Future City 7

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The Urban Forest

Cultivating Green Infrastructure for People and the Environment

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Future City

Volume 7

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Future City Description

As of 2008, for the first time in human history, half of the world's population now live in cities. And with concerns about issues such as climate change, energy supply and environmental health receiving increasing political attention, interest in the sustainable development of our future cities has grown dramatically.

Yet despite a wealth of literature on green architecture, evidence-based design and sustainable planning, only a fraction of the current literature successfully integrates the necessary theory and practice from across the full range of relevant disciplines.

Springer's Future City series combines expertise from designers, and from natural and social scientists, to discuss the wide range of issues facing the architects, planners, developers and inhabitants of the world's future cities. Its aim is to encourage the integration of ecological theory into the aesthetic, social and practical realities of contemporary urban development.

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Cover illustration: A tree-lined boulevard in Tel Aviv (Photo: D. Pearlmutter)

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Preface

This book is a collaborative effort among academics and practitioners who have developed an appreciation for the value of trees in cities. Its focus is on urban "green infrastructure" (GI) – the interconnected web of vegetated spaces, ranging from street trees and private gardens to neighborhood parks and peri-urban forests, which provide essential ecosystem services in densely populated areas. The concept of green infrastructure embodies the view that biotic systems are just as vital to the functioning of a modern city as any other type of infrastructure, be it roads, water, sewage, power, or communication. At the same time, green infrastructure is different – more dynamic, more heterogeneous, and often more fragile – because it is alive.

The services provided by this sort of infrastructure are more varied than those delivered by a system of roads or pipes. These services may have an immediate benefit, such as providing shade to a pedestrian on the street, or benefits which are longer term and somewhat removed from plain sight – like mitigating climate change or providing habitat for wildlife. In fact, the role of urban trees is tied up with the many other natural and man-made systems in the city, and their value lies in their mutual relationships with the soil, the atmosphere, and the people with whom they come in contact. What is provided, then, by the entirety of the "urban forest" (UF) is an array of *ecosystem services* – things like preventing damage from storm-water runoff, filtering dust and pollutants from the air, and providing an outlet for outdoor recreation – whose necessity often becomes most apparent when they are missing or insufficient.

The challenge of ensuring that these ecosystem services are indeed delivered, and that they may be enjoyed by the population in an equitable and sustainable way, is a multidimensional undertaking. It requires knowledge of the physical attributes of urban greenspace, including the biological and hydrological processes underlying the growth and viability of trees and other plant species. It requires a broad view of the environmental interactions between the built and the unbuilt and a solid base of knowledge on which strategic decisions can be made regarding the planning and maintenance of green assets. Furthermore, it requires a set of tools for coping with the social and cultural dynamics that can determine success or failure in a landscape that includes human actors. And finally, it requires an understanding of how the

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totality of these environmental and social factors can be integrated in better policy and in more effective "governance" of urban green infrastructure.

In this volume, we summarize the collaborative efforts of researchers and practitioners from across Europe to address these challenges. Its chapters convey the findings and recommendations of three working groups that were established within the framework of the European COST Action FP1204 *GreenInUrbs*, whose mandate is to develop a "green infrastructure approach, linking environmental with social aspects in studying and managing urban forests." The three groups set as their task the compilation of "best practices" in three respective realms: the environmental, social, and governance-related aspects of urban forestry and green infrastructure.

Members of the working groups represent some three dozen countries and embody a wealth of experience and expertise in fields ranging from plant physiology to landscape architecture to actor-network theory. By bringing together individuals from such diverse geographical and disciplinary backgrounds, the COST Action aspires to promote a common language – one which not only recognizes the distinctive needs of each country and region but informs a larger, more integrated approach to the cultivation of green cities.

We hope and expect that this book will be of value to a broad and diverse audience. While many of the topics are technical in nature, the presentation of these topics is geared toward a nonspecialist audience. This is to ensure that the information and insights gathered by the working groups will be accessible to citizen activists as well as scientists – and while rigorously grounded in empirical evidence, the lessons offered will find a receptive audience among those who can truly "make a difference" in the way that resources are managed and policies are made. In addition, we foresee that the findings presented here will stimulate renewed dialogue between practitioners and theoreticians, each of whom brings invaluable knowledge to the discussion of the role that trees, forests, and green infrastructure play in our urban life.

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Part I
Environmental Ecosystem Services Provided by Urban Forests and Green Infrastructure

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Chapter 1
Introduction: Urban Trees as Environmental Engineers

Roeland Samson

The human population is increasing at an unprecedented rate. Whereas it took over a 100 years for the global population to increase from one billion people in 1804 to two billion in 1927, it took only 12 years for these numbers to rise from 6 billion in 1999 to 7 billion in 2011 (United Nations 2010). At the same time, an inexorable trend toward urbanization has been observed, with the number of people living in cities recently surpassing the number of those in rural environments – and continuing to grow worldwide. Although there are large variations in this dynamic, with the rate of urbanisation in Europe actually holding steady at about 0.3%, cities are becoming more and more important, even at the European level (United Nations 2011). The concentration of people in urban environments has distinct ecological advantages, as it offers possibilities for protecting rural, and especially vulnerable, ecosystems. Moreover, concentrating human activity in a compact built environment can facilitate the efficient management of services like transport, energy supply and water treatment, and stimulate cultural vitality and technological innovation. However, these benefits come at a price – as urban citizens are increasingly becoming isolated and disconnected from nature.

Urban areas are characterized by a high human population density and a large proportion of sealed surfaces. Physically they are intensively built, often resulting in a fabric of dense street canyons and a lack of open, ventilated spaces. Also inherent to the urban environment is the high volume of anthropogenic activity, including building construction, vehicular traffic, space heating and cooling, and a wide variety of industrial processes. As a result they are typically characterized by high pollution levels in all their ecosystem components, including soil, water and air. Even more than agro-industrial regions, cities are differentiated from most ecosystems in that

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they are almost completely shaped by human activity – and they often contain a minimum of natural components, such as vegetation.

It may not be surprising, then, that some would hardly consider landscapes which are as artificially modified as cities to be "ecosystems" – but in fact they are. Indeed, *urban ecosystems* differ qualitatively from other ecosystems, as their energy and material flows are to a great extent anthropogenically driven. Nevertheless, it is important to recognize the city as an ecosystem, as it reminds citizens and decision makers that urban inhabitants ultimately depend on the essential ecosystem services it provides (Daily 1997).

Making cities healthy and attractive places to live is of vital importance for the long-term development of societies. Therefore, their environmental quality must constantly be maintained and improved by reducing soil, water and especially air pollution. Moreover, cities need to be places that nurture mental health – and interaction with living organisms in green spaces can give city dwellers a sense of relief and escape from urban life. When seen from this perspective, the city's natural amenities represent a network of urban green infrastructure (UGI) – which can play a critical role in both controlling pollution levels and enhancing the physical environment, and contributing directly to the general well-being of citizens. In fact, a vast array of benefits to humans can be attributed to interaction with nature, no matter if it is indirect, incidental or intentional. Interacting with nature has been found to produce positive impacts on physiological function and health, psychological and spiritual well-being, and the improvement of cognitive functions (Fuller et al. 2007).

A healthy ecosystem can provide many services to humans, which are known collectively as ecosystem services (ES). ES are defined as the direct and indirect contributions of ecosystems to human well-being (Brouwer et al. 2013). These ES support directly or indirectly our survival and quality of life, and can be divided in four categories: (i) cultural services, (ii) regulating services, (iii) provisioning services and (iv) habitat services. Besides the cultural services, all the other services provided by UGI form the core theme of this section, and are denoted as environmental ecosystem services (EES) as they are linked to the physical environmental aspects of these services. While conventional urban green management has tended to be primarily aimed at enhancing amenity values, and in some cases maintaining biodiversity, recently there has been a growing emphasis on the provision of "nature-based solutions" to environmental problems, and this includes EES relating to carbon sequestration, pollution mitigation, microclimate regulation, storm water attenuation, energy conservation, provisioning of goods and other services.

UGI comprises a wide range of vegetation types and structures, including grass lawns and green walls and roofs. However, in this section we will focus on urban trees – from the scale of the individual tree, to assemblages of trees along lanes and in parks, to entire forested areas in and around the city – which together comprise "the urban forest". Trees are the most consequential components of the urban ecosystem and urban landscape, both in terms of their size (which can be massive) and by virtue of the fact that citizens often feel a strong emotional connection to trees. Beyond this, trees are distinguished as "environmental engineers" – providing

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environmental ecosystem services that are indispensable for both their human and non-human neighbors, and which will be examined in the chapters that follow.

Attention will be given to the various aspects of the *regulating* services, including the moderation of microclimate and thermal stress (Chap. 2), mitigation of air pollution (Chap. 3), sequestration of CO_2 (Chap. 4), regulation and purification of water (Chap. 5) and enhancement of soil quality (Chap. 6). Chapter 7 looks at *provisioning* services, and deals with trees as a source of all kinds of timber and non-timber forest products, including food. The *habitat* services, by which trees provide habitat to a variety of biological species (plants, animals and microflora) are critical for increasing urban biodiversity and are discussed in Chap. 8. Alongside these services, Chap. 9 considers the *disservices* imposed by trees in urban environments, discussing the emission of pollen and biogenic volatile organic compounds, as well as a number of social aspects.

These chapters and sub-chapters aim to provide a better understanding of the EES that can be provided by urban trees and forests, as this kind of information is crucial for urban planners and designers in the process of decision making and to prioritize land management interventions. Building upon this theme, Chap. 10 deals with the use of models for estimating, predicting and quantifying the functioning of EES, especially for microclimate regulation and air pollution mitigation. Finally, Chap. 11 summarizes this knowledge in the form of insights and data which can be used as direct input for urban tree and forest management. This chapter starts with a discussion of the importance of urban tree inventories and the different approaches to performing them, and is followed by a catalog of the most important European urban tree species and their EES-related characteristics – presented as a resource to aid in the selection of the most appropriate species for a particular place and a given set of targeted services. Chapter 12 offers conclusions and recommendations on the use of trees in the urban environment, with an eye toward making our cities better places to live.

References

Brouwer R, Brander L, Kuik O et al (2013) A synthesis of approaches to assess and value ecosystem services in the EU in the context of TEEB. Final report

Daily GC (1997) Nature's services: societal dependence on natural ecosystems. Island Press, Washington, DC

Fuller RA, Irvine KN, Devine-Wright P et al (2007) Psychological benefits of greenspace increase with biodiversity. Biol Lett 3:390–394

United Nations (2010) World population prospects: the 2010 revision, vol I, Comprehensive tables. United Nations Publication, ST/ESA/SER.A/313

United Nations (2011) World urbanization prospects: the 2011 revision. United Nations Publication, ST/ESA/SER.A/322

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Chapter 2
The Urban Heat Island: Thermal Comfort and the Role of Urban Greening

Jelle A. Hiemstra, Hadas Saaroni, and Jorge H. Amorim

As the majority of people living in cities around the world continues to grow, the challenges connected with life in densely populated urban areas are growing as well. One of the most prominent environmental features of urbanization is the tendency of temperatures in cities to gradually rise in comparison to their rural surroundings, in a localized climatic phenomenon known as the *Urban Heat Island (UHI)* effect. Especially during periods of heat stress in warm-weather cities, the UHI may have a debilitating effect on the health and activity of the urban population. Urban green infrastructure in general, and urban trees and forests in particular, hold an unmatched potential as a means for mitigating the UHI effect and enhancing the thermal comfort of people in cities.

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Urban Heat Island (UHI): A phenomenon characterized by higher temperatures within a built-up urban area as compared with its rural surroundings, attributed to the modification of land surfaces and human activities within the city. The UHI is most prominently observed during nighttime and under calm weather conditions. Its intensity depends on the city's geographical location, size and population, urban structure, land use distribution, type of urban activities, and – notably – the relative presence or absence of trees and vegetated green space within a largely impermeable landscape. The difference in air temperature between the city center and the rural landscape can reach over 10 °C, but can be reduced significantly within the urban fabric by the presence of parks and greenery.

2.1 The Urban Heat Island

The typical UHI is characterized spatially by a peak in temperatures at the city's dense urban core, a surrounding 'plateau' of temperatures which are also elevated in comparison to the rural area outside the city, and localized *Park Cool Islands (PCIs)* – where green spaces maintain lower temperatures than their immediate built-up surroundings. The modified land surface (i.e. built and paved areas) and reduced vegetation in cities commonly cause an increase in the sensible heating of the environment, resulting from the absorption of incident solar radiation and the retention of heat by drier, denser surface materials (see Fig. 2.1). The three-dimensional geometry of densely packed buildings and 'urban street canyons' inhibits urban cooling by reducing the rate at which reflected solar radiation and emitted thermal radiation can escape the urban fabric and impairing ventilation, causing heat to become trapped within the city. The heat island effect is further exacerbated by anthropogenic waste heat – especially from air conditioning in southern Europe and the Mediterranean region, and from heating in temperate, continental and northern Europe – as well as industrial processes, motorized traffic and other urban activities (e.g., Oke 1982, 1987).

Park Cool Island (PCI): The temperature gradient between vegetated and urbanized areas that expresses the cooling effect of urban parks. The PCI intensity has been shown to vary with land cover, type of vegetation, tree species and coverage, park size and across seasons and weather conditions.

The UHI may be observed in terms of the relative temperature of terrestrial surfaces, or of the air at different heights above them (Oke 1982, 1987; Parlow et al. 2014). Especially relevant for the thermal comfort of pedestrians is the heat island observed within the 'urban canopy layer' (UCL), or the volume of air extending

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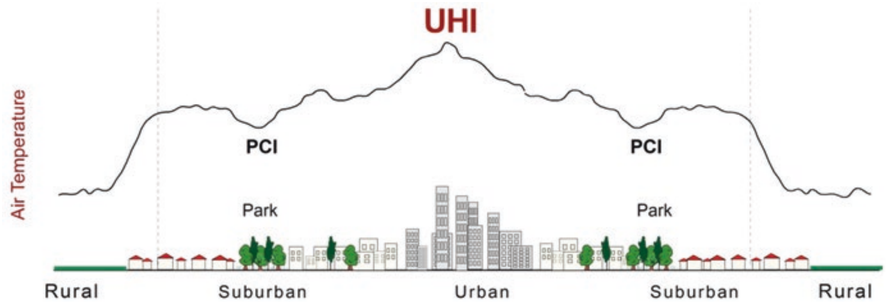

Fig. 2.1 Schematic transect illustrating the increased air temperatures in the urban area (Urban Heat Island: UHI), being maximal in the central urban district, in comparison to the rural area outside the city, and the cooling effect of parks (PCI) within the urban area (Figure courtesy of Dr. Zafrir-Reuven based on Oke 1987)

from street level to the average height of surrounding buildings and trees. In this layer, the maximum UHI intensity (measured as the urban-rural temperature difference) is typically in the range of 1-3 °C and occurs during the nighttime hours. During stable nights with calm air and cloudless skies, however, it can be considerably more intense – and in some large cities can reach as high as 12 °C (Voogt 2004).

Thus UHI intensity is highly dependent on weather conditions as well as anthropogenic activities and various characteristics of the urban environment, with population size and density being two of the prominent factors (Oke 1987; Arnfield 2003). The most intensive UHIs develop in mid-latitude regions (Wienert and Kuttler 2005), but significant UHIs have been observed in tropical and sub-tropical regions as well, where they can amplify the already severe thermal discomfort (e.g., Balling and Brazel 1987; Chow and Roth 2006; Sofer and Potchter et al. 2006; Velazquez-Lozada et al. 2006). However, it should be noted that the UHI strongly varies within and among cities and that there are even cities where no UHI is present. For example in arid environments, cities which contain a large amount of irrigated areas may actually be cooler than the surrounding dry land (e.g. Grimmond et al. 1993).

2.2 Thermal Comfort

The extent to which people perceive their environment as thermally pleasant or stressful depends not only on the temperature of the surrounding air, but also on its humidity and the speed at which it is moving – and especially in outdoor urban settings, on the exposure of their body to solar and thermal radiation. These environmental factors combine with personal factors like clothing and metabolism to

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determine the rate at which the body is losing or gaining heat, and the intensity of response (e.g. sweating) that is required to maintain thermal equilibrium. This in turn has a decisive influence on a person's sensation of *thermal comfort*.

Thermal comfort: The state of mind which expresses satisfaction with the thermal environment (ASHRAE 2004). Human thermal comfort is decisively influenced by the exchanges of energy between the body and the surrounding environment, primarily by radiation (often quantified by the *mean radiant temperature*), convection (a function of air temperature and wind speed) and sweat evaporation (limited by humidity). It can be quantified using biometeorological indices such as the Physiologically Equivalent Temperature (PET), Universal Thermal Climate Index (UTCI) and Index of Thermal Stress (ITS).

Various indices combining meteorological parameters with thermo-physiological parameters have been developed in order to assess human thermal comfort, with as many as 40 of them listed in a survey by Epstein and Moran (2006). Among the most commonly used is the Physiologically Equivalent Temperature (PET), whose values express the hypothetical temperature of a standard room that is thermally "equivalent" to the actual conditions in a complex environment (Mayer and Höppe 1987). PET values between 18 and 23 °C are regarded as being comfortable, while values of 29 °C, 35 °C and 41 °C define the respective thresholds between mild, moderate, severe and extreme heat stress (Höppe 1999; Matzarakis et al. 2009).

Thermal stress negatively affects the functioning and health of people. Elderly people, the chronically ill and pregnant women are especially susceptible and are likely to suffer from moderate heat stress even under prevailing conditions. During periods of heat waves, however, the risks to vulnerable urban populations increase – with increased mortality rates having been reported for many countries, including France, Russia and the Netherlands (Daanen et al. 2010; Norton et al. 2015).

While UHI intensity has already reached significant levels under current climatic conditions, thermal stress in cities can be expected to further increase with projected global warming (IPCC 2013). Although the projected increase of air temperature due to global climate change is more gradual than the local increase due to UHI effects in many cities (Grimmond 2007), the *combined* effect of both processes is expected to accentuate thermal stress within the urban environment (Potchter and Ben-Shalom 2013) – and the two may even be synergistic (Li and Bou-Zeid 2013). Moreover, the increase in frequency, intensity and duration of heat waves, also projected by climate models, will further aggravate thermal stress and discomfort of citizens and is liable to have a significant impact on health, leading to increased morbidity and mortality of the population in urban areas.

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2.3 The Beneficial Role of Urban Greening

One of the most promising measures for mitigating heat stress in urban areas is the deliberate planting of vegetated green spaces (Gill et al. 2007; Bowler et al. 2010; Norton et al. 2015). The large-scale planting of trees in the city, known as 'urban forestation', is considered to be especially effective for creating cooler areas (Brown et al. 2015; Yoshida et al. 2015). The Park Cool Island (PCI) effect, typically generated by green spaces which include mature trees, results from two complementary mechanisms: shading and evapotranspiration.

In terms of the localized benefit for pedestrian thermal comfort, the shading effect tends to be the dominant factor. By blocking a significant part of the incoming solar energy, shade trees can reduce a person's exposure to short-wave radiation from the sun, as well as to long-wave radiation from underlying ground surfaces – both of which reduce the radiant heat load on the person. In the latter case this is due to the lower surface temperature of the shaded terrain (Fig. 2.2), and with extensive tree coverage this effect can even produce a noticeable reduction in air temperature, further enhancing thermal comfort.

Air temperature can also be reduced by *evapotranspiration* from extensive vegetated ground cover, and at larger scales by transpiration from the tree canopy. At the scale of a pedestrian, however, the leaves of a tree can be beneficial not just because of their transpiration, but because their multi-tiered structure ensures effective shading without raising the radiative temperature of the tree canopy itself. It should be emphasized that the effectiveness of cooling by evapotranspiration is highly dependent on soil water availability, and it is limited by the volume and biomass of the tree – which are also crucial parameters in determining the amount of shade provided. Therefore tall trees with large, dense crowns are much more effective than smaller trees.

Evapotranspiration: The combined effect of evaporation from water bodies or moist ground surfaces and transpiration from the leaves of trees and other plants. Evapotranspiration in urban green spaces reduces the sensible heating of air while increasing its latent counterpart, and thus results in cooler conditions than those typically found in urban areas dominated by "dry" or impermeable materials. Along with shading from trees, which lowers the temperature of adjacent surfaces, evapotranspiration is a dominant component of the cooling provided by urban greening.

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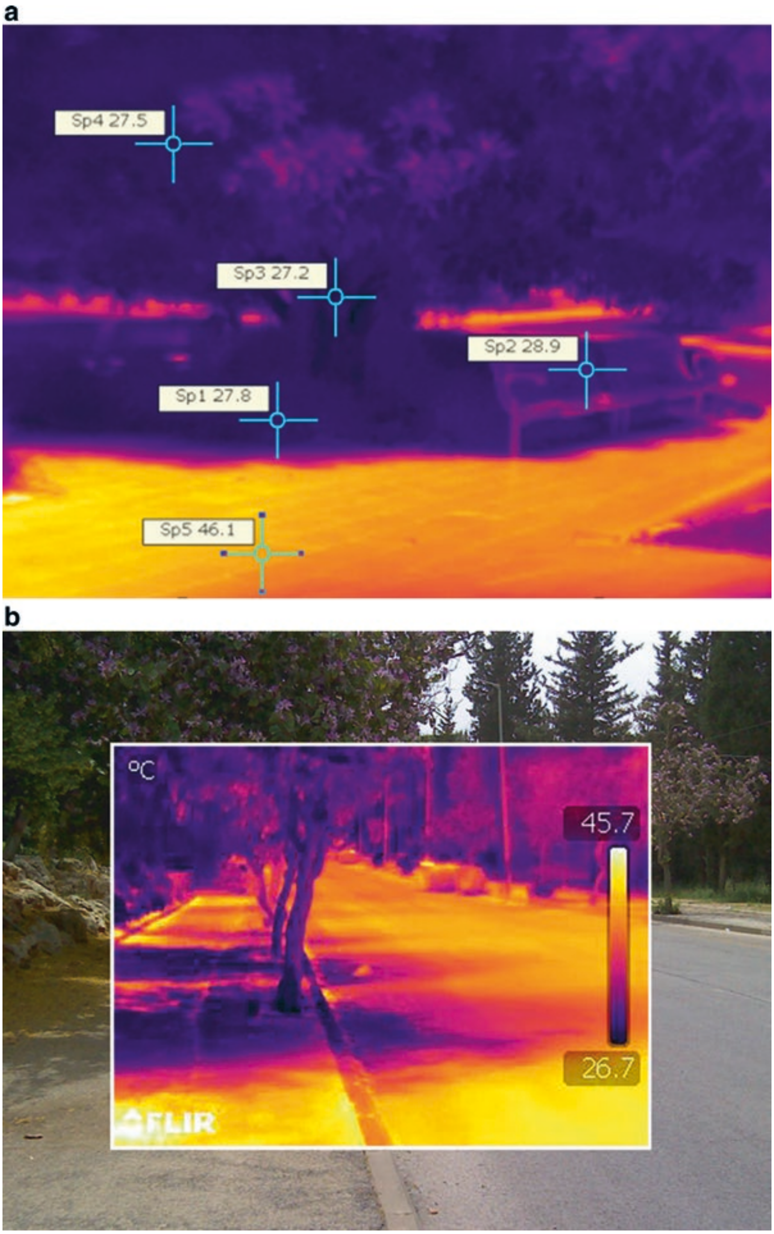

Fig. 2.2 Thermal infrared (IR) images indicating the daytime difference in radiative surface temperature between exposed and tree-shaded street paving in (**a**) Sydney, Australia (Reprinted with permission from Samuels 2010); and (**b**) a town in northern Israel. In both cases the surface temperature differences reach approximately 18 °C

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2.4 Examples from Different European and Mediterranean Countries

The following review presents state-of-the-art findings from a number of countries located in different climatic regions, regarding the contribution of urban greening to UHI mitigation and to improved thermal comfort. Measured temperature reductions due to urban greening (i.e. the PCI magnitude) are compared in Fig. 2.3. The findings reported here are based on a wide variety of research approaches, and they cover a broad range of spatial and temporal scales. In addition to the quantitative evaluation of cooling by urban green space and its contribution to thermal comfort, subjective thermal perception by human subjects is discussed and shown to largely validate what the physical results would suggest.

Israel. A large body of research in Israel – including more than 30 studies – has provided extensive evidence confirming the effectiveness of cooling by urban vegetation, and the relief it provides from thermal stress under hot summer conditions. These investigations focus on various types of green spaces, including urban parks,

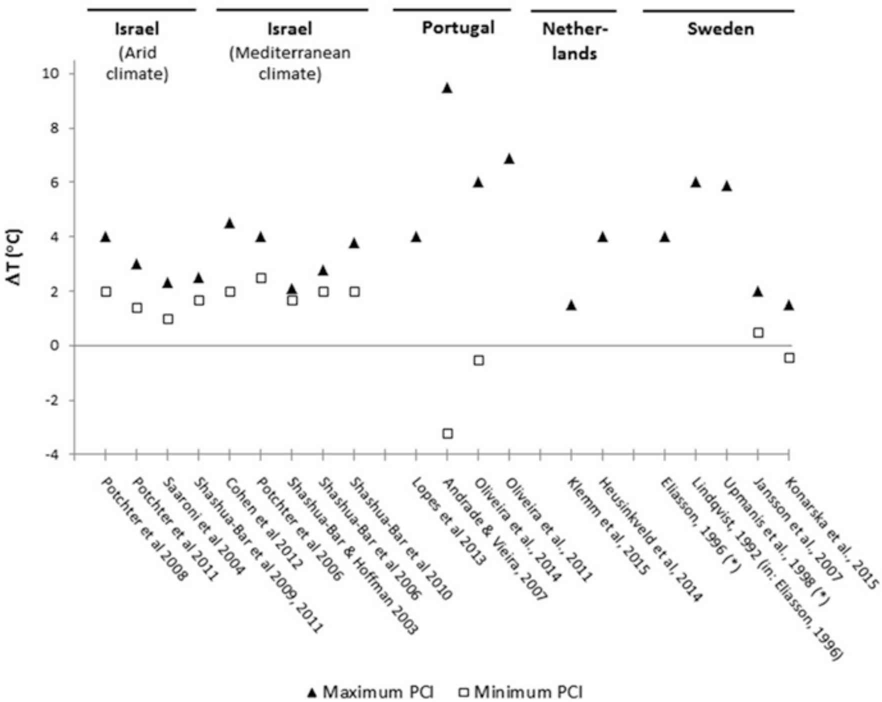

Fig. 2.3 The Park Cool Island (PCI) magnitude as reported in literature from four different countries, shown as the maximum and minimum observed air temperature difference ($T_{built}-T_{park}$). The strong heterogeneity among results from different studies reflects differences in both climate and green space characteristics. **measurements carried out during nighttime*

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streets and courtyards, and they highlight the benefits of wooded urban areas for moderating thermal stress – with the magnitude of the cooling effect generally increasing with canopy coverage and tree density. Schiller (2001) concluded that thermal comfort in a Mediterranean climate is best achieved by a dense overhead canopy closure of tall trees, similar to Aleppo pine (*Pinus halepensis*), which enable better ventilation than oak trees with similar canopy closure. Date Palms (*Phoenix dactylifera*) were ineffective cooling agents in residential streets in Tel-Aviv, and the recommended street cooling policy is planting broad-leaf trees, such as *Ficus* species and *Tipuana tipu*, at minimal planting intervals, so that their canopies will overlap at maturity (Shashua-Bar et al. 2010a).

Shashua-Bar and Hoffman (2003) showed that in a Mediterranean city, the cooling effect of trees at midday in summer reaches 3–4 °C, which is equal to about 50% of the air temperature increase between sunrise and noon. They indicated that the cooling effect of trees corresponds to the coverage ratio of tree coverage, so that a 70% tree cover reduces street temperature by about 2.8 °C, with the cooling effect perceivable as far as 100 m into adjoining streets (Shashua-Bar and Hoffman 2002, 2004). The cooling effect of a grass lawn from evapotranspiration was only half of the effect of shade trees (Shashua-Bar et al. 2006), whereas a park with mostly exposed lawns was found during the day to be even warmer (up to 1 °C) than the built-up surroundings (Potchter et al. 2006). The daytime cooling effect of wooded parks in Tel Aviv sometimes reached 4 °C, reducing heat stress accordingly, despite increased relative humidity. Moreover, vegetated green space in a coastal urban park was found to reduce human-biometeorological stress even when there was no significant air temperature reduction. In addition to dramatic reductions in radiative ground temperatures and consequent easing of the overall heat load, this was attributed to the subjective perception of the green amenity by park users (Saaroni et al. 2015).

The cooling effects of urban greening were also examined in the arid southern region of Israel, where water scarcity is an important consideration in urban landscaping. Shashua-Bar et al. investigated street trees in the city of Beer Sheva (Shashua-Bar et al. 2010b), and the combination of shade trees and grass in an urban courtyard (2009), in the latter case finding daytime air temperature reductions of as much as 2.5 °C compared to a non-shaded grass courtyard. By evaluating the "cooling efficiency" of different landscape treatments in terms of the irrigation water required to obtain a given reduction in thermal stress, it was found that shade trees alone provide the most efficient green solution – and when these trees were combined with shaded grass, the overall water requirement was *less* than for exposed grass alone (Shashua-Bar et al. 2011).

Portugal. Measurements carried out in the 900 ha urban forest of Monsanto in Lisbon reveal a PCI intensity of 2 to 4 °C in nearly 80% of the night time and 60% of the daytime (Lopes et al. 2013). Even in smaller scale parks, maximum differences between 2.5 °C and 6 °C were measured depending on the location within the green area (Andrade and Vieira 2007; Oliveira et al. 2014), while maximum differences as high as 6.9 °C in air temperature and 39.2 °C in mean radiant temperature (T_{mrt}) were captured in a 0.6 ha garden (Oliveira et al. 2011).

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A particularly pronounced PCI effect was found under very hot weather conditions, with differences exceeding 9 °C for a mean local air temperature above 35 °C (Andrade and Vieira 2007), stressing the important role played by green spaces in mitigating situations of extreme heat. The role of urban green in reducing heat-related excess mortality is evidenced in a 10-year study by Burkart et al. (2015), which showed a 14.7% elderly mortality increase in association with a 1 °C increase in UTCI in areas with a very low green cover, as opposed to an increase of only 3.0% in highly vegetated areas.

The Netherlands. In a large-scale survey of the UHI effect in Dutch cities and villages it was concluded that in general, a 10% increase in urban green area leads to a 0.6 °C decrease in the UHI (Steeneveld et al. 2011). Similarly an analysis of the variation in UHI levels in the city of Rotterdam revealed that each one percent increase in urban green reduces the UHI effect by 0.058 °C. Also differences up to 4 °C were observed between temperatures measured in a park area and in the inner city (Heusinkveld et al. 2014).

In an interdisciplinary study by Klemm et al. (2015) relating perceived thermal comfort to objective thermal comfort based on micrometeorological measurements in three Dutch cities, it was concluded that urban green spaces are generally perceived as thermally comfortable on warm summer days. Micrometeorological measurements showed that the examined parks indeed are cool islands within the urban area, with maximum air temperatures being 0.3–1.5 °C lower than those in the city center. Shading was shown to be a major factor; it was calculated that an increase of 10% tree cover in a park lowers T_{mrt} and PET by about 3.2 and 1.5 °C, respectively; also 10% tree cover lowers T_{mrt} within a street canyon by about 1 °C. As the upwind urban characteristics were shown to influence the cooling effect of green areas, the authors concluded that for improvement of thermal conditions in urban areas green infrastructure should be implemented on various scale levels; i.e. from house gardens through street trees and green areas up to parks (Klemm et al. 2015).

Locally applied vegetation measures can have a mitigating effect on temperatures at pedestrian level in a street canyon. Gromke et al. (2015) found avenue trees to have the strongest mitigating effect, with mean and maximum levels calculated of 0.4 and 1.6 °C respectively. Façade greening also had a noticeable, though relatively small effect when compared to that of the street trees, while roof greening was shown to have no noticeable effect on temperatures at street level.

Sweden. In all large Swedish cities (> 100,000 inhabitants), at least 40% of the urban space is occupied by green and blue areas – a ratio that clearly marks Sweden off from the great majority of the European countries (EEA 2012). Since the 1990s an important body of literature on urban climate has been produced, specifically addressing the interactions with plants, and with a focus on the city of Gothenburg. Systematic observations have shown that the PCI extends over a distance of up to 1.5 km, increasing in magnitude and extent with park size (Lindqvist 1992; Upmanis et al. 1998). While for smaller parks (< 0.2 km^2) temperature gradients below 2 °C were reported (Upmanis et al. 1998; Jansson et al. 2007; Konarska et al. 2015), for

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larger parks stronger temperature differences ranging from 4 °C (Eliasson 1996) to 6 °C (Lindqvist 1992; Upmanis et al. 1998) were observed – which are of the same order of magnitude as the city's UHI itself (Eliasson 1996). Other observations have shown that faster night-cooling rates occur in green areas than in built-up ones (Upmanis et al. 1998; Holmer et al. 2007), and park breezes have been detected at distances of up to 250 m from the park border (Eliasson and Upmanis 2000) – though of weak intensity (< 0.5 m s^{-1}).

Since even defoliated trees present relatively low transmissivity of direct solar radiation (40 to 52% according to Konarska et al. 2014), climate sensitive planning in high latitude cities should account for undesired shadowing in winter as well as desired shading in summer. Therefore outdoor urban spaces characterized by a variety of shadow and ventilation patterns are recommended, together with a multi-layer planning of vegetation (Lindberg et al. 2014). In a recent literature review by Andersson-Sköld et al. (2015), the highest-ranked measures for reducing outdoor heat stress were 1) to increase the fraction of parks and urban forests, and 2) to increase the fraction of street trees and locate them in sun exposed locations prone to heating.

2.5 Conclusions

In summary, the cultivation of green elements in a city can be extensively used to mitigate the effects of the UHI and enhance people's thermal comfort. Of all green features, urban trees seem to be the most effective in this respect. Moreover, as discussed in the following chapters, they have the additional benefit of simultaneously contributing to a variety of ecological functions in any given setting. From the information available so far, the following conclusions may be drawn for the use of vegetation to mitigate thermal stress within the urban environment:

- Increasing the spatial extent of urban green spaces, and especially of 'urban forestation' projects, can significantly moderate the intensity of the UHI in cities.
- Across countries and climatic regions in Europe, the PCI effect is found to be substantial – with its magnitude ultimately depending on the size of the park, the type of vegetation employed, the particular tree species and coverage, as well as the season and weather conditions.
- A combination of small green spaces in a densely distributed network covering many streets and squares, in combination with larger green areas in parks and gardens, is probably the most effective approach to lowering the UHI intensity.
- To lower the temperature and reduce pedestrian thermal stress in street canyons, a combination of green measures including vegetated terrain, green walls and especially street trees, is most effective.
- Large trees providing deep shade contribute strongly to thermal comfort at pedestrian level.

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- And finally: in order to benefit optimally from urban greening, the local availability of water should be taken into account by employing strategies that maximize the cooling "efficiency" of the city's green infrastructure.

