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Urban Forestry and the Eco-City: Today and Tomorrow

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In 1990, the Chicago Academy of Sciences held a conference, Sustainable Cities: Preserving and Restoring Urban Biodiversity, which led to the publication of a book entitled *The Ecological City* (Platt et al., 1994). This symposium differed from others on cities at that time by focusing principally on cities as habitats for biodiversity. The thrust of the symposium was that interactions between people and nonhuman biological entities in urban landscapes had not received much scientific attention and warranted increased ecological investigation. More than a decade later in Shanghai, the International Meeting on Urban Forestry and Eco-Cities conference explored the role of urban forestry in creating more environmentally sound cities that enhance people's quality of life. During the interval between these two symposia, urban ecology has rapidly developed as an ecological discipline exploring the myriad elements that comprise an urban landscape. No longer are urban ecologists trying to convince the ecological community that urban landscapes are important and productive subjects for research, trying to convince planners that ecological concepts need to be incorporated into urban design, or trying to convince environmental managers that a multiple scale approach is needed to manage ecological goods and services and to restore habitats. However, this symposium also revealed that implementation of these principles can be difficult for a variety of reasons, not the least of which is that we still do not understand the nuances of the political and socioecological interactions that affect the structure and function of urban landscapes and how they can be influenced to improve environmental conditions citywide (e.g., Perkins et al., 2004).

The reality is that if our cities are to move in the direction of becoming *eco*-cities, a greater awareness of the ecosystem services provided by a city's urban forest (its entire green infrastructure) must be fostered not only among practitioners and scientists, but also among political leaders and the public. More opportunities should be created to formally and informally educate the public on the roles that urban nature plays in reducing a city's resource and energy use, in improving air and water quality, in decreasing flooding, and in maintaining our physical and psychological well-being. Such education provides the foundation for change. Making cities more comfortable places for people to live by incorporating more of the natural world into our daily lives, and by working *with* nature to prevent or

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mitigate problems that otherwise require costly engineered solutions are means of linking local quality of life for urban residents with global sustainability for the human species. Therefore, an environmentally educated populace with a greater shared vision of the future is essential, if the long-term goal of creating more ecologically sound and resource-efficient cities is to succeed.

The studies collected in this volume represent a global snapshot of many perspectives and activities of planners, managers, and environmental scientists centered on integrating more and better-planned green infrastructure into the hardscapes of our burgeoning cities. Such diverse experimentation is exciting and essential at this stage in the development of international urban forestry, if professionals are to assess which urban greening strategies are successful in their respective cities. Yet within all this diversity of approaches and opinion, shared ideas and needs have emerged. This concluding chapter highlights and reinforces the following major cross-cutting themes expressed by the international authors who contributed to this book:

- Defining the scope of the urban forest and the need for holistic management
- Quantifying the urban forest and its ecological services
- Expanding research in urban ecology and forestry
- Building partnerships for implementation, planning, and research
- Incorporating urban forestry into the vision of the eco-city

We recognize that most of the recommendations and issues described in this chapter and book have not benefited from the experiences of people in cities on all continents, but mainly reflect current urban forestry concerns in selected countries in Europe, Asia, and North America, where conference participants live and work. In addition, the urban forestry issues and studies included in this book deal primarily with cities in countries that have the economic capability of supporting an urban forestry program and mostly with cities in temperate climates. Therefore, this chapter also cites some potential contrasts with the urban forestry needs and challenges faced by cities in developing countries with fewer economic resources, many of which are in more tropical regions. By doing so, we hope to stimulate more international dialogue in identifying and articulating a spectrum of urban forestry goals that would match the varying needs of people in different cities throughout the world.

Defining the Urban Forest and the Need for Holistic Management

The simple act of defining the domain of urban forestry highlights its diversity rather than its unity. The urban forest is a mosaic of trees and other vegetation, some of which are managed intensively by different agencies or people, and others where natural successional forces, indirectly affected by urban conditions, determine species composition and regeneration (McDonnell et al., 1997; Zipperer et al., 1997; Silva Matos et al., 2002; also see Chapter 11). Therefore,

the urban forest consists of street trees, remnant and emergent forest patches, tree plantations, and vegetation in parks, yards, highway verges, utility rights-of-way, and business and institutional campuses. A city's urban forest may also be considered to extend beyond its municipal boundary to encompass peri-urban agroforests or forested watersheds that provide a city's drinking water, such as the Catskill Mountain area does for New York City 160 kilometers away (Chichilnisky and Heal, 1998; Blaine et al., 2006). Such forests or plantations may often require complex management to sustain the multiple social, ecological, and economic services they provide for the urban public, a challenge described by Schulzke and Stoll (Chapter 18) and Jestaedt (Chapter 19). We also feel that urban forestry should expressly include consideration of the soil substrate, since soils, too, are within the purview and care of managers of these varied habitats and are critical determinants of long-term forest sustainability in all urban locales (Carreiro, 2005; also see Chapter 12).

Such an overarching definition enables the urban forest to be viewed more holistically, and provides a conceptual foundation for it to be managed for goods and services in a more integrative way. In addition, urban forestry can be studied and practiced from multiple perspectives that vary in focus over time and according to the developmental stage of urban forestry in different countries. For example, in developed countries, a prime focus in the past was management of the urban forest for aesthetic purposes (Howard, 1902; Pitt et al., 1979), whereas now, as urban populations have grown, intensified, and expanded, it has shifted to management for enhancing ecosystem services (e.g., Nowak and Dwyer, 2000). In developing countries, a more important focus may be managing vegetation to provide materials, such as firewood, fruit and timber, at very local scales (Carter, 1995). Over time, each city and region may manage its urban forest for an increasingly broader and more inclusive range of benefits. Hence, in defining the bounds of urban forestry as a discipline, it is important to consider the current developmental needs of a population as they establish urban forestry goals most suited to their city's social, economic, and geographic context. It may not be as important to rigorously define which vegetative elements are to be considered part of the urban forest as much as to identify the diverse contributions and functions of vegetation and unpaved soils, both within and outside the city, to a particular community's well-being.

