vegetation of Tokyo and Sendai, Japan. In: *Man's Impact on Vegetation*, ed. W. Holzner, M.J.A. Werger & I. Ikusima, pp. 335–40. The Hague, The Netherlands: Dr W. Junk.

Jim, C.Y. (1986) *Urban Tree Survey 1985: Pavement Trees Managed by the Urban Council*. Hong Kong: Urban Council: 84 pp.

Jim, C.Y. (1987*a*) The status and prospects of urban trees in Hong Kong. *Landscape and Urban Planning* 14: 1–20.

Jim, C.Y. (1987*b*) Land use and amenity trees in urban Hong Kong. *Land Use Policy* 4: 281–93.

Jim, C.Y. (1988) Preservation of a large Chinese Banyan on a construction site. *Journal of Arboriculture* 14: 176–80.

Jim, C.Y. (1989*a*) The distribution and configuration of tree cover in urban Hong Kong. *GeoJournal* 18: 175–88.

Jim, C.Y. (1989*b*) Tree canopy cover, land use and planning implications in urban Hong Kong. *Geoforum* 20: 57–68.

Jim, C.Y. (1990*a*) Tree canopy characteristics and urban development in Hong Kong. *Geographical Review* 79: 210–25.

Jim, C.Y. (1990*b*) *Trees in Hong Kong: Species for Landscape Planting*. Hong Kong: Hong Kong University Press: 434 pp.

Jim, C.Y. (1990*c*) Selection of tree species for urban plantings in tropical cities. In: *Proceedings 19th World Congress of the International Union of Forest Research Organizations*, August 1990. Montreal: Division 1, Volume 1, pp. 236–47. Montreal: International Union of Forest Research Organizations.

Jim, C.Y. (1990*d*) Evaluation of tree species for amenity planting in Hong Kong. *Arboricultural Journal* 14: 27–44.

Jim, C.Y. (1990*e*) *Nature Interpretation in Lei Yue Mun Park – Native Woodland Trees*. Hong Kong: Horticultural Section, Urban Council: 54 pp.

Jim, C.Y. (1991) Diversity of amenity species in Hong Kong. *Quarterly Journal of Forestry* 55: 233–43.

Jim, C.Y. (1992*a*) Provenance of amenity-tree species in Hong Kong. *Arboricultural Journal* 16: 11–23.

Jim, C.Y. (1992*b*) Tree-habitat relationships in urban Hong Kong. *Environmental Conservation* 19: 209–18.

Jim, C.Y. (1993*a*) Trees and high-density urban development: opportunities out of constraints. *Habitat International* 17: 1–17.

Jim, C.Y. (1993*b*) Trees and landscape of a suburban residential neighbourhood in Hong Kong. *Landscape and Urban Planning* 23: 119–43.

Jim, C.Y. (1993*c*) Soil compaction as a constraint to tree growth in tropical and subtropical urban habitats. *Environmental Conservation* 20: 35–49.

Jim, C.Y. (1994*a*) *Champion Trees in Urban Hong Kong*. Hong Kong: Urban Council: 294 pp.

Jim, C.Y. (1994*b*) Evaluation and preservation of champion trees in urban Hong Kong. *Arboricultural Journal* 18: 25–51.

Jim, C.Y. (1994*c*) *Urban Tree Survey 1994 Roadside Trees Managed by the Urban Council*. Hong Kong: Urban Council: 470 pp.

Jim, C.Y. (1994*d*) Urban renewal and environmental planning in Hong Kong. *The Environmentalist* 14: 163–81.

Jim, C.Y. (1995) Transplanting two champion specimens of mature Chinese Banyans. *Journal of Arboriculture* 21: 289–95.

Jim, C.Y. (1996*a*) Roadside trees in urban Hong Kong: Part I Census methodology. *Arboricultural Journal* 20: 221–37.

Jim, C.Y. (1996*b*) Roadside trees in urban Hong Kong: Part II Species composition. *Arboricultural Journal* 20: 279–98.

Jim, C.Y. (1996*c*) Stone walls and their companion trees as a landscape element in urban Hong Kong. *Yuen Lin* (Journal of the Hong Kong Institute of Landscape Architects) 96: 36–41.

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

Jim, C.Y. (1997*b*) Roadside trees in urban Hong Kong: Part IV Tree growth and environmental condition. *Arboricultural Journal* 21: 89–99.

Jim, C.Y. (1998*a*) Soil characteristics and management in an urban park in Hong Kong. *Environmental Management* 22 (in press).

Jim, C.Y. (1998*b*) Urban soil characteristics and limitations for landscape planting in Hong Kong. *Landscape and Urban Planning* 39 (in press).

Johnston, J. (1990) *Nature Areas for City People*. Ecology Handbook 14. London: London Ecology Unit: 116 pp.

KCR (1997) *West Rail*. Hong Kong: Kowloon Canton Railway Corporation: 16 pp.

Kelcey, J.G. (1978) The green environment of inner urban areas. *Environmental Conservation* 5: 197–203.

Kopinga, J. (1994) Aspects of damage to asphalt road pavings caused by tree roots. In: *The Landscape Below Ground*, ed. G.W. Watson & D. Neely, pp. 165–78. Savoy, Illinois: International Society of Arboriculture.

Lawrence, H.W. (1988) Origins of the tree-lined boulevard. *The Geographical Review* 78: 355–74.

Lo, C.P. (1992) *Hong Kong*. London: Belhaven: 200 pp.

Manning, O. (1979) Designing for nature in cities. In: *Nature in Cities*, ed. I.C. Laurie, pp. 3–36. Chichester: John Wiley & Sons.

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

Messenger, S. (1986) Alkaline runoff, soil pH and white oak manganese deficiency. *Tree Physiology* 2: 317–25.