References

Andersson-Sköld Y, Thorsson S, Rayner D et al (2015) An integrated method for assessing climate-related risks and adaptation alternatives in urban areas. Clim Risk Manage 7:31–50

Andrade H, Vieira R (2007) A climatic study of an urban green space: the Gulbenkian Park in Lisbon (Portugal). Finisterra – Rev Port Geogr XLII(84):27–46

Arnfield JA (2003) Two decades of urban climate research: a review of turbulence, exchanges of energy and water, and the urban heat island. Int J Climatol 23:1–26

ASHRAE Standard 55 (2004) Thermal environmental conditions for human occupancy. American Society of Heating, Refrigerating and Air-Conditioning Engineers (ANSI/ASHRAE) Standard, Atlanta

Balling RC, Brazel SW (1987) Time and space characteristics of the Phoenix urban heat island. J Ariz-Nev Acad Sci 21:75–81

Bowler DE, Buyung-Ali L, Knight TM et al (2010) Urban greening to cool towns and cities: a systematic review of the empirical evidence. Landsc Urban Plan 97(3):147–155. doi:10.1016/j.landurbplan.2010.05.006

Brown RD, Vanos J, Kenny N et al (2015) Designing urban parks that ameliorate the effects of climate change. Landsc Urban Plan 138:118–131. doi:10.1016/j.landurbplan.2015.02.006

Burkart K, Meier F, Schneider A et al. (2015) Modification of heat-related mortality in an elderly urban population by vegetation (urban green) and proximity to water (urban blue): evidence from Lisbon, Portugal. Environ Health Perspect Nov 13. doi:10.1289/ehp.1409529

Chow WTL, Roth M (2006) Temporal dynamics of the urban heat island of Singapore. Int J Climatol 26:2243–2260

Daanen HAM, Simons M, Janssen SA (2010) De invloed van hitte op de gezondheid, toegespitst op de stad Rotterdam. TNO Defensie, Soesterberg

EEA (2012) Urban adaptation to climate change in Europe: challenges and opportunities for cities together with supportive national and European policies. European Environment Agency (EEA). Copenhagen, Denmark. 143 pp

Eliasson I (1996) Urban nocturnal temperatures, street geometry and land use. Atmos Environ 30:379–392

Eliasson I, Upmanis H (2000) Nocturnal airfow from urban parks-implications for city ventilation. Theor Appl Climatol 66:95–107

Epstein Y, Moran DS (2006) Thermal comfort and the heat stress indices. Ind Health 44(3):388–398

Gill SE, Handley JF, Ennos AR et al (2007) Adapting cities for climate change: the role of the green infrastructure. Built Environ 33(1):115–133

Grimmond S (2007) Urbanization and global environmental change: local effects of urban warming. The Geogr J 173(1):83–88

Grimmond CSB, Oke TR, Cleugh HA (1993) The role of 'rural' in comparisons of observed suburban–rural flux differences. Exchange processes at the land surface for a range of space and time scales. Int Assoc Hydrol Sci Pub 212:165–174

Gromke C, Blocken B, Janssen W et al (2015) CFD analysis of transpirational cooling by vegetation: case study for specific meteorological conditions during a heat wave in Arnhem, Netherlands. Build Environ 83:11–26

Heusinkveld BG, Steeneveld GJ, van Hove LWA et al (2014) Spatial variability of the Rotterdam urban heat island as influenced by urban land use. J Geophys Res D Atmospheres 119(2):677–692

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Holmer B, Thorsson S, Eliasson I (2007) Cooling rates, sky view factors and the development of intra-urban air temperature differences. Geogr Ann 89A:237–248

Höppe P (1999) The physiological equivalent temperature – a universal index for the biometeorological assessment of the thermal environment. Int J Biometeor 43(2):71–75

IPCC (2013) Summary for policymakers. In: Stocker TF, Qin D, Plattner GK et al (eds) Climate change 2013: the physical science basis. Contribution of working group I to the fifth assessment report of the intergovernmental panel on climate change. Cambridge University Press, Cambridge/New York

Jansson C, Jansson PE, Gustafsson D (2007) Near surface climate in an urban vegetated park and its surroundings. Theor Appl Climatol 89(3):185–193

Klemm W, Heusinkveld BG, Lenzholzer S et al (2015) Psychological and physical impact of urban green spaces on outdoor thermal comfort during summertime in The Netherlands. Build Environ 83:120–128

Konarska J, Lindberg F, Larsson A et al (2014) Transmissivity of solar radiation through crowns of single urban trees – application for outdoor thermal climate modelling. Theor Appl Climatol 117:363–376

Konarska J, Holmer B, Lindberg F et al (2015) Influence of vegetation and building geometry on the spatial variations of air temperature and cooling rates in a high-latitude city. Int J Climatol 36:2379–2395

Li D, Bou-Zeid E (2013) Synergistic interactions between urban heat islands and heat waves: the impact in cities is larger than the sum of its parts. J Appl Meteor Climatol 52:2051–2064

Lindberg F, Holmer B, Thorsson S et al (2014) Characteristics of the mean radiant temperature in high latitude cities—implications for sensitive climate planning applications. Int J Biometeorol 58:613–627

Lindqvist S (1992) Local climatological modelling for road stretches and urban areas. Geografiska Annaler 74A(273) (in Swedish):265

Lopes A, Alves E, Alcoforado MJ et al (2013) Lisbon urban heat island updated: new highlights about the relationships between thermal patterns and wind regimes. Adv Meteor Article ID 487695

Matzarakis A, De Rocco M, Najjar G (2009) Thermal bioclimate in Strasbourg – the 2003 heat wave. Theor Appl Climatol 98(3–4):209–220. doi:10.1007/s00704-009-0102-4

Mayer H, Höppe PR (1987) Thermal comfort of man in different urban environments. Theor Appl Climatol 38:43–49

Norton BA, Coutts AM, Livesley SJ et al (2015) Planning for cooler cities: a framework to prioritise green infrastructure to mitigate high temperatures in urban landscapes. Landsc Urban Plan 134:127–138. doi:10.1016/j.landurbplan.2014.10.018

Oke TR (1982) The energetic basis of the urban heat island. Q J Roy Meteor Soc 108(455):1–24

Oke TR (1987) Boundary layer climates. Routledge, New York

Oliveira S, Andrade H, Vaz T (2011) The cooling effect of green spaces as a contribution to the mitigation of urban heat: a case study in Lisbon. Build Environ 46:2186–2194

Oliveira S, Vaz T, Andrade H (2014) Perception of thermal comfort by users of urban green areas in Lisbon. Finisterra – Rev Port Geogr XLIX 98:113–131

Parlow E, Vogt R, Feigenwinter C (2014) The urban heat island of Basel – seen from different perspectives. DIE ERDE J Geograp Soc Berlin 145(1–2):96–110

Potchter O, Ben-Shalom H (2013) Urban warming and global warming: combined effect on thermal discomfort in the desert city of Beer Sheva, Israel. J Arid Environ 98:113–122

Potchter O, Cohen P, Bitan A (2006) Climatic behavior of various urban parks during hot and humid summer in the Mediterranean city of Tel Aviv, Israel. Int J Climatol 26:1695–1711

Saaroni H, Ziv B (2010) Isolating the urban heat island contribution in a complex terrain and its application for an arid city. J Appl Meteor Climatol 49:2159–2166. doi:10.1175/2010JAMC2473.1

Saaroni H, Pearlmutter D, Hatuka T (2015) Human-biometeorological conditions and thermal perception in a Mediterranean coastal park. Int J Biometeor 59(10):1347–1362. doi:10.1007/s00484-014-0944-z

liz.obrien@forestry.gsi.gov.uk

Schiller G (2001) Biometeorology and recreation in east. Mediterranean For Landsc Urban Plan 57(1):1–12

Shashua-Bar L, Hoffman ME (2002) The green CTTC model for predicting the air temperature in small urban wooded sites. Build Environ 37(12):1279–1288

Shashua-Bar L, Hoffman ME (2003) Geometry and orientation aspects in passive cooling of canyon streets with trees. Energy Build 35(1):61–68

Shashua-Bar L, Hoffman ME (2004) Quantitative evaluation of passive cooling of the UCL microclimate in hot regions in summer, case study: urban streets and courtyards with trees. Build Environ 39(9):1087–1099

Shashua-Bar L, Hoffman ME, Tzamir Y (2006) Integrated thermal effects of generic built forms and vegetation on the UCL microclimate. Build Environ 41:343–354

Shashua Bar L, Erell E, Pearlmutter D (2009) The cooling efficiency of urban landscape strategies in a hot dry climate. Landsc Urban Plan 92(3–4):179–186

Shashua-Bar L, Potchter O, Bitan A et al (2010a) Microclimate modelling of street tree species effects within the varied urban morphology in the Mediterranean city of Tel Aviv, Israel. Int J Climatol 30(1):44–57

Shashua-Bar L, Cohen S, Potchter O et al. (2010b) The use of street trees for heat stress mitigation in hot and arid regions. Case study: Beer Sheba, Israel. In: Proceedings of the 7th International Conference BIOMET 2010, Freiburg, Germany, 2010

Shashua-Bar L, Pearlmutter D, Erell E (2011) The influence of trees and grass on outdoor thermal comfort in a hot-arid environment. Int J Climatol 31:1498–1506

Sofer M, Potchter O (2006) The urban heat island of a city in an arid zone: the case of Eilat, Israel. Theor Appl Climatol 85:81–88

Steeneveld GJ, Koopmans S, Heusinkveld BG et al (2011) Quantifying urban heat island effects and human comfort for cities of variable size and urban morphology in the Netherlands. J Geophys Res D, Atmospheres 116(D20129)

Upmanis H, Eliasson I, Lindqvist S (1998) The influence of green areas on nocturnal temperatures in a high latitude city (Göteborg, Sweden). Int J Climatol 18:681–700

Voogt JA (2004) Urban Heat Islands: Hotter Cities. http://www.actionbioscience.org/environment/voogt.html. Accessed 6 July 2015

Velazquez-Lozada A, Gonzalez JE et al (2006) Urban heat island effect analysis for San Juan, Puerto Rico. Atmos Environ 40(9):1731–1741

Wienert U, Kuttler W (2005) The dependence of the urban heat island intensity on latitude – a statistical approach. Meteor Zeitschrift 14(5):677–686

Yoshida A, Hisabayashi T, Kashihara K et al (2015) Evaluation of effect of tree canopy on thermal environment, thermal sensation, and mental state. Urban Clim 14(2):240–250. doi:10.1016/j.uclim.2015.09.004

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Chapter 3
Urban Trees and Their Relation to Air Pollution

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3.1 Introduction

One of the most studied services of urban forests and trees is their positive effect on air quality, which is expected to improve human health by removing gaseous air pollutants and particulate matter (PM) (Weber 2013). A prominent measure in urban development plans that is meant to achieve this goal is to increase the number of trees. But trees can be found in various forms and shapes, both at canopy and leaf level. Moreover, their uptake activity differs widely and depends on species-specific

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characteristics as well as their susceptibility to environmental stresses. How does the overall impact of trees on local air quality depend on species' specific traits, and what potential tradeoffs connected to these traits might decrease other environmental services, like carbon uptake (see Chap. 4)?

When air pollutants are emitted, they are transported within the atmosphere and then 'return to earth' primarily by two processes: wet and dry deposition. In the case of wet deposition, pollutants are washed out from the atmosphere with precipitation, and the dissolved material is evenly spread over a variety of surfaces. If the deposition is dry then pollutants simply settle on surfaces, and in both cases deposition tends to be highest on 'rough' surfaces such as the bark, branches, stems and leaves of trees. Normally the leaf area of a tree is much higher than its stem and branch area, though the latter remain throughout the whole year while for many deciduous and some coniferous species leaves are lost during winter.

In addition to the deposition of particles, air pollutants which are in the form of gases are taken up by plant stomata – small openings (about 10 μm) in active tree organs (mainly leaves) which can be opened or closed and which constitute the main interface between the atmosphere and the plants' interior. Through the stomata, CO_2 is taken up for photosynthesis (see Chap. 4) and water is transpired (see Chap. 5). Gaseous pollutants can enter these openings and even damage the plant if concentrations are high or pollution lasts long. In order to maximize photosynthesis, minimize transpiration and minimize damage, plants are able to adapt their stomatal apparatus according to the environmental conditions they experience. As a response to pollution, plants will close their stomata, thus increasing their resistance to pollution uptake. Apart from air pollution concentrations and meteorological conditions, stomatal uptake and plant deposition rates depend on three bulk processes: air movement in the crown space, transfer through the boundary layer adjacent to surfaces, and absorption based on the capacity of surfaces themselves including stomatal opening (Wesely and Hicks 2000). These processes are controlled by vegetation properties on different scales: community (from single trees to forests), canopy (i.e. crown size, shape and density) and leaf scale (e.g. shape, surface properties and physiology). This subchapter focuses on species-specific traits at the canopy and leaf scale.

It is important to mention that trees also affect air quality by their emission of pollen, which may act as allergens, and of BVOCs (biogenic volatile organic compounds) which take part in the formation of ozone, secondary organic aerosols and PM (Cariñanos et al. 2016; Fuentes et al. 2000). Pollen allergenicity and BVOC emission are likely to respond to future higher temperatures, pollutants and CO_2 concentrations. These traits have thus been suggested to play an increasingly important role for air quality in the future (Calfapietra et al. 2013; Grote et al. 2016).

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3.2 How Trees Are Doing the Good Deed

3.2.1 Air Flow Impact by Tree Crowns

The majority of studies on the impacts of urban tree crowns on air flow have been conducted for street environments (e.g. Amorim et al. 2013). Crown traits (i.e. crown geometry, foliage distribution, etc.) provoke deceleration or acceleration of wind and determine the residence time of air pollution close to the plant surface. In particular, trees with dense crowns are prominent obstacles to airflow in poorly ventilated streets (Pugh et al. 2012). A positive consequence is that the higher residence time due to low turbulence allows for more chemical reactions between reactive gaseous pollutants and emitted BVOCs, which favors the destruction (chemical deposition) of the highly reactive ozone molecule. As a negative consequence, reduced ventilation due to trees in streets may lead to a local increase in the concentration of pollutants (e.g. Amorim et al. 2013), though this depends very much on the local urban structure. Overall, coniferous trees tend to remove more pollution from the air because they feature a continuous canopy cover, a high Leaf Area Index (LAI), and relatively large deposition velocities (Tiwary et al. 2016). However the variability between plant species groups is large, as are the uncertainties in the different traits. Moreover, certain traits change during the season, such as LAI, leaf hairiness, stomatal conductance, or even over lifetime, e.g. tree architecture.

Ozone: Ozone is a secondary pollutant, photochemically formed in sunny and warm environments. Its formation is initiated by the oxidation of gaseous hydrocarbons and nitrogen oxides mostly emitted from combustion sources. Due to their high levels of ozone precursors, urban and periurban areas represent hot spots for ozone formation. Certain tree species (see Table 12.1) emit BVOC (Biogenic Volatile Organic Compounds) in the atmosphere, represented by thousands of volatile and highly reactive hydrocarbons. Isoprenoids are the most typical BVOC emitted by leaves. These hydrocarbons easily oxidize to form ozone, therefore high BVOC-emitting tree species contribute to the urban ozone concentrations.

3.2.2 Capturing and Holding Air Pollutants with Leaves and Needles

The majority of gaseous and particle deposition occurs at the leaf surface (Figs. 3.1, 3.2, and 3.3). However, for deciduous species during winter time, branches and stems are the only receptors. Particle deposition in urban woodlands has been extensively studied and there are many characteristics that influence this process (see e.g. a review by Janhäll 2015). For example, the occurrence of leaf hairs (Fig. 3.1) or the

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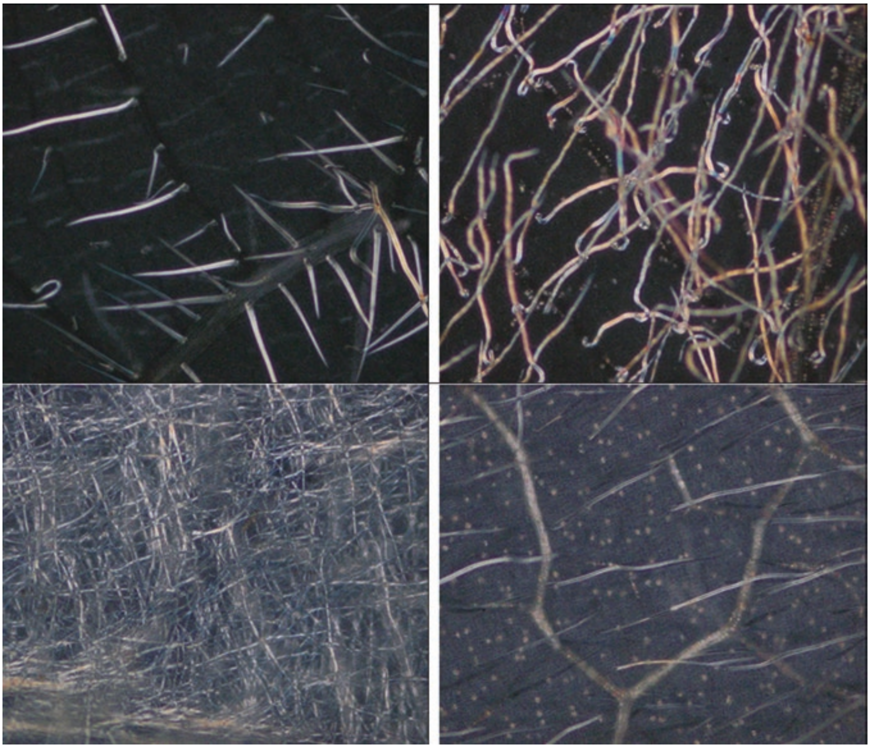

Fig. 3.1 Lower leaf surface with trichomes (hairs that enhance particle capture) and stomata of *Tilia platyphyllos* (*top left*), *Sorbus aucuparia* (*top right*), *Buddleja davidii* (*bottom left*) and *Salix alba* (*bottom right*), viewed with electron microscope ZEISS962 SEM (Photo: Muhammad Samira)

availability of waxes, salts and ions on the leaf surface can increase the rate of deposition (Altimir et al. 2006). Wax characteristics have been found to almost double PM deposition in *Tilia* and *Acer*, both hydrophilic species, compared to *Platanus* (Dzierzanowski et al. 2011). As water droplets on hydrophilic leaves spread out (Fig. 3.2), PM is easily deposited on these wet surfaces. If the pollutant is water soluble, e.g. NO_2 or SO_2, direct dissolution on wet plant surfaces is also possible. Measurements suggest encapsulation of particulates in the wax layer during the growing season, thereby immobilizing particles (Hofman et al. 2014) and increasing the leaves' efficiency for PM removal (Fig. 3.3). Also, the complexity of the leaf structure is positively correlated with potential deposition. Genera with complex leaves, such as *Pseudotsuga* (evergreen) or *Fraxinus* (deciduous), are able to take up significantly higher PM quantities than genera with simple leaves (Beckett et al. 2000; Freer-Smith et al. 2005).

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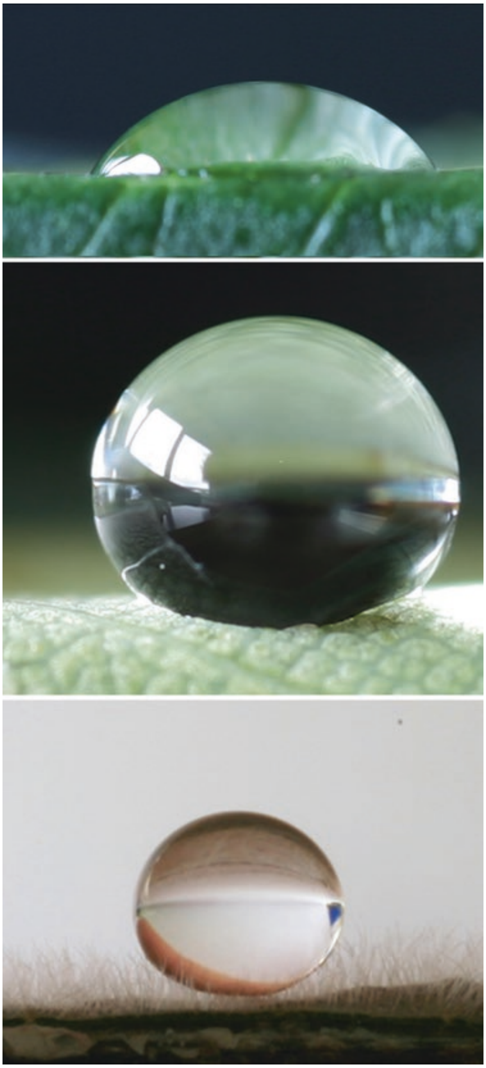

Fig. 3.2 Droplets on a leaf's surface illustrate how the interaction of leaves with their environment partly depends on leaf surface characteristics: (*top*) the hydrophilic character of *Sambucus nigra* leaves, (*middle*) the hydrophobic character of *Quercus robur*, and (*bottom*) leaf hairs (trichomes) preventing droplets from making contact with the leaf surface of *Alchemilla mollis* (Photos: Fatemeh Kardel, top and middle; Lies Snauwaert, bottom)

3.2.3 Stomatal Uptake Is Driven by Physiological Properties

Stomatal uptake is particularly important for gaseous pollution. Stomatal opening, and in turn the ease by which atmospheric pollutants can penetrate the plant, are dependent on soil water availability and atmospheric humidity. For example, stomatal uptake in a Mediterranean evergreen forest was considerably higher in spring when the soil water supply was more favorable than in the dry and warm summer period (Fares et al. 2014). In addition, different water use strategies of trees determine the timing, degree and duration of stomatal opening: anisohydric tree species

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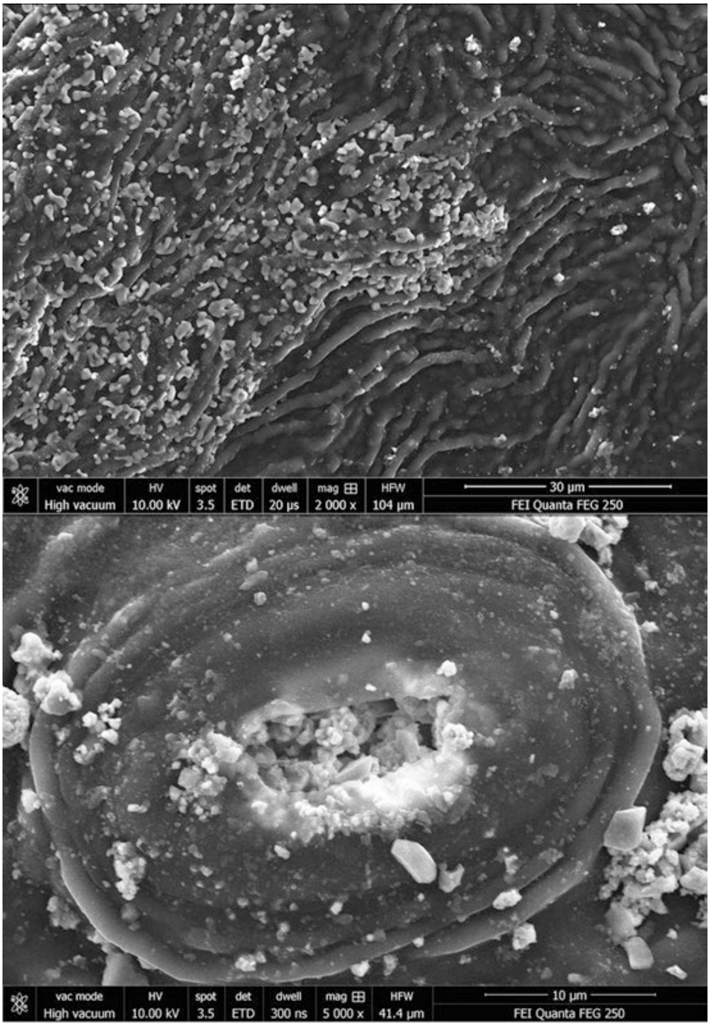

Fig. 3.3 Electron microscopic image of particles deposited on the upper leaf layer and trapped between the wax ridges (*top*) and in a stomata at the lower leaf surface (*bottom*) of the climber species *Hedera helix* (Photos: Ana Castanheiro)

(e.g. poplars and deciduous oaks) keep their stomata open as long as possible and are thus more efficient in pollution uptake than "water saving" isohydric species (e.g. *Pinus* or *Platanus*), which tend to close their stomata early in response to decreasing soil water availability. Pollutant uptake through stomata is high as long as the respective compounds are quickly metabolized, as is the case for ozone and NO_2 – which means that the uptake increases with atmospheric concentrations, as long as the plants are not seriously damaged.

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3.3 The Darker Side of Tree-Atmosphere Interactions

3.3.1 Pollen and Other Biological Particles

There is PM of biological origin (BPM) that is mainly emitted by fungi (spores) and plants during flowering (pollen). Although pollen can be as large as 90 µm, part of the BPM also appear in lower sized fragments due to the rupture of pollen grains while their allergenic activities remain intact (Cariñanos et al. 2001). Therefore, pollen emissions are considered as one of the key ecosystem-disservices of urban vegetation (Cariñanos et al. 2016) (see Chap. 9). Allergenicity of pollen, despite being species-specific, is modified by atmospheric pollutants, due to larger amounts of allergenic proteins or changes in lipid composition (Beck et al. 2013). For city-planners this might represent a dilemma, as placing trees close to the pollutant source in order to increase pollutant removal may at the same time increase the allergenicity of pollen grains. Potential allergenic impacts should thus be considered when selecting trees (see also Chap. 9).

3.3.2 Emissions of Volatile Organic Compounds

BVOC emissions are generally expressed as a function of environmental conditions, while BVOC deposition through stomatal uptake and surface degradation is considered negligible (Nguyen et al. 2015). Plant species strongly differ in their capacity to release BVOCs. For example, *Populus* and *Quercus* are intensely emitting isoprene (Churkina et al. 2015), and can therefore significantly contribute to the formation of atmospheric ozone, provided a sufficiently high NO_x level. This effect is able to over-compensate for their capacity to sequester ozone. Secondary PM formation is closely related to the presence of monoterpenes and sesquiterpenes, which are emitted by species such as *Pinus, Betula* and *Aesculus* (Derwent et al. 1996). Furthermore, flowering and plant stress induces the emission of oxygenated compounds and terpenoids (Xu et al. 2012), which take part in photochemical reactions. Therefore, flowering plants may not always be the preferable choice for parks and gardens (Niinemets and Peñuelas 2008).

3.4 The Spatial and Temporal Plasticity of Traits

Leaf structural and physiological traits also vary within canopies, reflecting their acclimation to light gradients (Niinemets 2015; Van Wittenberghe et al. 2014) – but the degree of acclimation varies significantly among species and plant functional types (Niinemets 2015). Moreover, leaf particle deposition might create a shadow layer on the leaf, and reduce the light available for photosynthesis in highly polluted

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environments (Delegido et al. 2014). Concentrations of (traffic derived) PM decreases with height (Hofman et al. 2013), which might in addition influence the vertical gradient of traits.

Traits vary over the course of seasons, as new foliage develops, matures and ages, in particular in deciduous species. This is obvious for pollen emissions which usually take place during a couple of weeks, but is also true for specific leaf area, leaf nitrogen content, photosynthesis activity and BVOC emission capacity, which increase in developing foliage, remain stable in mature leaves and rapidly decline in senescing leaves (Wilson et al. 2000). During these stages, the composition of emission compounds is also changing.

Climate scenarios suggest increasing atmospheric CO_2 concentrations (a doubling by the end of this century) and air temperatures (by 1.7 °C to 4 °C), coming on top of the already elevated concentrations and temperatures experienced by urban trees compared to those growing in more rural environments (see Chap. 2). Additionally, the frequency and severity of drought stress and heat waves are expected to increase. A known effect of higher temperatures is an extension of the growing season, accelerating bud burst, flowering, and stem elongation in spring; while in autumn, they may postpone litter fall (Cleland et al. 2007). Seasonality is thus different inside and outside urban areas (Jochner and Menzel 2015). BVOC emissions are expected to rise with higher temperatures, and decrease with elevated CO_2 (Possell and Hewitt 2011). However, good nutrient availability – as is common in gardens and urban green spaces – is expected to enhance emissions in response to elevated CO_2 (Sun et al. 2013). Plants respond to drought by adjusting their stomatal opening. Intensive drought is furthermore inducing leaf shedding, decreasing leaf growth, size and branching, and increasing wax abundance. Temperature and CO_2 also increases the amount and size of produced pollen (Bartra et al. 2007; Hamaoui-Laguel et al. 2015) as well as their allergenicity (Ahlholm et al. 1998).

Although the viability of pollen decreases with increasing air pollution, ozone has been found to increase the allergenicity of pollen (Bartra et al. 2007; Beck et al. 2013). High ozone (O_3) also decreases photosynthesis and thus stomatal opening, and chronic O_3 exposure impairs the ability of stomata to close rapidly in response to drought (Hoshika et al. 2014). In contrast, BVOC emissions are initially enhanced under ozone exposure but chronic exposure leads to decreased emissions (Calfapietra et al. 2013). Other air pollution impacts are similarly complex although generally less intense.

3.5 Air Pollution in Relation to Other Ecosystem Services

Some of the traits that are beneficial for air pollution mitigation may act in opposite directions for specific services: for instance, uptake capacity increases air quality but decreases plant health, while other traits such as a large leaf area help cool the environment and at the same time reduce air pollutants. It should also be mentioned that ecosystem services are sometimes indirectly related, for example by modifying

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the microclimate and thus energy consumption, which then reduces anthropogenic emissions. The complexity of the matter has prevented holistic investigations for specific cities or regions, although model approaches that integrate at least some aspects are already available (Nowak et al. 2008).

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References

Ahlholm JU, Helander ML, Savolainen J (1998) Genetic and environmental factors affecting the allergenicity of birch (*Betula pubescens ssp. czerepavonii* [Orl.] Hämet-Ahti) pollen. Clin Exp Allergy 28:1384–1388

Altimir N, Kolari P, Tuovinen JP et al (2006) Foliage surface ozone deposition: a role for surface moisture? Biogeosciences 3:209–228

Amorim JH, Rodrigues V, Tavares R et al (2013) CFD modelling of the aerodynamic effect of trees on urban air pollution dispersion. Sci Total Environ 461-462:541–551

Bartra J, Mullol J, del Cuvillo A et al (2007) Air pollution and allergens. J Invest Allerg Clin 17:3–8

Beck I, Jochner S, Gilles S et al (2013) High environmental ozone levels lead to enhanced allergenicity of birch pollen. PLoS One 8(11):e80147

Beckett KP, Freer-Smith PH, Taylor G (2000) Particulate pollution capture by urban trees: effect of species and windspeed. Glob Chang Biol 6(8):995–1003

Calfapietra C, Pallozzi E, Lusini I et al (2013) Modification of BVOC emissions by changes in atmospheric [CO_2] and air pollution. In: Niinemets Ü, Monson RK (eds) Biology controls and models of tree volatile organic compound emissions. Tree physiology. Springer, Berlin, pp 253–284

Cariñanos P, Prieto JC, Galán C et al (2001) Solid suspended particles affecting the quality of air in urban environments. B Environ Contam Tox 67(3):0385–0391

Cariñanos P, Adinolfi C, Díaz de la Guardia C et al (2016) Characterization of allergen-emission sources in urban areas. J Environ Qual 45:244–252

Churkina G, Grote R, Butler TM et al (2015) Natural selection? Picking the right trees for urban greening. Environ Sci Pol 47:12–17

Cleland EE, Chuine I, Menzel A et al (2007) Shifting plant phenology in response to global change. Trends Ecol Evol 22(7):357–365

Delegido J, Van Wittenberghe S, Verrelst J et al (2014) Chlorophyll content mapping of urban vegetation in the city of Valencia based on the hyperspectral NAOC index. Ecol Indic 40:34–42

Derwent RG, Jenkin ME, Saunders SM (1996) Photochemical ozone creation potentials for a large number of reactive hydrocarbons under European conditions. Atmos Environ 30(2):181–199

Dzierzanowski K, Popek R, Gawronska H et al (2011) Deposition of particulate matter of different size fractions on leaf surfaces and in waxes of urban forest species. Int J Theor Phys 13(10):1037–1046

Fares S, Savi F, Muller J et al (2014) Simultaneous measurements of above and below canopy ozone fluxes help partitioning ozone deposition between its various sinks in a Mediterranean Oak Forest. Agric For Meteorol 198–199:181–191

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Freer-Smith PH, Beckett KP, Taylor G (2005) Deposition velocities to *Sorbus aria, Acer campestre, Populus deltoides* × *trichocarpa* 'Beaupré', *Pinus nigra* and *Cupressocyparis leylandii* for coarse, fine and ultra-fine particles in the urban environment. Environ Pollut 133(1):157–167

Fuentes JD, Lerdau M, Atkinson R et al (2000) Biogenic hydrocarbons in the atmosphere boundary layer: a review. B Am Meteorol Soc 81:1537–1575

Grote R, Samson R, Alonso R et al. 2016. Functional traits of urban trees in relation to their air pollution mitigation potential: a holistic discussion. Fron Ecol Environ doi:10.1002/fee.1426

Hamaoui-Laguel L, Vautard R, Liu L et al (2015) Effects of climate change and seed dispersal on airborne ragweed pollen loads in Europe. Nat Clim Chang 5(8):766–771

Hofman J, Stokkaer I, Snauwaert L et al (2013) Spatial distribution assessment of particulate matter in an urban street canyon using biomagnetic leaf monitoring of tree crown deposited particles. Environ Pollut 183:123–132

Hofman J, Wuyts K, Van Wittenberghe S et al (2014) On the temporal variation of leaf magnetic parameters: seasonal accumulation of leaf-deposited and leaf-encapsulated particles of a roadside tree crown. Sci Total Environ 493:766–772

Hoshika Y, Carriero G, Feng Z et al (2014) Determinants of stomatal sluggishness in ozone-exposed deciduous tree species. Sci Total Environ 481:453–458

Janhäll S (2015) Review on urban vegetation and particle air pollution – deposition and dispersion. Atmos Environ 105:130–137

Jochner S, Menzel A (2015) Urban phenological studies – past, present, future. Environ Pollut 203:250–261

Nguyen TB, Crounse JD, Teng AP et al (2015) Rapid deposition of oxidized biogenic compounds to a temperate forest. P Natl Acad of Sci USA 112(5):E392–E401

Niinemets Ü (2015) Is there a species spectrum within the world-wide leaf economics spectrum? Major variations in leaf functional traits in the Mediterranean sclerophyll *Quercus ilex*. New Phytol 205(1):79–96

Niinemets Ü, Peñuelas J (2008) Gardening and urban landscaping: significant players in global change. Trends Plant Sci 13(2):60–65

Nowak DJ, Crane DE, Stevens JC et al (2008) A ground-based method of assessing urban forest structure and ecosystem services. Arboric Urban For 34(6):347–358

Possell M, Hewitt CN (2011) Isoprene emissions from plants are mediated by atmospheric CO_2 concentrations. Glob Chang Biol 17(4):1595–1610

Pugh TAM, Mackenzie R, Whyatt JD et al (2012) Effectiveness of green infrastructure for improvement of air quality in urban street canyons. Environ Sci Technol 46(14):7692–7699

Sun Z, Niinemets Ü, Hüve K et al (2013) Elevated atmospheric CO_2 concentration leads to increased whole-plant isoprene emission in hybrid aspen (*Populus tremula x Populus-tremuloides*). New Phytol 198(3):788–800

Tiwary A, Williams ID, Heidrich O et al (2016) Development of multi-functional streetscape green infrastructure using a performance index approach. Environ Pollut 208A:209–220

Van Wittenberghe S, Alonso L, Verrelst J et al (2014) A field study on solar-induced chlorophyll fluorescence and pigment parameters along a vertical canopy gradient of four tree species in an urban environment. Sci Total Environ 466–467:185–194

Weber C (2013) Ecosystem services provided by urban vegetation: a literature review. In: Rauch S, Morrison G, Norra S et al (eds) Urban Environment. Springer, Dordrecht, pp 119–131

Wesely ML, Hicks BB (2000) A review of the current status of knowledge on dry deposition. Atmos Environ 34(12–14):2261–2282

Wilson KB, Baldocchi DD, Hanson PJ (2000) Spatial and seasonal variability of photosynthetic parameters and their relationship to leaf nitrogen in a deciduous forest. Tree Physiol 20:565–578

Xu S, Chen W, Huang Y et al (2012) Responses of growth, photosynthesis and VOC emissions of *Pinus tabulaeformis* Carr. exposure to elevated CO_2 and/or elevated O_3 in an urban area. B Environ Contam Tox 88(3):443–448

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Chapter 4
Carbon Sequestration by Urban Trees

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4.1 Introduction

Carbon dioxide (CO_2) is the most prominent component of anthropogenic greenhouse gas emissions, resulting mainly from fuel combustion in the built environment – for activities such as heating of buildings, urban mobility and cooking. The concentration of near-surface CO_2 in cities is affected by a range of factors, including traffic density and atmospheric stability. Plants have the capacity to sequester CO_2 through photosynthesis, and can therefore store carbon in plant biomass and in the soil. Green areas in the city may significantly affect local concentrations of atmospheric CO_2, as observed in urban-to-rural comparisons showing lower CO_2 concentration in the presence of vegetation. CO_2 sequestration over the 'urban

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forest' displays diurnal variation during the growing period, with uptake during daytime when plants are photosynthetically active, and nocturnal emissions in response to respiration. High atmospheric CO_2 concentrations represent a fertilizer for plants, promoting more efficient photosynthesis. However, urban plants often experience environmental stresses which compromise the photosynthetic apparatus, and in extreme cases may turn plants from carbon sinks into carbon sources. In this chapter, we review the most recent studies and highlight emerging research needs for a better understanding of present and future roles of urban trees in removing CO_2 from the atmosphere.

4.2 Increasing CO_2 Emissions

The atmospheric concentration of carbon dioxide has increased dramatically since the start of the industrial revolution. Close to 280 ppmv (parts per million by volume) in 1870, the average global concentration surpassed 400 ppmv for the first time in May 2013. The *rate of increase* in CO_2 concentration is also growing: from 0.7 ppmv per year recorded in the early 1960s, it rose to 2.0 ppmv per year between 2000 and 2010. This acceleration is similar to the rise in fossil CO_2 emissions, due notably to the use of fossil fuels (primarily coal, oil and gas).

Cities are responsible for more than 80% of global greenhouse gas emissions (Hoornweg et al. 2011). A study by Luck et al. (2001) showed that the 20 largest U.S. cities contribute more CO_2 each year to the global atmosphere than the total land area of the continental United States can absorb. This finding highlights the importance of urban areas for overall CO_2 emissions, and their impact on the global carbon cycle. In a study which involved the main cities of India (Ramachandra et al. 2015), the transportation sector was found to be the main source of CO_2 in the urban atmosphere, followed by the domestic and industrial sectors. In the city of Essen, Germany, more than 70% of the near-surface urban CO_2 was found to be affected by traffic density and atmospheric stability (Henninger 2008). Pataki et al. (2007) studied CO_2 concentrations at three locations along an urban-to-rural gradient in the Salt Lake Valley, Utah, and found daily averages exceeding 500 ppm at the city center and much lower concentrations in a non-urbanized, rural region of the valley. In Seoul, Park et al. (2013) described peak concentrations and emissions of CO_2 in the early morning and afternoon, in response to the large-scale use of liquefied natural gas for cooking and heating by residents surrounding the measurement site.