Environmental professionals increasingly recognize the ecological reality that the different green areas in a city are, indeed, interacting in diverse ways with each other, with aquatic systems, with the built infrastructure and with people (see Chapter 7). However, the social reality is that the degree and type of management given to vegetation is compartmentalized, varies greatly depending on the group responsible for its care, and seldom involves interactive, coherent planning among these groups (see Chapters 9 and 16). One important dichotomy is the distinction between trees and other vegetation that occur in the public versus the private domain. Public trees can be managed by different agencies within a local government and are a primary means of providing a more socially equitable distribution of vegetation in a city. Hence, the contribution of public trees to total

tree cover in lower income areas can be considerable (Heynan et al., 2006). In a recent paper, Escobedo et al. (2006) observed for the City of Santiago, Chile, that higher income *comunas* (an administrative unit approximately equivalent to a municipality) had a higher mean value of tree cover (33.4%) than lower income *comunas* (11.8%). But the higher income *comunas* had a lower mean value of public trees (29%) than lower income *comunas* (54%). Without public support, the lower income *comunas* would have little tree cover, since residents often cannot plant trees for a variety of reasons including financial limitation, land ownership, and lack of available planting space (Perkins et al., 2004).

Escobedo et al. (2006) and Heynan et al. (2006) also point out the importance of trees in the private sector, since they often comprise the greatest proportion of total canopy coverage in cities. Trees and other plants in the private domain are managed by homeowners, community associations, utility companies, and businesses. This socially diverse management can greatly affect the distribution of canopy coverage in cities, thereby creating urban inequities in apportionment of ecosystem services in different neighborhoods. This possible imbalance is a dimension of environmental justice that is not often considered and needs to be given more attention by the public and decision makers. Vegetation management in private lands may also contribute significantly to the total plant diversity found throughout human settlements (Rapoport, 1993; see also Chapter 16). The vertical complexity, species composition, health, and distribution patterns of this green urban mosaic will then reflect the variation in ownership patterns, professional training, aesthetic sensibilities and choices, perceived value of vegetation, funding levels, and education of these diverse managers. Understanding how such diversity affects the ecological functioning of the landscape as a whole remains an important challenge for urban ecologists and practitioners wishing to promote and distribute particular ecological functions at a citywide scale, while enhancing community well-being at the local level.

One means of achieving the goal of improved allocation of social benefits (Westphal, 2003), ecosystem services, and materials from urban vegetation is for the public and private sectors to work together. For example, at the neighborhood scale, homeowners and small businesses can collaborate with municipal government and developers to implement a plan that better meets local needs (e.g., Ames and Dewald, 2003; Wolf, 2003). Similarly, at the city scale professionals and stakeholders can collaborate to develop a comprehensive Urban Forest Master Plan. Establishing such a communication network among groups of individuals can reduce the negative impacts that fragmented responsibility and care engenders, while clarifying and prioritizing local and city-wide urban forestry goals. Throughout the process of developing a plan of action, site assessments need to include input from not only landowners and businesses, but also renters and even those employed but not living in the area (for related examples, see Wolf, 2003; Elmendorf et al., 2005; Yli-Pelkonen and Kohl, 2005). Furthermore, by working together in a cooperative way, this network can create a more unified political advocacy for urban and community forestry and other community needs as well.

Quantifying the Urban Forest and Its Ecological Services

Effective management and planning of urban forests for promoting ecological and social benefits depends on obtaining information and creating databases on the abundance and distribution of vegetation across the city in relation to such variables as social context and land use, both current and planned. In some cases, the primary focus may be to improve ecosystem services and biodiversity conservation at the city scale (Löfvenhaft et al., 2002). In others, urban forest management may be more focused on providing tangible commodities for residents, such as food or fuel (Carter, 1995). Through the use of geographic information systems (GIS), spatial overlays of current and planned development or management together with environmental maps can identify locations for new plantings that enhance social and ecological benefits, and identify opportunities for linking isolated forest components to provide greater ecological and social connectivity.

Several authors contributing to this book highlighted the critical need to take stock of our urban forest resource as an essential first step in creating an effective urban forestry program (see Chapters 15, 16, 17, and 22). Inventories can simply be lists of trees by species and their locations, or contain detailed information such as tree size, vertical structure and health in relation to site conditions, land use, distribution of canopy cover and vegetation, and cultural importance. Such inventories should also be updated regularly so they can be used to determine change in characteristics important to management, such as mortality and growth rates of trees, species composition, and distribution of canopy cover in private and public sectors (Nowak et al., 2004). The spatial analysis capacity afforded by using GIS can also permit comparison of these urban forest attributes over time to assess policy efficacy and inform adaptive management decision making for the future (e.g., Dwyer et al., 2000). Surprisingly, despite the economic value of trees and the expense of their maintenance, the proportion of cities with organized urban forestry programs or an urban forestry master plan is still quite low even in developed countries, as indicated by Kielbaso (see Chapter 15), Kielbaso (1990), and Elmendorf et al. (2003) for the United States. Therefore, professional and stakeholder support should be sought to urge municipal government agencies to create a position of urban forester to lead efforts to inventory the city's tree resources. However, even with the creation of such a position, municipalities need to support the position with additional resources so that management objectives can be carried out effectively.