Miller, R.W. (1988) *Urban Forestry: Planning and Managing Urban Greenspaces*. Englewood Cliffs, New Jersey: Prentice Hall: 404 pp.

Mitchell, A.F., Hallett, V.E. & White, J.E.J. (1990) *Champion Trees in the British Isles*. Forestry Commission, Field Book 10. London: HMSO: 33 pp.

Moll, G. (1987) Improving the health of the urban forest. *American Forests* 93(11/12): 61–4.

Morell, J.D. (1992) Competition for space in the urban infrastructure. *Journal of Arboriculture* 18(2): 73–5.

National Joint Utilities Group (1995) *Guidelines for planning, installation and maintenance of utility services in proximity to trees*. Publication Number 10. London: NJUG: 23 pp.

NHBC (1992) NHBC Standards: building near trees. Amersham, Bucks, UK: National House Builders Corporation: 48 pp.

Nowak, D.J. (1993) Historical vegetation change in Oakland and its implications for urban forest management. *Journal of Arboriculture* 19(5): 313–19.

Nowak, D.J. (1994) Understanding the structure of urban forests. *Journal of Forestry* 92(10): 42–6.

Olembo, R.J. & de Rham, P. (1987) Urban forestry in two different worlds. *Unasylva* 39: 26–35.

Pearce, H. (1994) Growing rootlessness. *New Statesman and Society* 7 (312): 37–8.

Perry, T.O. (1982) The ecology of tree roots and the practical significance thereof. In: *Urban Forest Soils: A Reference Workbook*, ed. P.J. Craul, pp. 2.1–2.43. Syracuse, New York: College of Environmental Science and Forestry, State University of New York.

Perry, T.O. (1994) Size, design and management of tree planting sites. In: *The Landscape Below Ground*, ed. G.W. Watson & D. Neely, pp. 3–15. Savoy, Illinois: International Society of Arboriculture.

Planning Department (1993) Territorial Development Strategy Review Foundation Report. Hong Kong: Hong Kong Government: ix + 92 pp.

Planning Department (1996) *Annual Report 1995*. Hong Kong: Hong Kong Government: 49 + xxiv pp.

Profous, G.V. & Loeb, R.E. (1990) The legal protection of urban trees: a comparative world survey. *Journal of Environmental Law* 2(2): 179–93.

Profous, G.V., Rowntree, R.A. & Loeb, R.E. (1988) The urban forest landscape of Athens, Greece: aspects of structure, planning and management. *Arboricultural Journal* 12: 83–107.

Randall, C.E. & Clepper, H. (1977) *Famous and Historic Trees*. Washington, District of Columbia: American Forestry Association: 90 pp.

Richards, N.A. & Stevens, J.C. (1979) *Streetside space and street trees in Syracuse – 1978*. Syracuse, New York: College of Environmental Science and Forestry, State University of New York: 66 pp.

Sanders, R.A. (1984) Some determinants of urban forest structure. *Urban Ecology* 8: 13–27.

Schmid, J.A. (1975) *Urban Vegetation: A Review and Chicago Case Study*. Research Paper Number 161, Department of Geography, University of Chicago, Chicago: 266 pp.

Scott, D., Greenwood, R.D., Moffatt, J.D. & Tregay, R.J. (1986) Warrington New Town: an ecological approach to landscape design and management. In: *Ecology and Design in Landscape*, ed. A.D. Bradshaw, D.A. Goode & E.H.P. Thorp, pp. 143–60. Oxford: Blackwell.

Shaw, K. (1977) Girdling roots. *Arnoldia* 37: 242–7.

Shigo, A.L. (1989) *A New Tree Biology*, 2nd edn. Burham, New Hampshire: Shigo and Trees Associates: 618 pp.

Talarchek, C.M. (1990) The urban forest of New Orleans: exploratory analysis of relationships. *Urban Geography* 11(1): 65–86.

Thrower, S.L. (1975) The flora of Hong Kong in its geographical context. In: *The Vegetation of Hong Kong*, ed. L.B. Thrower, pp. 5–19. Hong Kong: Royal Asiatic Society.

Tregay, R. (1979) Urban woodlands. In: *Nature in Cities*, ed. I.C. Laurie, pp. 267–95. Chichester: John Wiley & Sons.

Tregear, T.R. & Berry, L. (1959) *The Development of Hong Kong as Told in Maps*. Hong Kong: Hong Kong University Press: 31 pp.

Urban, J., Sievert, R. & Patterson, J. (1988) Trees and space: a blueprint for tomorrow. *American Forests* 94(7/8): 58–74.

Ware, G. (1990) Constraints to tree growth imposed by urban soil alkalinity. *Journal of Arboriculture* 16: 35–8.

Warner, J. (1979) *Fragrant Harbour: Early Photographs of Hong Kong*, 3rd edn. Hong Kong: John Warner: 192 pp.

Watson, G.W., Clark, S. & Johnson, K. (1990) Formation of girdling roots. *Journal of Arboriculture* 16(8): 197–202.

Watson, G.W., Kelsey, P. & Woodtli, K. (1996) Replacing soil in the root zone of mature trees for better growth. *Journal of Arboriculture* 22(4): 167–73.

Watson, G.W. & Neely, D., eds. (1994) *The Landscape Below Ground*. Savoy, Illinois: International Society of Arboriculture: 222 pp.

Whitlow, T.H., Bassuk, N. & Reichert, D. (1992) A 3-year study of water relations of urban street trees. *Journal of Applied Ecology* 29: 436–50.

Wong, Y.C.R., Chau, K.W. & Lai, L.W.C. (1996) *Prices and Competition in Property Markets: Analysis and Policy Issues*. Hong Kong: Hong Kong Centre for Economic Research, University of Hong Kong: 156 pp.