4.3 Urban Vegetation as a Carbon Stock

Beyond efforts to reduce the emission of CO_2 in cities, there is also the possibility of capturing carbon from the atmosphere and cumulatively storing it within different components of the urban environment (Fig. 4.1). This uptake of CO_2 is referred

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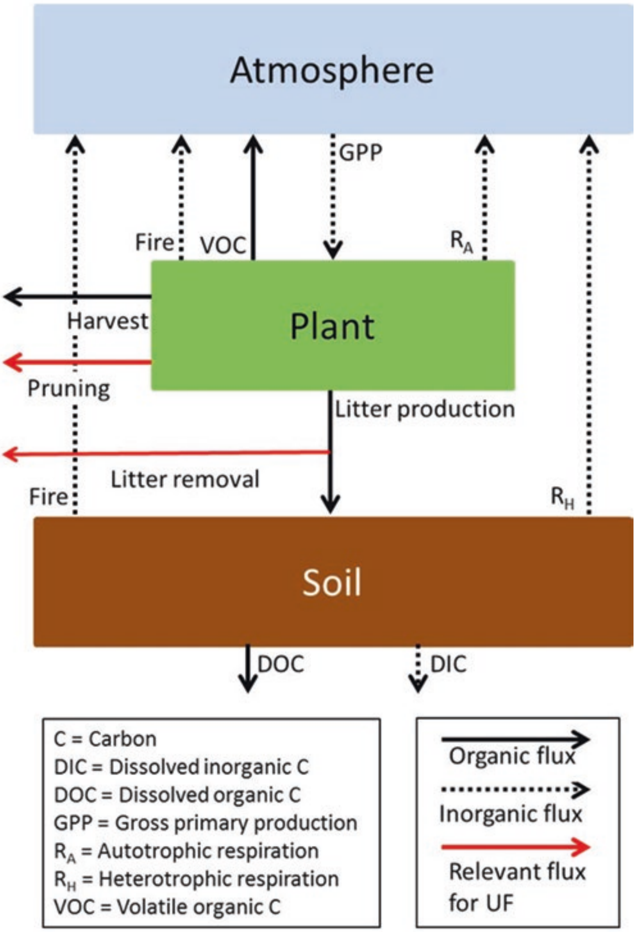

Fig. 4.1 Carbon flow in the soil-plant-atmosphere continuum. Carbon is exchanged in both organic and inorganic form. *Red arrows* show C fluxes of particular interest in urban forests where trees are managed more intensively with pruning and litter removal (The figure is based on Hyvönen et al. 2007)

to as carbon *sequestration*, and urban trees in parks and forested areas can in fact sequester and store large amounts of carbon in underground and above-ground woody biomass (Nowak and Crane 2002). When planted near buildings they can indirectly reduce carbon emissions as well, by moderating the amount of energy that is required for space cooling (Akbari and Konopacki 2005).

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Carbon sequestration: The absorption of atmospheric carbon dioxide by tree leaves is accomplished through *photosynthesis*, the primary biosynthetic pathway in which CO_2 and water (H_2O) are used to produce carbohydrates and return oxygen (O_2) to the atmosphere. Through the process of *respiration*, these carbohydrates are metabolized to provide the plant with the energy needed for its growth and functioning.

While trees and forests undoubtedly sequester CO_2 during their growth phases, deadwood that is in the process of decomposition also releases stored carbon. For trees, the composition of dry matter can be classified according to the distribution of biomass in different parts of the tree: approximately 20% of the biomass is in the crown, 60% is in stemwood, and 20% is in the root system. The volume of the tree is estimated by allometric equations from the DBH (Diameter at Breast Height), which corresponds to the diameter of the trunk at a height of about 1.3–1.4 m. For this calculation, a variety of quantitative relationships have been defined according to the particular tree species – but most of these relationships are established for forest trees and are not necessarily valid for trees growing in urban environments. The main additional factors influencing the total mass of sequestered carbon are: (1) the number of trees and their spatial coverage, (2) the age and health of these trees, (3) their rate of mortality, (4) their interaction with the soil and (5) the disposal and/or use of these trees (e.g. as lumber for building construction).

Compared to semi-natural ecosystems, vegetation in urban areas is often created artificially by the planting and subsequent management of different species. Often intensive, such management includes activities such as the removal of deadwood from the felling of individual trees, pruning, fertilization, irrigation and removal of dead leaves, which further leads to CO_2 emissions (Nowak and Crane 2002). A direct estimation of carbon sequestration by urban vegetation is difficult to perform due to the complex characteristics of the urban ecosystem and the high variability in tree distribution and species. Remote sensing, eddy covariance and coupled inventory-modelling are among the approaches which have been employed so far for this purpose.

Using high resolution aerial photographs, it has been estimated that tree-covered urban areas in Canada store approximately 34 million tons of carbon (tC) and annually sequester approximately 2.5 million tons of CO_2 (Pashera et al. 2014). By combining inventory data from ten cities with the UFORE model, urban forests in the USA were estimated to sequester 712 million tC, corresponding to a gross uptake of 22 million tC/year (Nowak and Crane 2002). The average US urban forest carbon storage density was 25.1 tC/ha, compared with 53.5 tC/ha for forest stands which are not intensively managed (Nowak and Crane 2002). In the only nation-wide comparison of land-based carbon sinks, Woodbury et al. (2007) reported that urban and suburban forests in the USA stock 16% of the carbon stored into natural forests. Outside North America, knowledge about urban forest carbon sequestration is spo-

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radic. Combining satellite images, field surveys and the UFORE model, Yang et al. (2005) found that the 2.4 million trees in the central part of Beijing, the capital of China, stored about 0.2 million tons of CO_2. Based on the growth rate of the main tree species, allometric biomass regression was used to calculate species-specific carbon sequestration in an African city, which was then extrapolated to determine the total carbon stock achievable by planting in the next 30 years, i.e. 54,630 tC sequestered (Stoffberg et al. 2010).

It can be concluded that cities with developed compact green vegetation (e.g. trees and grass with a high density of coverage, such as urban forest parks) have the potential to store more carbon than is possible in cases which have only sporadic single trees. Park zone management can increase carbon storage (Fig. 4.1), while additional input of organic substrates (e.g. green fertilization, cutting, composting) in park zones can further contribute to the increase of soil carbon stocks.

4.4 Urban Vegetation Affects CO_2 Concentrations in Cities

The variation in, and intensity of, CO_2 sources depend on the habits of citizens, local economies and local climates. Therefore, designing a clear seasonal dynamic of CO_2 is difficult and remains site-specific. A common condition for many urban areas is that a shallower boundary layer (i.e. the lower part of atmosphere in which gas exchanges take place) in colder seasons, due to a decrease of convective movement of the air, generally leads to a lower dilution of CO_2 emitted from anthropogenic and biogenic sources into the atmosphere leading to a direct increase in atmospheric CO_2 concentration (Fig. 4.2).

The presence of vegetation in urban areas can affect the concentration and fluxes of CO_2. In the city of Rome, Gratani and Varone (2005) showed an increase in mean annual CO_2 concentration from 1995 (367 ppm) to 2004 (477 ppm). The annual dynamics showed a peak in winter, which was highly correlated with traffic density and atmospheric stability. The authors found that during weekends, when traffic density was reduced by 72%, CO_2 concentrations were also lower. The daily trend in Rome's city center showed a peak in the early morning, corresponding with rush hour as well as the hours when the atmosphere was more stable.

Park et al. (2013) showed that CO_2 concentrations over two urban sites (one in a residential area and one inside an urban forest) followed a similar diurnal variation, with maximum values occurring during night and minimum values occurring during daytime. Also a similar seasonal variation was observed, with a maximum value during the non-growing season (early spring) and a minimum value during the growing season (summer). Interestingly, due to photosynthesis the rate of CO_2 sequestration over the urban forest was high during daytime in the growing period, while this was not observed in the residential site. In central London, Helfter et al. (2011) studied emission/sequestration of CO_2 with micrometeorological techniques and found that CO_2 exchange was mainly controlled by fossil fuel combustion (e.g. traffic, commercial and domestic heating). The authors also found that exchanges

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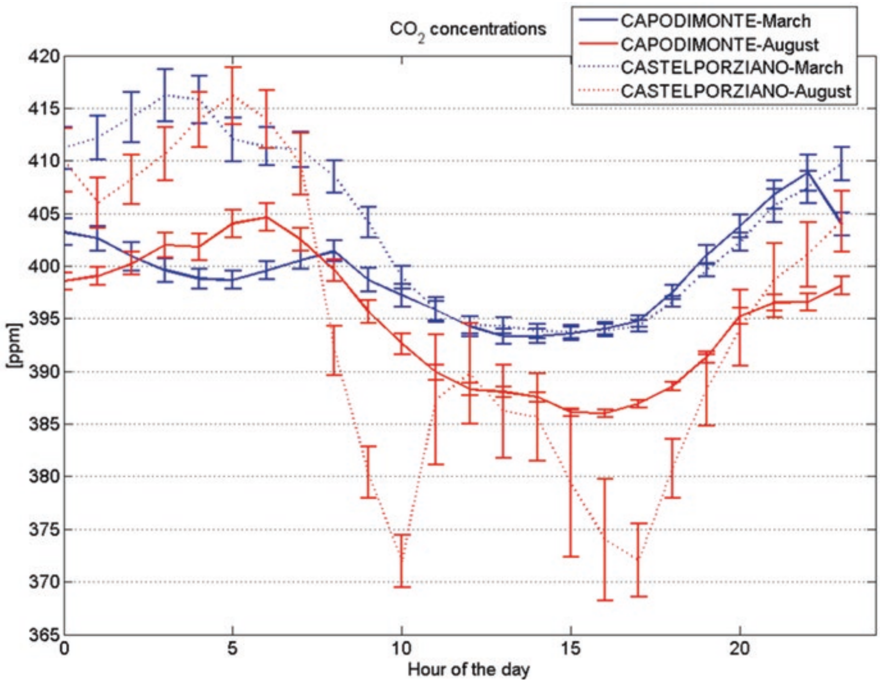

Fig. 4.2 Comparison of CO_2 concentrations in spring and summer in two urban forest sites in Italy: Castelporziano, a Mediterranean forest 25 km away from downtown Rome, and Capodimonte, an urban park inside Naples. The daily pattern shows a typical decrease in CO_2 concentrations due to an expansion of the atmospheric boundary layer and CO_2 dilution in the atmosphere, also favoured by the photosynthetic process active during the day. Lower summer CO_2 concentrations generally suggest that the boundary layer is expanded, the anthropogenic source is reduced, and the overall effects of vegetation in CO_2 sequestration are larger

were affected by changes in natural gas consumption for heating, but also that to a lesser extent, photosynthetic activity controlled the seasonal variability.

4.5 How Will Urban Plants Sequester CO_2 Under Future Climates?

Conditions recorded in urban areas today can be considered as an indicator of what the general environmental conditions could be in the next decades, assuming that the atmospheric concentration will continue to rise due to anthropogenic emissions. Therefore cities are places where the effect of future levels of CO_2 on plants can be studied (Calfapietra et al. 2015). The increased concentration of CO_2 has a fertilizing effect, stimulating photosynthesis and forest productivity and therefore rendering this “trap” more efficient. Will the terrestrial carbon sink continue to be as

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effective in the future? This is not certain. It could become increasingly less effective, or even stop working altogether due to two different mechanisms: the first is that forest biomass and soils in the terrestrial ecosystems could become saturated, which would reduce the capacity for carbon sequestration; the second is that future climate warming and a higher frequency of droughts could affect these ecosystems by turning CO_2 sinks into sources, as photosynthesis would be reduced and decomposition of soil organic matter would be stimulated. The reduction in productivity and carbon sequestration observed across Europe as a result of the drought and heat wave in 2003 may be considered as an example of what could happen (Rennenberg et al. 2006). Using urban areas as a proxy for climate change, an urban–rural gradient showed acclimatization to daily and seasonal extremes of temperature and CO_2 concentration that affect photosynthesis and isoprene emission (Lahr et al. 2015). Future stress conditions may trigger alternative biosynthetic pathways which may release carbon in the form of volatile organic compounds.

In urban areas, the effects of climate change are therefore exacerbated. CO_2 increases in cities are often associated with drought conditions, since plants experience 'urban heat island' effects (see Chap. 2) by which higher air temperatures accelerate water loss by evapotranspiration. Moreover, soil sealing often impedes water from reaching the root system. Plants have two main mechanisms to survive soil drought, including *avoidance* (the ability to avoid decreases in pre-dawn leaf water potential and relative water content during drought), and *tolerance* (the ability to maintain physiological and metabolic processes during decreasing pre-dawn water potential). Plants might adapt to soil drought through reduced water loss, by changing morpho-physiological and biochemical traits such as cuticle resistance and leaf coverage by trichomes, early stomatal closure, deeper rooting systems to harvest more water and osmotic adjustment (Bussotti et al. 2014). Moreover, urban plants grown under high CO_2 may respond to drought with biochemical responses via deactivation of Rubisco, the primary enzyme involved in the photosynthetic process (Flexas and Medrano 2002). Recently, Osone et al. (2014) found that during unusually hot and dry summers, street trees in Tokyo exhibited a substantially decreased photosynthetic rate and found that the most resistant species had a conservative water use strategy, characterised by a lower stomatal conductance and carbon gain during the favourable season, but higher leaf gas exchange and water-use efficiency during drought.

Pollution could represent a major threat to carbon sequestration: preliminary studies have shown that oxidant effects of pollutants such as ozone compromise carbon sequestration by forest trees (Fares et al. 2013). Finally, nitrogen deposition may improve carbon sequestration in urban forests (as reviewed in Bai et al. 2015), unless chronic nitrogen deposition results in an early nitrogen loss due to faster nitrogen saturation and soil acidification in urban forests compared to rural forests. Depending on their capacity to photosynthesize, urban and suburban vegetation will be able to partially offset some anthropogenic emissions, especially in suburban areas – as recently discussed by Ward et al. (2015). However, future policies of pollution and carbon emission control will be crucial in determining whether trees will be able to sequester significant amounts of CO_2 to improve air quality, or rather an excessive urban atmospheric pollution load will render the plants' contribution negligible.

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References

Akbari H, Konopacki S (2005) Calculating energy-saving potentials of heat-island reduction strategies. Energ Policy 33:721–756

Bai SH, Blumfield TJ, Reverchon F (2015) Human footprints in urban forests: implication of nitrogen deposition for nitrogen and carbon storage. J Soils Sediments 15:1927–1936

Bussotti F, Pollastrini M, Killi D et al (2014) Ecophysiology of urban trees in a perspective of climate change. Agrochimica 58:247–268

Calfapietra C, Peñuelas J, Niinemets Ü (2015) Urban plant physiology: adaptation-mitigation strategies under permanent stress. Trends Plant Sci 20:72–75

Fares S, Vargas R, Detto M et al (2013) Tropospheric ozone reduces carbon assimilation in trees: estimates from analysis of continuous flux measurements. Glob Chang Biol 19:2427–2443

Flexas J, Medrano H (2002) Drought-inhibition of photosynthesis in C_3 plants: stomatal and non-stomatal limitation revisited. Ann Bot 89:183–189

Gratani L, Varone L (2005) Daily and seasonal variation of CO_2 in the city of Rome in relationship with the traffic volume. Atmos Environ 39:2619–2624

Helfter C, Famulari D, Phillips GJ, Barlow JF, Wood CR, Grimmond CSB, Nemitz E (2011) Controls of carbon dioxide concentrations and fluxes above central London. Atmos Chem Phys 11:1913–1928

Henninger S (2008) Analysis of near surface CO_2 variability within the urban area of Essen, Germany. Meteorol Z 17:19–27

Hoornweg D, Sugar L, Trejos-Gomez CL (2011) Cities and greenhouse gas emissions: moving forward. Environ Urban 23:207–227

Hyvönen R, Agren GI, Linder S et al (2007) The likely impact of elevated [CO_2], nitrogen deposition, increased temperature and management on carbon sequestration in temperate and boreal forest ecosystems: a literature review. New Phytol 173:463–480

Lahr EC, Schade GW, Crossett CC et al (2015) Photosynthesis and isoprene emission from trees along an urban-rural gradient in Texas. Glob Chang Biol 21:4221–4236

Luck MA, Jenerette GD, Wu J et al (2001) The urban funnel model and the spatially heterogeneous ecological footprint. Ecosystems 4:782–796

Nowak DJ, Crane DE (2002) Carbon storage and sequestration by urban trees in the USA. Environ Pollut 116:381–389

Osone Y, Kawarasaki S, Ishida A et al (2014) Responses of gas-exchange rates and water relations to annual fluctuations of weather in three species of urban street trees. Tree Physiol 34:1056–1068

Park M, Joo SJ, Lee CS (2013) Effects of an urban park and residential area on the atmospheric CO_2 concentration and flux in Seoul, Korea. Adv Atmos Sci 30:503–514

Pashera J, Mc Govern M, Khoury M et al (2014) Assessing carbon storage and sequestration by Canada's urban-forests using high resolution earth observation data. Urban For Urban Gree 13:484–494

Pataki DE, Xu T, Luo YQ, Ehleringer JR (2007) Inferring biogenic and anthropogenic carbon dioxide sources across an urban to rural gradient. Oecologia 152:307–322

Ramachandra TV, Aithal BH, Sreejith K (2015) GHG footprint of major cities in India. Renew Sust Energ Rev 44:473–495

Rennenberg H, Loreto F, Polle A et al (2006) Physiological responses of forest trees to heat and drought. Plant Biol 8:556–571

Stoffberg GH, van Rooyen MW, van der Linde MJ et al (2010) Carbon sequestration estimates of indigenous street trees in the City of Tshwane, South Africa. Urban For Urban Gree 9:9–14

liz.obrien@forestry.gsi.gov.uk

Ward HC, Kotthaus S, Grimmond CSB et al (2015) Effects of urban density on carbon dioxide exchanges: observations of dense urban, suburban and woodland areas of southern England. Environ Pollut 198:186–200

Woodbury PB, Smith JE, Heath LS (2007) Carbon sequestration in the US forest sector from 1990 to 2010. Forest Ecol Manag 241:14–27

Yang J, McBride J, Zhou J et al (2005) The urban forest in Beijing and its role in air pollution reduction. Urban For Urban Gree 3:65–78

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Chapter 5
Water Regulation and Purification

Urša Vilhar

5.1 Introduction

As detailed in previous chapters, urban forests and trees are an integral part of a city's green infrastructure (Benedict and McMahon 2006; Sanesi et al. 2011) and provide an array of different ecosystem services (Bolund and Hunhammar 1999; Tyrväinen et al. 2005; Livesley et al. 2014). Among the most critical of these services, in many cases, is the contribution of urban forestation to water retention and flood regulation (Sanders 1986).

Overwhelming stormwater volumes in urban environments have become a worldwide environmental and financial concern. The potential causes for increased flooding in European cities include higher rainfall intensities, ongoing urbanization and surface sealing, aging urban infrastructure, and deficient infrastructure capacities – since the existing infrastructures were not designed for current rainfall intensities (Kirnbauer et al. 2013). As a result, the ability to mitigate stormwater runoff in many urbanized watersheds around Europe has been strained. Published research has provided clear evidence that stormwater runoff associated with impervious surface coverage in cities is responsible for poor water quality (Duda et al. 1982; Gallo et al. 2012), flooding (Armson et al. 2013), and deteriorating stream health (Walsh et al. 2005).

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5.2 How Do Urban Trees Affect the Water Cycle?

Urban forests and trees are part of the water cycle, as illustrated in Fig. 5.1. When it rains, most of the raindrops hit leaf or branch surfaces and remain in "temporary storage" in the urban forest's canopy before they either evaporate into the atmosphere (*canopy interception*), flow down the tree trunk to the base of the tree (*stemflow*), or fall to the ground (*throughfall*). Characteristics that may influence rainfall interception are extremely heterogeneous, and include tree species, tree size, canopy density and bark type (Livesley et al. 2014), planting density and canopy storage capacity (Armson et al. 2013), seasonal presence or absence of foliage (Crockford and Richardson 2000; Inkiläinen et al. 2013; Kermavnar 2015; Schooling and Carlyle-Moses 2015), rainfall spatial distribution and intensity (Šraj et al. 2008; Kermavnar 2015; Schooling and Carlyle-Moses 2015), and the hillslope position within a catchment (Siegert et al. 2016). The presence of foliage in the forest canopy during winter contributes to higher annual canopy interception (Siegert et al. 2016; Vilhar 2016). Trees also absorb water in the soil by root uptake, and *transpire* water (see Chap. 2) through tiny openings on the surface of their leaves known as *stomata*. However, in response to dry atmospheric or soil conditions, many urban tree species control transpiration by closing their stomata (Chen et al. 2012). Together, the roots and leaf litter *stabilize* the soil and reduce erosion (Seitz and Escobedo 2008).

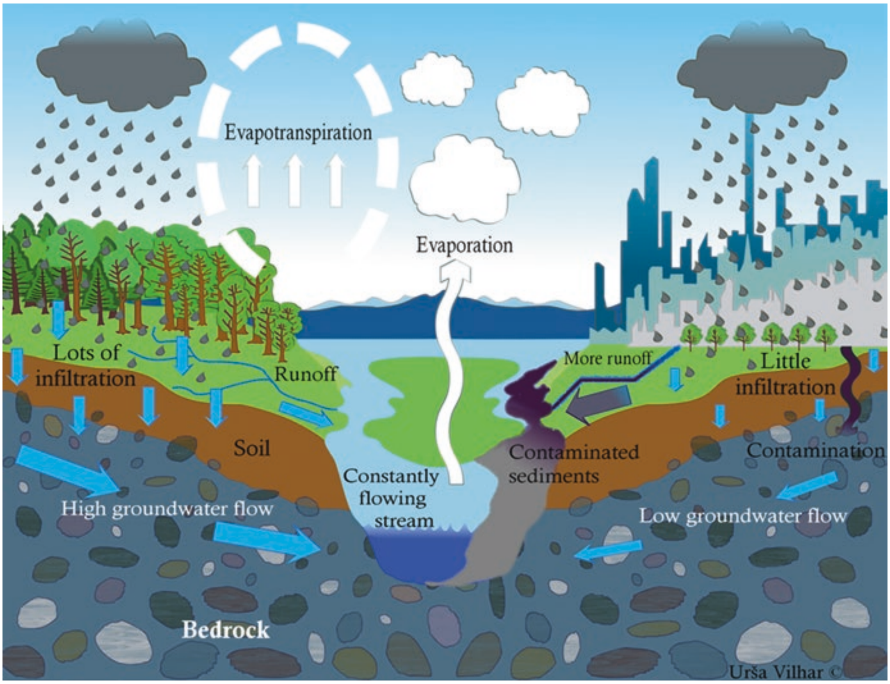

Fig. 5.1 Water cycle in a forest (*left*) and a city (*right*). The larger the *blue arrows*, the larger the relative magnitude of the indicated flow

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Canopy interception loss varies over a wide range, from as little as 4% to as much as 50% of annual or seasonal precipitation in urban forests of Central Europe (Kermavnar 2015). Canopy interception from individual city trees may even be greater, due to relatively large canopy volumes associated with open-grown canopies, greater evaporation rates attributed to the urban heat island effect (Armson et al. 2012 – see also Chap. 2) and/or the enhanced influence of wind due to canopies being isolated from one another rather than being sheltered as in a forest (Asadian 2010).

5.3 How Can Urban Trees Reduce Stormwater?

Urban trees and forested areas have a great potential for reducing stormwater damage, by enhancing evapotranspiration and water infiltration into the soil as well as regulating the amount of throughfall reaching the ground and mitigating erosion processes (Asadian 2010). Since the amount of impervious surfaces (such as parking lots, roof tops, driveways, and roads) is increasing in many urban communities, rainwater cannot infiltrate and therefore runs off as stormwater. Urban vegetation and pervious soils, due to their ability to intercept, evaporate, transpire, infiltrate, and store rainfall, beneficially affect watershed hydrology, particularly storm and dry-weather flow (Seitz and Escobedo 2008). Surfaces such as asphalt respond quickly to rainfall and can shed 90% of received rainfall to drain (Pauleit and Duhme 2000), pushing the limits of drainage systems in heavy rainfall events. As urban subsoils are often relatively impermeable, strategies encouraging better infiltration can enhance groundwater recharge and water quality (Bartens et al. 2008). Root paths can act as conduits for water, but this function has not been demonstrated for stormwater, where standing water and dense subsoils create a unique environment. For example, in the area of Munich (Germany) a 10% increase of built-up area reduced rainfall infiltration per unit land area by 5% on average (Pauleit and Duhme 2000). To maintain infiltration rates comparable to that under natural woodland cover, the amount of built-up areas should not exceed an average of 17%.

5.4 How Can Urban Trees Improve Water Quality?

Water quality is strongly related to runoff (Xiao et al. 1998). Stormwater flows into the community's stormwater system and ends up in a stormwater treatment/management system or flows directly into a water body. Before reaching a stormwater system or waterway, stormwater picks up and transports loads of nutrients, heavy metals, organic pollutants, and other harmful substances (Le Pape et al. 2012) from roadways, sidewalks, yards, and homes to surface and ground water (Seitz and Escobedo 2008; Gallo et al. 2012). Tree roots, leaf litter, and vegetation can remove pollutants, sediment, and nutrients from the stormwater, lessening the

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amount of harmful substances reaching the ground or surface waters. Among plant types, trees have an exceptional ability to capture and filter multiple air pollutants, including ground-level ozone, sulphur dioxide, nitrogen oxides, particulate matter and fertilizers (see also Chap. 3). Finally, tree canopy cover over streams and wetlands can reduce water temperatures, thereby increasing dissolved oxygen and reducing the formation of problematic algae (Newham et al. 2011).

5.5 Any Best Management Practice Examples in Europe?

It is important to note that most European cities are in need of better stormwater management. Using natural vegetation as a form of low-impact development and best management practice can be an effective technique – as it controls stormwater runoff on site, mitigating the impacts of urbanization on surface runoff and pollutant delivery at a local scale (Walsh et al. 2005; Asadian 2010). A recent study on the costs and benefits of street trees in Lisbon, Portugal revealed that the largest contribution of monetary value was associated with the reduction of stormwater runoff (48 USD per tree), with per tree values noticeably higher than those obtained for US cities (Soares et al. 2011). Species that played a major role in rainfall interception (on average 5 m^3 of rainfall annually) were *Platanus* spp., *Celtis australis*, *Pinus nigra*, *Fraxinus angustifolia*, and *Populus* × *canadensis*. Maintaining the health and longevity of these trees is critical to sustain a high level of benefits. Recent efforts to increase species diversity should be expanded to reduce the risk of catastrophic loss if one or more of these predominant species were to succumb.

The effect of street trees and amenity grass on urban surface water runoff was investigated in Manchester, UK (Armson et al. 2013). While grass almost totally eliminated surface runoff, trees and their associated tree pits reduced runoff from asphalt by as much as 62%. The reduction was more than interception alone could have produced, and relative to the canopy area was much more than estimated by many previous studies. This was probably because of infiltration into the tree pit, which would considerably increase the value of urban trees in reducing surface water runoff.

Due to the high heterogeneity of trees and understory vegetation in urban forests, the extent of canopy interception, regulation and stormwater control is subject to local conditions and it quantification is fraught with technical and methodological difficulties (Mell et al. 2013). As a consequence, generalized management strategies that can be transferred from the scale of street trees to the scale of forests and plantations – or from one city to another – may be highly elusive. Therefore, local studies are needed for the attribution of economic value to urban forests and trees for stormwater regulation and water purification that can be used to guide future policy-making (Tyrväinen 2001) in European cities. For instance, a study in Ljubljana, Slovenia has shown that canopy interception in selected urban forests was mainly affected by tree species composition, canopy cover seasonality and tree dimensions (Kermavnar 2015). Canopy interception was highest in mixed forest (18.0% of bulk

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precipitation), while riparian pine forest had the lowest interception (3.9%) and the floodplain hardwood forest had intermediate interception (7.1%). The mixed forest exhibited a substantial assemblage of coniferous evergreen trees (46% of growing stock), and had the highest canopy cover and the highest growing stock – all characteristics of stand structure which contribute to higher canopy interception (Toba and Ohta 2005; Vilhar 2016). Furthermore, rainfall intensity has proven to be an important factor for seasonal partitioning of canopy interception. Thus a better understanding of interception processes in urban forests is needed to assist in the managing and planning of urban forests for hydrological benefits.

5.6 Conclusions

Urban trees and forested areas are valuable parts of our urban ecosystem for the numerous benefits they provide to communities. Proper management of the urban forest can reduce stormwater runoff and improve water quality, and the following practices can help achieve this:

- Maximize the amount of growing space and understory vegetation around a tree.
- Preserve established trees and minimize soil compaction, displacement, and erosion around a tree.
- Minimize clearing of trees and vegetation to preserve their benefits.
- Do not over-fertilize or over-irrigate trees, lawns or gardens.
- Route excess stormwater to bio-retention areas made of a vegetated buffer and a soil bed to filter pollutants, store water, and prevent erosion.
- Include tree and vegetative strips in parking lots to collect, store, and treat the runoff.
- Maintain and increase the amount and width of urban forest buffers around urban streams, lakes, and wetlands.

References

Armson D, Stringer P, Ennos AR (2012) The effect of tree shade and grass on surface and globe temperatures in an urban area. Urban For Urban Green 11:245–255

Armson D, Stringer P, Ennos AR (2013) The effect of street trees and amenity grass on urban surface water runoff in Manchester, UK. Urban For Urban Green 12:282–286

Asadian YUMSD (2010) Rainfall interception in an urban environment. Master of science thesis. University of British Columbia, Faculty of Graduate Studies. The University of British Columbia, Vancouver

Bartens J, Day SD, Harris JR et al (2008) Can urban tree roots improve infiltration through compacted subsoils for stormwater management? J Environ Qual 37:2048–2057

Benedict MA, McMahon ET (2006) Green infrastructure: linking landscapes and communities. Island Press, Washington, DC, 320 p

liz.obrien@forestry.gsi.gov.uk

Chen L, Zhang Z, Ewers BE (2012) Urban tree species show the same hydraulic response to vapor pressure deficit across varying tree size and environmental conditions. PLoS One 7:e47882

Crockford RH, Richardson DP (2000) Partitioning of rainfall into throughfall, stemflow and interception: effect of forest type, ground cover and climate. Hydrol Process 14:2903–2920

Duda AM, Lenat DR, Penrose DL (1982) Water quality in urban streams: what we can expect. J Water Pollut Control Fed 54(7):1139–1147

Gallo EL, Lohse KA, Brooks PD et al (2012) Quantifying the effects of stream channels on storm water quality in a semi-arid urban environment. J Hydrol 470–471:98–110

Inkiläinen ENM, Mchale MR, Blank GB, James AL, Nikinmaa E (2013) The role of the residential urban forest in regulating throughfall: a case study in Raleigh, North Carolina, USA. Landsc Urban Plan 119:91–103

Kermavnar J (2015) Sestojne padavine v izbranih urbanih gozdovih Ljubljane. Stand precipitation in selected urban forests in the city of Ljubljana. Magistrsko delo. Master of science thesis. Biotehniška fakulteta. Oddelek za gozdarstvo in obnovljive gozdne vire. Univerza v Ljubljani, Ljubljana

Kirnbauer MC, Baetz BW, Kenney WA (2013) Estimating the stormwater attenuation benefits derived from planting four monoculture species of deciduous trees on vacant and underutilized urban land parcels. Urban For Urban Green 12:401–407

Le Pape P, Ayrault S, Quantin C (2012) Trace element behavior and partition versus urbanization gradient in an urban river (Orge River, France). J Hydrol 472–473:99–110

Livesley SJ, Baudinette B, Glover D (2014) Rainfall interception and stem flow by eucalypt street trees – The impacts of canopy density and bark type. Urban For Urban Green 13:192–197

Mell IC, Henneberry J, Hehl-Lange S et al (2013) Promoting urban greening: valuing the development of green infrastructure investments in the urban core of Manchester, UK. Urban For Urban Gree 12:296–306

Newham M, Fellows C, Sheldon F (2011) Functions of riparian forest in urban catchments: a case study from sub-tropical Brisbane, Australia. Urban Ecosyst 14:165–180

Pauleit S, Duhme F (2000) Assessing the environmental performance of land cover types for urban planning. Landsc Urban Plan 52:1–20

Sanesi G, Gallis C, Kasperidus HD (2011) Urban forests and their ecosystem services in relation to human health. In: Nilsson K, Sangster M, Gallis C, Hartig T, De Vries S, Seeland K, Schipperijn J (eds) Forests, trees and human health. Springer Netherlands, Dordrecht, pp 23–40

Schooling JT, Carlyle-Moses DE (2015) The influence of rainfall depth class and deciduous tree traits on stemflow production in an urban park. Urban Ecosyst 18(4):1261–1284

Seitz J, Escobedo F (2008) Urban forests in Florida: trees control stormwater runoff and improve water quality. For 239:1–4

Siegert CM, Levia DF, Hudson SA et al (2016) Small-scale topographic variability influences tree species distribution and canopy throughfall partitioning in a temperate deciduous forest. For Ecol Manag 359:109–117

Soares AL, Rego FC, Mcpherson EG et al (2011) Benefits and costs of street trees in Lisbon, Portugal. Urban For Urban Green 10:69–78

Šraj M, Lah A, Brilly M (2008) Meritve in analiza prestreženih padavin navadne breze (*Betula pendula* Roth.) in rdečega bora (*Pinus sylvestris* L.) v urbanem okolju. Measurements and analysis of intercepted precipitation of silver birch (*Betula pendula* Roth.) and Scots pine (*Pinus sylvestris* L.) in urban area. Gozdarski vestnik 66:406–416

Toba T, Ohta T (2005) An observational study of the factors that influence interception loss in boreal and temperate forests. J Hydrol 313:208–220

Tyrväinen L (2001) Economic valuation of urban forest benefits in Finland. J Environ Manag 62:75–92

Vilhar U (2016) Sestojne padavine v mešanih sestojih smreke in bukve na Pohorju. Throughfall in mixed beech-spruce forest in the Pohorje mountains. Gozdarski vestnik 74:28–45

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Vilhar U, Kobal M, Žlindra D et al. (2015) Urban ecosystem services, related to regulation of water flow, water purification and air pollution reduction. Landscape ecology of urban forests: enhancing ecosystem services. University of Ljubljana, Biotechnical Faculty, Department of Forestry, Ljubljana, Slovenia

Walsh CJ, Fletcher TD, Ladson AR (2005) Stream restoration in urban catchments through redesigning stormwater systems: looking to the catchment to save the stream. J N Am Benthol Soc 24:690–705

Xiao QF, Mcpherson EG, Simpson JR et al (1998) Rainfall interception by Sacramento's urban forest. J Arboric 24:235–244

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Chapter 6
Soil Quality

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6.1 Introduction

Urbanization is the main driver of rapid land-use change around the world, with important consequences for soil quantity and quality. Urban soils, in addition to their slow formation due to long-term natural processes, are decisively modified by urbanization. High levels of soil disturbance and new substrates added to the soil due to human activities change the morphology of the soil profile and the overall soil processes and functions. This is important because soils play an essential role in sustaining the provisioning of ecosystem services (ES). However, the protection of urban soils is still poorly considered in the planning and development of urban areas – and there is a lack of knowledge regarding the potential of different types of vegetation cover and plant species to moderate the degradation of, or even improve, urban soils.

In terms of environmental ES, the direct role of soils in urban ecosystems is mainly expressed through the provision of regulation and maintenance services linked to soil formation and composition, climate regulation related to the soil's vast capacity as a carbon sink (Haines-Young and Potschin 2013), and water regulation by reducing surface water runoff. Soil is fundamental for the growth and development of different plant species, and forms the environment for a wide complex of

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below-ground biodiversity (see Chap. 8). Soil quality is a complex indicator of conditions in different types of urban ecosystems: by determining parameters such as the level of soil degradation and/or soil organic matter stock (see Chap. 4), the ability of the soil to supply environmental ES in urban areas can be assessed. Urban soils are the main basis for creation and existence of urban green infrastructure (UGI), designed and managed to deliver ES and protect biodiversity in urban settings (Morel et al. 2005). However, urban soils differ from their natural counterparts and are influenced to a greater extent by human activities. Urban soil is material that has been manipulated, disturbed or transported by human activities in the urban environment and is formed as a result of the combined effect of natural factors of soil formation and anthropogenic factors (Stroganova, Prokofieva 2001; Zhiyanski et al. 2015). Compaction, restriction of water movement and of aeration, presence of anthropogenic materials, limited or confined rooting space and interrupted nutrient cycling are among the major problems commonly encountered when planting and maintaining UGI. Urban environments in general are highly disturbed and fragmented ecosystems, commonly having a lower mycorrhizal fungal species richness and diversity than rural or natural ecosystems (McDonnell and Pickett 1990). Here some of the main soil degradation processes in urban areas are described in terms their effect on UGI, along with some of positive effects of UGI on soil.