Different tools and statistical design approaches have been developed to assist managers and scientists in obtaining data on urban forest structure. For example, several sampling strategies were described by Chen and Jim (Chapter 16) and Wu et al. (Chapter 17). Recently, the U.S. Forest Service developed i-Tree (http://www.itreetools.org), an inventory software package to assist urban forest managers in caring for the different components of the urban forest. Although published methods and software now exist to assist urban ecologists and foresters in obtaining and archiving inventory data, the purpose or objectives of the inventory,

and not the capabilities of the software itself, should guide decisions as to which variables need to be collected and which methods or protocols should be used. Because of the complexities of these issues, the data needs of a local neighborhood wishing to plant fruit-bearing trees along its streets may be quite different from the data needs of a citywide analysis for air pollution removal by vegetation, for example. Both management activities require knowledge of species, species performance, and site conditions. However, for the citywide analysis above, information such as air pollution sources, meteorological patterns, and areas of greater human susceptibility to pollution (e.g., schools and hospitals) are also needed if management activities for air pollution removal are to be more effective in improving human health and comfort. Furthermore, other factors, such as available funds and personnel, dictate which variables receive priority for collection and analysis. Finally, it should be noted that many tools linked to ecosystem service models (e.g., Urban Forest Effects model [UFORE];, Nowak and Crane, 2000) were developed for a specific region and, therefore, need to be parameterized to local conditions. Nonetheless, judicious use of these tools and models can greatly assist management activities at the neighborhood and city scales once specific goals and objectives are defined.

If the science and management of urban areas are to benefit fully from the landscape ecology perspective described by Wu (Chapter 2), then information from remote-sensing images should also be obtained and integrated more regularly into the planning and management assessments of urban forest distribution (e.g., Löfvenhaft et al., 2002; Freeman and Buck, 2003). The areal extent and resolution of satellite and other aerial images are well matched to the citywide and regional scales needed for urban planning. Information on the spatial distribution of different types of vegetation patches and their canopy coverage and condition can also be determined remotely using multispectral scanning imagery. Once validated by sampling on the ground, additional attributes of the forest can then be measured remotely (Waring and Running, 1998; Kerr and Ostrovsky, 2003), like dominant taxa and species richness (Martin et al., 1998; Gould, 2000), leaf area index (see Chapter 21), productivity (Smith et al., 2002), degree of moisture stress (Zarco-Tejada et al., 2003), and infection by pathogens or pests (Nilsson, 1995; Xiao and McPherson, 2005). After spatial patterns of distribution are identified, appropriate management responses can be deployed more efficiently and at the local scale. Remote images from different points in time can be used to determine where trees and forest patches have accrued or been lost over the interval. The effectiveness of different planting or land-use policies in increasing and distributing forest canopy cover in ways that are socially equitable, improve ecosystem service delivery, or meet conservation goals can also be gauged over time by using remote sensing, as described in Yang et al. (Chapter 22).

Sophistication in computer modeling of ecosystem services has grown since the 1990 conference in Chicago. A recent modeling effort, UFORE (Nowak and Crane, 2000), has been used in Canada, Chile, China, and the United States to quantify ecosystem benefits of the urban forest at the city scale and by land use (http://www.fs.fed.us/ne/syracuse/Data/Internation/data_inter.htm). The model uses tree

species composition and detailed measurements of canopy structure and condition, diameter at breast height, and tree position to estimate air pollution removal and carbon sequestration. By stratifying sampling plots according to land use, one can begin to examine how land use affects ecosystem goods and services. However, one limitation of this approach is that it does not capture the spatial heterogeneity of vegetation or built infrastructure *within* a land use, and so limits our understanding of how finer-grained variation in built and vegetated land-cover types influences the movement of materials, energy, organisms, and water throughout a city, that is, the actual ecosystem processes that influence the goods and services being estimated. High-resolution models linking land use and land cover to environmental quality are, therefore, needed to improve planning for greater urban sustainability.

To address this need, Pauleit and Duhme (2000) developed a spatially explicit model at scales useful for planning to quantify the effects of different urban land covers on urban climate, energy use, CO_2 emissions, and water flow in Munich, Germany. They accomplished this by developing a typology that delineated distinct configurations (generally of 4.6 ha or less) of built-up infrastructure, other physical features, and vegetation. Although Pauleit and Duhme were able to capture the spatial heterogeneity within a land use and to evaluate how it influenced urban hydrology at small scales, such intensive effort may be beyond the capabilities of many cities and towns in both developed and developing nations. Therefore, there is a need to develop spatially explicit models for estimating ecosystem services that capture not only the heterogeneity of a land use, but are also more user-friendly for managers and planners. For example, Heidt and Neef (Chapter 6) maintain that quantitative models, like that of Bruse (1999), are useful for evaluating the relative benefits of small-scale structural changes of buildings and vegetation for relieving heat stress caused by stagnant air at the street level. In this way, urban greening can become a more readily appreciated strategy for infilling and improving environmental conditions in dense urban neighborhoods, an important need also addressed by Jim (Chapter 9).

In contrast to managing urban forests for ecosystem services at the broad-city scale, management for material services, such as fruit tree and fuel wood production, often occurs at the local, finer scale of a neighborhood. Such management for material services may seem to be in conflict with the goals of holistically managing the urban forest, because decisions are often made on a piecemeal basis with neighborhoods making decisions independent of each other rather than optimizing resources in a synergistic way. But they are not. For example, biotope and ecotope mapping of a city, a GIS-based approach that can provide information on the diversity, abundance, and distribution of a city's available resources in relation to existing neighborhoods, can be used to link disparate resources with planning and management activities (Sukopp and Weiler, 1988). Biotope mapping, for example, can assist planners with spatially explicit information on a city's natural resources and provide a basis for evaluating how any particular management action taken by residents to supply specific goods may affect adjacent areas. In South Africa, biotope mapping is used to identify areas within neighborhoods for afforestation

and small agricultural plots that supplement people's diet and income (Sarel Cilliers, personal communication). Over time, these patches of vegetation, managed for materials and food, may coalesce to form an urban forest in locations where a forest did not exist before and be linked with existing vegetation in other portions of the city to create additional citywide or even regional benefits, such as producing vegetation corridors important for movement of organisms and people (Zipperer et al., 2000; Löfvenhaft et al., 2002) or air and water pollution buffer strips. Therefore, as both management and the forest evolve, a shift in management philosophy may occur from one that emphasizes providing specific goods to one providing an array of ecosystem services, thus enhancing material and environmental quality benefits at both the neighborhood and broader city scales.

If the ecosystem services provided by green infrastructure and unpaved soils are to become a more integral part of cost-benefit analyses in urban planning, then service quantification (for example, tons of pollutant removed, or degrees of cooling) must be translated into monetary units and those values incorporated systematically in municipal tree and shrub value appraisals. Currently, tree appraisal by municipal arborists does not normally incorporate ecosystem services in these valuations (Council of Tree and Landscape Appraisers, 2000; Watson, 2002). However, several cost-benefit analyses that do include noncommodity values and ecosystem services have been conducted for public trees in different communities in the United States (e.g., McPherson et al., 1997, 2006). Such analyses are especially important in urban and suburban areas in more developed countries where logging and farming activities are less likely to occur and add market value to trees. Chen and Jim (Chapter 16) and others (Farber et al. 2002; Chaudry, 2006) have also observed that the value to society of ecosystem services and other nonmarket benefits, which natural areas and vegetation contribute, needs to be incorporated more regularly into land-use planning processes and legal land-use regulatory frameworks (Arnold, in press). Although scientific research that estimates the ecosystem services provided by natural ecosystems has been increasing over the last 15 years, there is a need for more research in ecological economics to develop improved and generally agreed upon methods for converting ecosystem services to monetary units so that trade-offs of different land uses or other changes to the natural components of the environment can be evaluated. Such methods should also include weighting factors that allow the social and ecological context of the parcel and the parcel type's rarity to contribute to the value outcome (e.g., Duever and Noss, 1990). This is especially important in urban areas, where the value of a plot of natural land or a particular tree can be greater than in equivalent rural areas due to the larger human population benefiting from that plot or tree's services (Farber, 2005).

Expanding Research in Urban Forestry and Urban Ecology

While the ability to acquire tools, staff, and adequate funding probably constitutes a major bottleneck to managing our urban forests, the knowledge base for managing the forest more sustainably does exist, but in a limited context and for a limited

number of biomes, principally temperate forests. This knowledge base must be continually expanded through applied and basic scientific research, and greater information exchange between the academic and practitioner communities. Furthermore, there is a critical need for multidisciplinary research within and among the social, physical, and natural sciences to understand the interactions and feedbacks between green infrastructure and its social and physical context (e.g., Alberti et al., 2003). The Urban Long-term Ecological Research sites in Baltimore (http://www.beslter.org/) and Phoenix (http://caplter.asu.edu/), funded by the National Science Foundation, are examples of programs addressing such research needs. Increasing the hierarchical scales of scientific inquiry can then parallel the disciplinary, multidisciplinary, and transdisciplinary research that can improve not only our management of urban green environments, but also our understanding of how a city functions as an ecosystem (see Chapter 2). Incentives for promoting networks of academics and practitioners to perform research at these larger scales would not only inform policy making, but in time increase our ability to understand the ecology *of* the city as an ecosystem and not simply the responses of green ecological units *in* cities, an important distinction made by Grimm et al. (2000) and Wu (Chapter 2). Positive signs that such networks are, indeed, being rapidly created and formalized into academic, governmental, or "think-tank" centers and institutes can be appreciated simply by searching the Internet using the key words *center (centre), institute, urban, ecology,* and *sustainability*.

While complex multi- and transdisciplinary research is at the pioneering edge of science, contributions at the disciplinary and interdisciplinary levels are still needed to lay the foundations for a more holistic understanding of the reciprocal impacts of the sociophysical city environment and its urban forests (e.g., Stewart et al., 2004). For example, greater practical and scientific understanding of the biological and ecological responses of native and exotic vegetation to varying and often stressful conditions needs to be gained from the scale of individual species and cultivars to that of communities in natural patches. This knowledge can then be applied in many ways, including improving site matching for planting of street trees, increasing the native species palette at nurseries for public and private use, improving restoration techniques for deteriorating natural areas (see Chapters 12 and 24), and improving reclamation strategies for unvegetated and derelict sites, such as landfills (Robinson and Handel, 2000) and former mining areas (see Chapter 23). In addition, comparative ecological research among cities (e.g., Globenet et al., 2000) would lay a foundation for distinguishing common urban effects and responses from those specific to a particular city or group of cities due to variation in factors such as geography, climate, soils, urban morphology, cultural values, and political and economic systems.

Climate change, biological species invasions, pests, diseases, and regional pollution threaten urban vegetation, as well as natural ecosystems throughout the world. Some urban natural areas, such as forest remnants, can be used as laboratories for basic ecological research to understand species and ecosystem responses not only to climate change, but also to invasive species, altered community trophic structures and disturbances, and elevated air pollutants including CO_2, (Carreiro

and Tripler, 2005; also see Chapter 11). This information would be particularly pertinent for predicting the health and regeneration of urban forest patches where successional forces, rather than direct human planting and management, determine future species composition (Zipperer, 2002; Lugo, 2004; Lugo and Helmer, 2004). For instance, negative effects of urban land use on seedling regeneration could compromise the future ability of these forested patches to provide the ecosystem services of air pollution reduction, microclimate mediation, carbon sequestration, and flood control. Plant demographic research, coupled with successional trajectory modeling, (e.g., Pacala et al., 1996; Meurk and Hall, 2006) could inform timely mitigation interventions to prevent or reduce undesirable outcomes. Basic research is also needed on the effects of varying the abundance and distribution of urban vegetation patches on landscape connectivity, a factor important for maintaining meta-population and ecosystem processes at the landscape level (Byers and Mitchell, 2005; Ray, 2005; Reice, 2005; Sanjayan and Crooks, 2005). Such studies could then contribute to species conservation efforts from local to regional scales as well as to estimation of ecosystem services.