Mycorrhizal fungi increase absorption and transport of water and mineral nutrients from the soil solution to the symbiotic plant and, in return, obtain carbohydrates produced by the plant via its photosynthesis process. Mycorrhizas enhance plant growth and vitality (Perez-Moreno, Read 2000) and can protect plants against toxic compounds (Bothe et al. 2010; Bojarczuk, Kieliszewska-Rokicka 2010) which is extremely important for the sustainability of UGI developed on nutrient-poor soils (Smith, Read 2008).

6.2 Soil Heterogeneity in Urban Ecosystems

In addition to built structures, urban areas contain a rich variety of land cover types – including green spaces such as parks, yards, street planting, green roads, and urban rivers. These UGI elements ensure the functioning of urban ecosystems, and profoundly influence the characteristics of the local urban environment by mitigating a range of negative environmental effects (Gülten et al. 2016). At the same time, urban soils are commonly afflicted by compaction, low content of organic substances and high contamination levels, usually from the deposition of atmospheric pollutants or historical uses of the site.

The urban heat island (see Chap. 2), together with modifications in local precipitation patterns and the hydrological regime, can strongly affect the soil microclimate, water availability, and vitality and activity of soil organisms (Oke 1995). Urbanization also affects the soil's chemical properties (Groffman et al. 2009;

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Pouyat et al. 1995), as a result of the increased concentration of heavy metals (Pouyat 1991) and the levels of nitrogen and sulfur added to the soil (Lovett et al. 2000). Kaye et al. (2005) showed that cities have a fundamentally different biogeochemistry than ‘natural’ systems as a result of human activity, which can modify biogeochemical flows in urban ecosystems. The specific properties of urban soils are a function of the level of urbanization and the interaction between local environmental and climatic conditions (Zhiyanski et al. 2015, Doichinova et al. 2014), and variations in anthropogenic pressure affect each local urban ecosystem in a different way (McIntyre et al. 2001). Therefore, patterns described for a particular city cannot directly be applied to other urban regions (Carreiro et al. 2009; Pouyat et al. 2010).

6.3 Soil Degradation and Urban Green Infrastructure

Soil degradation is often observed in urban regions and is expressed as a complete or partial loss of individual soil functions. It is often imperceptible, since it is a slow process of which the immediate dramatic consequences are rarely exhibited. Degradation processes are present if i) the whole soil profile or part of it is exposed to a continuous physical disruption or destruction (soil erosion), or ii) the integrity of the soil profile is well preserved (physical characteristics are not disturbed or destroyed), but soil composition, properties and fertility are changed negatively (acidification, pollution, salinization, compaction, waterlogging, soil “sealing”, loss of soil organic matter and loss of soil biodiversity).

UGI can potentially mitigate the soil degradation accompanying rapid urbanization, through a range of benefits and services. In parks, not just in natural areas, vegetation protects soil from direct solar radiation, and thereby moderates increases in soil temperature and evaporation, so that its moisture content is maintained at a higher level than that of bare soil (Sarah 2002; Kotzen 2003). The canopy of trees and shrubs also prevents the direct impact of raindrops on the soil, thereby preventing the formation of impermeable soil crusts, and thus increasing the infiltration capacity and soil moisture content (Janeau et al. 1999; Sarah 2002).

The importance of urban green spaces, and particularly the ES they provide, are gaining increasing recognition as contributors to environmental sustainability and the wellbeing of urban dwellers (Bolund and Hunhammar 1999; RCEP 2006). Soils are the foundation of most terrestrial ES, storing nutrients and water, providing physical anchorage required for plants to produce food, fuel and fibers. In addition, soils store carbon, play important roles in flood mitigation, purification of water, and the immobilization of air pollution, and they also provide structural support for buildings (Dominati et al. 2010). Soils from urban forests may accumulate organic carbon in amounts comparable with those in naturally distributed peri-urban forest soils, and they play a crucial role in sustaining the regulating ecosystem services (Zhiyanski et al. 2015).

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6.3.1 Soil Erosion

Soil erosion is a phenomenon related to the separation and transfer of soil particles by wind, rain and water due to natural and/or anthropogenic processes. The latter increase the magnitude and frequency of the erosion process (Van Camp et al. 2004). Erosion reduces the depth of the root layer, the amount of nutrients and soil moisture reserves, the soil's filtering and buffering capacity, and its organic matter content. Biodiversity, soil structure, soil crust formation, and the distribution and accumulation of pollutants in water streams and sediments are also impacted.

UGI has a great potential for mitigating erosion (Asadian et al. 2010), especially in reducing stormwater damage by enhancing evapotranspiration and water infiltration into the soil, as well as by regulating the amount of throughfall (see Chap. 5). Since the area of impervious surfaces, e.g. parking lots, roof tops, driveways, and roads is increasing in many urban areas, rainwater cannot infiltrate and runs off as stormwater. A good knowledge of areas susceptible to erosion can allow the prediction of the risk and reduction of erosion through preventive measures and proper land-use management.

6.3.2 Soil Pollution

Soil pollution is a major problem in urban environments, caused by industrialization over the last 200 years. The most common contaminants are heavy metals and petroleum hydrocarbons, which contaminate soils mainly by atmospheric deposition, agricultural practices and local sources. Pollution can be local or diffuse: local contamination is a problem in restricted areas or sites with a direct link to the source of contamination (EEA 2000), while diffuse contamination is generally caused by contaminants transported over wide areas, often far from the source. As a result of soil contamination, defined as the presence of 'dangerous substances', changes in soil quality occur – affecting all ecosystem components and posing significant risks for people (Van Camp et al. 2004).

There are a number of technologies for onsite remediation of polluted soils, which vary in their cost and effectiveness. *Phytoremediation* refers to the use of green plants and their associated microbiota, soil amendments, and agronomic techniques to remove, contain, or render harmless environmental contaminants (Cunningham, Ow 1996). This natural approach can be highly cost-efficient, conserving soil resources and supporting the supply of ES in urban areas. Oh et al. (2014) for instance, recommend the use of plants that may have an economic benefit such as biofuel crops for the utilization and remediation of contaminated sites.

The establishment of a vegetation cover is also essential to stabilize the bare area and to minimize the pollution problem, while the selection of appropriate plant species is important to ensure a self-sustaining vegetation cover (Wong 2003). In

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strongly urbanised environments the use of trees is typically most convenient for this purpose, especially fast growing species like willows and poplars.

6.3.3 Soil Compaction

The compaction of urban soils is connected with heavy machinery and intense movement of people, and it is one of the main degradation processes in urban areas (Fig. 6.1). The expansion of cities is inevitably associated with soil compaction, resulting from the construction of the entire urban infrastructure – residential areas, transport and industrial zones. The compaction of the surface layers and the building of a solid coverage lead to a lack of oxygen and deteriorated water drainage, which negatively affects plant root growth, soil heat balance and normal soil gas exchange, thus exposing vegetation to risks. Soil compaction is also reflected in the reduction of water permeability and thus the increase in surface runoff potential, which can increase the intensity of water erosion and the risk of flooding. Besides

Fig. 6.1 Soil compaction due to anthropogenic impacts, in an urban park in Varna, Bulgaria (Photo: Miglena Zhiyanski)

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technical measures avoiding compaction during construction, soil structure can be improved by establishing appropriate UGI, and thus increasing the organic matter content.

Urban soils are often thought to be highly modified and of poor quality (Lorenz and Lal 2009). Severe compaction reduces soil pore space, thereby increasing bulk density. High bulk density impedes plant growth, increases overland flow of storm waters leading to an increased likelihood of erosion and flooding, and alters biogeochemical cycling (Scalenghe, Marsan 2009).

Agricultural soil compaction has been intensively studied, but there are few studies investigating the extent of compaction in urban ecosystems. Urban soil bulk density is lowest under trees and shrubs and highest under herbaceous vegetation (e.g. lawns), where the values are typically similar to many semi-natural habitats, particularly those underlying woody vegetation (Edmondson et al. 2011).

6.3.4 Surface Waterlogging

Surface waterlogging is observed in soils occupying flat and depressed terrain, with textural differentiation of the soil profile or the presence of clay structures in the entire profile. Human activities such as land consolidation, infrastructure works such as embankments, and inappropriate management practices all significantly affect soil permeability and in turn the functioning of UGI (Mullaney et al. 2015). Surface waterlogging leads to flood stress and a number of unfavorable impacts on UGI and the urban water drainage system. Trees and grass species which develop significantly higher root porosity under flooded conditions are appropriate for sites where surface waterlogging appears (Anderson and Pezeshki 2001). Moreover, UGI mitigates surface runoff in urban ecosystems. While grass almost totally eliminates surface runoff, trees and their associated tree pits have been seen to reduce runoff from asphalt by as much as 62% (Armsona et al. 2013).

6.3.5 Soil Sealing

Soil sealing refers to the covering of the soil surface with impermeable materials when constructing urban infrastructures. It often affects fertile lands, increasing the risk of biodiversity loss by reducing the number of habitats and living space of different species and increasing the fragmentation of ecosystems. Soil sealing has strong negative effects on the eco-physiological and health status of UGI, and it decreases the associated biodiversity of both below-ground and above-ground species. It also increases the risks of flooding or drought, both of which are intensifying with climate change. Green infrastructure integrated with concrete or asphalt surfaces can meaningfully reduce the consequences of sealing, by allowing at least

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some exchange between the soils and their environment – including gas exchange, water infiltration, and solute fluxes.

6.3.6 Loss of Soil Biodiversity

Soil biodiversity is generally defined as the variety of soil organisms and the ecological complexes of which they are part. This includes diversity within species, between species and between ecosystems. The soil biota plays many fundamental roles in providing key ecosystem goods and services, and they are both directly and indirectly responsible for carrying out many important functions – including the production food, materials and certain pharmaceuticals, the detoxification of xenobiotics and pollutants and the regulation of atmospheric composition. A decline in soil biodiversity is generally considered as a reduction in the forms of life living in soils, in terms of both quantity and variety (Kibblewhite et al. 2008; Martinova et al. 2016).

Mycorrhizal fungal colonization, which generally improves the growth and health of trees and herbaceous species, is significantly lower in trees growing in urban, as opposed to rural environments – and this is likely due the process of urbanization itself (Bainard et al. 2011). Mycorrhizal fungi can be affected directly by the soil pH, availability of nutrients, concentration of toxic elements, soil nitrogen, and drought – or indirectly via the host plant, due to reduced carbon allocation to roots after leaf yellowing or loss (Tyburska et al. 2013). The decreased availability of carbohydrates may also hinder the production of fine roots, on which mycorrhizal associations can develop (Kernaghan 2005).

Efforts at mitigating global biodiversity loss have often been focused on preserving intact natural habitats. Preserving soil biodiversity should also be an important goal in the urban environment, especially in highly urbanized areas, as the urban forest will increasingly become an important reserve of biodiversity (Alvey 2006).

6.4 Conclusions

Landscape fragmentation caused by urban infrastructure and soil sealing have a number of further negative effects – reducing the size and persistence of wildlife populations, changing local climate, and increasing pollution and noise from traffic, all contributing to a further loss in biodiversity.

Through appropriate management of UGI and selection of appropriate tree species for urban greening, the quality of urban soils can be improved and the appearance of negative effects such as erosion, higher compaction and bonded toxic elements can be avoided. The establishement of UGI improves the soil energy balance and increases evapotranspiration, moderating urban heat island effects

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and indirectly enhancing other ecosystem services – bringing more benefits for people living in cities.

Optimising the design of urban areas by incorporating parks and green spaces, as well as preserving unsealed open strips ('fresh air corridors') to support the ventilation of city centres, is becoming increasingly important (Früh et al. 2011). Soil sealing can be limited by the rehabilitation of abandoned industrial areas. Effective mitigation of impacts includes the use of permeable materials instead of concrete or asphalt, support for UGI, and increased application of systems to collect water from natural sources. If these mitigation measures are insufficient, the implementation of compensation measures for improvement of soil characteristics and functioning in other areas should be considered.

One of the most important mitigation measures in 'best-practice' cases is to avoid unnecessary damage to soils that are not directly affected by construction activity, for example land to be used as gardens or communal green space. Cultivation measures can also reduce the compaction and waterlogging caused by the passage of large machines over the soil. On the other hand urban design, inspired by the GI concept, can help to maintain or increase the infiltration potential of land. As part of UGI, green roofs can help to reduce some of the negative effects of soil sealing and can help to a certain extent in preventing surface runoff.

The values of carbon stocks (see Chap. 4) have been seen to increase when management activities are applied in city parks (Zhiyanski et al. 2015). However, the assessment of carbon stocks needs to include the complex role of the below-ground tree biomass. The need to maintain and enhance the natural function of forest ecosystems, as part of the UGI, is clear, but the role of this UGI, and of distinct species, on various soil process needs further research and attention.

One of the most effective ways of building GI is to adopt a more integrated approach to land management. The implementation of an integrated approach to spatial planning and the adoption of specific methods at the regional level – as well as mobilizing the unused resources at the local level – have a great importance.

References

Alvey AA (2006) Promoting and preserving biodiversity in the urban forest. Urban For Urban Green 5:195–201

Anderson PH, Pezeshki SR (2001) Effect of flood pre-conditioning on responses of three bottomland tree species to soil waterlogging. J Plant Physiol 158:227–233

Armsona D, Stringerb P, Ennosa AR (2013) The effect of street trees and amenity grass on urban surface water runoff in Manchester UK. Urban For Urban Green 12:282–286

Asadian F, Arzjani Z, Varavipour M (2010) Changes of microenvironment in Gilan City due to landslides. CJEES 5(1):93–102

Bainard LD, Klironomos JN, Gordon AM (2011) The mycorrhizal status and colonization of 26 tree species growing in urban and rural environments. Mycorrihiza 21(2):91–96

Bojarczuk K, Kieliszewska-Rokicka B (2010) Effect of ectomycorrhiza on Cu and Pb accumulation in leaves and roots of silver birch (*Betula pendula* Roth.) seedlings grown in metal-contaminated soil. Water Air Soil Pollut 207:227–240

liz.obrien@forestry.gsi.gov.uk

Bolund P, Hunhammar S (1999) Ecosystem services in urban areas. Ecol Econ 29:293–301

Bothe H, Turnau K, Regvar M (2010) The potential role of arbuscular mycorrhizal fungi in protecting endangered plants and habitats. Mycorrhiza 20(7):445–457

Carreiro MM, Pouyat RV, Tripler CE et al (2009) Carbon and nitrogen cycling in soils of remnant forests along urban–rural gradients: case studies in the New York metropolitan area and Louisville, Kentucky. In: McDonnell MJ et al (eds) Ecology of cities and towns: a comparative approach. Cambridge University Press, Cambridge, pp 308–328

Cunningham SD, Ow DW (1996) Promises and prospects of phytoremediation – update on biotechnology. Plant Physiol 110:715–719

Doichinova V, Zhiyanski M, Hursthouse A et al (2014) Study on the mobility and bioavailability of PTEs in soils from urban forest parks in Sofia, Bulgaria. J Geochem Explor 147(Part B):222–228. doi:10.1016/j.gexplo.2014.03.011

Dominati E, Patterson M, Mackay A (2010) A framework for classifying and quantifying the natural capital and ecosystem services of soils. Ecol Econ 69:1858–1868

Edmondson J, Davies Z, McCormack S et al (2011) Are soils in urban ecosystems compacted? A citywide analysis. Biol Lett 7:771–774

European Environment Agency EEA (2000) Down to earth: soil degradation and sustainable development in Europe, Environmental issue series No 16. EEA, Copenhagen

Früh B, Becker P, Deutschländer T et al (2011) Estimation of climate-change impacts on the urban heat load using an urban climate model and regional climate projections. J Appl Meteorol Climatol 50:167–184

Groffman PM, Williams CO, Pouyat RV et al (2009) Nitrate leaching and nitrous oxide flux in urban forests and grasslands. J Environ Qual 38:1848–1860

Gülten A, Aksoy UT, Öztop HF (2016) Influence of trees on heat island potential in an urban canyon. Sustain Cities Soc. doi:10.1016/j.scs.2016.04.006

Haines-Young R, Potschin M (2013) Common International Classification of Ecosystem Services (CICES): consultation on version 4, August-December 2012

Janeau JL, Mauchamp A, Tarin G (1999) The soil surface characteristics of vegetation stripes in Northern Mexico and their influences on system hydrodynamics: an experimental approach. Catena 37:165–173

Kaye JP, Mcculley RL, Burke IC (2005) Carbon fluxes, nitrogen cycling, and soil microbial communities in adjacent urban, native and agricultural ecosystems. Glob Change Biol 11:575–587

Kernaghan G (2005) Mycorrhizal diversity: cause and effect. Pedobiologia 49:511–520

Kibblewhite MG, Jones RJA, Baritz R, et al (2008) ENVASSO final report part I: scientific and technical activities. ENVASSO Project (Contract 022713) coordinated by Cranfield University, UK, for Scientific Support to Policy, European Commission 6th Framework Research Program

Kotzen B (2003) An investigation of shade under six different tree species of the Negev desert towards their potential use for enhancing micro-climatic conditions in landscape architectural development. J Arid Environ 2:231–274

Livesley SJ, Ossola A, Threlfall CG et al (2016) Soil carbon and carbon/nitrogen ratio change under tree canopy, tall grass, and turf grass areas of urban green space. J Environ Qual 45:215–223

Lorenz K, Lal R (2009) Biochemical C and N cycles in urban soils. Environ Int 35:1–8

Lovett GM, Traynor MM, Pouyat RV et al (2000) Atmospheric deposition to oak forests along an urban-rural gradient. Environ Sci Technol 34:4294–4300

Martinová V, van Geel M, Lievens B, Honnay O (2016) Strong differences in *Quercus robur*-associated ectomycorrhizal fungal communities along a forest-city soil sealing gradient. Fungal Ecol 20:88–96

McDonnell MJ, Pickett STA (1990) Ecosystem structure and function along urban–rural gradients: an unexploited opportunity for ecology. Ecology 71:1232–1237

McIntyre NE, Rango J, Fagan WF et al (2001) Ground arthropod community structure in a heterogeneous urban environment. Landsc Urban Plan 52:257–274

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Morel J, Schwartz C, Florentin L et al (2005) Urban soils. In: Hillel D (ed) Encyclopedia of soils in the environment, vol 4. Elsevier, Oxford, pp 202–208

Mullaney J, Lucke T, Trueman SJ (2015) A review of benefits and challenges in growing street trees in paved urban environments. Landsc Urban Plan 134:157–166

Oh K, Cao T, Li T et al (2014) Study on application of phytoremediation technology in management and remediation of contaminated soils. JOCET 2(3):216–220

Oke TR (1995) The heat island of the urban boundary layer: characteristics, causes and effects. In: Cermak JE et al (eds) Wind climate in cities. Kluwer Academic Publishers, Dordrecht, pp 81–107

Perez-Moreno J, Read DJ (2000) Mobilization and transfer of nutrients from litter to tree seedlings via the vegetative mycelium of ectomycorrhizal plants. New Phytol 145:301–309

Pouyat RV (1991) The urban–rural gradient: an opportunity to better understand human impacts on forest soils. In: Proceedings of the society of American foresters, 1990 annual convention, Washington, DC. Society of American Foresters, Washington, DC

Pouyat RV, Mcdonnell MJ, Pickett STA (1995) Soil characteristics of oak stands along an urban–rural land use gradient. J Environ Qual 24:516–526

Pouyat RV, Szlavecz K, Yesilonis ID (2010) Chemical, physical and biological characteristics of urban soils. Urban ecosystem ecology (Agronomy monograph 55), American Society of Crop Agronomy, Crop Science Society of America, Soil Science Society of America, Madison, pp 119–152

RCEP (2006) The urban environment. 26th report. Royal Commission on Environmental Pollution, London

Sarah P (2002) Spatial patterns of soil moisture as affected by shrubs, in different climatic conditions. Environ Monit Assess 73:237–251

Scalenghe R, Marsan FA (2009) The anthropogenic sealing of soil in urban areas. Landsc Urban Plan 90:1–10

Smith SE, Read DJ (2008) Mycorrhizal symbiosis. Academic Press, London

Stroganova M, Prokofieva T (2001) Urban soils classification for Russian cities of the taiga zone. In: Micheli E, Nachtergaele FO, Jones RJA et al (eds) Soil classification, European soil Bureau research report №7, EUR 20398 EN, (2002), vol 248. Office for Official Publications of the European Communities, Luxembourg, pp 153–156

Tyburska J, Frymark-Szymkowiak A, Kulczyk-Skrzeszewska M et al (2013) Mycorrhizal status of forest trees grown in urban and rural environments in Poland. Ecol Quest 18(1):51–59

Van Camp L, Bujjarabal B, Gentile A-R et al (2004) Reports of the technical working groups established under the thematic strategy for soil protection, EUR 21319 EN/1. Office for Official Publications of the European Communities, Luxemburg, p. 872

Wong MH (2003) Ecological restoration of mine degraded soils, with emphasis *on* metal contaminated soils. Chemosphere 50(6):775–780

Zhiyanski M, Hursthouse A, Doncheva S (2015) Role of different components of urban and peri-urban forests to store carbon – a case-study of the Sandanski region, Bulgaria. JCBPS 5(3):3114–3128 E- ISSN:2249 –1929

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Chapter 7
Delivery of Goods and Services

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7.1 Overview: The Provision of Urban Forest Products

Over the last several decades, as a consequence of intensified industrialization and urbanization, there has been a shift in the management of natural resources from predominantly economic motives to an emphasis on environmental and socio-cultural values (Kennedy and Quigley 1998; Colding and Barthel 2013). It is projected that by 2050 about 75% of the world's population will live in cities and their peri-urban surroundings (UN 2012), which has led to an inadvertently increased demand for land to provide the energy, resources, water and waste disposal needs of the growing urban population. Currently, the majority of mega-cities in the world are still continuing to grow, leading to severe scarcity of resources and limited availability of land. In this respect, there is growing emphasis on circular economy principles in future planning for the construction of sustainable urban infrastructure, which include measures for enhanced "provisioning services" – i.e. the preservation and conservation of the environment through urban green infrastructure (UGI), combined with more efficient use of resources with a minimal carbon footprint. In a broad sense, UGI includes parks, forest reserves, hedgerows, restored and preserved wetlands and marine areas, and artificial features such as eco-products. In many cases these urban green areas can have the capacity to provide people with

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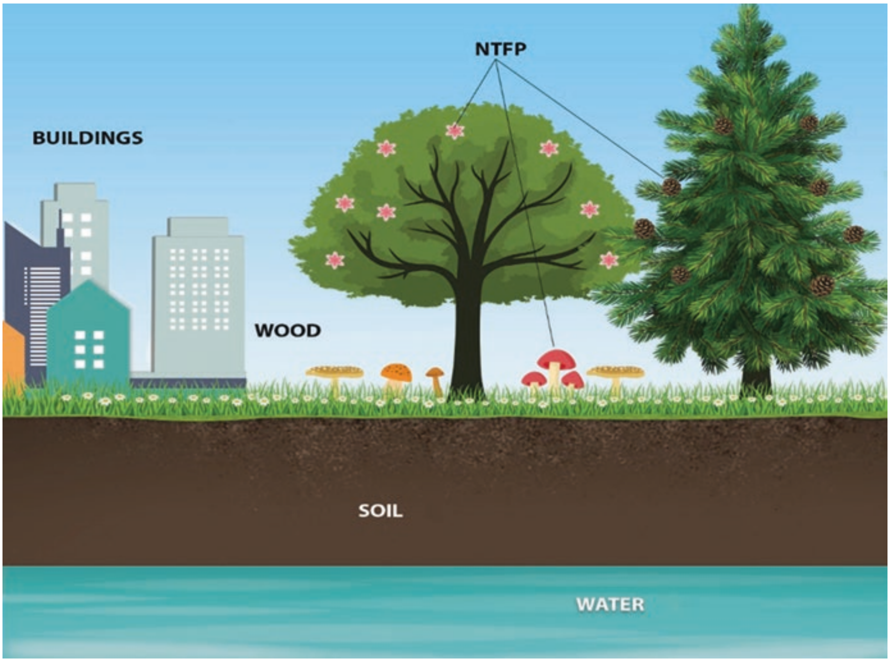

Fig. 7.1 Graphical representation of the goods and other provisioning services from urban green infrastructure, classified in the broad categories of wood, soil, water and non-timber forest products (NTFP). The latter comprises raw materials, food and ornamental and medicinal resources. An additional role of trees in building preservation is also included

many of the traditional products associated with forest ecosystems, including food, fodder, fuel, wood, and timber for construction (Tyrvainen et al. 2005).

Knowledge about ecosystem services is thus important for maintaining the quality of life in metropolitan areas, by preserving "the capacity of natural processes and components to provide goods and services that satisfy human needs, directly or indirectly". Based on this concept, *provisioning services* are tangible ecosystem services that describe the material or energy outputs from ecosystems. They include food (e.g. fish, game and fruit), water (e.g. for drinking, irrigation and cooling), raw materials (e.g. fibre, timber, fuel wood, fodder, fertilizer, soil, and non-timber forest products – NTFP), genetic resources (e.g. for crop-improvement and medicinal purposes), medicinal resources (e.g. biochemical products, models and test-organisms), ornamental resources (e.g. artisan work, decorative plants, pet animals, fashion), and building preservation (Fig. 7.1).

Taking a holistic view of the urban ecosystem, it is possible to differentiate between three macro-categories of UGI functions: (i) the recovery of energy, nutrition and products (ii) the provision of clean water and soil, and (iii) the provision of infrastructure resilience. Each function is the result of natural processes within the total ecological subsystem of which it is a part. These natural processes, in turn, are

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the result of complex interactions between biotic (living) and abiotic (chemical and physical) components of ecosystems through the universal driving forces of matter and energy (de Groot et al. 2002).

7.2 European Perspectives

As Europe is getting more heavily urbanized, people are becoming increasingly aware of the beneficial provisioning services offered by urban forests and even single trees within the urban landscape. Still, it is noteworthy that some of the benefits derived from UGI are commonly underestimated and/or overlooked – and therefore it is useful to specify these resources in some detail:

- *Food* – Ecosystems provide the conditions for growing food. Food comes principally from managed agro-ecosystems but marine and freshwater systems or forests also provide food for human consumption. Wild foods from urban forests and parks are often underestimated.
- *Raw materials* – Ecosystems provide a great diversity of materials for construction and fuel including wood, bio-fuels and plant oils that are directly derived from wild and cultivated plant species.
- *Fresh water* – Ecosystems play a vital role in the global hydrological cycle, as they regulate the flow and purification of water. Vegetation and forests influence the quantity of water available locally for drinking, irrigation and cooling.
- *Medicinal resources* – Ecosystems and biodiversity provide many plants used as traditional medicines as well as providing essential inputs for the pharmaceutical industry.

According to the European Environment Agency (2010), the status of most provisioning services has been worsening since the 1950s (see Table 7.1). Although overpopulation has induced pressures related to resource depletion, pollution, climate change, habitat loss and invasive species penetration, to date there is no comprehensive assessment of the way these challenges can be addressed through the provisioning services afforded by urban greening, and particularly by urban trees.

Across Europe there is a sharp contrast in the ways that the different roles of UGI are acknowledged. On one hand, the majority of EU member states have initiated programs which encourage the urban population to develop a positive relationship with their local green resources. For example, London has developed 'Friends of' groups that involve a diverse range of people in activities such as volunteer work, community initiatives, local fruit picking and food harvesting campaigns. On the other hand, despite an abundance of legacy urban greenspace, the utilization of provisioning services from urban forestry is a relatively new concept. In many cases, the composition, species distribution, and structure of urban forests – and in turn the patterns of acquiring goods and services from them – are largely dictated by the distribution of wealth and power within the society, rather than by a holistic ecosystems-based strategy.

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Table 7.1 Status of European provisioning services between 1950 and 2010

Provisioning services	Agro-ecosystems	Forests	Grasslands	Heath and scrubs	Wetlands	Lakes and rivers
Crops/timber	↓	↑			↓	
Livestock	↓	–	–	–	↓	
Wild Foods	–	↓	↓		–	
Wood fuel		–		–		
Capture fisheries					–	–
Aquaculture					↓	↓
Genetic	–	↓	↓	–	–	□
Fresh water		↓			↑	↑

Trends between periods	↑	–	↓
	Positive change between periods 1950-1990 and 1990-2010	No change between periods 1950-1990 and 1990-2010	Negative change between periods 1950-1990 and 1990-2010

Status for period 1990-2010	Degraded	Mixed	Enhanced	Unknown	Not applicable

Source: European Environment Agency (2010)

Attempts to address this imbalance can be seen in the South East Europe (SEE) region, where the regulating and cultural services of urban forestry have been widely acknowledged but relatively little has been written about the potential of provisioning services – highlighting the need for more comparative information on what modes of urban forest governance exist and how they work (Bentsen et al. 2010). Trees and forests, despite being the most prominent elements of urban nature, are grossly underutilized in the SEE countries in terms of their goods and services. At the same time, these countries have faced dynamic social changes with a rapid transition from socialism to democratic governance, fast growth of the population in the cities, urbanization and modernization. All these factors have led to significant changes in the cultural lifestyle of the citizens, which have been reflected in recent policy initiatives. For example, the Green regulation of the Belgrade region recognizes the following two main aspects of goods and services provisioning, in and around cities:

(i) *Energy plantations*: This plan proposes the establishment of "energy plantations" utilizing willow trees (*Salix viminalis*) as an alternative solution for the long-term supply of clean energy. Energy willow are to be grown on agricultural land, as well as in the residual spaces along transport routes and in green belts. Integrating energy plantations in the system of green areas of Belgrade is seen to achieve multiple benefits, especially in terms of improved environmental quality. When adapted to local climatic and soil conditions, *Salix* can provide a real solution for achieving large yields of woody biomass per hectare in a short time, even within the city. There is also an untapped potential for utilizing local community gardens, to stimulate the local population to grow alternative, less invasive tree species and acquire local goods.

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(ii) *Plant-based wastewater treatment system* s *(wetlands, reed beds)*: The partial or complete lack of sewage systems in some settlements in Belgrade has emerged as a serious problem, due to the risk of infections from polluted ground and surface water, the occurrence of landslides and the overall reduction in security for neighbourhood residents. Accordingly, this planning decision proposes the application of specially designed wastewater treatment systems using aquatic plants. Further spatial planning and refinement of these schemes will allow for quantification of the potential services (provision of clean water) and goods (woody biomass for energy, timber and food) that they may offer.

It is noteworthy that when it comes to other potential goods from urban forests, most forests in the Belgrade administrative area have a protected status which prohibits the gathering of mushrooms and berries, as well as logging for firewood.

7.3 Emerging Trends and Future Potentials

In 1950 less than 30% of the world's population lived in cities, a proportion which is expected to double by 2025. The planning and governance of future cities must increasingly incorporate the role of urban ecosystems in providing goods and services to meet local demand, while overcoming some of the limiting factors in the process. For enhanced utilization of urban trees in the provision of goods and services, it is necessary to emphasize that they involve systems engineering as well as technologies and practices that imitate natural processes in order to improve the environment and provide utility services to the population. Supportive urban planning and design approaches and appropriate land management are crucial to the formation and distribution of UGI elements and therefore, they provide significant opportunities for maximizing the services they render.

A better understanding of ecosystem services can provide vital information for decision making by urban planners and designers, to more effectively prioritize land management interventions. For instance, recent activities on mapping and assessing the economic value of urban ecosystems and their services are being driven by the EU Biodiversity Strategy (EC 2011). Several municipalities have begun adopting a 'natural capital' approach towards promoting multifunctional ecosystem services from their UGI, aiming to promote the integration of these values into accounting and reporting systems by 2020. A Green Infrastructure Task Force has been established following the publication of the London Infrastructure Plan 2050, which sets out the infrastructure needs for London over the coming decades (GLA 2016). The plan emphasizes that green infrastructure must be considered as an integral part of the city's vital systems – as essential as the city's transport, energy, water, waste and digital infrastructure.

However, exploring the potential of quantitative and qualitative approaches for assessing ecosystem services is a relatively new science, developing rapidly through a combination of numerical modelling and spatial analysis tools (Busch et al. 2012).

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We reckon this is an essential first step towards establishing sustainable policy strategies for the role of UGI in modifying the ecological footprint of future cities in terms of the available resources to meet the growing demand (Wackernagel et al. 2006). The overall outlook emerging from the available literature is indicative of a strongly supportive role for urban trees in developing a green economy through the provision of benefits to the residential population. These trends parallel those identified in environmental psychology and cultural ecology studies of the effects of gardening and being in nature (Mclain et al. 2012). However, currently there seems to be a greater emphasis on certain categories like water, soil, and biomass and there is still potential for further enhancing the services related to building preservation and promoting the acquisition of material resources in terms of non-timber forest products.

7.4 Conclusions

The creation of high performing urban green infrastructure is integral to the livability of future cities, supporting society's aspiration to achieve harmony with nature and at the same time to meet its growing resource demands. Efforts are being aimed at achieving sustainable management of this infrastructure, to ensure the supply of ecosystem services for the current population and for future generations. Better management of existing green space and the creation of new green areas, both play an important role in any policy that aims to increase the prosperity and quality of life of the urban population. Solutions for sustainable management of UGI should be based on an integrated understanding of the status, operation and modification of the provisioning services offered by green systems. It would be a contribution towards achieving the objectives set out in the operational programs of the EU for developing an economy based on knowledge and innovation and to achieve a higher quality of life. Effective management can enable us to realize a Europe-wide vision of future urban living, with an enhanced utilization of the material flow of nutrition, goods and services directly arising from these components of the UGI.

References

Bentsen P, Lindholst AC, Konijnendijk CC (2010) Reviewing eight years of urban forestry & urban greening: taking stock, looking ahead. Urban For Urban Green 9:273–280

Busch M, La Notte A, Laporte V et al (2012) Potentials of quantitative and qualitative approaches to assessing ecosystem services. Ecol Indic 21:89–103

Colding J, Barthel S (2013) The potential of 'Urban Green Commons' in the resilience building of cities. Ecol Econ 86:156–166

de Groot RS, Wilson M, Boumans RMJ (2002) A typology for the classification, description and valuation of ecosystem functions, goods and services. Ecol Econ 41:393–408

liz.obrien@forestry.gsi.gov.uk

EC (2011) Communication from the Commission to the European Parliament, the Council, the European Economic and Social Committee and the Committee of the Regions — our life insurance, our natural capital: an EU biodiversity strategy to 2020, COM/2011/0244 final, Brussels

EEA (2010) Ecosystem services in the EU: ecosystem services still degrading. European Environment Agency Report, Copenhagen

GLA (2016) Green infrastructure task force report. Greater London Authority, London

Kennedy JJ, Quigley TM (1998) Evolution of USDA Forest Service organizational culture and adaptation issues in embracing an ecosystem management paradigm. Landsc Urban Plan 40(1):113–122

McLain RJ, MacFarland K, Brody L et al. (2012). Gathering in the city: an annotated bibliography and review of the literature about human-plant interactions in urban ecosystems. Gen. Tech. Rep. PNW-GTR-849. US Department of Agriculture, Forest Service, Pacific Northwest Research Station, Portland, p 107

Tyrvainen L, Pauleit S, Seeland K et al. (2005) Chapter 4: Benefits and uses of urban forests and trees. In: Konijnendijk CC, Nilsson K, Randrup, Schipperjin J (ed) Urban forests and trees. Springer, Berlin

United Nations (2012) World urbanization prospects the 2011 revision. World Urbanization Prospects, Department of Economic and Social Affairs, New York

Wackernagel M, Kitzes J, Moran D et al (2006) The ecological footprint of cities and regions: comparing resource availability with resource demand. Environ Urban 18:103–112

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Chapter 8
Biodiversity as Support for Ecosystem Services and Human Wellbeing

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8.1 Introduction

Biodiversity in cities embodies two important relationships: on the one hand, it is strongly influenced and shaped by the urban environment, while on the other it underlies many ecosystem services (ES) that are essential for human wellbeing. These biodiversity-supported services are allocated through a city's green infrastructure, and include, for example, the regulation of microclimate and air quality that is driven by trees and the cultural enrichment of urban landscapes by gardens. Forested areas are frequently regarded as hotspots for both biodiversity and ES, because adding trees to an ecosystem enriches its ecological structure – and thus its

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biodiversity. This effect is further boosted in large forested areas, with multiple tree species of different ages along with decaying wood.

The composition of species which reflects a city's biodiversity is not the same as that found in the surrounding countryside or natural areas – because these species must cope with, and make use of, the urban environment. Consequently, biodiversity in cities has inevitably been shaped by the urban environment, and is composed of a subset of native species, plus a number of exotic ones (Fig. 8.1). This ecological filtering of species works at the functional level. For example, cities have high amounts of dust and thus promote species which thrive on high nutrient levels rather than those which do not; also, their management tends to exclude shrubs, giving a relative advantage to birds that nest in trees rather than bushes. In this chapter, we will show how biodiversity is seen as the basis for ecosystem services and how that biodiversity is important for human wellbeing. Then we will present how biodiversity in cities has been shaped by the urban environment, and how management can boost urban biodiversity – and the services provided by it.

Biodiversity: variability among living organisms and the ecological complexes of which they are part. This includes diversity within species as well as between species and ecosystems (UN 1992), and may relate to taxonomic, ecological, morphological, genetic and functional diversity.