Since cities are human-dominated ecosystems, flows of information among and within groups of professionals, policy-makers, and the public are paramount for understanding how urban systems function ecologically as well as socially. Human activities engender responses from the socioeconomic and natural components of cities, some of which may require technical "translation" by experts before they can be perceived by policy makers and the public. Human and institutional reactions (or lack thereof) to these environmental responses then constitute feedback circuits that either perpetuate the same conditions or change them. Researchers in the social, economic, and natural sciences create and use aggregative indices as a means of measuring and communicating the multiple responses of their respective systems to internal and external forces, either human or natural. Examples in these disciplines include the Index of Social Health (http://iisp.vassar.edu/ish.html), the gross domestic product, and the Index of Biotic Integrity (http://www.epa.gov/bioindicators/ html/ibi-hist.html). One of the reasons for acquiring and creating such information is to provide early warning of undesirable change before the system itself "informs" us after reaching a more observable tipping point where corrective action becomes more costly. As Zhang et al. (Chapter 4) point out, while index development for measuring environmental sustainability at the national and regional levels is progressing (e.g., Heinz Center, 2002, http://www.heinzctr.org/ecosystems/report.html), sustainability indicator development at the city scale is still in its early stages (e.g., Urban Quality Index of Song and Gao, Chapter 6; Menegat, 2002). One of the research issues involved is the construction of indicators that are sensitive enough to capture the most important interactions among the social, ecological, and economic components of cities, and yet are simple enough for communicating to the public and policy makers. Among these are the interactions between people and the natural habitats in cities. The ecosystem services concept is proving valuable for communicating the important roles that nature plays in supporting human societies (Millennium Ecosystem Assessment, 2005, http://www.millenniumassessment.

org/en/Index.aspx), but the importance of ecosystems services in contributing to human well-being in urban landscapes is perhaps less publicly appreciated. However, as discussed earlier in this chapter, research and tools for converting nature's services into monetary terms would greatly assist the planning and management communities in evaluating different development options for urban and urbanizing areas. The construction of urban sustainability indices and the valuation of ecosystem services will be critical particularly in the near-term, if we are to prevent undesirable trajectories and gauge the efficacy of our collective actions in creating more ecologically sound cities.

Building Partnerships for Implementation, Planning, and Research

As cities grow and competition for space intensifies, the need for integrative planning and management of green infrastructure becomes more apparent. Indeed, the need for a more holistic approach to urban forest planning and management was perhaps the most recurring point made by the contributors to this book. Building partnerships to conserve, restore, and manage urban forests was advocated as one means of achieving this goal. Assembling a diverse expertise base with multiple viewpoints into partnerships to address a city's urban forestry issues can inform plans and their implementation at the outset, thereby avoiding some costly problems during and after project completion (Ames and Dewald, 2003). The perceived benefits of integration through partnerships include improving delivery of ecosystem services and materials to the most appropriate locations, reducing vegetation care and maintenance costs, distributing the health and recreation benefits of trees and parks in a more socially equitable manner, and providing habitat for wildlife in the most suitable sites.

It is not surprising that creating and maintaining a healthy diversity of vegetation and adequate levels of ecosystem services for people requires greater planning and integration of human effort, particularly in an ecosystem that is, after all, human-dominated and dynamic. More simply stated, "it takes more than an understanding of trees to sustain a successful urban forest" (Jones, Chapter 8). Partnerships among governmental and nongovernmental agencies, academic researchers, educators, and businesses can provide opportunities for stimulating public awareness and involvement in supporting a city's green infrastructure (Johnson, 2002), thereby providing social, environmental, and economic benefits for settlements large and small (e.g., African Conservation Trust's Manukelana Project, http://www.projectafrica.com/ manukelana.htm). People's involvement in planting and growing trees in their neighborhoods, schools, and public places is generally thought to promote the long-term success of urban greening programs. Participation of people in various greening activities in cities can build a sense of ownership that helps prevent problems like vandalism and may create a greater appreciation of a city's local biotic legacy and uniqueness (e.g., http://www.olmstedparks.org/conservancy/volunteer.html).

Greening activities may also provide social benefits to individuals and entire communities. However, claims of success or failure in the accrual of social improvements due to urban greening projects should be evaluated more rigorously than is often done, so that future activities can benefit from past insights (Westphal, 2003).

In some cases, bottom-up demand and follow-through from the public has affected forestry restoration and reclamation at a regional scale. As Jones (Chapter 8) describes, urban forestry in England arose in the early 20th century from the efforts of a volunteer community association that planted trees on lands badly despoiled by coal mining and metal smelting. Today, these plantings are an important part of the green infrastructure of some cities in the British Midlands. The current Urban Forest program in this "Black Country" of England involves partnerships among public, private, and volunteer organizations, and such partnerships have provided important models for successful restoration and greening activities elsewhere in the United Kingdom. Miyawaki (Chapter 12) has codified his philosophy (known internationally as the Miyawaki method) to restoring and constructing new urban forest patches, one that depends on partnerships. Miyawaki's approach relies on knowledge from basic and applied vegetation and soil science for selecting and growing native trees and shrubs, relies on government and private businesses for funding planting endeavors, and uses public volunteers as labor for the initial plantings. As he states (Chapter 12), "Reforestation can be viewed as analogous to dramas: vegetation ecologists write play scenarios, government and private companies work as producers and directors, and citizens, including school children, play the part of leading characters on the stage. Everyone has the opportunity to play a role in reforesting their region." The success of his method over the last 30 years is attested to by his estimate of having planted 30 million trees in over 1200 sites in Asia and Brazil.

Partnerships also inform the planning process. For example, university researchers Secco and Zulian (Chapter 20) offer urban planners a quantitative modeling tool, sensitive to social context, for making decisions about the location and equipment needs of urban recreational parks that best match neighborhood demographics and available transportation. Linking ecological and social systems provides decision makers with information for developing comprehensive management plans for the urban forest that also improve ecosystem and material benefits for urban residents (Yli-Pelkonen and Niemelä, 2005). Decision-making tools, especially those with scenario-building capacity, are needed to assist planners and decision makers with these complex assessments. For example, Keith Jones (Chapter 13) has described the development and use of the GIS-based Public Benefit Recording System that ranks different patches in a city using four criteria of public benefit: social, public access, economic, and environmental. These multiple dimensions of benefit can also provide a basis for fostering partnerships between the public and private sectors when positive synergies among the four categories are identified.

Perhaps the experience of the citizens of Porto Alegre, Brazil, best illustrates the benefits of widespread and continuous public involvement in urban planning. The city has a broad-based participatory budgeting and planning process, one that has directly involved approximately 150,000 residents (Menegat, 2002). This

evolving social and political experiment begun in 1989 has led to resident-driven, environmental management plans and programs in a city of 1.3 million, which now boasts the highest standard of living and the highest amount of green space per inhabitant in Brazil (14 m^2/person). As part of this process, the need to understand the city's environmental setting and biotic resources for planning and management purposes was identified and resulted in the publication of the *Environmental Atlas of Porto Alegre* (Menegat et al., 1998, http://www6.ufrgs.br/gaia/gb/atlas/atlasframe.html). Environmental management and planning in Porto Alegre is based on six principles, three of which are as follows: (1) the city is an integral part of its natural ecosystems, (2) the watershed is the unit of environmental management, and (3) education and communication with citizens about the city's green environments is essential to secure long-term societal commitment to increasing and maintaining environmental quality and green space allocation. To meet the objectives of this last principle, parts of the atlas were published in a series of inserts in the local newspaper in order to disseminate that knowledge more broadly to the public. The atlas was also freely distributed to all municipal schools in the city, and as a consequence triggered the construction of urban environmental intelligence laboratories in the schools (Alexandre Ruszczyk, personal communication).

Through participatory research, partnerships among academic researchers, environmental managers, other practitioners, and stakeholders not only improve the implementation of management plans and practices, but also expand the breadth of research questions and research opportunities. Thus both the management and scientific knowledge base in urban ecology and urban forestry is increased at local and global scales. For example, ecological restoration of natural habitats in cities, a major management activity in urban environments, is one way of achieving this goal at the same time as it improves urban forest quality (e.g., Silva Matos et al., 2002). Often, managers do not have the time or possibly the resources to document restoration activities. By partnering with the academic community, a more rigorous evaluation of a restoration's efficacy can be conducted using proper statistical designs and analyses (Giardina et al., 2007). A properly designed project would include setting benchmarks for determining success before the restoration is initiated, replicating procedures or treatments at proper scales, using reference sites or treatment controls, and collecting pre- and post-treatment data to establish baseline and document the range of variability in habitat responses (see Chapters 23, 24, and 26). Additional benefits of partnering on a restoration project might also occur, and include: (1) the opportunity to build in long-term commitments for project evaluation, (2) the ability to determine the ecological mechanisms that underlie a project's success or failure, and (3) the opportunity to train future managers. Higgs (1997) further argues for partnerships with the broader local community to increase the democratization of restoration projects and to identify the unique cultural and ethical contexts of project sites. Such multifaceted discussions that capture the needs and understanding of many individuals at the local scale by their very nature require diverse partnerships and benefit long-term restoration success by promoting what Higgs calls "place awareness" and "authentic engagements between people and ecosystems" (e.g., Primack et al., 2000).

Incorporating Urban Forestry Into the Vision of the Eco-City

Over the last decade it has become increasingly apparent that the ability of our planet to provide people with resources for supporting current population levels without compromising future generations and other species has become strained. The fact that the planet's economic "metabolism" is now large enough to affect our planet's "metabolism" and climate regulatory system has become ever more accepted and mainstream (Stern, 2007). Climate uncertainty further complicates our ability to predict our planet's capacity to provide food, water, materials, and ecosystem services for our exponentially growing populations (Intergovernmental Panel on Climate Change (IPCC) report, http://www.ipcc.ch/). We are reaching, or perhaps have already reached, a critical threshold that requires bold and widespread responses from the human community to avoid a downturn in our collective quality of life. Finding ways to partner with the natural world in solving environmental problems, instead of viewing nature primarily as a commodity or amenity, must become an integral component of our adaptation to changing global conditions.

Progress in addressing these global challenges is increasing. In the early phase of this international awareness, the United Nations convened the Earth Summit in Rio de Janeiro, Brazil in 1992. Among other accomplishments, delegates to this conference provided a declaration of principles and a roadmap for promoting human sustainability known as the Agenda for the 21st Century (Agenda 21, for short; http://www.un.org/esa/sustdev/documents/agenda21/index.htm). Since a growing proportion of humanity was and still is becoming urban, delegates also realized that the solutions to many global problems lay in changing the activities and resource consumption patterns of people in cities. These challenges were addressed in Chapter 28 of Agenda 21, known as Local Agenda 21. This document created the impetus for subsequent conferences where policy and implementation frameworks for achieving sustainability goals consonant with Agenda 21 principles were produced. One of the better known of these was the first European Conference on Sustainable Cities and Towns held in Aalborg, Denmark, in 1994, which resulted in the Charter of European Cities and Towns Towards Sustainability (the Aalborg Charter; http://www.aalborgplus10.dk/ default.aspx?m=2&i=371). As of the Aalborg-Plus 10 meeting in 2004 (http://www.aalborgplus10.dk/default.aspx?m=2&i=308), 497 European cities and towns have committed to charter goals as full signatories and 531 additional cities have declared their intention to sign, indicating a groundswell of support from leaders and the public for the realization that we must learn to live within the bounds of earth's carrying capacity for our species.