8.2 Biodiversity as the Basis for Ecosystem Services

Cities can be a harsh environment for life, including human life, due to the impact of stressors like atmospheric pollution and noise. Urban green areas, especially forested ones, are seen as a way to alleviate these effects and improve human wellbeing in cities. The vast majority of ecosystem services depend upon biodiversity, and consequently, forested areas in cities maximize these services (Robinson and Lundholm 2012) and also maintain more native species than do non-forest green areas (Croci et al. 2008). It is thus not surprising that the Common International Classification of Ecosystem Services (CICES, developed by the European Environment Agency) includes living beings as direct indicators of ES (Haines-Young and Potschin 2013). These services range from *provision* (e.g. of plant biomass), to *regulation and maintenance* (with most cycles directly regulated by the biota) and *cultural* services. Therefore, the second part of this chapter will show how human wellbeing in cities can be linked to biodiversity in a city's green spaces.

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Fig. 8.1 Urban park area with low intensity management, dominated by exotic species, in Lisboa, Portugal (Photo: Otília Correia)

Aimed at increasing human wellbeing in cities, biodiversity-friendly policies and planning are a win-win solution: while they provide improved conditions for biodiversity, they also have the potential to boost the ecosystem services provided by it. As an example, soil organic carbon is higher in city gardens than in non-domestic green areas or even in countryside agriculture soils (Edmondson et al. 2014) – an effect mediated by plant species found in each area. Nevertheless, the conditions for optimizing biodiversity in cities are not the same for all biological groups. In fact, each biological group is influenced by a number of typical urban environmental factors, such as pollution, and has specific requirements to thrive. Therefore, the third part of this chapter will show how urban biodiversity is shaped by the urban environment and how improving that environment can benefit biodiversity. In general, different species are affected by different environmental constraints, an effect mediated by their functional traits. For example, lichens, birds and mammals with forest-related traits have been shown to be positively influenced by larger green areas surrounded by less dense urbanization, while butterflies seem more influenced by habitat type and quality inside the green area (Pinho et al. 2016). Other environmental factors which might have a negligible impact in the countryside can be a problem in urban ecosystems – as exemplified by city lights, which can act as a barrier to bats crossing at night between gardens (Hale et al. 2015). Thus, managing for improved biodiversity is critical for optimizing the ES provided by forest-base urban green infrastructure, and ultimately for improving human wellbeing.

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Functional diversity: a component of biodiversity that is linked to the range of functions that organisms can perform in communities and ecosystems (Petchey and Gaston 2006). It can be measured by quantifying the value and range of species traits that influence ecosystem functioning (Tilman 2001). ***Functional traits***: are a component of an organism's phenotype that can influence ecosystem processes (Petchey and Gaston 2006). Because functional diversity refers to functions in ecosystems, it is regarded as a way to quantify the influence of biodiversity in ecosystem services (Diaz et al. 2007).

8.3 Urban Biodiversity and Human Wellbeing

An enormous range of benefits to humans can be obtained from the interaction with nature, whether it is indirect, incidental or intentional. Interacting with nature has positive impacts on physiological functioning and health, as well as psychological and spiritual wellbeing, and it also improves the cognitive functions (Fuller et al. 2007). In cities, where the world's population is becoming steadily concentrated and increasingly isolated from nature, interaction with biodiversity in urban green spaces can give city dwellers a sense of relief and escape from urban life. Also, it can promote a sense of place with direct implications for stress alleviation and mental wellbeing. Though the linkage between the interaction with nature and an array of the positive benefits in physical and mental wellbeing (Keniger et al. 2013) is well-established, much less is known about the specific attributes of nature which produce these effects (Keniger et al. 2013). Although this remains to be generalized for all types of green infrastructure, some studies have shown that the amount of tree cover (or urban woodland and forest) can deliver substantial benefits, both for human wellbeing and for urban biodiversity conservation (Dallimer et al. 2014). Moreover, psychological wellbeing measures in cities are closely related not only with the actual level of biodiversity, measured as plant and bird species richness and number of habitats (Fuller et al. 2007), but also with the perceived level of biodiversity (Dallimer et al. 2012).

City dwellers may have close contact with urban forested areas in parks, woods and botanical gardens. These large wooded areas contribute to buffering urban temperatures (see Chap. 2) while impeding water run-off (see Chap. 5) and soil erosion (see Chap. 6). Their woody plant biomass functions as a vehicle for carbon storage (see Chap. 4) and particle filtration (see Chap. 3), contributing to better air quality within the urban area. In addition, these vegetation patches constitute important recreation areas, valued for aesthetic or spiritual reasons, and for social relations, education and scientific purposes. Parks and woods are small green patches that have remained in the urban matrix, and to the extent that local plant species and vegetation structure are maintained, they may be regarded as urban "biodiversity islands" – consisting of semi-natural ecosystems with a mix of exotic and native

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Fig. 8.2 Botanical garden and research centre, Kew Gardens, London, UK (Photo: Pedro Pinho)

species. Spontaneous regeneration contributes to the diversity of trees, shrubs, perennial and annual herbs.

Unlike parks and woods, gardens are created outside natural areas and are neither all nature nor all art, but both. Botanical gardens (Fig. 8.2) in particular, are shaped by botanists to provide visitors with information about plants from different parts of the world, and more recently to contribute to the preservation of native plant biodiversity (Martins-Loução and Gaio-Oliveira 2016). Consequently, they often contain a mix of exotic and native species that are able to co-exist thanks to the intervention of gardeners – whereas in unmanaged settings, such smooth interactions are the cumulative result of long periods during which species adapt to spatial constraints, and undergo a process of gradual acclimation.

8.4 Soil

Soil biodiversity comprises many biological groups, such as bacteria, algae, fungi, protozoa, nematodes, earthworms, mites, beetles, spiders, ants, centipedes and millipedes, slugs and snails, mice, moles, voles and groundhogs. Some types of ES can be intuitively linked to the functioning of the living soil, but the extent of the functional role of soil biodiversity remains largely unknown. This knowledge gap applies to both urban and non-urban soils. When looking at ES provision by soil biodiversity, it is critical to look at the abundance or relative frequency of functional groups.

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For example, eutrophication in agricultural soils has been seen to increase the abundance of bacteria relative to fungi, which likely increases the nitrogen leaching potential of the soils (de Vries et al. 2006). In urban soils the functional types of vegetation greatly influence soil proprieties; thus, promoting the addition of trees, shrubs and litter to eutrophication-prone locations in cities has been suggested to improve soil conditions and to buffer eutrophication (Livesley et al. 2016).

8.5 Lichens and Bryophytes

Lichens are the result of a symbiotic association between a fungus and a green algae and/or cyanobacteria (Fig. 8.3a). They lack roots and cannot regulate their water content: when the air is humid they are wet, and otherwise they dry out. They absorb both nutrients and pollutants from the atmosphere, in direct proportion to their concentration. Species differ in their sensitivity to atmospheric conditions: some are extremely sensitive and disappear with high levels of pollutants or changes in microclimate, while others are more tolerant (Matos et al. 2015). Thus, lichen diversity in urban areas is quite different from that in the countryside, because usually urban areas tend to be more polluted and warmer. The extent to which a green area with trees regulates its microclimate depends on its physical size, and lichen diversity reflects this – with hygrophytic species being more abundant in larger forests (Pinho et al. 2016). Also, smaller species with less surface area are more common in urban areas, while species with three-dimensional growth forms are more typical for the countryside.

Bryophytes are the simplest plants, and, similarly to lichens they lack a root system – so water and nutrients are directly absorbed from their surrounding environment. Although urban environments may not differ significantly from their surroundings in terms of the richness of bryophytes species (Sabovljevic and Sabovljevic 2009), their composition may be different (Stevenson and Hill 2008). In cities, bryophytes respond mainly to local climate, nutrient availability and disturbances. Due to the heat island effect (see Chap. 2), dense life forms such as short turfs and cushions are dominant since they enable a higher desiccation tolerance. The presence of urban forests favors bryophyte richness, which is mainly dependent on habitat and substrate diversity. In Vienna, the size and percentage of green areas in a district were found to influence species richness, but the green area internal patchiness was found to be even more important (Hohenwallner and Zechmeister 2001). Bryophyte diversity is an indicator of air quality, but it also influences the aesthetic value of cities. Due to their capacity to absorb large amounts of particles and water, bryophytes contribute to a reduction of particulate matter, as well as to water retention during flash floods after extreme rain events.

The differential sensitivity of lichens and bryophytes to environmental changes has been used throughout the world to monitor air quality. Lichen species occurring in a certain area can help understand the type and intensity of pollution in that area (Branquinho et al. 2015). For example, the number of lichen species in urban areas

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Fig. 8.3 (**a**) A frequent lichen in cities, tolerant to mildly polluted and warmer sites, *Xanthoria parietina*, Lisboa, Portugal (Photo: Pedro Pinho); (**b**) Wild bee (*Apidae*) pollinating an ornamental garden plant, Almada, Portugal (Photo: Pedro Pinho); (**c**) Southern scarce swallowtail (*Iphiclides feisthamelii*) mating in an exotic tree species (*Jacaranda mimosifolia*) in an urban garden, Almada, Portugal (Photo: Pedro Pinho); (**d**) Red admiral (*Vanessa atalanta*) feeding on a native plant (*Viburnum tinus*) in an urban garden, Almada, Portugal (Photo: Pedro Pinho); (**e**) Bird species resting on a water feature in an urban park. Hyde Park, London, UK (Pedro Pinho); (**f**) Areas with low-intensity management within urban parks are a safe haven for wildlife: Parque da Paz, Almada, Portugal (Photo: Pedro Pinho)

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was used as an ecological indicator of sulphur dioxide (SO_2) pollution from the beginning of the Industrial Revolution until the 1980s, when SO_2 levels decreased drastically due to controlled emissions. Lichens are also sensitive to environmental factors related to microclimate, and thus they can be used as indicators of the urban heat island effect (Munzi et al. 2014).

8.6 Plant-Dwelling Invertebrates

Among the more diverse and important communities of plant-dwelling species are those that live on or in trees. Inhabiting all parts and stages of the tree, including its trunk, roots, bark, canopy, leaves and holes, or in the case of fungi growing on rotten and dead wood, these tree-dwelling invertebrates encompass a large number of species belonging to all trophic levels, from carnivores and herbivores to decomposers, parasites and parasitoids. Carnivorous invertebrates contribute to controlling the populations of possible pests (Stutz and Entling 2011), and herbivore species can be either generalists (i.e. feeding on multiple plant species) or specialists (i.e. feeding on a restricted number plant species). With a relatively high proportion of ornamental woody plants occurring in urban green spaces, the number of specialist herbivore species is particular high compared to the rural areas (Trivellone et al. 2015). Flower dwellers play an important role in pollination (Fig. 8.3b), while leaf litter macro-detritivores control litter diversity effects on decomposition and nutrient cycling (Hättenschwiler and Gasser 2005).

Saproxylic invertebrates, mainly beetles (Grove 2002), strongly depend upon decaying wood and microhabitat bearing trees (Larrieu et al. 2014) or on the presence of other tree-dwelling organisms (Speight 1989). They are the main actors in key ecosystem processes such as wood decomposition and nutrient cycling (Dajoz 2000), and their richness, community composition and genetic diversity depend mainly on tree species identity and distribution (Horak 2011), as well as on the connectivity and management regime of old trees and woody debris (Vandekerkhove et al. 2013). For that reason, removal of dead trees and debris from forested urban areas causes serious problems to saproxylic insects, because their population is liable to recover very slowly, even if later the dead wood levels increase (Vandekerkhove et al. 2013). Because many adult saproxylic invertebrates feed on nectar and sugary items, the distribution and configuration of floral feeding resources (meadows, flowering bushes and trees) in sunny urban areas not more than few hundred meters away from their nesting places are important to maintain viable populations within the urban matrix (Matteson and Gail 2010).

Floral feeding resources are also important for many other plant-dwelling species, such as bees (Fig. 8.3b), wasps, hoverflies and butterflies. Urban butterflies (Fig. 8.3c–d) are a charismatic group appreciated by people, and they are mostly generalist species without very specific habitat requirements and their larvae can feed on a large variety of plants. Together with bees, the presence of a healthy and rich butterfly community in the urban environment is important for flower pollina-

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tion (Fig. 8.3b–d), facilitating garden sustainability and the development of urban agriculture. Butterfly larvae are also an important food source for a variety of other animals, namely other insects and birds. They also have an important cultural value, due to their aesthetic appeal and popularity, and consequently their presence in urban environments represents an opportunity for human interaction with nature.

8.7 Birds and Mammals

Urban birds are the only wild vertebrates that most city dwellers can see and recognize, which makes them especially important for connecting citizens to nature (Fig. 8.3e). In recent decades the improvement of many cities' green infrastructure, along with success in their control of rats, stray cats and dogs – and most importantly, a drastic fall in human persecution – have led to a revolution in urban bird communities. Urban avifauna was once dominated by a few abundant species, like pigeons, sparrows or crows, but nowadays most cities are being colonized by a few medium sized exotics (parrots, mynahs) as well as several native woodland species like blackbirds, jays, or even raptors, like kestrels or falcons (Moller et al. 2012). These species depend on trees for some part of their life cycle (e.g. for building nests or feeding), which makes the functional diversity of birds in large urban parks very different from that in small urban gardens (Pinho et al. 2016). In fact, apart from increasing the extent of green areas, one of the easiest ways to increase bird diversity is to diversify the vegetation structure of parks and gardens.

In comparison to birds, urban mammals are less commonly seen by humans in cities. Still, mammals have an important role in ecosystem structuring and functioning by being population regulators (namely of pests, as in the predation of insects by bats), important seed dispersers (e.g. rodents) and good indicators of the ecosystem integrity (e.g. carnivores). In large cities, forested green spaces are important refuge and connectivity elements for native species. In general, mammals prefer forested parks and woods, although some species (e.g. stone martens in Budapest, Hungary) have adapted their behavior to explore a great variety of urban environments, such as old houses with courtyards (Toth et al. 2009). However, 'wildlife-friendly' management in urban areas may also have deleterious effects on native biodiversity, by facilitating the introduction of exotic species such as the raccoon dog (Kauhala and Kowalczyk 2011) and by being a source of food for invasive predators such as domestic cats (Baker et al. 2008).

8.8 Conclusions and Recommendations

Because biodiversity is the basis for multiple ecosystem services, managing urban ecosystems in a biodiversity-friendly way can optimize the provision of ES in cities and ultimately enhance human wellbeing. Biodiversity also increases the value of

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the urban green infrastructure, creating a win-win situation. In general, the size of the green area and the intensity of its management are key aspects influencing biodiversity (Beninde et al. 2015), and in fact green areas within cities can be successfully planned either as a network of numerous small areas with more intensive management, or as a few larger areas with low-intensity management (Fig. 8.3f). The first option, consisting of multiple small managed forested areas, is important for urban biodiversity both as a series of 'stepping stones' for species with reduced mobility, and in the provision of cultural services by allowing frequent contact between people and nature. However, many works have suggested that providing at least one large patch of semi-natural green space is critical for the accomodation of unique species and functional groups, and is responsible for providing more unique ES (Stott et al. 2015). Mammals, birds, tree dwelling insects and lichens are examples of how important the existence of large forested areas is, especially with low-intensity management. This importance derives from the reduction of human disturbance (Hamberg et al. 2008) and pollution (Coffey and Fahrig 2012; Hale et al. 2015) in larger forested areas.

Because plants are ecosystem elements which are key to the flourishing of all other biological groups, one important way to manage for biodiversity in cities is by managing vegetation. Examples of this management include the use of native plant species to promote birds and butterflies (Chong et al. 2014) (Fig. 8.3d) and the cultivation of low-intensity management areas (Fig. 8.3f) where decaying wood and old trees are not removed (Ikin et al. 2015) and where habitat structures, such as hollow- and cavity-bearing trees (Treby and Castley 2015) can exist. These features are globally recognised as important for wildlife conservation in forests, and for providing important structural heterogeneity in natural and modified landscapes.

References

Baker PJ, Molony SE, Stone E et al (2008) Cats about town: is predation by free-ranging pet cats *Felis catus* likely to affect urban bird populations? Ibis 150:86–99

Beninde J, Veith M, Hochkirch A (2015) Biodiversity in cities needs space: a meta-analysis of factors determining intra-urban biodiversity variation. Ecol Lett 18:581–592

Branquinho C, Matos P, Pinho P (2015) Lichens as ecological indicators to track atmospheric changes: future challenges. In: Lindenmeyer DB, Pierson J, Barton P (eds) Surrogates and indicators in ecology, conservation and environmental managment. CSIRO Publishing, London

Chong KY, Teo SY, Kurukulasuriya B et al (2014) Not all green is as good: different effects of the natural and cultivated components of urban vegetation on bird and butterfly diversity. Biol Conserv 171:299–309

Coffey HMP, Fahrig L (2012) Relative effects of vehicle pollution, moisture and colonization sources on urban lichens. J Appl Ecol 49:1467–1474

Croci S, Butet A, Georges A, Aguejdad R et al (2008) Small urban woodlands as biodiversity conservation hot-spot: a multi-taxon approach. Land Econ 23:1171–1186

Dajoz R (2000) Insects and forests: the role and diversity of insects in the forest environment. Intercept Lavoisier, Paris

liz.obrien@forestry.gsi.gov.uk

Dallimer M, Rouquette JR, Skinner AMJ et al (2012) Contrasting patterns in species richness of birds, butterflies and plants along riparian corridors in an urban landscape. Divers Distrib 18:742–753

Dallimer M, Davies ZG, Irvine KN et al (2014) What personal and environmental factors determine frequency of urban greenspace use? Int J Env Res Pub He 11:7977–7992

de Vries FT, Hoffland E, van Eekeren N et al (2006) Fungal/bacterial ratios in grasslands with contrasting nitrogen management. Soil Biol Biochem 38:2092–2103

Diaz S, Lavorel S, de Bello F et al (2007) Incorporating plant functional diversity effects in ecosystem service assessments. P Natl Acad Sci USA 104:20684–20689

Edmondson JL, Davies ZG, McCormack SA et al (2014) Land-cover effects on soil organic carbon stocks in a European city. Sci Total Environ 472:444–453

Fuller RA, Irvine KN, Devine-Wright P et al (2007) Psychological benefits of greenspace increase with biodiversity. Biol Lett 3:390–394

Grove SJ (2002) The influence of forest management history on the integrity of the saproxylic beetle fauna in an Australian lowland tropical rainforest. Biol Conserv 104:149–171

Haines-Young R, Potschin M (2013) CICES:Towards a common classification of ecosystem services, v. 4.3.European Environment Agency

Hale JD, Fairbrass AJ, Matthews TJ et al (2015) The ecological impact of city lighting scenarios: exploring gap crossing thresholds for urban bats. Glob Chang Biol 21:2467–2478

Hamberg L, Lehvavirta S, Malmivaara-Lamsa M et al (2008) The effects of habitat edges and trampling on understorey vegetation in urban forests in Helsinki, Finland. Appl Veg Sci 11:83–U86

Hättenschwiler S, Gasser P (2005) Soil animals alter plant litter diversity effects on decomposition. P Natl Acad Sci USA 102:1519–1524

Hohenwallner D, Zechmeister HG (2001) Factors influencing bryophyte species richness and populations in urban environments: a case study. Nova Hedwigia 73:87–96

Horak J (2011) Response of saproxylic beetles to tree species composition in a secondary urban forest area. Urban Urban Gree 10:213–222

Ikin K, Le Roux DS, Rayner L et al (2015) Key lessons for achieving biodiversity-sensitive cities and towns. Ecol Manag Restor 16:206–214

Kauhala K, Kowalczyk R (2011) Invasion of the raccoon dog *Nyctereutes procyonoides* in Europe: history of colonization, features behind its success, and threats to native fauna. Curr Zool 57:584–598

Keniger LE, Gaston KJ, Irvine KN et al (2013) What are the benefits of interacting with nature? Int J Env Res Pub He 10:913–935

Larrieu L, Cabanettes A, Brin A et al (2014) Tree microhabitats at the stand scale in montane beech-fir forests: practical information for taxa conservation in forestry. Eur J For Res 133:355–367

Livesley SJ, Ossola A, Threlfall CG et al (2016) Soil carbon and carbon/nitrogen ratio change under tree canopy, tall grass, and turf grass areas of urban green space. J Environ Qual 45:215–223

Martins-Loução MA, Gaio-Oliveira G (2016) New challenges to promote botany's practice using botanic gardens: the case study of the lisbon botanic garden. In: Ansari A, Gill MD (eds) Plant Biodiversity. Assessment and Conservation. CABI Publishers, pp. 1–17

Matos P, Pinho P, Aragón G et al (2015) Lichen traits responding to aridity. J Ecol 103(2):451–458

Matteson KCL, Gail A (2010) Determinates of inner city butterfly and bee species richness. Urban Ecosys 13(3):333–347

Moller AP, Diaz M, Flensted-Jensen E et al (2012) High urban population density of birds reflects their timing of urbanization. Oecol 170:867–875

Munzi S, Correia O, Silva P et al (2014) Lichens as ecological indicators in urban areas: beyond the effects of pollutants. J Appl Ecol 51:1750–1757

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Petchey OL, Gaston KJ (2006) Functional diversity: back to basics and looking forward. Ecol Lett 9:741–758

Pinho P, Correia O, Lecoq M et al (2016) Evaluating green infrastructure in urban environments using a multi-taxa and functional diversity approach. Environ Res 147:601–610

Robinson SL, Lundholm JT (2012) Ecosystem services provided by urban spontaneous vegetation. Urban Ecosyst 15:545–557

Sabovljevic M, Sabovljevic A (2009) Biodiversity within urban areas: a case study on bryophytes of the city of Cologne (NRW, Germany). Plant Biol 143:473–481

Speight MCD (1989) Saproxylic invertebrates and their conservation. Council of Europe, Strasburg

Stevenson CR, Hill MO (2008) Urban myths exploded: results of a bryological survey of King's Lynn (Norfolk, UK). J Bryol 30:12–22

Stott I, Soga M, Inger R et al (2015) Land sparing is crucial for urban ecosystem services. Front Ecol Environ 13:387–393

Stutz S, Entling MH (2011) Effects of the landscape context on aphid-ant-predator interactions on cherry trees. Biol Control 57:37–43

Tilman D (2001) Functional diversity. In: Levin SA (ed) Encyclopaedia of biodiversity. Academic Press, San Diego, pp 109–120

Toth M, Barany A, Kis R (2009) An evaluation of stone marten (*Martes foina*) records in the city of Budapest, Hungary. Acta Zool Acad Sci H 55:199–209

Treby DL, Castley JG (2015) Distribution and abundance of hollow-bearing trees in urban forest fragments. Urban For Urban Gree 14:655–663

Trivellone V, Knop E, Turrini T et al (2015) New and remarkable leafhoppers and planthoppers (Hemiptera: Auchenorrhyncha) from Switzerland. Mitt Schweiz Entomol G 88:273–284

UN (1992) Convention on biological diversity. In: Nations U (ed) Rio de Janeiro, p 214

Vandekerkhove K, Thomaes A, Jonsson BG (2013) Connectivity and fragmentation: island biogeography and metapopulation applied to old-growth elements. In: Kraus D, Krumm F (eds) Integrative approaches as an opportunity for the conservation of forest biodiversity. European Forest Institute, Joensuu, pp 104–115

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Chapter 9
The Cost of Greening: Disservices of Urban Trees

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9.1 Introduction

Urban trees as part of urban forests generate a range of environmental, economic, social and cultural benefits that contribute to the well-being and health of citizens. Nevertheless, sometimes in the development of these functions and ecosystem services (ES), a series of end products that negatively affect the quality of life or costs entailed to the economy and society are produced. The hazards associated with urban trees that can occur alongside ES have been defined by some authors as the cost of the ecosystem, or "ecosystem disservices" (ED) (Lyytimäki and Sipilä 2009; Tomalak et al. 2011). More specifically, they are defined as functions or properties of ecosystems that are perceived as negative for human well-being (Lyytimäki 2014). These nuisances and harmful effects can be derived from the natural functions of trees, such as the loss of leaves or emissions of VOCs and pollen, but they may also be caused by a deliberate manipulation of ecosystems and anthropogenic

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biodiversity management. Sometimes considerable environmental, economic and social damage occurs, which can significantly alter the welfare of the population and the positive net balance of ES.

To determine the extent that these negative effects can have, factors such as context and scale have to be considered (Escobedo et al. 2011), as the same function can be experienced differently by individuals and communities, or change over time and space. This makes it difficult to establish types of ED in relation to ecosystem functions, because even though some of them could have a direct relationship (e.g. pollen emissions and allergy symptoms in sensitive people), in other cases it is the psychological perception of the individual that causes the disservice, e.g. the insecurity or fear of crime experienced by having to go through parks at certain hours (Morris et al. 2011). Furthermore, the same effect can be qualified as a service or disservice depending on the context and the scale. For example, the shade effect provided by trees can be perceived as an ES in areas and localities exposed to many hours of sunshine and high temperatures, and as a disservice in locations where the number of sunshine hours is lower (Lyytimäki 2014).

In this chapter some of the potential negative effects of urban trees are reviewed. These impacts have been clustered into different categories: Environmental-ecological services, Impact on health, Economic costs, and Social hazards, as identified by a number of authors (Escobedo et al. 2011; Roy et al. 2012; Von Döhren and Haase 2015; Gomez-Baggethun and Barton 2013) and summarized in Table 9.1.

Table 9.1 Environmental, ecological, economic, health and social costs related to urban trees (ecosystem disservices)

Environmental/ecological	Health hazards	Economic costs	Social hazards
Pollutant emissions (pollen, BVOCs)	Pollen-related allergies	Maintenance costs[a]	Fear of crime
Water consumption	Insect bites	Costs to repair damage to infrastructure (pavements, side-walks, sanitary pipes, telecommunications)	Fear of animals (insects, rodents, snakes, bats)
Introduction of non-native /invasive species	Toxic/poisonous substances (mushrooms, berries)	Costs of treatment of pests and diseases	Psychological impact caused by trees (sound, smell, behavior)
Displacement of native species	Injuries caused by falling trees/ branches		
Emission of greenhouse gases	Slippages caused by leaves, fruits	Cost to remove remains of pruning, debris, etc.	Disgust caused by plant litter or blocked views
	Reactions caused by agents supported by trees (caterpillars, birds, ticks)		

[a]Extra costs not included in routine management

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9.2 Environmental-Ecological Disservices

This category includes the processes and services that negatively affect regulating ES, such as urban temperature regulation, carbon sequestration and storage, wastewater treatment, pollination or biological control (Sukhdev et al. 2010). Urban trees improve air quality by removing pollutants from the atmosphere, including gases (O_3, SO_2, NO_x, CO) and particulate matter (see also Chap. 3), but under certain circumstances urban vegetation can act as an emitting source of other pollutants (Calfapietra et al. 2013; Cariñanos et al. 2015). Pollen emissions from plants (Fig. 9.1) can be considered as the main source of emission of coarse particulate matter in urban environments. Given that some of the most common trees in European cities are those with a greater capacity for pollen emission, the presence

Fig. 9.1 *Cupressus sempervirens* pollen emissions can alter air quality and affect human health (Photo: Paloma Cariñanos)

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of high concentrations of Biological Particulate Matter (BPM) in urban air can be considered one of the main elements that impair air quality (Cariñanos et al. 2015). To this we must add the lower micron-sized particles resulting from the rupture of pollen grains when exposed to different environmental conditions, so that episodes of air pollution by high levels of biological particles can be relatively frequent throughout the year (Cariñanos et al. 2001).

The emission of Biogenic Volatile Organic Compounds (BVOCs) by some tree species can have serious implications for biosphere-atmosphere interactions (Niinemets and Peñuelas 2008; Calfapietra et al. 2013). The contribution of urban vegetation to the load of BVOCs in the air and the interactions between biogenic emissions and urban pollution, including the likely formation of ozone and photochemical smog, needs to be investigated. At an urban level it is crucial to create tree inventories in order to evaluate the consequences for air quality – but to forecast the formation of pollutants, especially ozone, in cities is very challenging (Calfapietra et al. 2013). This is related to the fact that the emission potential of species within the same genus can be highly variable (Loreto et al. 1998). Another point is that BVOCs can be stimulated or suppressed by environmental factors, in particular temperature, drought, CO_2 and the concentration of air pollutants. These factors vary considerably between urban and rural areas and often within the city itself. This means that the urban environment offers a kind of 'open lab' to study the effects of these changes on BVOC emission by urban vegetation (Calfapietra et al. 2015).

The disproportionate consumption of water necessary for the maintenance of those species that have been inadequately incorporated in sites with incompatible environmental conditions can also be considered as a negative factor (Ferguson 2007). This situation may worsen due to climate change, as there are areas (e.g. the Mediterranean basin), where a significant increase in drought periods is expected (Roloff et al. 2009).

Finally, some of these disservices may be related to anthropogenic biodiversity management whose effects go beyond the local urban level. The introduction of non-native invasive species in urban environments is severely modifying the regulatory capacity of the ecosystem, as they not only threaten biodiversity and displace native species, but they are also a source of pests and diseases (Tubby and Weber 2010).

9.3 Impact on Health

This category considers the disservices that directly or indirectly affect human health in an adverse way. These disservices can be divided into three groups: (1) those derived from the inherent characteristics of trees, (2) those involving air pollutants and meteorological parameters, and (3) those in which the trees serve to support the factor causing harm or discomfort.

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The first group includes the negative effects caused by products which are issued directly by trees, such as BVOCs and pollen grains. It should be noted that susceptibility to allergic reactions caused by the release of allergens from plants into the atmosphere has an incidence of more than 20% amongst the European population (D'Amato et al. 2007). Among the main sources of allergen emissions in urban areas are some of the most commonly used ornamental trees in European cities: *Acer, Cupressus, Pinus*, *Platanus*, *Quercus* and *Tilia*. Health effects are even more serious when in addition to pollen grains, other factors such as elevated atmospheric CO_2 concentrations and elevated air temperature are present (as they often are in urban environments) – since these conditions may increase both pollen production and potential allergenicity (Bartra et al. 2007). This group also includes the toxic and poisonous substances contained in parts of trees such as seeds (e.g. of *Melia* spp. and *Brachychiton* spp.), leaves and corks (*Robinia pseudoacacia*), or the whole plant (such as *Taxus baccata*), which can also be a hazard to health (Tomalak et al. 2011).

Secondly, disservices can be related to air pollutants and meteorological parameters. Whilst there is little information on the direct effect of BVOCs on human health, in the presence of nitrogen oxides (NO_x) BVOCs are the main precursors of photochemical ozone (O_3) production in the troposphere, which is known to be detrimental for human health (Zscheppang et al. 2008). Moreover, ozone acts as a potent greenhouse gas and at current concentrations the ozone radiative forcing is of near-equal magnitude to that of methane, making it the third largest contributor to anthropogenic warming (IPCC 2014).

Thirdly, trees can also indirectly have an impact on health by serving as support for various agents. Examples are the skin reactions to pine caterpillar (Bonamonte et al. 2013) or the expansion of rodents and ticks that find suitable habitats and food availability (Cavia et al. 2009). Trees have also been the cause of numerous personal injuries, both directly by falling branches or whole trees (Calaza-Martínez and Iglesias-Díaz 2016) or from people slipping due to the presence of fleshy fruits or leaves on the ground (Barker 1986).

9.4 Economic Costs

This category considers the monetary costs that potentially arise from disservices which are specifically generated by urban trees – i.e. excluding those incurred in the routine management of urban vegetation. The costs associated with different disservices can be classified into three main groups: (1) direct economic costs, which are intrinsic to the species and mostly stem from an incorrect selection for a particular location; (2) indirect economic costs, including those that are caused by interference with the built environment; and (3) costs associated with health and well-being issues.

The direct economic costs may include the cleaning of pavements from fruit stains or withdrawal of smelly fruit. These costs can be regarded as complementary

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Fig. 9.2 The economic costs for repairing damage caused by interference between urban trees and infrastructure like playground equipment (**a**) or sidewalk paving (**b**) can be very high and variable, and even require diagnostic tools (Photos: Pedro Calaza and Forestry Commission)

to routine maintenance, but it is a disservice caused by the characteristics of the plant material (Soares et al. 2011). Indirect costs include repairing damage to urban infrastructure (Fig. 9.2) such as pavements and sidewalks or networks of water, sanitation and electricity, or special pruning to clear views (e.g., near traffic lights). These costs are highly variable and depend on many factors, not just the species itself, but the type of soil, climate, management or infrastructure construction system (Conway and Yip 2015).

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Much more serious are the unaffordable costs in human lives caused by breakdown and broken trees, such as those that occurred in the city of Madrid in 2015 resulting in several deaths and numerous injuries in some wooded areas. This situation has forced the urgent establishment of programs for management and evaluation of incidents and risk of urban trees, involving both special and specific costs out of annual budgets, as well as compensation for personal injury and property damage (Calaza-Martinez and Iglesias-Díaz 2016).

9.5 Social Problems/Hazards

This category is the most complex. Morris et al. (2011) drew on twenty forest research projects to create a typology of barriers to accessing forests; this included physical and structural barriers occurring both on site (e.g. lack of facilities) and off site (e.g. lack of transport), and socio-cultural and personal barriers such as concerns that forests are not safe (fear of crime), lack of motivation and confidence to visit urban forests and lack of knowledge and awareness of which forests are accessible. This perception of fear as well as personal and social attributes (gender, age, social and cultural strata) can also have an influence on some physical or environmental characteristics (Maruthaveeran and Konijnendijk 2014). For example, an urban green area that is not managed can be perceived not only as unpleasant and ugly, but also as a potential site for a criminal to hide (Lindgren and Nilsen 2012).

Fear related to encounters with animals is another social problem. On one hand, fear may be caused by animals that use trees as habitat, such as rodents, insects, birds, bats and snakes; on the other hand, problems can arise with the presence of wild animals, such as wolves and foxes (Lyytimäki 2014). Stresses on wildlife habitat that cause the territory of such animals to become increasingly restricted, coupled with the ease of finding food in urban areas, means that sightings in cities are no longer rare. A third group of animals that can cause fear are stray animals or those who are released from leashes by their owners when they reach parks (Louza 2007).

9.6 Conclusion

In this chapter we have reviewed some of the undesirable effects that can result from the development of ecosystem functions by urban trees. Given estimates that more than 60% of the world's population will live in cities in the next 25 years, the consideration of these disservices – which if not sufficiently addressed, can alter the net balance of ecosystem services in the urban environment – is critically important. Only by understanding and remedying these issues can we ensure that urban trees will continue to provide welfare and vital benefits to the population, in addition to making healthier, more sustainable and more livable urban ecosystems.

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References

Barker PA (1986) Fruit litter from urban trees. J Arboric 12(12):293–298

Bartra J, Mullol J, del Cuvillo A et al (2007) Air Pollution and allergens. J Invest Allergol Clin Immunol 17:3–8

Bonamonte D, Foli C, Vestita M et al (2013) Skin reactions to pine processionary Caterpillar *Thaumetopea pityocampa* schiff. Sci World J, Article ID 867431

Calaza-Martinez P, Iglesias-Díaz I (2016) The risk of urban trees. Concept, context and evaluation (In Spanish). MundiPrensa, Madrid

Calfapietra C, Fares S, Manes F et al (2013) Role of Biogenic Volatile Organic Compounds (BVOC) emitted by urban trees on ozone concentration in cities: a review. Environ Pollut 183:71–80

Calfapietra C, Niinemets Ü, Peñuelas J (2015) Urban plant physiology: adaptation-mitigation strategies under permanent stress. Trends Plant Sci 20:72–75

Cariñanos P, Prieto JC, Galán C et al (2001) Solid suspended particles affecting the quality of air in urban environments. B Environ Contam Tox 67(3):385–391

Cariñanos P, Adinolfi C, Díaz de la Guardia C et al (2015) Characterization of allergen emission sources in urban areas. J Environ Qual 45:244–252

Cavia R, Cueto GR, Suarez OV (2009) Changes in rodent communities according to the landscape structure in an urban ecosystem. Landsc Urban Plan 90:11–19

Conway TM, Yip V (2015) Residents reactions to urban forest disservices: a case Study of a Major Ice Storm. Working paper, House Lab. Department of Geography. University of Toronto, Canada

D'Amato G, Cecchi L, Bonini S et al. (2007) Allergenic pollen and pollen allergy in Europe. Allergy 62:976–990

Escobedo FJ, Kroeger T, Wagner JE (2011) Urban forests and pollution mitigation: analyzing ecosystem services and disservices. Environ Pollut 159:2078–2087

Ferguson BK (2007) Water conservation methods in urban landscape irrigation: an exploratory overview 1. J Amer Water Res Assoc 23:147–152

Gómez-Baggethun E, Barton DN (2013) Classifying and valuing ecosystem services for urban planning. Ecol Econ 86:235–245

IPCC (2014) Climate change 2014: synthesis report. In: Pachauri RK, Meyer LA (eds) Contribution of working groups I, II and III to the fifth assessment report of the Intergovernmental Panel on Climate Change. IPCC, Geneva

Lindgren T, Nilsen MR (2012) Safety in residential areas. Tijdschr Econ Soc Geogr 2:196–208

Loreto F, Ciccioli P, Brancaleoni E et al (1998) A hypothesis on the evolution of isoprenoid emission by oaks based on the correlation between emission type and Quercus taxonomy. Oecologia 115:302–305

Louza AC (2007) The sharing of urban areas by man and animals. In: Seabro PM (ed) A portrait of state of the art research at the technical university of lisbon. Springer, Dordrecht, pp 479–490

Lyytimäki J (2014) Bad nature: newspaper representations of ecosystem disservices. Urban For Urban Gree 13:418–424

Lyytimäki J, Sipilä M (2009) Hopping on one leg – the challenge of ecosystem disservices for urban green management. Urban For Urban Gree 8:309–315

Maruthaveeran S, Konijnendijk van den Bosch CC (2014) A socio-ecological exploration of fear of crime in urban green spaces – a systematic review. Urban For Urban Gree 13:1–18

Morris J, O'Brien L, Ambrose-Oji B et al (2011) Access for all? Barriers to accessing woodlands and forests in Britain. Local Environ 16:375–396

Niinemets U, Peñuelas J (2008) Gardening and urban landscaping: significant players in global change. Trends Plant Sci 13:60–65

Roloff A, Korn S, Gillner S (2009) The Climate-Species-Matrix to select tree species for urban habitats considering climate change. Urban For Urban Gree 8:295–308

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Roy S, Byrne J, Pickering C (2012) A systematic quantitative review of urban tree benefits, costs, and assessment methods across cities in different climatic zones. Urban For Urban Gree 11:351–363

Soares AL, Rego FC, Mcpherson EG et al (2011) Benefits and costs of street trees in Lisbon, Portugal. Urban For Urban Gree 10:69–78

Sukhdev P, Wittmer H, Schröter-Schlaack C et al (2010) The economics of ecosystems and biodiversity: mainstreaming the economics of nature: a synthesis of the approach, conclusions and recommendations of TEEB, UNEP

Tomalak M, Rossi E, Ferrini F et al. (2011) Negative aspects and hazardous effects of forests environment on human health. In: Nilsson K, Sangster M, Gallis C et al. (eds) Forests, trees and human health. Springer, New York, p 343–374

Tubby KV, Webber JF (2010) Pests and diseases threatening urban trees under a changing climate. Forestry 83:451–459

Von Döhren P, Haase D (2015) Ecosystem disservices research: A review of the state of the art with a focus on cities. Ecol Indic 52:490–497

Zscheppang A, Manes F, La Torre G et al (2008) Methodology for measuring environmental health within Europe. health risk from environmental pollution levels in urban systems (HEREPLUS). Ital J Pub Health 5(4):286–287

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Chapter 10
Case Studies: Modeling the Atmospheric Benefits of Urban Greening

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10.1 Introduction

Urban green infrastructure (UGI) holds the potential to mitigate increasing temperatures as a result of climate change, and vegetation can contribute to urban air quality through air pollution mitigation (Nowak et al. 2006). Along with these environmental benefits, however, the presence of vegetation can have unwanted and unexpected effects on local air quality, for example through the emission of biogenic volatile organic compounds (BVOCs) that can act as precursors of secondary air pollutants (Nowak et al. 2000).

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These processes are all influenced by the nature of air circulation within the urban area, and it has been shown in field campaigns (Kikuchi et al. 2007), wind-tunnel experiments (Gromke and Ruck 2009) and numerical modelling (Mochida et al. 2008; Buccolieri et al. 2009), that the complexity of wind flow in a given urban space is significantly increased in the presence of urban vegetation.

The interactions of UGI with its environment are a consequence of several urban phenomena, which range from microscale processes (10^1–10^2 m), such as the effect of a tree on the atmospheric flow in an avenue or street 'canyon', to mesoscale processes (10^4–10^5 m) that are related to the entire city as differentiated from its surroundings. Local scale (10^2–10^4 m) processes, representing the integrated response of spatially variable 'roughness elements' like buildings and trees, also have to be considered.

In addition to observation-based techniques (e.g. on-site measurements and remote sensing), modeling systems have been developed and are nowadays one of the best tools for quantifying the influences of vegetation on urban climate and air quality, at different scales. Mesoscale atmospheric models, with typical horizontal resolutions ranging from one to hundreds of kilometers, are one of the numerical modeling tools available to study Air Quality (AQ) and the Urban Heat Island (UHI) effect (see Chap. 2). Another option is the use of microscale computational fluid dynamics models (CFD), which allow much smaller spatial resolutions and, therefore, more accurate information within the urban canopy. Mesoscale models' poorer resolution and the parameterization of urban areas allow the study of an entire urban area/region, while the heavy computational costs of a high resolution CFD application, with urban areas being explicitly resolved, only allows the study of a domain of a few hundred squared meters.

Street-canyon models can be applied to specific areas within a city and they are not as computationally expensive as CFD. Pugh et al. (2012), for instance, applied the CiTTy-Street model to calculate the effects of urban vegetation on pollutant concentrations, taking central London as a case study and concluding that increasing deposition by the planting of vegetation in street canyons can reduce street-level concentrations in those canyons by as much as 40% for nitrogen dioxide and 60% for particulate matter.

This chapter gives an overview of the potential uses of urban atmospheric models, covering different spatio-temporal scales and different aspects of environmental ecosystem services (ES) through the presentation of two case studies. The first of these examines the microclimatic (and particularly heat island-related) effects of expanding an existing green area in the city of Porto through numerical simulations conducted with an urbanized mesoscale off-line modeling system. The second case study concerns the simulation of the effect of trees on human exposure to air pollution within a particular urban area, using a CFD model.

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10.2 UGI and Urban Climate

The heat wave of 2003 in Europe has been widely studied, and it is considered to provide a glimpse of what summer conditions could be like under future climate change scenarios (e.g. Schär et al. 2004; Vautard et al. 2007). The 2-day heat wave period of July 31st–August 1st 2003 was selected for the application of a mesoscale meteorological model (WRF-UCM) aiming to evaluate the effect of urban green areas on climate change mitigation in cities, particularly in the Porto urban area, where maximum daily temperature values reached 34 °C. Porto was selected as it stands out as the Portuguese urban area with the smallest share of green (vegetated) and blue (water-based) areas (European Environment Agency 2012), which together with the foreseen increase in the number of warm-humid nights and hot days in the future will likely intensify the UHI effect. The urban area of Porto is also one of the European urban areas that have expanded most in recent decades.

Land use in the Porto study area was characterized using data from the *Urban Atlas* of the European Environment Agency, which provides land use data at high spatial resolution (2.5 m) for large European urban areas (> 100,000 inhabitants). In this study, Porto's City Park was selected as the urban green area to hypothetically expand (Fig. 10.1) in order to study the effects of such an expansion on the local meteorology and heat island intensity.

According to the *Urban Atlas*, the City Park currently has an area of 68.4 ha, divided between 64.9 ha of green areas and 3.5 ha of aquatic surfaces. In the land use change scenario, the green area is enlarged by 80% to a total of 123 ha.

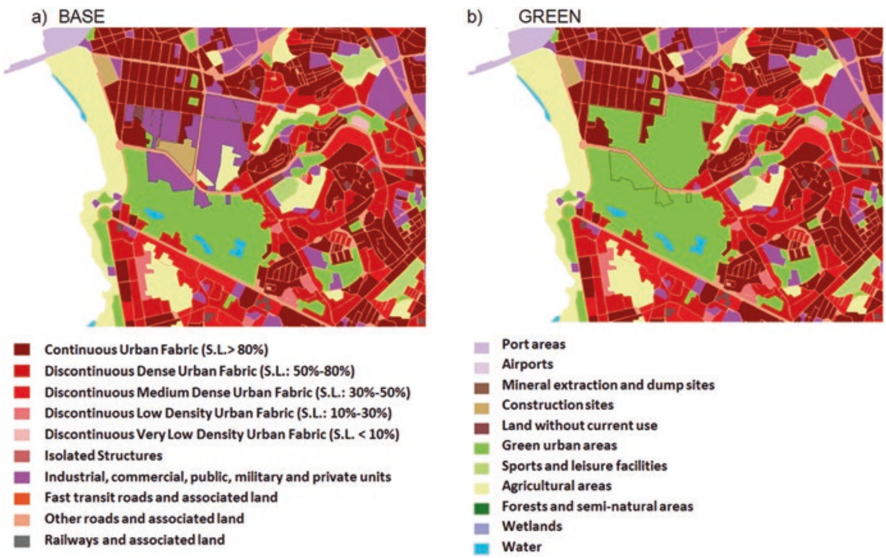

Fig. 10.1 Land use for (**a**) the existing situation (BASE), and for (**b**) a scenario of expansion of the City Park (GREEN) in the city of Porto, Portugal

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This expansion of the City Park is achieved through the conversion of parcels of land adjacent to the park: industrial and commercial areas (45.2 ha), semi-natural and agricultural areas (6.1 ha) and unused land (6.5 ha).

For the mesoscale urban simulation domain, which covered the entire metropolitan area of Porto, the meteorological effects of the City Park expansion were analyzed in terms of differences in air temperature and wind speed and direction between the existing park (BASE) and the expanded park (GREEN – see Fig. 10.1). Figure 10.2 illustrates this temperature difference, highlighting the effect of the expansion of the green infrastructure on the meteorological urban conditions for the entire simulation domain, and indicating in particular the Park intervention area.

The largest decrease of temperatures is simulated in the City Park area, with a maximum reduction of 2.3 °C, while for the remaining domain differences vary between −0.5 °C and +0.2 °C (Fig. 10.2). The simulations show that the GREEN scenario presents lower temperatures during practically the entire simulation period, including during night. Maximum differences reach −1.6 °C and −2.3 °C, corresponding to the maximum daily simulated temperatures, for July 31st and August 1st, respectively. No significant differences in wind speed or direction (varying between NW and NE) were found for the study area, besides an increase of 0.5 m.s^{-1} in the average wind speed, for the GREEN scenario, which probably will not strongly affect human comfort in the area.

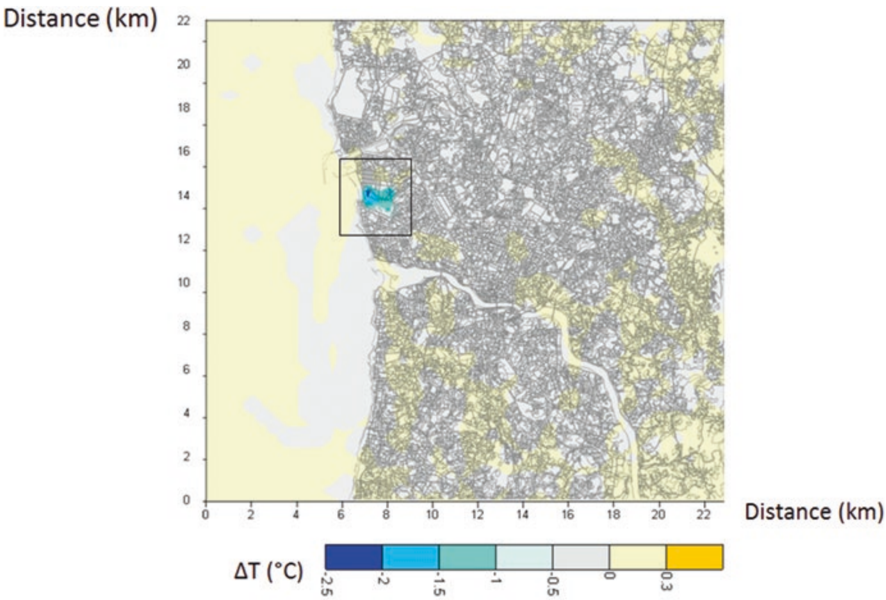

Fig. 10.2 Temperature differences between the GREEN and BASE scenarios for 1st August at 13:00 that correspond to the simulation period for which the maximum differences were found. The *rectangle* indicates the domain as shown in Fig. 10.1

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Although the climatic benefits of the enlarged City Park identified in this modeling study are mainly restricted to the park area and its surroundings, the potential of green urban areas for UHI mitigation should not be neglected. Instead, measures like the one implemented in this work should be combined with other mitigation measures in order to reach the highest mitigation potential. Other measures can be applied as well, such as the widespread use of building-integrated vegetation (e.g. green roofs and walls), or the use of new building and road materials to increase the albedo.

10.3 UGI and Air Quality

Higher temperatures in urban areas are expected to make episodes of air pollution more frequent, by promoting situations of stagnant atmospheric circulation and the formation of photochemical pollutants such as tropospheric ozone. Urban trees can contribute to the removal of air pollutants, and one of the most comprehensive and commonly used models to estimate the magnitude of this contribution is the Urban Forest Effects (UFORE) model developed by Nowak et al. (2006, 2008). This local scale model is designed to use standardized allometric tree data and local hourly air pollution and meteorological data to quantify various urban forest structure ES at the city level. This approach has allowed estimations of total annual air pollution removal in different cities around the world (Bealey et al. 2007; Escobedo and Nowak 2009; Nowak et al. 2006; Paoletti 2009; Yang et al. 2005).

Mesoscale air quality models (or Chemical Transport Models – CTM) offer the advantage of considering both dry and wet deposition and biogenic emissions, together with atmospheric chemistry, dispersion processes, land cover data and emission inventories in order to evaluate the effects of urban vegetation on air quality in a more comprehensive manner. To estimate air pollutant concentrations, the CTM solves a mass balance for each pollutant, taking into account different chemical and physical processes affecting its concentration: emissions, advective transport, turbulent vertical mixing, chemistry and deposition. The main limitation of these mesoscale models to quantify the role of urban vegetation for improving air quality is, however, the limited spatial resolution of the model (usually 1 km x 1 km is the maximum resolution).

Microscale atmospheric models, in particular CFD models, can be an alternative to this limitation. The capability of CFD models to deal with complex geometries and computational meshes, with urban areas being explicitly resolved, allows the simulation of urban green canopies as porous bodies, in opposition to the coarser approach of mesoscale models. Depending on the actual configuration of the canopy, trees can be defined in 3D for individual trees, tree rows (along sidewalks), squares or parks. As such, specific tree traits can be assigned to each individual porous volume describing its geometrical properties, namely: total height, crown dimensions and shape. It is a common practice to consider simplified crown shapes

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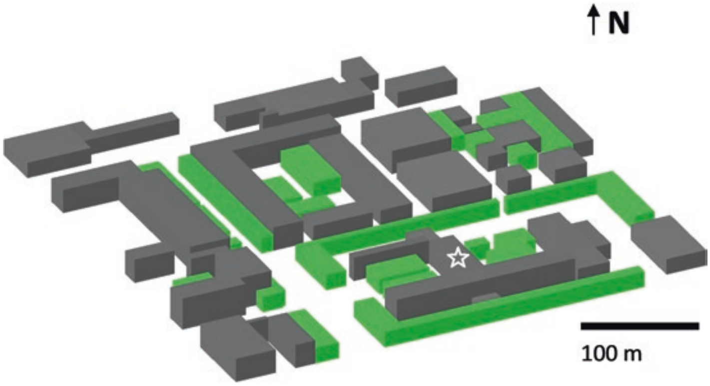

Fig. 10.3 Computational domain generated by VADIS for the set of buildings (in *grey*) and trees (in *green*) for the study area in Aveiro, Portugal. The *star* indicates the location of the school

(spheres, cubes or cuboids), although this is largely dependent on the number of resulting cells and the available computational power.

Modelling approaches can go further, contributing to the assessment of air pollution effects on human health. These health effects are the result of a sequence of events, which includes the release of pollutants, their transport and dispersion in the atmosphere, and their contact with and uptake by humans. Therefore, the use of numerical air quality models allows for estimating the spatial and temporal distribution of air pollutants (Borrego et al. 2006) together with a micro-environment approach (Hertel et al. 2001) for exposure estimation. The particular case study presented here aims to assess the air pollution exposure of students in their morning walk to a High School in Aveiro, a medium-sized town located in central Portugal. For this purpose the CFD model VADIS (Borrego et al. 2003), with its URban VEgetation canopy module – URVE (Amorim et al. 2013a), was applied.

The study domain area has dimensions of approximately 0.4 × 0.2 km, and includes the High School and one of the most important traffic lanes in the town. The 3D configuration of buildings and trees was virtually created in VADIS and the resulting computational domain is shown in Fig. 10.3. For more details on the air quality simulations see Amorim et al. (2013b).

Seven different walking routes to the school were defined (see Fig. 10.4). GPS tracking allowed for realistic estimation of walking speeds for each pathway, and for the effect of potential delays – caused, for example, by traffic lights at road crossings.

In order to evaluate the effects induced by the vegetation canopy, the VADIS modelling system was applied with the URVE vegetation module activated and deactivated. Simulations correspond to the period between 8 and 9 am, representing the start of classes in the morning. Simulated hourly concentrations of carbon monoxide (CO) are shown in Fig. 10.5.

In an inhomogeneous urban canopy, the magnitude of the effect of trees on air quality is mostly determined by the characteristics of buildings and trees and by the

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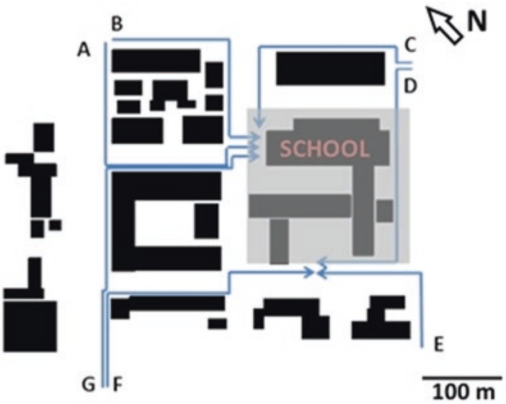
Fig. 10.4 Tracked walking routes (A–G) to school. The *light grey square* indicates the perimeter of the schoolyard, while the school building itself is shown in *dark grey*



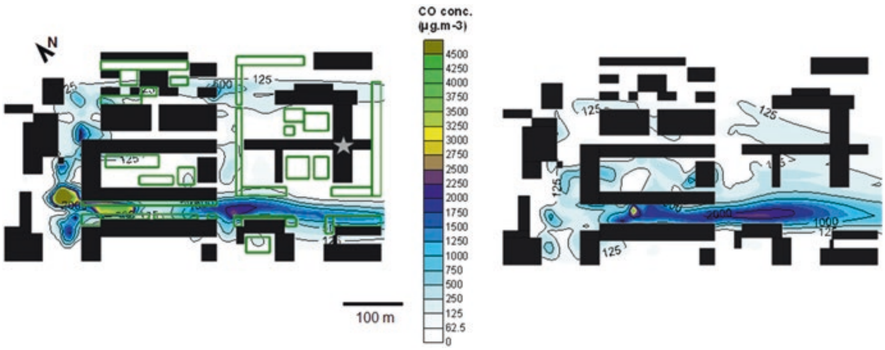


Fig. 10.5 Comparison of ground level carbon monoxide (CO) concentration fields, with (*left*) and without (*right*) the effect of trees (shown in *green*), for the period between 8 and 9 am. The *star* indicates the location of the school

angle between the prevailing wind and the street canyons. This heterogeneous role of trees leads to specific areas benefiting from their action over the wind flow and dispersion, while others have their ventilation capacity diminished (thus promoting the formation of air pollution hot-spots). Fig. 10.5 (left) shows that the CO emitted by traffic in the main avenue is partially 'contained' by the rows of trees in the sidewalks, causing an air quality improvement at the front of the school yard. On the contrary, without the windbreak action induced by trees the pollutant is more easily dispersed into the school, as shown in Fig. 10.5 (right). It should be noted that as a consequence of the 'barrier effect' shown in Fig. 10.5 (left), a clear hot-spot is formed on the left end of the avenue, highlighting the strong spatial heterogeneity of the impact of trees on urban air quality.

By superimposing the pollutant concentration values on the location of the students' walking paths, it is possible to estimate the severity of exposure to CO during their trip to school, with and without the effect of vegetation. Figure 10.6 shows these estimated exposure values for walking routes A to D, which are the ones

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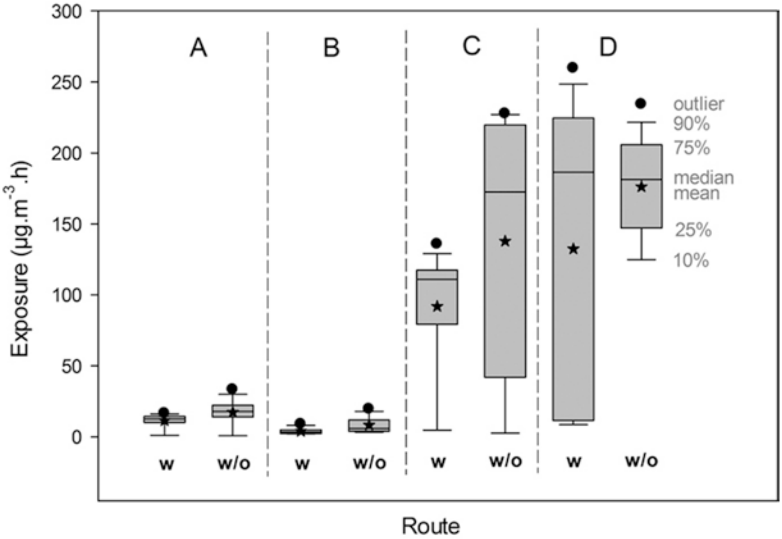

Fig. 10.6 Box plot of the simulated exposure values for each walking route (see Fig. 10.4), comparing the results obtained with (w) and without (w/o) the influence of trees (Amorim et al. 2013b)

mostly used by students. In all routes, the trees promote a decrease in the mean exposure value – and except in D, peak values are decreased by the vegetation as well.

As shown by the CFD simulations, the individual exposure of pedestrians (which is closely linked with the local air quality) is strongly dependent on the synergies between the meteorological conditions, the 3D configuration of the street-canyons and the presence of vegetation. The effect of the urban canopy (as a mosaic of buildings and trees) over the dispersion of air pollutants, and resulting exposure, is complex and highly spatially dependent. The variability of the exposure results obtained in this study indicates the potential error that can be committed when a single value of air quality is used as a surrogate of air pollution exposure. This conclusion is valid for a small domain, such as the one studied in this work, and it can be easily concluded that the error may be significantly higher when larger domains are considered.

10.4 Final Comments

Atmospheric models have the capacity to portray the spatial and temporal fields of weather and air quality variables and to anticipate, in a quantitative way, the effect of different urban planning options on urban climate, urban air quality and human comfort and health. They can, therefore, be used to diagnose the current urban condition in relation to the provision of ecosystem services, to study temporal trends, and to forecast the impact of urban development scenarios and strategies.

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These models can provide climatic information for an entire city, areas within the city or particular urban spaces, accordingly to the type of selected model. Mesoscale weather models, such as the Weather Research and Forecasting (WRF) Model, serve a wide range of meteorological applications across scales from tens of meters to thousands of kilometers. They can be applied to simulate the effect of anticipated climate change in a city, specifically addressing problems like the UHI. Nowadays this type of model can already include the effect of green infrastructure in a city, allowing the user to comparatively evaluate its contribution to urban environmental quality. By driving chemical transport models they are capable of simulating the effect of green areas on air quality, taking into consideration biogenic emissions by vegetation and including the main chemical reactions at mesoscale, in particular simulating the photochemical production of ozone. At the same time, most mesoscale air quality models do not properly include the influence of vegetation behaviour on the atmospheric dynamics. For example, the Jarvis model included in the CHIMERE model to calculate stomatal conductance frequently underestimates high stomatal conductance values (Emberson et al. 2000; Alonso et al. 2008). These numerical mesoscale modelling systems require substantial computational capacities to be applied, and they are not able to simulate entire cities with a fine spatial resolution, which means at the local and micro scale.

Urban vegetated areas can improve wind comfort conditions for most pedestrian activities. Micro-scale models, and in particular CFD models, can simulate the effects of green urban form on local air flow, contributing to the effective design of natural windbreaks such as trees and/or shrubs, promoting the mitigation of wind channeling effects and providing a friendlier environment for pedestrians. In fact, the positioning of these windbreaks is critical as they may also counteract the desired effect, and therefore CFD models have a great potential to deliver information which can assist authorities and stakeholders in their decision-making on urban planning.

Substantial street-level air quality improvements can be gained through action at the scale of a single street canyon or across several street canyons within a city. Models of street-canyon chemistry and deposition can be used to show that the judicious use of enhanced deposition surfaces in concert with the urban form can substantially reduce pollutant concentrations in the part of the atmosphere where people are most likely to be exposed, i.e., at street level in street canyons.

The fact that vegetation may also have detrimental effects on local air quality, and consequently on pedestrian exposure and public health, clearly indicates that detailed exposure studies are worth developing when a planning intervention is envisioned. The simulation of different planning alternatives, in which the position and type of vegetation are explored in terms of their effect on air quality and exposure in combination with various building geometries or neighbourhood designs, should be supported by modelling tools that allow an enhanced understanding of the symbiosis between the city morphology and the population dynamics. This is a needed step towards healthier and sustainable future cities.

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Finally, models specifically developed to help managers and researchers quantitatively describe the structure and functioning of an urban forest (e.g. UFORE) can be very important operational tools to be applied at the urban scale (to the entire city or to particular areas within the city). The UFORE model even offers a monetary valuation of the climate and air pollution mitigation offered by urban forests. Such models can be easily used to improve urban planning and policy management by optimizing the ES provided by urban trees and urban greening in general.

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References

Alonso R, Elvira S, Sanz MJ et al (2008) Sensitivity analysis of a parameterization of the stomatal component of the DO3SE model for *Quercus ilex* to estimate ozone fluxes. Environ Pollut 155:473–480

Amorim JH, Rodrigues V, Tavares R et al (2013a) CFD modelling of the aerodynamic effect of trees on urban air pollution dispersion. Sci Total Environ 461-462:541–551

Amorim JH, Valente J, Cascão P et al (2013b) Pedestrian exposure to air pollution in cities: modelling the effect of roadside trees. Adv Meteorol. doi:10.1155/2013/964904

Bealey WJ, McDonald AG, Nemitz E et al (2007) Estimating the reduction of urban PM10 concentrations by trees within an environmental information system for planners. J Environ Manag 85:44–58

Borrego C, Tchepel O, Costa AM et al (2003) Emission and dispersion modelling of Lisbon air quality at local scale. Atmos Environ 37:5197–5205

Borrego C, Tchepel O, Costa AM et al (2006) Traffic-related particulate air pollution exposure in urban areas. Atmos Environ 40:7205–7214

Buccolieri R, Gromke C, Di Sabatino S et al (2009) Aerodynamic effects of trees on pollutant concentration in street canyons. Sci Total Environ 407(19):5247–5256

Emberson LD, Wieser G, Ashmore MR (2000) Modelling of stomatal conductance and ozone flux of Norway spruce: comparison with field data. Environ Pollut 109(3):393–402

Escobedo FJ, Nowak DJ (2009) Spatial heterogeneity and air pollution removal by an urban forest. Landsc Urban Plan 90:102–110

European Environment Agency (2012) Urban adaptation to climate change in Europe: Challenges and opportunities for cities together with supportive national and European policies. Report No 2/2012, Copenhagen

Gromke C, Ruck B (2009) On the impact of trees on dispersion processes of traffic emissions in street canyons. Bound-Layer Meteorol 131(1):19–34

Hertel O, de Leeuw F, Raaschou-Nielsen O et al (2001) Human exposure to outdoor air pollution (IUPAC technical report). Pure Appl Chem 73(6):933–958

Kikuchi A, Hataya N, Mochida A et al (2007) Field study of the influences of roadside trees and moving automobiles on turbulent diffusion of air pollutants and thermal environment in urban street canyons. In: Proceedings of the 6th international conference on Indoor Air Quality, Ventilation and Energy Conservation in Buildings (IAQVEC '07), Sendai, Japan, pp 137–144

Mochida A, Tabata Y, Iwata T et al (2008) Examining tree canopy models for CFD prediction of wind environment at pedestrian level. J Wind Eng Ind Aerodyn 96(10–11):1667–1677

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Nowak DJ, Civerolo KL, Rao ST et al (2000) A modeling study of the impact of urban trees on ozone. Atmos Environ 34:1610–1613

Nowak DJ, Crane DE, Stevens JC (2006) Air pollution removal by urban trees and shrubs in the United States. Urban For Urban Gree 4:115–123

Nowak DJ, Crane DE, Stevens JC et al (2008) A ground-based method of assessing urban forest structure and ecosystem services. Arboricult Urban For 34:347–358

Paoletti E (2009) Ozone and urban forests in Italy. Environ Pollut 157:1506–1512

Pugh T, MacKenzie R, Whyatt J et al (2012) Effectiveness of green infrastructure for improvement of air quality in urban street canyons. Environ Sci Technol 46:7692–7699

Schär C, Vidal PL, Lüthi D et al (2004) The role of increasing temperature variability in European summer heatwaves. Nature 427:332–336

Vautard R, Beekman M, Desplat J et al (2007) Air quality in Europe during the summer of 2003 as a prototype of air quality in a warmer climate. Compt Rendus Geosci 339:747–763

Yang J, McBride J, Zhou J et al (2005) The urban forest in Beijing and its role in air pollution reduction. Urban For Urban Gree 3:65–78

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Chapter 11
Assessing the Ecosystem Services Deliverable: The Critical Role of the Urban Tree Inventory

Naomi Zürcher

The tree in front of my home is a word,
the trees on my street are a sentence,
the trees in my neighborhood are a paragraph
and all the trees in the community are a story.
That story tells us about our relationship to nature, past and present.
The future of this story lies in the hands of all residents…

– Greg McPherson, USDA Forest Service

With the ever-increasing urbanization of Europe and its impact on people's quality of life, there is a heightened awareness of the important role played by the Urban Forest in delivering essential ecosystem services. This, in turn, has highlighted the need to assess the actual ability of the Urban Forest resource to provide these tangible "deliverables".

Given that the Urban Forest is a living resource, its critical needs must be met if we are to realize the benefits the Urban Forest can yield. Management of any tangible resource usually begins with an assessment of what already exists, and that is no less true for the green resource. In fact, it is the essential first step in developing an Urban Forest Strategic Plan. Regardless of the questions that policy makers, planners or urban foresters might pose from their varied perspectives, answers can only be provided if the resource has been accurately quantified. Quantifying begins with an urban tree inventory – from deciding on objectives and the appropriate type of inventory, to using the resulting data for management: in policy-making, land use planning, design, maintenance and valuation of ecosystem services (ES).

Urban Forests and related green infrastructure (GI) are normally managed and maintained by the municipality in which they are located, and thus, a detailed urban tree inventory would usually be conducted at that municipal level. Initially, inventories were conducted to facilitate some aspect of management that was maintenance

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oriented and / or to reduce the incidence of public tree failure, especially its impact on life and property. Inventories were and still are very helpful in determining which trees are dead or in need of maintenance interventions such as pruning, which in turn aids in identifying and scheduling tree work. In addition, they can provide information on the tree resource (e.g. species diversity) and on the spatial resource (e.g. available planting locations).

More recently, the focus on ecosystem services has spurred interest in methodologies that can be used for valuing the Urban Forest resource in terms of its ES functions. Knowing specifically what exists can:

- help develop remediation between ecosystem services and disservices,
- assist planners and landscape architects with greater specificity in terms of land use and design, and
- create a basis for informed official policies that consider the needs of trees and their associates.

Inventories can be time-consuming and costly, depending on how the data are collected and by whom. Thus the importance of determining all potential uses of the collected data cannot be stressed enough. Before any urban tree inventory is undertaken, it is critical to first determine its objectives by answering the questions "Why do we need an inventory?" and "What will the resulting data be used for?"

An inventory establishes the state of our Urban Forest. Therefore, all relevant professionals should be at the inventory strategy table – from policy-makers, planners and landscape architects to urban foresters, arborists / consulting arborists and green NGO program leaders. The Urban Forest, as a public resource, belongs to everyone and if it is to be a well-managed, healthy resource, it will take an informed and invested constituency to make this possible.

11.1 Types of Inventories: Pros and Cons

There are several types of inventories which have been researched for their accuracy and discussed at length in both the scientific and practitioner literature. A thorough discussion was offered by Smiley and Baker (1988) in "Options in Street Tree Inventories", which classified inventories into four functional types.

1. *Specific Problem Inventories* are geared toward risk assessment for trees which are seen as potential hazards. This type of inventory can be done quickly and has the narrowest focus. Because of its methodology however, it can often miss problems, which if left unattended can lead to risk. In addition, it is employing the municipality's personnel resources to obtain only minimal data.
2. *Partial Inventories* represent sampling approaches, as exemplified by "windshield" (drive-by) or "on-ground" techniques. They can be cost-effective in situations where a complete inventory cannot be funded or a complete dataset is not warranted. However, the sample collected is just an estimate of the area's resource and as such, may provide an inaccurate picture of the total resource.

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In addition, specific location information is usually not included in a sampling, which makes the resulting data less applicable to planning future plantings and assessing the demands of required maintenance.

3. *Complete Inventories* examine the entire urban tree resource within a specified area, and they are therefore the most costly of all inventory types. Trained volunteers can be used to offset some of the costs, but if the inventory is to be truly complete in terms of the data collected, volunteers should be accompanied by tree experts to verify species information and to perform the condition/risk assessment. These ground-based inventories also take the longest to complete, although the targeted area can be broken down into sections.
4. *Cover Type Surveys* can be used to facilitate land-use planning, and when aided by aerial imagery, are an excellent method for determining the cover extent for the entire resource, including private property. Such surveys, however, do not provide the structural data that is critical for Urban Forest management. Valuation methodologies, such as i-Tree, offer the ability to 'combine apples and pears' – i.e. sample data can be combined with complete inventory data which, when using data to determine value outputs, would provide a much more complete picture of the entire resource.[1]

11.2 What Data Should Be Collected

Regardless of the objectives of the inventory, a compilation of certain basic data relating to the Urban Forest's structure is critical, not only to establish management priorities and assess benefit functions but to establish a cost-benefit analysis. Table 11.1 summarizes the absolute basic data required as well as additional crucial data for both management and valuation methodology implementation. Also included are recommendations for subsequent occurrences that are essential additions for monitoring and maintaining an Urban Forest.

11.3 Decisions, Decisions: What the Collected Data Can Accomplish

Invariably, it is the objectives that have been decided on which will determine the information that needs to be obtained and the amount of detail to be included. In developing a list of objectives, the larger demands of Best Management Practices need to be part of the discussion so the resulting decisions are based on an informed

[1] Numerous additional steps would have to be taken to manually combine the two sets of data, and an analysis of costs versus benefits would determine if the potential outcomes would warrant the expense (Personal communication with Dr. David Nowak, i-Tree Program Leader, USDA Forest Service).

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Table 11.1 Inventory data to be collected for the purpose of management and valuation

Inventory Data to be Collected	Basic Data	Additional Essential Data	Subsequent Management Data
Location			
Physical - the address being surveyed	✔		
GPS coordinates for GIS mapping	✔		
Spatial Resource: Site Characteristics / Condition			
Land use or site class	✔		
Planting area type			
• tree lawn / grass strip		✔	
• curbside cutout		✔	
• street mall / median strip		✔	
• parking island		✔	
• urban park		✔	
• open field		✔	
• urban woodland		✔	
Planting area dimension		✔	
Planting area treatment			
• open accessible soil volume		✔	
• permeable or impermeable pavement / surface		✔	
• ground cover		✔	
• open landscape		✔	
Paved walkway condition		✔	
Amount of street traffic		✔	
Presence of overhead wires		✔	
Presence of underground utilities		✔	
Adjacent use			
• buildings including type and size (e.g. single/multi-family residence, business, etc.)		✔	
• parking lot		✔	
• public or private green space		✔	
• vacant land		✔	
Tree Resource: Current			
General Tree Metrics			
• Genus and species + cultivar or variety, if known	✔		
• DBH (diameter at breast height, specific or class)	✔		
• estimated height as well as height of the bole		✔	
• canopy cover / crown diameter using aerial photos		✔	
• proximity to buildings		✔	

(continued)

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Table 11.1 (continued)

Condition			
• incremental annual growth		✔	
• percentage of dieback		✔	
• risk assessment and rating	✔		
• mechanical injury		✔	
• pathogens	✔		
• abiotic impacts		✔	
• condition notes (e.g.specific observations affecting maintenance)		✔	
Conflicts with infrastructure			
• pavement	✔		
• buildings	✔		
• overhead wires	✔		
• street / roadway signage	✔		
• street / roadway lighting	✔		
Actions recommended			
• maintenance, e.g. pruning	✔		
• removal	✔		
• risk mitigation	✔		
Tree Resource: Subsequent			
New Planting Data			
• GPS / GIS coordinates			✔
• Genus, species, cultivar / variety			✔
• Provenance, if known			✔
• date planted			✔
• caliper / height at planting			✔
• production type e.g. field grown, container grown			✔
• package type e.g. balled-and-burlapped, bare root, container specifics			✔
Public Construction Project Inventory Data (to be submitted at Project conclusion)			
• GPS / GIS coordinates			✔
• Genus, species, cultivar / variety if known			✔
• planned intervention e.g. clearance pruning, root pruning, transplanting, irrigation, removal, including dates of occurrence			✔
• documented - dated construction impacts / mitigation (e.g. soil compaction)			✔

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body of knowledge. Good quality tree information, gleaned from tree surveys, is a key ingredient of sustainable urban forestry (Dwyer et al. 2003) – and sustainable urban forestry is a pre-requisite for enhancing the ES deliverable.