Progress in creating more support for a sustainable cities movement has been made by other groups as well. The eco-cities movement (http://www.ecocitybuilders.org/), now almost 20 years old, has provided a venue for supporting projects, creating networks, and accelerating transdisciplinary exchange of information on urban sustainability, and has hosted six international conferences since 1990, with a seventh planned for 2008. While cities in the U.S. have not explicitly adopted the United Nations's Local Agenda 21, many have become more engaged in their

commitment to urban sustainability planning and implementation (Sustain Lane, http://www.sustainlane.com/us-city-rankings/). So far in the U.S., the impetus for change has come mostly from the bottom up, as evidenced by 185 U.S. cities joining a total of 627 cities in 67 countries worldwide as members of the International Council for Local Environmental Initiatives–Local Governments for Sustainability (http://www.iclei.org/index.php?id=772). Mayors from 600 U.S. cities in all 50 states have also demonstrated leadership in committing to reductions in greenhouse gas emissions by signing a climate protection agreement (http://usmayors.org/climateprotection/). There are also encouraging signs that in addition to governmental and nongovernmental organizations, businesses are more willing to respond to the complex challenges imposed by climate change and urban sustainability (The Climate Group, http://theclimategroup.org/index.php/ reducing_emissions/case_studies/). And recently, the William J. Clinton Foundation in an alliance with several banks is financing green building technology in major cities worldwide to reduce urban energy use and CO_2 emissions (http://www.lintonfoundation.org/cf-pgm-cci-home.htm).

As a result of this rapid increase in awareness of sustainability issues, concepts such as "ecological footprint," "green technology," "cyclic economies," and "sustainability" are heard more often in the public parlance. They are no longer terms used only by academics and environmentalists, but are increasingly discussed by policy makers, businesses, and the public. However, even as we use a term that represents the color of plant life, ironically people seem not to think first about "greening" in terms of enhancing vegetation cover in their surroundings, but instead apply "green" more reflexively to items and processes that are human engineered. Perhaps this is due to the fact that most people and their leadership live in urban centers, where the built infrastructure dominates, and plants are often viewed as ornamental "extras" and not as integral contributors to the health, comfort, safety, and material needs of a city's people. This is also probably indicative of how far urban forestry professionals and advocates have yet to go in pressing home the fact that a city's plant life and soils are vital urban infrastructure, requiring and deserving as much deliberate, scientifically informed management and long-term commitment to care as our built infrastructure.

How can professionals and the public work with nature to move their cities closer to the eco-city ideal? Increasing the "amount and kind of nature ... through conservation and restoration activities" is one of the five principles listed by Wittig (Chapter 3) for guiding this transformational process. Many opportunities exist in urban areas for increasing and integrating nature into human settlements. One of the most successful has been the development of greenway or greenbelt plantings in cities throughout the world (Fábos and Ryan, 2006). In many cases, strategies for creating corridor networks begin with identifying, from aerial photographs or other forms of remote sensing, linear vegetation features that are already part of the landscape. Most linear arrangements of trees and other vegetation occur along rivers, streams, canals, highways, and other transportation corridors and can serve as nucleating sites for restoration projects aimed at increasing the connectivity of green elements across the landscape. The motivations for creating greenways have

varied over time and have reflected changing and varied societal needs from local to national scales (Fábos and Ryan, 2006). In some countries greenways are constructed primarily to preserve air and water quality, and reduce flooding. In others, initial reasons were to provide shelter-belts for agriculture and urban protection from storms (Yu et al., 2006), but are now expanding to include additional network functions, such as recreation, escape routes for disasters, and the conservation of biological communities and historic and cultural features (Bryant, 2006; Fábos and Ryan, 2006; see also Chapters 10, 14, and 25). However, while creating greater landscape connectivity through use of greenways is a common planning goal, certain caveats should be heeded, particularly in urban areas, since unintended negative consequences can sometimes occur after an ecological patch of high quality becomes linked to one of low quality (Simberloff and Cox, 1987; Environmental Law Institute, 2003). Also, political structures, which vary in their top-down versus bottom-up approaches to planning and implementation of environmental projects, may also influence the type, extent, and success of greenway plantings, as noted by Yu et al. (2006) in their comparison of greenway projects in China with those in Europe and North America.

Opportunities for greening cities as part of a path toward developing into an eco-city will also vary with economic status and changing demographics of cities. For example, the needs and opportunities for tree and vegetation planting differ greatly between the rapidly growing cities of developing nations and postindustrial shrinking cities in more developed nations. In developing cities, urbanization and the rapid influx of rural migrants often occur without benefit of government planning, infrastructure, and services. Consequently, supplying people's fundamental needs such as sanitation and potable water is grossly inadequate (Carter, 1995). In addition, food, energy, and materials for housing construction may also be insufficient. By improving soil stability, mitigating flooding, reducing air and water pollution, and providing fuel wood and shade, urban and periurban forestry projects, if integrated with economic and health policies and programs, have the potential to ameliorate many of the negative consequences of crowded and polluted environments (Konijnendijk et al., 2004). Trees in developing cities can also supply food, honey, fodder, spices, medicine, and craft supplies—all of which supplement diet or incomes (Carter, 1995). However, the difficulties in promoting greening can be formidable under these circumstances. For example, since other forms of energy are expensive, the urban poor in developing countries often rely on wood for fuel. This can result in the stripping of trees in streets and local parks and the creation of zones of desertification around a city (Olembo and de Rham, 1987; Carter, 1995). Livestock browsing in these cities can also destroy saplings, which then require extra protection strategies after planting. As a consequence, the United Nations Food and Agricultural Organization (FAO) has provided resources for the establishment of periurban agroforests for multiple purposes throughout the world. Over the years these experiments have met with mixed success (Haque, 1987; Konijnendijk et al., 2004). If the potential benefits of urban forestry are to be achieved in these difficult circumstances, then planning for the types and locations of greening must meet the direct material and environmental needs of people and cannot occur without

considerable public support and partnership in their continued management and protection (Kuchelmeister and Braatz, 1993; Carter, 1995).