- Scheduled maintenance of the resource is a critical reality, given the dynamic stress that the human population imposes on it. The capacity to determine maintenance needs must be based on accurate structural data.
- The ability to compare species' success or failure rates in relation to the spatial resource can help guide future planting decisions. Many urban sites have extreme spatial limitations. While it is difficult to assess the probability of an individual tree's potential to break out of the confines of such limited rooting space, a determination based on a larger sampling for each species can allow some generalization of species-specific tolerance for constrained sites. This information and the resulting analysis could and should be used to guide species selection for future plantings. In addition, spatial resource intolerance on the part of some species should also guide an approach to improving these sites, facilitating a wider selection palette.
- Determining viable tree planting locations that will actually support health and therefore, long term growth, is critical to realizing environmental benefits.
- Post-inventory incorporation of all new planting data is needed in order to have a better understanding of tree responses to varying abiotic situations and circumstances, and to improve survivability and sustainability. We also need to be able to share this data on a global scale. Capturing at-planting data informs comparisons in growth rate, species-specific site adaptation and thus, survivability.
- Public infrastructure construction inventory data should be incorporated, helping to maintain up-to-date records as well as documenting construction impacts/ mitigation procedures.

11.4 How Should the Data Be Collected: The Use of GPS/ GIS Technology

The incorporation of GPS (Global Positioning System) and GIS (Geographic Information System) technologies into urban tree surveys was initiated in the late 1990s (Widdicombe and Carlisle 1999). Because of the importance of precision in urban tree data collection, combined with the increased availability and greater affordability of GPS and GIS software programs, computer-driven technology should be routinely integrated into urban tree field assessments to record the locations of trees with reference to a local coordinate system. The spatial data collected with GPS can then be readily transferred to a land-oriented GIS software program which can be used to construct GIS map layers representing trees and the surrounding spatial resource and also to create a GIS database for all data collected including the Ordnance Survey map coordinates.

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There are clearly additional expenditures attached to such an endeavor, given the time required to create and maintain the database. At the same time, a cost-benefit analysis is likely to show that the additional costs are justified by a number of distinct advantages:

- Planning for future land use and / or planting sites using digitized spatial data can proceed much more efficiently based on sharable accurate and current data.
- Presenting an enhanced green overview gives land use planners the ability to visualize an entire city's Urban Forest, and in turn, to provide a more informed assessment of proposed development and its probable impact on specific neighborhoods as well as an urban area in its entirety.
- The potential to compare and analyze species success or failure rates, as they relate to the spatial resource and maintenance history, is significant.
- Documentation of observable site impacts and conflicts can assist with anticipating potential risk issues.
- Accurate tree location and real time tree size data facilitates the planning, design and construction of public infrastructure, providing an increased possibility to preserve and protect trees within the proposed work footprint.
- Computerized in-the-field access to the dataset during any and all field operations affords an ability to continually update the data records without additional cost.
- Maintenance tasks, e.g. pruning or removals, can be sorted by priority and / or location and scheduled through the software, reducing staff time and enabling proactive maintenance and its documentation.
- Computerized access to the dataset is also a Public Relations asset, facilitating response to residents' calls regarding tree issues, promoting confidence in the management team and the Standards and Protocols they work with.
- Access to digitized species composition data greatly enhances the ability to manage infestations / disease epidemics such as Asian Longhorned Beetle or Chalara Dieback of Ash, by expediting the identification of host tree planting locations.

An excellent comparison of internationally-available urban tree inventory software packages was originally produced by the USDA Urban Forestry South (2009), offering a thorough evaluation of the capabilities of various systems. More recently, the USDA Northeastern Area State & Private Forestry (2014) updated the list of available commercial and freeware software packages with current links to all products.

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11.5 Standardizing the Approach: Facilitating the International Sharing of Data

The extent of global environmental phenomena – how we impact each other across vast distances – combined with the urbanization of rural locations and the ever increasing population shift to urban centers, has brought the study of the Urban Forest to the fore in many parts of the world.

The interest in inclusion of data on urban tree resources at the national and international levels, as well as the anticipated roll-out of the i-Tree Europe Valuation Methodology freeware by 2017, has added impetus to the need for a standardized approach to data collection and dissemination. Such standardization can facilitate ongoing research and address environmental issues, globally as well as locally – for instance:

- Standardizing the collected data, especially on individually planted urban trees, would greatly enhance the global effort to evaluate and value the Urban Forest resource.
- Extensive Urban Forest research has been conducted worldwide, but the lack of a common language has made much of it inaccessible globally and has set the stage for unnecessary duplication.
- There is a growing interest in quantifying carbon stocks, but the expression of this data varies from country to country, impeding the sharing of data and researchers' global calculations to move this effort forwards.
- Standardized measurement criteria are needed to monitor tree growth and to identify the effects of drought, flooding or climatic changes over the life of a tree. At-planting (caliper / height) and field inventory (DBH) measurements, for example, must have standardized measurement locations to increase the accuracy and sharing of the data collected.
- The extensive research on urban-tolerant tree species has instigated the use of these species internationally, regardless of their origins. Standardizing the codes used to represent Genus, species and cultivar/variety would facilitate a greater understanding of data outputs on these species.

11.6 Conclusions

The ability to truly quantify the entire Urban Forest resource is a process in which an understanding of the "urban" aspect is essential. Although almost all trees that exist in an Urban Forest originate in a forest somewhere in the world, the importance of species origin must share the stage with the equal importance of the urban center dynamic and its inherent impacts on the life of an urbanized tree. The bottom line for human health and well-being is that we can't survive urban stresses without

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our urban trees and they can't survive, thrive and provide ES benefits for us if we don't provide for their health and well-being.

The relevance of this exchange, between humans as stewards and urban trees as benefactors, needs to drive the planning, design and management of this resource that is so integrally connected to our quality of life. For this to occur, it is inherent upon us to inventory and assess the resource – our urban trees. If the specifics of what we have are not known, we cannot proceed with a viable strategic plan. While traditional forests can thrive without human intervention, trees planted within an urban setting require informed stewardship to create the healthy and viable Urban Forest so critical to urban living.

A thorough ground-based inventory, incorporating all the data that has been recommended, will provide the necessary foundation for implementation of Best Management Practices, the development of an Urban Forest Strategic Plan, facilitation of valuation methodology quantification and a thorough cost-benefit analysis. It will also provide an increasing recognition of the environmental, economic and social benefits of the entire Urban Forest – not just forest remnants within an urban footprint or those areas classified as peri-urban, but the individual trees planted in and around communities and the wide array of benefits they contribute. A healthy Urban Forest is an initiator of health and well-being amongst all the Urban Forest's associates, especially us.

> *Respect trees – trees have dignity too.*
> *Learn about trees and their associates*
> *so that you can help make better decisions*
> *for their long-term, high quality survival.*
> – Dr. Alex Shigo, father of Modern Arboriculture

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References

Dwyer JF, Nowak DJ, Noble MH (2003) Sustaining urban forests. J Arboric 29(1):49–55

Smiley ET, Baker FA (1988) Options in street tree inventories. J Arboric 14(2):36–42

USDA Urban Forestry South (2009) Comparison of urban forest inventory & management software systems. http://www.urbanforestrysouth.org/resources/library/citations/comparison-of-urban-forest-inventory-management-software-systems. Accessed 2 Aug 2016

USDA Northeastern Area State & Private Forestry (2014) Tree inventory and management software. http://www.na.fs.fed.us/urban/inforesources/inventory/Tree%20Inventory%20and%20Management%20Software%20-%20October%202014.pdf. Accessed 2 Aug 2016

Widdicombe RC, Carlisle B (1999) Geographic information and global positioning systems for tree management. J Arboric 25(3):175–178

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Additional Bibliography

American Public Works Association (2011) Urban forestry best management practices for public works managers: urban forest management plan. https://www2.apwa.net/Documents/About/CoopAgreements/UrbanForestry/UrbanForestry-2.pdf. Accessed. 25 Sept 2016

Climate Action Reserve (2014) Urban forest management quantification guidance. June 2014. http://www.climateactionreserve.org/how/protocols/urban-forest/. Accessed 25 Sept 2016

North Carolina Forest Service (2015) Urban & community tree inventories. http://ncforestservice.gov/Urban/urban_tree_inventories.htm. Accessed 23 Sep 2016

Nowak DJ (2008) Assessing urban forest structure: summary and conclusions. Arboriculture & Urban Forestry 34(6):391–392

Shafer L (2014) Urban tree monitoring protocols: field manual for the minimum data set draft, urban tree growth & longevity, May 2014. http://www.urbantreegrowth.org/field-guide.html. Accessed 18 Aug 2016

The Tree & Design Action Group (2012) Trees in the townscape: a guide for decision-makers. http://www.tdag.org.uk/uploads/4/2/8/0/4280686/tdag_treesinthetownscape.pdf. Accessed 12 Aug 2016

The Tree & Design Action Group (2014) Trees in hard landscapes. http://www.tdag.org.uk/uploads/4/2/8/0/4280686/tdag_trees-in-hard-landscapes_september_2014_colour.pdf. Accessed 18 Aug 2016

Urban Forestry Standards (2010) A field guide: standards for urban forestry data collection, Draft 2.0. http://www.unri.org/standards/wp-content/uploads/2010/08/Version-2.0-082010.pdf. Accessed 25 Sept 2016

Vogt JM, Mincey SK, Fischer BC et al (2014) Planted tree re-inventory protocol, Bloomington Urban Forestry Research Group at the Center for the Study of Institutions Populations and Environmental Change. https://www.indiana.edu/~cipec/research/bufrg_publications.php Accessed 12 Aug 2016

Vogt JM, Watkins SL, Mincey SK et al (2015) Explaining planted-tree survival and growth in urban neighborhoods: a social-ecological approach to studying recently-planted trees in Indianapolis. Landsc Urban Plan 136:130–143

Wagar JA, Smiley ET (1990) Computer assisted management of urban trees. J Arboric 16(8):209–215

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Chapter 12
Species-Specific Information for Enhancing Ecosystem Services

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Understanding the multiple processes involved in the interactions between urban trees and their surrounding environment is of the utmost importance to determine the relationship between them and to assess what might happen under altered conditions such as those imposed by climate change or by increasing concentrations of air pollutants. In order to meet this objective and to evaluate the impact on different ecosystem services they provide, the numerous interactions between trees and their urban environment have to be considered holistically.

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Because planting new trees in cities is just not a simple action –space is limited and needs are crucial – and trees do not exist in a void, we do not just want to plant *any* tree. We want to plant the *right* tree - the one that is most appropriate. In a typical urban setting, this means a tree that requires minimal management, can tolerate limited space, does not produce annoying litter and feeds our urban bees. But the successful candidate tree should also be able to address the major environmental issues at hand at that particular place, such as enhancing thermal comfort, mitigating air pollution, supporting biodiversity or contributing to stormwater alleviation. Moreover, as we want to solve problems and not create additional ones, care needs to be taken that the species of our choice does not introduce major disservices that could overwhelm their associated positive benefits.

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To help urban foresters, decision makers, urban planners, landscape architects, arborists, scientists and citizens in making informed choices, we have summarized in Table 12.1 the attributes of 150 of the most important urban tree species in Europe for their contribution to various environmental ecosystem services and disservices – as discussed in the preceding chapters.

The urban tree species list presented here is the result of a unique combination of information reported in scientific literature, data provided by urban green services and expert judgment. As a first step, we compiled a list of approximately 300 urban tree and shrub species common in Europe. This list was distributed to scientists involved in urban forestry, primarily from an environmental perspective, from all over Europe. These scientists were asked to indicate the 50 most important urban tree species for their climatic zones. Based on more than 700 'votes', the list presented here contains the 150 most frequently indicated species.

Although the norm for the list is the species level, we sometimes added varieties or subspecies as either they are the only ones available in the trade, the species is prone to many diseases or they are the only varieties used in urban environments, e.g. *Gleditsia triacanthos var. inermis*. The variety 'inermis' is the only commercially available one suitable for an urban environment because it has no thorns, whereas the species as such has very long, dangerous thorns along the entire trunk, which is obviously a less desired characteristic in urban environments.

Also, some species were added which are not commonly used in European cities, but which are available and have shown to be well suited as urban species in other regions, such as *Gymnocladus dioicus* and *Cercidiphyllum japonicum*.

In a final step, several species were eliminated from the list as they were judged to be shrubs, while the focus of the list is trees, i.e. *Juniperus communis*, *Hibiscus syriacus* and *Corylus avellana*.

Moreover, *Magnolia grandiflora* and *Magnolia kobus* were grouped into *Magnolia* spp. as the differences between them were minimal except for their evergreen/deciduous character. *Betula jacquemontii* was removed as this is not a species but rather a variety of *B. utilis*.

Some species were retained on the list because they can be commonly found, although they are less suited for urban environments and are thus not recommended for planting. These are:

– *Ailanthus altissima*: a weed tree wherever it appears, threatening less aggressive as well as native species, being highly invasive and extremely weak-wooded;
– *Crataegus monogyna*: susceptible to an array of leaf diseases, having rooting problems in urban environments and fairly thorny; and
– *Eleagnus angustifolia*: more of a large shrub than a small tree and requires extensive pruning while young to have a viable tree form; susceptible to a number of diseases, especially verticillium wilt.

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Table 12.1 Catalog of common and potential urban tree species in Europe, and their ecosystem More detailed information on how to read, interpret and understand the table is given in the this

Species	General tree characteristics			Contribution to environmental ecosystem services			
Scientific name	Hardiness	Soil pH	Drought tolerance	Microclimate regulation	Air pollution mitigation	Soil quality	Net CO_2-sequestration
Acer buergerianum (D)	6b–8	<7.0	Moderate	H			
Acer campestre (D)	5–8	<5.5–>7.5	High	M	High	Moderate	Low
Acer negundo (D)	4–8	<7.5	Low	H	Moderate	Moderate	Moderate
Acer platanoides (D)	4–7	<5.5–<7.5	Moderate	H	Moderate	Moderate	Moderate
Acer pseudoplatanus (D)	4–7	<5.5–<7.5	Moderate	H	Moderate	Moderate	Moderate
Acer rubrum (D)	4–9	<5.5–<7.0	Low	H	High		Moderate
Acer saccharinum (D)	5b–8	<7.0	NT	H	Moderate	Moderate	Moderate
Acer tataricum ssp. ginnala (D)	4–8	<7.5	Moderate	M	Moderate	Moderate	Moderate
Aesculus hippocastanum (D)	4–7	<5.5–<7.5	NT	H	Moderate	Moderate	High
Aesculus x carnea (D)	6b–7	<5.5–<7.5	Low	H	Low		High
Ailanthus altissima (D)	6b–8	<5.5–>8.0		H	Low	Moderate	High
Albizia julibrissin (D)	7b–9	<5.5–>8.0	Low	L		Moderate	Moderate
Alnus cordata (D)	6b–?	<5.5–<7.5		M			High
Alnus glutinosa (D)	3–7	<5.5–<7.5	Low	M		Moderate	High
Alnus incana (D)	2–?	<5.5–<7.0	NT	M		Moderate	Moderate
Alnus spaethii (D)	6–?			M	High		Moderate
Amelanchier arborea (D)	5–8	<5.5–<7.0	NT	L		Low	
Amelanchier lamarckii (D)	5–?		NT	L			
Arbutus unedo (E)	8–?	<5.5–<7.5	Low	L			Low
Betula nigra (D)	4–8	<5.5–<7.5	Low	M			Moderate

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service-related traits. Species are indicated as coniferous (C), deciduous (D) or evergreen (E). chapter's text

			Disservices		Sensitivity	
Precipitation interception	Delivery of goods	Food source	Allergenicity*/ toxicity	BVOC emission*	Salinity tolerance	Snow tolerance
	Low		Moderate	Moderate	Moderate	
Low	Moderate (t)	Pollinators (n+p)	Moderate	Moderate	High	
Low	Moderate (t)	Pollinators (n+p)	High (male)	Moderate	Moderate	
Moderate	Moderate (t)	Pollinators (n+p)	High	Moderate	Moderate	High
Moderate	Moderate (t)	Pollinators (n+p)	High	Moderate	Moderate	
Low	Moderate (t)	Pollinators (n+p)	High (depend. cultivar)	Moderate	Low	Moderate
Moderate	Moderate (t)	Pollinators (n+p)	High (male)	Moderate	Moderate	
Moderate	Low	Pollinators (n+p)	Moderate	Moderate	High	
Moderate	Moderate (m)	Pollinators (n+p)	Moderate/ Tox: b; fr.	Moderate	High	
	Moderate (m)	Pollinators (n+p)	Moderate	Moderate	Moderate	
	Moderate (m)	Pollinators (n+p)	High (male)/ Tox.: l; fl.	Moderate	High	
	Low		Low	High	Moderate	
Moderate	Low	Pollinators (p)	High	Low	Moderate	
Moderate	High (m, t)	Pollinators (p)	High	Low	Moderate	Moderate
Low	Low	Pollinators (p)	High	Low		
	Low	Pollinators	High	Low		
	High (m, f)	Pollinators (n); Birds	Low	Moderate	Low	Moderate
	Moderate (f)	Pollinators (p); Birds	Low	Moderate		Moderate
Low	High (m, f, t)	Pollinators (n+p)	Low/Tox.: fr.	Moderate		
Moderate	High (m, f, o)	Birds	High	Moderate	Moderate	

(continued)

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Table 12.1 (continued)

Species	General tree characteristics			Contribution to environmental ecosystem services			
Scientific name	Hardiness	Soil pH	Drought tolerance	Microclimate regulation	Air pollution mitigation	Soil quality	Net CO_2-sequestration
Betula papyrifera (D)	3–6	<5.5–<7.0	NT	M		Moderate	Moderate
Betula pendula (D)	3–6	<5.5–<8.0	NT	M	High	Moderate	Moderate
Betula pubescens (D)	1–?	<5.5–<7.0	NT	M		Moderate	Moderate
Betula utilis (D)	7b–8	<5.5–<7.5	NT	M			Moderate
Brachychiton populneus (E)	9-11	>6.0–>8.0	Low	L			
Buxus sempervirens (E)	6b–?	<5.5–<7.0	NT	L		Low	Low
Carpinus betulus (D)	5b–7	<5.5–<7.5	Low	M	High	Moderate	Moderate
Castanea sativa (D)	6b–?	<5.5–<7.5	NT	H		Moderate	High
Catalpa bignonioides (D)	6b–9	<5.5–>8.0	Low	M	Low	Moderate	
Cedrus atlantica = C. libani ssp. atlantica (C)	7–8	<5.5–<7.5	Moderate	M		Moderate	Moderate
Cedrus libani (C)	7–10	<5.5–>8.0	Moderate	M		Moderate	Moderate
Ceiba insignis (D)	9–11	>7.0–<7.5	Low	M			Moderate
Celtis australis (D)	6b–9	>6.0–>8.0	Moderate	M		Moderate	Moderate
Celtis occidentalis (D)	5–9	<5.5–>8.0	Moderate	M	Moderate		Moderate
Cercidiphyllum japonicum (D)	5b–8	<5.5–<7.0	NT	M			
Cercis canadensis (D)	6b–9	<5.5–>8.0	NT	L			
Cercis siliquastrum (D)	7–?		Low	L		Moderate	Moderate
Chamaecyparis lawsoniana (C)	5b–7	<5.5–<7.0	Low	L		Low	
Citrus aurantium (E)	9-11		NT	L			Low

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			Disservices		Sensitivity	
Precipitation interception	Delivery of goods	Food source	Allergenicity*/ toxicity	BVOC emission*	Salinity tolerance	Snow tolerance
	High (m, f, o)	Birds	High	Moderate	High	
Moderate	High (m, f, o)	Birds	High	Moderate	Moderate (a)	
Moderate	High (m, f, o)	Birds	High	Moderate		
	High (m, t)	Birds	High	Moderate		
	Moderate (f)		Low	Low		
Low	Low	Pollinators (n+p)	Low/Tox.: wp.	High		
Moderate	Moderate (t)		High	Low	Low	
Moderate	High (f, m, t)	Pollinators (n+p)	Moderate	Moderate		
	Moderate (t)	Pollinators (n+p)	Moderate	Moderate	Moderate	
	High (m, o, t)		Low	Moderate	Moderate	
	High (t, m)		Low	Moderate	Moderate	
	High (t, o)		Low	Not available		
Moderate	High (t, m, f)	Pollinators	Moderate	Moderate	High	
Moderate	High (t, f)	Pollinators, Birds	Moderate	Low	Moderate	
Low	Moderate (t)		Moderate (male)	High	Moderate	
Moderate	High (m, h, f)	Pollinators (n+p)	Low	Low	Moderate	
Moderate	High (t, h)	Pollinators (n+p)	Low	Moderate	Moderate	
Moderate	High (t, o)		High	Low		
Low	High (t, f, m)		Low	Low	Moderate	

(continued)

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Table 12.1 (continued)

Species	General tree characteristics			Contribution to environmental ecosystem services			
Scientific name	Hardiness	Soil pH	Drought tolerance	Microclimate regulation	Air pollution mitigation	Soil quality	Net CO_2-sequestration
Cornus mas (D)	5–8	<5.5–>8.0	NT	L	Moderate (C. alba)	Low	Low
Corylus colurna (D)	5b–7	<5.5–<7.0	Low	L	Moderate	Low	Low
Crataegus coccinea (D)	5 ?		Low	L		Low	Low
Crataegus x lavallei (D)	5b–7		Low	L			Low
Crataegus monogyna (D)	5–?		Low	L	Moderate	Low	Low
Cupressus arizonica (C)	7b–9	<7.0	Moderate	L		Low	Moderate
Cupressus sempervirens (C)	8–10	<5.5–>8.0	Moderate	L	High	Low	Low
Elaeagnus angustifolia (D)	4–8	<5.5–>8.0	Moderate	L	High	Low	Low
Erythrina crista-galli (D)	9–	<5.5–>8.0	Low	M			
Fagus sylvatica (D)	5b–7	<5.5–<7.5	NT	H	Moderate	Moderate	High
Ficus microcarpa (E)	9b-11	>6.0–>8.0	NT	H	Moderate		Moderate
Fraxinus angustifolia (D)	6b–?	<5.5–>8.0	Low	M		Moderate	High
Fraxinus excelsior (D)	4–8	<5.5–>8.0	NT	H	Moderate	Moderate	High
Fraxinus ornus (D)	7–?	<5.5–<7.5	NT	M		Low	High
Fraxinus pennsylvanica (D)	4–9	<5.5–<7.5	Low	M	High		High
Ginkgo biloba (D)	5b–8	<5.5–<7.5	Moderate	L	Moderate	Moderate	Moderate
Gleditsia triacanthos var. inermis (D)	6–8	<5.5–>8.0	High	M	Moderate	Moderate	
Gymnocladus dioicus (D)	6–8	>6.0–>8.0	High	L			
Ilex aquifolium (E)	7–?	<5.5–<7.5	NT	L		Low	Low
Jacaranda mimosifolia (D)	10-11	>6.0–<7.5	NT	M	Low		

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			Disservices		Sensitivity	
Precipitation interception	Delivery of goods	Food source	Allergenicity*/ toxicity	BVOC emission*	Salinity tolerance	Snow tolerance
Low	High (f, m, t)	Pollinators (n+p); Birds	Low	Moderate	Moderate	
Low	High (f, m, t)	Pollinators (p)	High	Moderate	Low	
Low	Low	Pollinators (n+p)	Low	Moderate		
Low	Low		Low	Moderate		
Low	High (f, m, t)	Pollinators (n+p); Birds	Low	Moderate	Moderate	
Moderate	High (o, t)		High	Low	(a)	Low
Moderate	High (t, o, m)		High	Low	Moderate	Low
	High (m, h)	Pollinators	Moderate	Moderate	High	
	Moderate (h)		Low	Moderate	Medium	
Moderate	High (t, o, f)	Pollinators (p); Birds	Moderate	High	Low	
Moderate	Low		Low	Moderate		
Moderate	Moderate (t)	Birds	Nill (female)	Moderate	Moderate (a)	
Moderate	High (t, m)	Pollinators (p); Birds	High	Low	High	
Moderate	Moderate (m)	Pollinators (p); Birds	High	Low	Moderate	
	Moderate (t)	Birds	High	Moderate	High	Moderate
Moderate	High (m, o)		Moderate	High	Moderate	High
Moderate	High (t, f, m)	Pollinators (n+p)	Low	Low	High (a)	
	High (o, t, f)		Low (male)	Moderate	Moderate	High
Moderate	High (o, m)	Pollinators (n+p); Birds	Low(male)/ Tox.: fr; sd.	High		
	High (t, m)	Pollinators; Birds	Low	Low		

(continued)

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Table 12.1 (continued)

Species	General tree characteristics			Contribution to environmental ecosystem services			
Scientific name	Hardiness	Soil pH	Drought tolerance	Microclimate regulation	Air pollution mitigation	Soil quality	Net CO_2-sequestration
Juglans nigra (D)	5b–9	<5.5–<7.5	Moderate	H			High
Juglans regia (D)	6–?	<5.5–<7.5	Low	H	Moderate	Moderate	High
Koelreuteria paniculata (D)	7–9	<5.5–>8.0	High	L	Moderate	Moderate	
Lagerstroemia indica (D)	8–9	<5.5–<7.5	Moderate	L	Low	Low	
Larix decidua (CD)	4–?	<5.5–<7.5	NT	M		Moderate	Moderate
Laurus nobilis (E)	8b–?	<5.5–>8.0	Low	L		Low	Moderate
Ligustrum lucidum (E)	8–?	<5.5–>8.0	Moderate	L	Low	Low	Moderate
Liquidambar styraciflua (D)	6–10	<5.5–<7.0	Low	M		Moderate	Moderate
Liriodendron tulipifera (D)	6–9	<5.5–<7.5	NT	H		Low	Moderate
Magnolia spp. (D + E)	(D) 5–8; (E) 7–10	<5.5–<7.0	NT	H/M/L	Moderate	Low	Moderate
Malus baccata (D)	3–7	>6.0–>8.0	Low	L			Low
Malus domestica (D)	5–?	<5.5–>8.0	NT	L		Moderate	Low
Malus tschonoskii (D)	6b–?		Low	L			Low
Malus spp. (D)	5–?/6–?		Low	L	High	Low	Low
Melia azedarach (D)	7–?	<5.5–>8.0	Low	M	Moderate		
Metasequoia glyptostroboides (CD)	6b–8	<5.5–<7.5	Low	M	High	Moderate	
Morus alba (D)	5b–9	<5.5–>8.0	Low	M	Moderate	Moderate	Low
Morus nigra (D)	6b–?	>6.0–>8.0	NT	M	High	Moderate	Low
Olea europaea (E)	8b–?	>6.0–>8.0	Moderate	L			Low
Parrotia persica (D)	6–8	<5.5–<7.0	Moderate	M			

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			Disservices		Sensitivity	
Precipitation interception	Delivery of goods	Food source	Allergenicity*/ toxicity	BVOC emission*	Salinity tolerance	Snow tolerance
Moderate	High (t, f, m)	Birds	High	Moderate	Moderate	High
Moderate	High (t, f)		High	Moderate	Moderate	High
	High (f, m, o)	Pollinators (n+p)	Low	Low	High	
	Low	Pollinators	Low	Moderate	Low	
Moderate	Moderate (t)		Moderate	Moderate	High	High
Low	Moderate(f)	Pollinators	Moderate	High	High	
Low	Low	Pollinators; Birds	High/Tox.: b; l; fr.	Moderate	Moderate	
Moderate	Moderate(f)	Pollinators (n)	High	High	Low	Moderate
Moderate	High(h,t)	Pollinators (n+p)	Low	Moderate	Low	Moderate
Moderate	Low	Pollinators (p)	Low	High	Moderate	
Low	Moderate(f)	Pollinators (n+p); Birds	Low	Moderate	Moderate	High
Low	Moderate(f)	Pollinators (n+p); Birds	Low	Moderate		High
Low	Moderate(f)	Birds	Low	Moderate		High
Low	Moderate(f)	Pollinators (n+p); Birds	Low/Tox.: sd.	Moderate	Moderate	High
	High(t,o)		Low/Tox.:b; l; fl; fr.	Low	Moderate	
	High(t,o)		High	Moderate	Low	
Moderate	High(t,f)	Birds	High (male)	Moderate	High (a)	
Moderate	High(t,f)	Birds	Moderate	Moderate	(a)	
Low	Moderate (f)	Birds	High	Moderate		
	Low		Low	Not available		

(continued)

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Table 12.1 (continued)

Species	General tree characteristics			Contribution to environmental ecosystem services			
Scientific name	Hardiness	Soil pH	Drought tolerance	Microclimate regulation	Air pollution mitigation	Soil quality	Net CO_2-sequestration
Paulownia tomentosa (D)	7b–9	<5.5–>8.0	NT	M		Moderate	High
Phoenix dactylifera (E)	8b-11	>6.0–>8.0	Low	L			Low
Picea abies (C)	2–7	<5.5–<7.5	Low	M	High	Moderate	Moderate
Picea pungens (C)	4–7	<5.5–>8.0	Low	M	High	Moderate	Moderate
Pinus heldreichii var. leucodermis = *P. heldreichii* = *P. leucodermis* (C)	6–8	<7.5	Moderate	M		Moderate	Moderate
Pinus nigra (C)	5b–8	<5.5–<7.5	Low	M	High	Moderate	Moderate
Pinus pinaster (C)	8–?	<5.5–<7.5	Low	M		Moderate	Moderate
Pinus pinea (C)	8b–?	<5.5–>8.0	Moderate	M			Moderate
Pinus sylvestris (C)	1–8	<5.5–<7.5	Moderate	M	High	Moderate	Moderate
Platanus occidentalis (D)	6b–	<5.5–>8.0	Moderate	H	Moderate	Moderate	High
Platanus orientalis (D)	6b–9	<5.5–>8.0	Moderate	H		Moderate	High
Platanus x acerifolia = *P. x hispanica* (D)	6b–9	<5.5–>8.0	Moderate	H	Moderate	Moderate	High
Populus alba (D)	4–9	<5.5–>8.0	Moderate	H	High	Moderate	High
Populus nigra (D)	5b–?	<5.5–>8.0	Moderate	H		Moderate	High
Populus tremula (D)	1–?	<7.5	High	H	Moderate	Moderate	High
Populus x canadensis (D)	4–?		Low	H		Moderate	High
Populus x canescens (D)	5–?		Low	H		Moderate	High
Prunus avium (D)	5–?	<5.5–<7.5	NT	H	Low	Moderate	Low
Prunus cerasifera (D)	5–?	<7.0	NT	L	Moderate	Low	Low
Prunus cerasus (D)	5b–?	<5.5–<7.5	NT	L		Low	Low

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			Disservices		Sensitivity	
Precipitation interception	Delivery of goods	Food source	Allergenicity*/ toxicity	BVOC emission*	Salinity tolerance	Snow tolerance
Moderate	High (h,t)		Low	Low		
	Moderate (f)	Birds	High (male)	High		
High	High(t,o)	Birds	Low	Moderate	Low	High
	High(t,o)	Birds	Low	Moderate	Moderate	High
	High(t,o)		Low	Moderate		
Moderate	High(t,o)	Birds	Low	Moderate	High	
Moderate	High(t,o)	Birds	Low	Moderate		
Moderate	High(t,o)	Birds	Low	Moderate		
Moderate	High(t,o)	Birds	Low	Moderate	Low	Moderate
Moderate	Moderate(t)	Birds	High	High	Moderate	
Moderate	Moderate(t)	Birds	High	High		
Moderate	Moderate(t)		High	High	Moderate (a)	Low
Moderate	Moderate(t)	Birds	High (depend. cultivar)	High	High (a)	
Moderate	Moderate(t)	Pollinators (p); Birds	High (male)	High	High (a)	
Moderate	Moderate(t)	Pollinators (p); Birds	High ("Italica")	High	Mederate (a)	
Moderate	Moderate(t)	Birds	High	High	High (a)	
Moderate	Moderate(t)		High (male hybrids)	High	(a)	
Low	High (f, t)	Pollinators (n+p); Birds	Low	Moderate	Low	
Low	Moderate (f)	Pollinators (n+p)	Low	Moderate	Moderate	
Low	High (f, m)	Pollinators; Birds	Low/Tox.: l; sd.	Moderate	Moderate	

(continued)

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Table 12.1 (continued)

Species	General tree characteristics			Contribution to environmental ecosystem services			
Scientific name	Hardiness	Soil pH	Drought tolerance	Microclimate regulation	Air pollution mitigation	Soil quality	Net CO_2-sequestration
Prunus maackii (D)	4–6	<5.5–<7.5	Low	M			Low
Prunus padus (D)	3–?	<5.5–>8.0	Low	M		Low	Low
Prunus sargentii (D)	6–8	<5.5–<7.5	Low	M			Low
Prunus serrulata (D)	6b–?	<5.5–<7.5	Low	L	Low		Low
Prunus spinosa (D)	5–?			L		Low	Low
Prunus virginiana 'Shubert' (D)	4–7	<5.5–<7.5	Low	L	Low		Low
Pyrus calleryana (D)	6–9	<5.5–>8.0	High	L	Moderate		Low
Quercus cerris (D)	6–7	<7.5		H		Moderate	High
Quercus coccinea (D)	5b–8	<7.0	Low	H		Low	Moderate
Quercus frainetto (D)	6–?	>6.0–>8.0	Low	H		Moderate	High
Quercus ilex (E)	8–?	<5.5–>8.0	Low	M	High	Low	Moderate
Quercus palustris (D)	5b–8	<5.5–<7.5	Low	H	Moderate		High
Quercus petraea (D)	5b–?			H	Moderate	Moderate	High
Quercus robur (D)	5–8	<5.5–<7.5	Moderate	H	High	Moderate	High
Quercus rubra (D)	5b–8	<5.5–<7.5	Low	H	Low	Moderate	High
Robinia pseudoacacia (D)	6–8	<7.5	High	M	Low	Moderate	High
Salix alba (D)	4–?	<7.0		H	High (*S. cinerea*)	Moderate	High
Salix babylonica (D)	8–?	<5.5–>8.0	NT	M	Moderate	Moderate	Moderate
Salix caprea (D)	3- ?	<5.5–>8.0		L	Moderate	Moderate	Low
Salix fragilis (D)	4–?	<7.0		L		Moderate	Moderate

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			Disservices		Sensitivity	
Precipitation interception	Delivery of goods	Food source	Allergenicity*/ toxicity	BVOC emission*	Salinity tolerance	Snow tolerance
Low	Moderate (f)	Birds	Low	Moderate		
Low	Moderate (m)	Pollinators (n+p); Birds	Low	Moderate	Moderate	
	Low	Pollinators (n+p)	Low	Moderate	Moderate	
	Low	Pollinators (n+p); Birds	Low	Moderate	Low	
	High (f, m)	Pollinators (n+p); Birds	Low	Moderate		
	Low	Pollinators; Birds	Low	Moderate	Moderate	
	Moderate (o)	Pollinators; Birds	Low	Low	Moderate	
Moderate	High (t, o)	Birds	Moderate	High	Moderate	
Moderate	Moderate (o)	Birds	Moderate	High		
Moderate	Moderate (t, o)	Birds	Moderate	High		
Moderate	High (t, o, m)	Birds	Moderate	High		
	High (m, o)	Birds	Moderate	High	Low	
Moderate	High (t, o,)	Pollinators (p)	Moderate	High		
Moderate	High (t, o, m)	Pollinators (p); Birds	Moderate	High	High	
Moderate	High (t, o)	Pollinators (p); Birds	Moderate	High	High	
Moderate	High (h, t, m)	Pollinators (n+p); Birds	Lox/Tox.: r; b; sd.	High	High (a)	
Moderate	High (m, o)	Pollinators (n+p)	High (male)/ Tox.: b.	High	Moderate	
Moderate	Moderate (o)	Pollinators (n+p)	High (male)	High	High (a)	
Low	Moderate (o)	Pollinators (n+p); Birds	Moderate (male)	High		
	Moderate (o)	Pollinators (n+p)	High (male)	High	High	

(continued)

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Table 12.1 (continued)

Species	General tree characteristics			Contribution to environmental ecosystem services			
Scientific name	Hardiness	Soil pH	Drought tolerance	Microclimate regulation	Air pollution mitigation	Soil quality	Net CO_2-sequestration
Salix pentandra (D)	4–?	<7.0		L		Low	Moderate
Salix x sepulcralis (D)	6b–?			M			Moderate
Sambucus nigra (D)	5–?	<5.5–>8.0		L	Moderate	Low	Low
Sophora japonica = *Styphnolobium japonicum* (D)	6b–8	<5.5–>8.0	High	M	Low	Moderate	
Sorbus aria (D)	5–?	>5.5–>7.5		M	High	Moderate	Low
Sorbus aucuparia (D)	3–6	<5.5–>8.0	Low	L	Moderate	Moderate	Low
Sorbus intermedia (D)	5–?	<5.5–>8.0	Low	L	Moderate		Low
Sorbus latifolia (D)	5–?	<5.5–<7.5		L		Moderate	Low
Sorbus x thuringiaca (D)	5b–?		Low	L			Low
Syringa reticulata (D)	4–7	>6.0–>8.0	Moderate	L	High (*S. meyeri*)		
Tamarix gallica (D)	6b–?	>5.5–>8.0	Moderate	L			Low
Taxodium distichum (CD)	6b–10	<5.5–>8.0	Moderate	M	High		Moderate
Taxus baccata (C)	6–7	<5.5–>8.0	Moderate	M	High	Moderate	Moderate
Thuja occidentalis (C)	5–7	<5.5–>8.0	NT	M	High	Moderate	Moderate
Thuja plicata (C)	5b–8	<5.5–>7.5	Low	M		Moderate	Moderate
Tilia americana (D)	5–8	>5.5–<7.5	Low	H			High
Tilia cordata (D)	4–7	>5.5–<7.5	Low	H	Moderate	Moderate	High
Tilia platyphyllos (D)	4–?	>5.5–<7.5		H	Moderate	Moderate	High
Tilia tomentosa (D)	5–8	>5.5–<7.5	Moderate	H	Moderate	Moderate	High
Tilia x europaea (D)	4–?	>5.5–<7.5	Moderate	H	Moderate		High

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			Disservices		Sensitivity	
Precipitation interception	Delivery of goods	Food source	Allergenicity*/ toxicity	BVOC emission*	Salinity tolerance	Snow tolerance
	Low	Pollinators	Moderate	High		
	High (m, t, o)		High (male)	High		
Low	High (m, f)	Pollinators (flies); Birds	Low	Low	Moderate	
	Moderate (m)	Pollinators (n+p)	Low	High	Moderate (a)	
Low	High (t, f)	Pollinators (n+p)	Low	Moderate	High	
Low	High (m, f, t)	Pollinators (n+p); Birds	Low	Moderate	Moderate	
	Low	Pollinators (n); Birds	Low	Moderate	High	
	High (t, f)	Pollinators; Birds	Low	Moderate		
	Low		Low	Moderate		
	Moderate (o)	Pollinators	Moderate	High	Moderate	
Low	Modetate (m)	Pollinators; Birds	Moderate	Low	High	
Moderate	Modetate (t)		High	Moderate	High	High
Moderate	High (t, o, m)	Pollinators (n+p); Birds	High(male)/ Tox.: wp. except arillus	Moderate	Medium	Low
Moderate	High (m, o, t)		High	Low	Moderate (a)	Low
Moderate	High (t, o)		HIgh	Low	Low (a)	Low
Moderate	High (t, m, h)	Pollinators	Low	Moderate	Low	Low
Moderate	High (t, m, h)	Pollinators (n)	Low	Moderate	Low	
Moderate	High (t, m, h)	Pollinators (n+p)	Low	Moderate	Moderate	
Moderate	High (h, m, t)	Pollinators (n)	Low	Moderate	Moderate	
Moderate	High (h, m, t)		Low	Moderate	Low	

(continued)

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Table 12.1 (continued)

Species	General tree characteristics			Contribution to environmental ecosystem services			
Scientific name	Hardiness	Soil pH	Drought tolerance	Microclimate regulation	Air pollution mitigation	Soil quality	Net CO_2-sequestration
Tipuana tipu (D-E)	9b-11	<5.5–<7.5	Low	M			
Ulmus glabra (D)	5–?	>5.5–<7.5	NT	H	High	Moderate	Moderate
Ulmus laevis (D)	5–?			H		Moderate	Moderate
Ulmus minor (D)	5–?	>5.5–<7.5	NT	H		Moderate	Moderate
Ulmus procera (D)	5–?	>5.5–<7.5		H			Moderate
Ulmus pumila (D)	4–9	>5.5–<7.5	Low	H	Moderate	Low	Moderate
Washingtonia filifera (E)	9-11	>6.0–>8.0	Moderate	L			
Zelkova serrata (D)	6–?	>5.5–<7.5	Moderate	M	Moderate		High

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			Disservices		Sensitivity	
Precipitation interception	Delivery of goods	Food source	Allergenicity*/ toxicity	BVOC emission*	Salinity tolerance	Snow tolerance
	Low		Low	Moderate	Moderate	
Moderate	High (t, m, h)	Pollinators (p)	High	Moderate		
	Low	Pollinators (p)	High	Moderate		
Moderate	High (t, m, h)	Pollinators (n+p)	High	Moderate	High	
	High (t, m, f)		High	Moderate		
	Low		High	Moderate	High	Low
	High (f, o)		Low	High		
Moderate	Moderate (t)		High	Low	Moderate	

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To keep the table as a practical tool, it was decided to restrict the extent of information and indicators for each of the identified ecosystems services. In addition to species' scientific names, the reader can find information on hardiness, optimal soil pH range, drought tolerance, environmental ecosystem services and disservices, and sensitivity of the species to snow, salinity and diseases. The following discussion provides background information on the criteria used for selecting (or not selecting) tree species for certain services and disservices, and explains how the table should be read and interpreted. The selection of the information included is based on intensive discussions with European urban forestry experts.