The recent phenomenon of shrinking cities also creates new opportunities to rethink urban planning and green space distribution. In Europe and especially in the United States, urban planning has long been focused on dealing with economic growth and areal expansion of cities. However, since the mid-20th century, a combination of forces including suburbanization, the expansion of global markets, and shifts from industrial to service and information-based economies in these countries has resulted in the simultaneous decline in population and the economy in urban centers. Embracing urban contraction as an opportunity for improving the quality of life of the remaining residents is still novel and difficult for politicians and planners alike, given the many cascading social problems that follow the shrinking of cities. Yet, midsized cities in the rustbelt of the midwestern U.S., such as Youngstown and Cleveland, Ohio, and Detroit and Flint, Michigan, are rising to the challenge (http://www.governing.com/articles/11cities.htm). Residents in areas that were only partially developed or in declining neighborhoods that are now mostly abandoned are given incentives to leave so that these locations can be turned into woodland, wetland, prairie, parks, or community gardens. This not only increases the environmental value of the land and the ecosystem services delivered, but may also provide economic value for a city, due to compensatory wetland mitigation laws applied to developers who drain and build on wetlands in other locations. Cities in Eastern Europe have also been grappling with these difficulties, prompting recent discussions, exhibits, and special issues of professional journals focused on the shrinking cities phenomenon (Müller, 2004).

In both growing and shrinking cities, planners, designers, decision makers, urban foresters, and residents have recognized the link between the urban forest and community well-being and livability. Many cities have started to move toward becoming eco-cities, cities where inhabitants not only realize the importance of reducing their ecological footprint, but also of improving their urban forests. This has resulted in communities creating policies to protect, conserve, and manage their urban forests to optimize ecosystem services, materials, and social benefits, and in so doing also reduce the rate at which planetary wide global warming occurs. Although the eco-city will not stop global climate disruption by itself, it may create the realization among decision makers and the public that if our cities are to remain livable during these changing and uncertain times, then improving green infrastructure is equally as important as improving the gray. If greater allocation and improved siting of green infrastructure is not planned and implemented, then more costly engineered solutions become our only adaptive alternatives. Only through a comprehensive, broad-scale approach to planning and management can the urban forest be conserved during urbanization and maintained in a healthy condition in settled areas (LaGro, 2001). To achieve this, green infrastructure cannot be an afterthought in the development process and cannot be "last in line" for municipal budgeting. Likewise, only through working with local residents can managers identify collective needs and how best to afforest a neighborhood, and thereby contribute to the evolution of an eco-city.

Conclusion

We have provided a broad overview of the varied ways in which urban forestry professionals, policy makers, and citizens throughout the world are working to incorporate more trees and other green spaces into their cities, thereby realizing the potential of urban forests to contribute to their community's well-being and sense of place. For the most part in this chapter, we have stressed the utilitarian functions of trees, forests, and other green areas within dense human settlements, since these ecosystem and socioeconomic benefits are compelling and motivating reasons for increasing green space allocation for people in cities. However, by treating the incorporation of nature in cities as a purely pragmatic exercise in engineering for addressing our physical needs, we overlook other powerful reasons that many of us have for greening our homes and communities—the solace, pleasure, excitement, and joy that we experience by being part of a greater natural world (Kellert and Wilson, 1993). This in essence was another common theme expressed by many of the authors who contributed to this book—our shared desire to bring more grace into our lives and to live more harmoniously with nature. As our species enters its urban century, we must be proactive in assuring that the everyday environment for the greatest number of our descendants will contain places of natural beauty where we and they can regain and retain our humanity.

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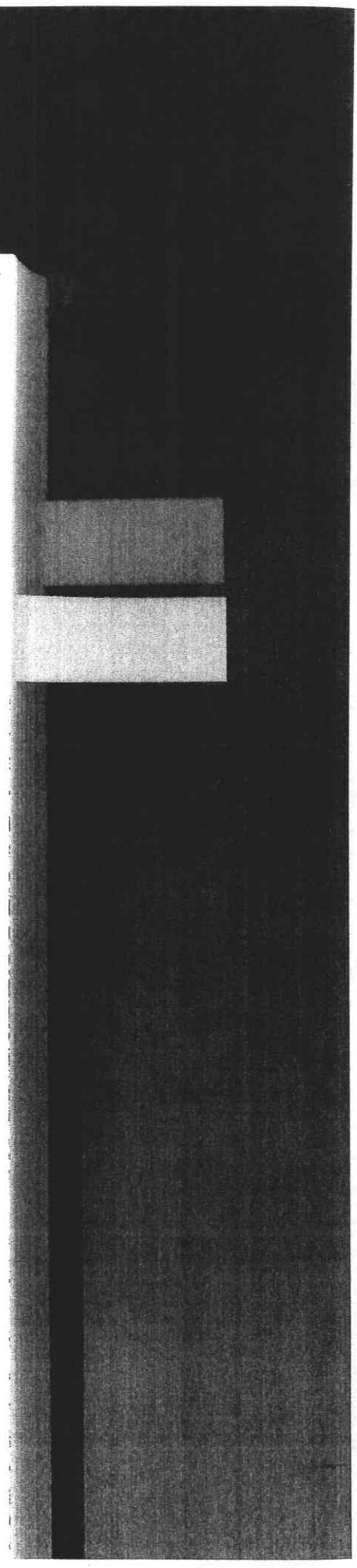
Ecology, Planning, and Management of Urban Forests

International Perspectives



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