12.1 Hardiness

Hardiness refers to, but is not limited to, specific categories of plants that are capable of growing within defined climatic zones. In other words, hardiness reflects the plant's ability to withstand and tolerate temperature conditions such as extreme cold or heat. The hardiness of a plant such as a tree is defined by its native geographic location; that is latitude, longitude and altitude or elevation. These geographic descriptors are then simplified to determine a hardiness zone.

Winter-hardy plants are known for their ability to withstand cold and continue growing in the winter, or at least to remain dormant and healthy. Many plants including trees are assigned hardiness zones that specify the climatic conditions in which they can survive. Published descriptions of plant hardiness have recently been expanding to include not only a plant's lower temperature limit, but its upper limit as well – thereby establishing a temperature tolerance range. It is believed that with ongoing global climate change, heat tolerance as reflected by this upper limit will become more and more important. In Table 12.1 the first temperature value represents the lower limit and is, for almost all entries, based on data provided by Roloff and Bärtels (2014). The second figure, representing the upper limit, is provided when available, based on various sources. A notation (b) attached to the lower limit signifies that the particular species only survives in the mildest part of that hardiness zone. In this respect it should be noted that when trees are planted near the limits of the natural growing range, or hardiness zone, there always is a risk of winter damage. For a few species missing in the work by Roloff & Bärtels (*Brachychiton*, *Ceiba*, *Citrus aurantium*, *Ficus microcarpa*, *Jacaranda*, *Phoenix*, *Tipuana*, *Washingtonia*) data were collected from online sources.

There are other considerations that affect a plant's ability to tolerate the designated hardiness rating. Provenance will directly affect a plant's tolerance for heat or cold; for instance a southern grown plant, cold hardy to 6 °C, will struggle to survive when planted in the north where temperatures routinely drop to -17 °C. In addition,

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trees that have evolved in locations where the ground is routinely covered with snow may struggle in areas where snow does not accumulate, even if air temperatures are similar. Remediation of such an issue can be accomplished with the application of a 7–10 cm deep installation of composted wood chip mulch, which will moderate soil temperatures during the winter, thus protecting the root zone.

12.2 Soil pH

There are certain characteristics we must give careful consideration to when selecting the right tree for the right place. One such characteristic, critical to successful planting, is soil pH tolerance. In a traditional forest, it is possible to determine the soil's pH from the assortment of species growing there – but as man-made constructs, urban environments do not necessarily offer nature-based information to guide tree selection decisions.

Soil pH is a measure of the soil's acidity or alkalinity. As shown in Fig. 12.1, the soil pH scale ranges from 4 (strongly acid) to 10 (strongly alkaline) and its value affects the availability of nutrients, and in particular minerals. Acid or alkaline

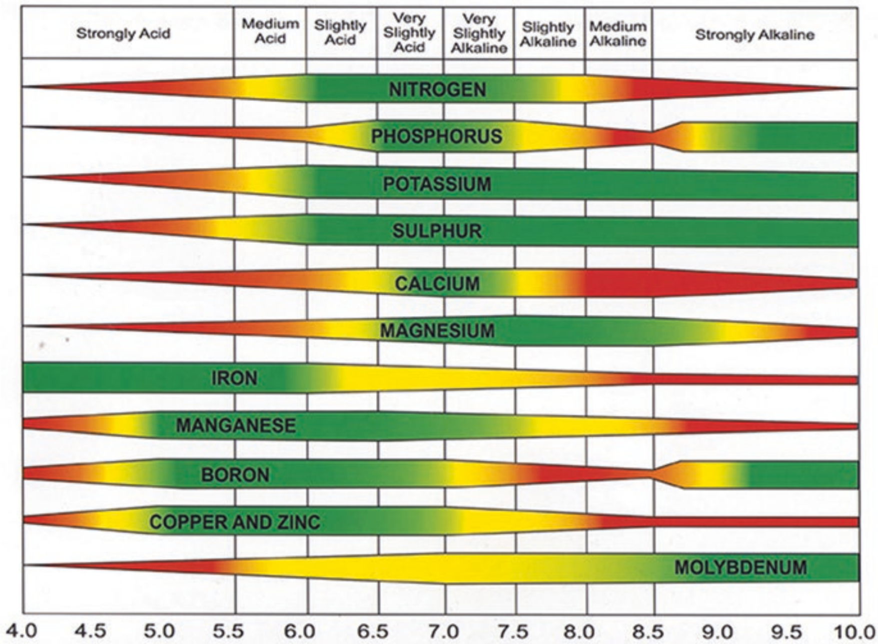

Fig. 12.1 The pH scale, showing the effects of soil acidity and alkalinity on the availability of different minerals. Colours indicate availability of the elements. *Green*: available; *yellow*: low availability; *red*: not availabile

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levels initiate the formation of chemical compounds that are insoluble in water, and thus unavailable for uptake by trees' roots. It is therefore critical to test the soil pH and to know the tolerances of the trees being selected for planting. Although soil pH can be adjusted with amendments, the soil will tend to revert to its original pH in short order, placing even greater emphasis on correct tree selection.

The pH entries provided in Table 12.1 are the known tolerances for the species listed, and are described as follows: values < 7.0 are considered acid, around 7.5 neutral and > 7.5 alkaline. Values of pH < 5.5 are very acid, and > 6.0 to < 7.0 slightly acid while pH-values > 8.0 are very alkaline. Within the given range, further exploration might reveal the preference for each species as opposed to the scope of tolerance, e.g., *Quercus palustris* prefers a pH in the range of 5.5 to 6.5 – moderately acid to slightly acid – but will tolerate 5.5 to 7.5 – moderately acid to neutral - as listed. The more we can provide the tree that is being planted with its preferred growing conditions, the greater the likelihood the tree will thrive and deliver the services we are depending on.

12.3 Drought Tolerance

Drought tolerance in trees indicates an ability to withstand a lack of regular moisture (due to limited access to irrigation, or non-retentive soil conditions) over prolonged periods. Consideration of this characteristic is especially important when selecting trees for curbside plantings where irrigation beyond rainwater or snowmelt is not likely. In general, trees with smaller leaves such as *Gleditsia triacanthos var. inermis* or a waxy cuticle, e.g. *Pyrus calleryana*, can better manage limited water resources than larger leaved or soft cuticle trees.

The entries in Table 12.1 have been rated for their tolerance according to available literature as *low*, *moderate*, *high*, or *no tolerance* (NT). This guidance should be used in tandem with additional information such as Provenance – upland or bottomland seed origin.

Newly planted urban trees, regardless of their drought tolerance classification, require regular irrigation during their establishment period of 2–3 years. Field grown trees have left 95% of their roots in the ground at the nursery and so it is critical to provide adequate irrigation to support the re-establishment of a fully functioning structural and fine root zone. In addition, trees that are planted into a water-restricted environment should not have their canopies excessively thinned. Trees maintain cooling strategies within their respective canopies and this contributes to their ability to manage transpiration during periods of reduced access to water.

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12.3.1 Ecosystem Services

The environmental ecosystem services considered in Table 12.1 are microclimate regulation, air pollution mitigation, improvement of soil quality, net carbon sequestration, precipitation interception, delivery of goods and contribution to biodiversity.

12.4 Microclimate Regulation

The consideration of microclimatic regulation by different tree species has been limited to their capacity for reducing air temperatures in the urban environment. The two main processes by which trees can contribute to this cooling effect are (1) evapotranspiration, and (2) surface temperature reduction through shading. While ideally, these two effects would be represented by separate indicators, here we concentrate on leaf area as an overall indicator for both processes, assuming that a greater leaf area means both more shade and more evapotranspiration. It is important to note that, in practice this relation might be modified by physiological (water use efficiency) or other morphological tree properties (size and distribution of leaves, crown architecture). In urban areas, moreover, and especially for street trees, the actual cooling potential as a result of transpiration may be strongly limited by the scarcity of available soil moisture.

The value of the microclimate regulation effect has been estimated as *high* when trees grow large (to a height of over 15 m) and develop broad and densely foliated crowns (e.g. *Quercus robur*, *Acer platanoides*), *moderate* for medium sized trees (10–15 m) or large trees with open or relatively small crowns (e.g. *Robinia* or *Sophora*), or *low* if the trees are small (10 m) or have narrow, columnar-shaped crowns (e.g *Cupressus*). These estimates are based on expert judgement and growth characteristics as provided by Roloff and Bärtels (2014) and refer to potential effects of mature and well-growing trees, such that the effect of young recently planted trees will be much less. Size limits are approximate and the final classification is offered as a general guide, given the limited empirical data available; this clearly is an area to be developed.

12.5 Air Pollution Mitigation

Air pollution mitigation comprises many factors, including the mitigation of particulate matter as well as various gaseous pollutants (see Chap. 3). The characteristics, from leaf to canopy level, favouring the mitigation of particulates or gases are not equal. Moreover, extensive knowledge on these overall mitigation capacities is largely missing, especially for urban tree species. Table 12.1 focuses on one of the

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major and most dangerous atmospheric pollutants for human health, especially in urban environments, which is particulate matter (PM).

Many sources and approaches were used to evaluate this PM mitigation potential, e.g. experimentally derived values from comparison experiments, and theoretically derived values from a combination of leaf and canopy characteristics. For some species, the values yielded by these two methods can be quite different. In the case of contrasting results, both (or all) are kept to indicate a good, but not absolute evaluation. In fact more knowledge is needed, especially on ways of comparing species in similar conditions so that they can be ranked according to their PM mitigation potential capacity.

Particle deposition, or mitigation, capacity might be considered as indicative for gaseous as well as particle deposition. However, further detailed research is needed to confirm this.

12.6 Soil Quality

Soil quality refers to the ability of soil to perform its functions. Urbanization often results in soil compaction, alkalinization, pollution and other degradation processes. Urban soils, with their specific characteristics, are fundamental for growth and development of plant species, but planting urban trees could improve the soil quality and therefore could positively affect the ecosystem services outputs in urban environments (See Chap. 6). Tree species strongly influence the chemistry of throughfall and soil solutions and may strongly influence soil pedogenic processes (Legout et al. 2016). Tree species induce changes in the properties of topsoil, while the N-fixing species perform better than other species in improving soil nutrient availability (Kooch et al. 2016). Furthermore, although trees stabilize slope surfaces to a large extent, their presence can also have a dual effect on slope stability due to tree uprooting and reducing erosion. Trees not only modulate pedological processes, but they also act as a direct or indirect agent of soil formation and improving soil quality. Based on their characteristics, tolerance and site suitability, urban tree species were rated – based on expert opinion - in three categories for their capacity to improve soil quality: *low*, *moderate*, and *high* (see Table 12.1). Small trees more often fall in the "low" category, while pioneer trees with high tolerance and extended root systems have been included in the "high" category in terms of "soil quality improvement".

12.7 Net Carbon Sequestration

Cities are responsible for more than 80% of global greenhouse gas emissions. CO_2 represents the major component of anthropogenic emissions, mainly a result of fuel combustion for heating, urban mobility and cooking. Plants have the capacity to sequester CO_2 through photosynthesis, and can therefore store carbon in plant

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biomass and in the soil, providing the soil has an organic component and an active microbial community. Green areas in the city may affect atmospheric CO_2 concentrations, as observed in several studies in which urban to rural transects showed lower CO_2 concentration in presence of vegetation. Based on the growth rate and the capacity of each species to store carbon in the aboveground and belowground biomass, typical urban tree species were rated – based on expert knowledge – in three categories: *low*, *moderate*, and *high* (see Table 12.1). Small trees more often fall in the "low" storage category, while fast growing trees with large canopies and extended rooting systems have been included in the "high" category.

12.8 Precipitation Interception

Precipitation interception refers to the interception, storage, and subsequent evaporation of precipitation by tree crowns (Livesley et al. 2014). Canopy interception is influenced by a number of tree characteristics, including tree species, tree size, canopy density (including its seasonality) and bark type (Armson et al. 2013; Livesley et al. 2014; Kermavnar 2015), which affects the proportion of intercepted precipitation that flows down the tree trunk to the base of the tree as stemflow. Consideration of the canopy interception capacity when selecting urban trees for planting can improve regulation of throughfall and the mitigation of soil erosion processes and related negative effects of intense weather phenomenon, e.g. water accumulation, stormwater runoff, flooding and its management costs (Asadian and Weiler 2009). Interception capacity of trees was judged to be *high* for trees that grow large (to a height of over 15 m), develop large densely foliated evergreen crowns and have negligible stemflow (e.g. *Picea abies*), *moderate* for medium sized trees (10–15 m) or large trees with open deciduous crowns (e.g. *Populus* or *Ginkgo*), or *low* if the trees are small (10 m) or have relatively small or columnar-shaped crowns with smooth bark contributing to considerable stemflow (e.g *Cercidiphyllum*). These estimates are based on expert knowledge and are offered as a general guide, given the limited availability of empirical data on precipitation partitioning of urban trees. They refer to potential effects of mature and well-growing trees, as the interception capacity of young recently planted trees will be much less.

12.9 Delivery of Goods

In the assessment of species (Table 12.1) under this category, the different subcategories of goods/services scoped are t=timber (e.g. *Juglans*), f=food (e.g. *Prunus avium*), h=honey (e.g. *Robinia*), m=medicinal (e.g. *Tilia* spp. for its flowers), and o=ornamental. The latter mainly takes into account the point of utilisation of different tree components and not the aesthetic value of the whole tree, e.g. *Pinus* spp. for the use of their cones in bouquets.

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12.10 Contribution to Biodiversity

Trees can contribute to the increase of biodiversity in urban environments in many ways, and for many taxa, from microbiota to birds and mammals. An increased awareness of the global plight of bees and butterflies has generated a huge interest in urban beekeeping, and pollinating insects in general. Moreover, birds are greatly appreciated by many urban residents. We have therefore focused the biodiversity contribution of the considered trees to that of forage for pollinators and birds. For pollinators, it is important to provide both nectar (n) and pollen (p) and so that distinction is included. Selection criteria for cultivars that provide pollinator forage should refrain from the use of "doubles", as the development of this larger flower required the confiscation of the nectaries as well as the reproductive organs and has thus eliminated the possibility of providing either nectar or pollen as the flower is now sterile.

12.11 Disservices

Three types of disservices are considered: allergenicity, toxicity and BVOC emission. For specific application to street environments, additional issues have been identified – such as litter from droppings of fruits and foliage (e.g. *Prunus*), or brittle limbs (e.g. *Robinia pseudoacacia*, *Fraxinus angustifolia*). The tree's root system is another important consideration, since vegetation with rooting systems that are invasive (e.g. *Populus*, *Salix*) or shallow (e.g. *Prunus*, *Betula*) are increasingly considered unfit for curbside environments. However, this was not included in Table 12.1 since there is limited information as yet for the range of species considered.

12.11.1 Allergenicity

Allergenicity refers to the ability of trees to emit allergens that generate symptomatic reactions in the population. Pollen grains emitted during the reproductive period are the major plant allergens, since their wall is formed by intraspecific recognition proteins that cause allergic responses in sensitive individuals. However, in some species (e.g. *Platanus*) small hairs from leaves can cause similar problems especially during pruning activities.

The pollen allergenicity of tree species has been valued as *low*, *moderate* or *high* according to the classification proposed by Cariñanos et al. (2016). These values result from the combination of three parameters: (1) strategy of pollination, either anemophilous (dispersion by wind), zoophilous (dispersion by animals) or amphiphilic (dispersion by wind and animals), (2) duration of the pollination event

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(in weeks), and (3) allergenic potential of the pollen grains. Each parameter has a numerical value between 0–3, so the ranges for each category are: *nil* (0), *low* (1–6), *moderate* (8–12) or *high* (16–27).

12.11.2 Toxicity

The toxicity indicator mainly includes those plant parts which are toxic or poisonous and could cause damage or injury if they are eaten, according to the following key: roots (*r*), bark (*b*), leaves (*l*), flowers (*fl*), fruits (*fr*), seeds (*sd*), or whole plant (*wp*).

12.11.3 BVOC Emission

Biogenic Volatile Organic Compounds (BVOCs) include a large number of compounds with different reactivities. The more reactive ones, e.g. isoprene, support the formation of ozone while the less reactive, such as monoterpenes and oxygenative compounds, are contributing to aerial particle formation. However, their actual impact depends very much on the reaction partners they find in the atmosphere such as NO_x molecules. BVOC emission depends on numerous environmental conditions with temperature being the most prominent. Therefore, the potential emission under standard conditions (1000 μmol PAR, 30 °C) is regarded as a species-specific indicator for the potential to influence air chemistry and thus air pollution.

The BVOC emission potentials presented in Table 12.1 are derived from cumulative emission factors (μg VOC g Dry Weight^{-1} h^{-1}) of isoprene, monoterpenes, and (if available) other VOCs. According to Singh et al. (2014), species were classified as either *low*, *moderate* or *high* emitters, with limit values of <1, <10 and >10 μg VOC g Dry Weight^{-1} h^{-1}, respectively. For 37 of the species, specific values could be used from various sources reporting on single species and reviews such as Nowak et al. (2002). For two species (*Ceiba insignis* and *Parrotia persica*), no values were found. For the remaining species, categorization was based on that of other species of the same family or genus, or were pooled from several species of the respective family.

Planting design can very much affect the extent of BVOC emission impact. Trees that emit BVOCs should not be planted alongside a busy thoroughfare as a closed canopy. Closing the canopy reduces air circulation, forcing emissions down to pedestrian level. It is important to understand disservices and how they are exacerbated so the full complement of urban-tolerant trees can be planted and their disservices mitigated in favor of their services.

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12.12 Sensitivity

Finally, also sensitivity of the species to snow, salinity and diseases are given.

12.12.1 Snow

In addition to the hardiness described previously, the sensitivity of trees to snow and freezing conditions is also an important feature when selecting the correct trees for cold climate cities. These features can primarily be divided into damage caused by accumulation of snow and ice on trees, and by frost. The accumulation of snow can cause bending and breakage of branches. For the latter, the most damaging conditions take place when temperature fluctuates below and above freezing, which commonly take place in spring and fall. In these conditions, trees can be subjected to sudden and possibly hard freezing that can cause frost cracks (Sano and Fukazawa 1996; Bräuning et al. 2016). The tree tolerance to snow and ice can be shown as *low*, *medium* and *high* tolerance.

12.12.2 Salinity

Trees can be exposed in two ways to saline conditions: via the soil and via the atmosphere. While for the latter type of exposure sea salt is transported inland via wind, soil salinity in European cities mainly originates from de-icing salts. The indicator in Table 12.1 is mainly focused on the tree's sensitivity to soil salinity, considering three different classes, i.e. *low, moderate* and *high*. Species which are sensitive to airborne salinity are indicated with (a).

It should be noted that tolerance among the same species can be different between climatic zones and/or researches. Therefore, the given indicators and proposed classes form a compromise between the information found in various sources.

12.12.3 Diseases

Urban trees, like any living being, may occasionally be attacked by diseases and insects. In fact, under normal conditions, many fungi and insects live and feed on trees without causing serious problems. This may develop into more serious problems when a tree is stressed as a result of urban circumstances (site not suitable, stem injuries, drought, root losses, de-icing salt, etc.). So the first condition to avoid stress in urban trees is to plant the right tree in the right place, i.e. the site characteristics should match the needs of the tree. Secondly, the allotted planting space

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should be sufficient when the tree matures in order to avoid diseases and disorders caused by negative effects of the urban environment.

Sensitivity to diseases is mentioned in a separate table (Table 12.2), as the aim was not to be exhaustive, but rather to give an overview of the major diseases and insect pests that can cause serious management problems (e.g. Dutch Elm Disease, Chalara Dieback of Ash, Oak Processionary Moth, etc.). Some of these major pathogen issues can be avoided by using resistant species or cultivars. In such cases this has been indicated in the table.

Table 12.2 List of diseases, pest infestations and other limitations to which different tree species are susceptible

Disease and insect problems	
1	*Buxus sempervirens* is on many "do not plant" lists because of the extent of Boxwood Blight infestations
2	*Crataegus* species are hosts to a number of diseases including Fire Blight; selecting a disease resistant cultivar is of utmost importance
3	*Fraxinus excelsior* generally is very susceptible to the Ash Dieback Disease caused by the fungus *Hymenoscyphus fraxineus* (Chalara). *F. angustifolia* and *F. pennsylvanica* also are susceptible to this disease. In areas where the disease is abundant, planting of these species is not advisable. *F. ornus* is much more resistant and can be used as an alternative
4	*Malus* species have a high incidence of disease including Fire Blight and apple-cedar rust; only disease resistant cultivars should be planted
5	*Picea* species cannot withstand droughty conditions, this instigates a plethora of diseases when consistent, adequate moisture is not available
6	*Pinus nigra* and *P. sylvestris* are host to numerous pests and diseases
7	*Platanus* species recently are more and more affected by Massaria which may lead to strong limbs suddenly falling down. Therefore in areas where Massaria disease is present adult plane trees with thick branches should be inspected regularly
8	*Prunus* species are host to numerous pests and diseases, therefore only disease resistant cultivars should be used
9	*Pyrus communis* is susceptible to Fire Blight
10	On many *Quercus* species including *Q. robur*, *Q. petraea*, *Q. frainetto* and *Q. cerris* the larvae (caterpillars) of the Oak Processionary Moth (*Thaumetopoea processionea*) can feed. The hairs of these caterpillars are highly allergenic and control (removal or killing by spraying control agents) is specialist work
11	*Ulmus glabra*, *U. minor* and *U. procera* are highly susceptible to Dutch Elm Disease (DED). Planting of these species therefore is not recommended. However, nowadays many resistant cultivars (usually interspecific crosses) are available as substitutes. *Ulmus laevis* usually does not get infected by DED and can be planted as well. *Ulmus pumila* is also resistant but is only suitable for parks and larger green areas, not as a street tree
Other limitations	
12	*Acer rubrum* - in this species provenance is critical for both hardiness and drought tolerance. Also this species should be own-rooted or grown on a *A. saccharinum* rootstock as delayed graft compatibility can be a problem on *A. platanoides*
13	*Acer saccharinum* (+ cultivars) is a fast growing tree that has very poor branch unions and thus does not do well in storms; it quickly gets too large for most urban sites and it volunteers very readily making it somewhat invasive

(continued)

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Table 12.2 (continued)

14	*Ailanthus altissima* is weak-wooded just like Robinia and is highly invasive as well
15	*Albizia julibrissin* is highly invasive and should not be planted.
16	*Alnus glutinosa* should not be planted near open natural areas as it may volunteer readily.
17	*Castanea sativa* requires a large park or a large open landscape
18	*Cedrus* species require large open landscapes to accommodate an ornamental canopy
19	*Eleagnus angustifolia* can be very invasive; growth habit will require pruning for clearance
20	*Fagus sylvatica* should be planted in large parks or large open landscapes given the mature size of the tree and its dislike of disturbance within its root zone
21	*Gymnocladus dioica* requires a large open landscape; seeds are highly toxic - only males should be planted
22	*Ilex aquifolium* is highly invasive, outcompeting native understory species in forests
23	*Jacaranda mimosifolia* must be single trunk-trained, as its wood is somewhat weak and multi-stems tend to break apart at the crotch
24	*Juglans* species need a lot of space and work well in large parks and large open landscapes; production of allelopathic chemicals limits landscaping the understory
25	*Koelreuteria paniculata* can be very invasive
26	*Larix decidua* is intolerant of air pollution - should be used only in parks
27	Ligustrum species tend to be extremely invasive, requiring monitoring - not recommended for urban settings where maintenance is an issue
28	*Liriodendron tulipifera* needs to be sited in a large park or a large open landscape
29	*Magnolia denudata*, *M. grandiflora*, *M. kobus, M.* x *soulangeana* are intolerant of soil extremes as well as urban pollutants;
30	*Melia azedarach* is highly invasive; fruits are poisonous to humans if eaten in quantity
31	*Morus alba* is highly invasive – therefore only a fruitless cultivar should be planted
32	*Paulownia tomentosa* tends to be invasive, very messy and subject to breakage from wind storms.
33	*Populus* species are highly invasive, often overwhelming and out-competing native species
34	*Pyrus calleryana* is susceptible to limb breakage and can be invasive
35	*Quercus coccinea* and *Q. robur* require a large open area with adequate rooting and canopy space to sustain healthy growth
36	*Quercus palustris* and *Q. rubra* require acid soil
37	*Quercus cerris* should be own-rooted or grown on a *Q. cerris* rootstock as delayed graft compatibility can be a problem on *Q. robur* and *Q. rubra* rootstocks
38	*Robinia pseudoaccacia* (+ cultivars) is often very weak-wooded so it may break apart in storms and it's highly invasive
39	*Salix alba* and *S. babylonica* are weak wooded, disease prone and too moisture demanding for urban landscapes; ideal for riparian zones
40	*Tilia* species require a large open area with adequate rooting and canopy space to sustain healthy growth

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References

Hardiness

http://www.houzz.com/europeZoneFinder. Accessed 27 July 2016
http://selectree.calpoly.edu. Accessed 27 July 2016
http://hort.ufl.edu/database/trees/trees_scientific.shtml. Accessed 27 July 2016
http://www.pfaf.org/user/Default.aspx. Accessed 27 July 2016
Roloff A, Bärtels A (2014) Flora der Gehölzer. Verlag, Ulmer

Soil pH

http://hort.ufl.edu/database/trees/trees_scientific.shtml. Accessed 2 Sept 2016
http://selectree.calpoly.edu. Accessed 2 Sept 2016

Drought Tolerance

http://hort.ufl.edu/database/trees/trees_scientific.shtml. Accessed 5 Aug 2016
http://selectree.calpoly.edu. Accessed 5 Aug 2016

Microclimate References

Roloff A, Bärtels A (2014) Flora der Gehölzer. Verlag, Ulmer

Air Pollution Mitigation

Beckett KP, Freer-Smith PH, Taylor G (2000) Effective tree species for local air quality management. J Arboric 26(1):12–19
Burkhardt J (2010) Hygroscopic particles on leaves: nutrients or desiccants? Ecol Monogr 80(3):369–399
Chen X, Zhou Z, Teng M et al (2015) Accumulation of three different sizes of particulate matter on plant leaf surfaces: effect on leaf traits. Arch Biol Sci 67(4):1257–1267
Dzierżanowski K, Popek R, Gawrońska H et al (2011) Deposition of particulate matter of different size fractions on leaf surfaces and in waxes of urban forest species. Int J Phytoremediat 13:1037–1046
EL-Khatib AA, Abd El-Rahman AM, Elsheikh OM (2011) Leaf geometric design of urban trees: potentiality to capture airborne particle pollutants. J Environ Stud 7:49–59

liz.obrien@forestry.gsi.gov.uk

Freer-Smith PH, Beckett KP, Taylor G (2005) Deposition velocities to *Sorbus aria*, *Acer campestre*, *Populus deltoides* x *trichocarpa* 'Beaupre´ ', *Pinus nigra* and *X Cupressocyparis leylandii* for coarse, fine and ultra-fine particles in the urban environment. Environ Pollut 133:157–167

Popek R, Gawrońska H, Wrochna M et al (2013) Particulate matter on foliage of 13 woody species: deposition on surfaces and phytostabilisation in waxes – a 3-year study. Int J Phytoremediat 15:245–256

Przybysz A, Sæbø A, Hanslin HM et al (2014) Accumulation of particulate matter and trace elements on vegetation as affected by pollution level, rainfall and the passage of time. Sci Total Environ 481:360–369

Sæbø A, Popek R, Nawrot B et al (2012) Plant species differences in particulate matter accumulation on leaf surfaces. Sci Total Environ 427–428:347–354

Sgrigna G, Sæbø A, Gawroński S et al (2015) Particulate Matter deposition on *Quercus ilex* leaves in an industrial city of central Italy. Sci Total Environ 197:187–194

Wang L, Gong H, Liao W et al (2015) Accumulation of particles on the surface of leaves during leaf expansion. Sci Total Environ 532:420–434

Yang J, Chang Y, Yan P (2015) Ranking the suitability of common urban tree species for controlling PM2.5 pollution. Atmos Pollut Res 6:267–277

Soil Quality

Kooch Y, Rostayee F, Hosseini SM (2016) Effects of tree species on topsoil properties and nitrogen cycling in natural forest and tree plantations of northern Iran. CATENA 144:65–73

Legout A, van der Heijden G, Jaffrain J et al (2016) Tree species effects on solution chemistry and major element fluxes: a case study in the Morvan (Breuil, France). Forest Ecol Manag 378:244–258

Precipitation Interception

Armson D, Stringer P, Ennos AR (2013) The effect of street trees and amenity grass on urban surface water runoff in Manchester, UK. Urban For Urban Gree 12(3):282–286

Asadian Y, Weiler M (2009) A new approach in measuring rainfall interception by urban trees in coastal British Columbia. Water Qual Res J Can 1:16–25

Kermavnar J (2015) Sestojne padavine v izbranih urbanih gozdovih Ljubljane. Stand precipitation in selected urban forests in the city of Ljubljana. Biotehniška fakulteta. Oddelek za gozdarstvo in obnovljive gozdne vire. Ljubljana, Univerza v Ljubljani

Livesley SJ, Baudinette B, Glover D (2014) Rainfall interception and stem flow by eucalypt street trees – the impacts of canopy density and bark type. Urban For Urban Gree 13(1):192–197

Contribution to Biodiversity

Crawford M (2000) Bee plants. Agroforestry Research Trust

http://pfaf.org/user/Default.aspx. Accessed 16 Aug 2016

http://selectree.calpoly.edu. Accessed 16 Aug 2016

http://www.tlamp.in-berlin.de/beefood.html. Accessed 16 Aug 2016

liz.obrien@forestry.gsi.gov.uk

Allergenicity

Cariñanos P, Casares-porcel M, Quesada-Rubio JM (2014) Estimating the allergenic potential of urban green spaces: a case-study in Granada, Spain. Landsc Urban Plan 123:134–144
Cariñanos P, Adinolfi C, Díaz de la Guardia C et al (2016) Characterization of allergen emission sources in urban areas. J Environ Qual 45:244–252

Toxicity

Nelson LS, Shih RP, Ballick MJ et al (2007) Handbook of poisonous and injurious plants. Springer, The New York Botanical Gardens
Wagstaff J (2008) International poisonous plants checklist. An evidence-based reference. CRC Press/Taylor & Francis Group, Boca Raton

BVOC Emissions

Guenther A, Zimmerman P, Wildermuth M (1994) Natural volatile organic compound emission rate estimates for U.S. woodland landscapes. Atmos Environ 28:1197–1210
Karl M, Guenther A, Köble R et al (2009) A new European plant-specific emission inventory of biogenic volatile organic compounds for use in atmospheric transport models. Biogeosciences 6:1059–1087
Kesselmeier J, Staudt M (1999) Biogenic volatile organic compounds (VOC): an overview on emission, physiology and ecology. J Atmos Chem 33(1):23–88
Klinger LF, Li QJ, Guenther AB et al (2002) Assessment of volatile organic compound emissions from ecosystems of China. J Geophys Res 107(D21):4603
Nowak DJ, Crane DE, Stevens JC et al (2002) Brooklyn's urban forest. USDA Forest Service, Newtown Square, pp. 1–107
Parra R, Gasso S, Baldasano JM (2004) Estimating the biogenic emissions of non-methane volatile organic compounds from the North Western Mediterranean vegetation of Catalonia, Spain. Sci Total Environ 329:241–259
Simon V, Dumergues L, Ponche JL et al (2006) The biogenic volatile organic compounds emission inventory in France: application to plant ecosystems in the Berre-Marseilles area (France). Sci Total Environ 372:164–182
Singh R, Singh MP, Singh AP (2014) Ozone forming potential of tropical plant species of the Vidarbha region of Maharashtra state of India. Urban For Urban Gree 13(4):814–820

Snow

Bräuning A, De Riddder M, Zafirov N et al (2016) Tree-ring features: Inidcators of extremem weather impacts. IAWA J 37(2):206–231
Sano Y, Fukazawa K (1996) Timing of the occurrence of frost cracks in winter. Trees 11(1):47–53

liz.obrien@forestry.gsi.gov.uk

Salinity

http://encyklopediadrzew.pl/encyklopedia.php?pwej=tak (Polish page about trees/shrubs). Accessed 8 Sept 2016

https://w110.bcn.cat/portal/site/MediAmbient/menuitem.37ea1e76b6660e13e9c5e9c5a2ef8a0c/index5b9e.html?vgnextoid=3cc37037aed1a210VgnVCM10000074fea8c0RCRD&vgnextchannel=3cc37037aed1a210VgnVCM10000074fea8c0RCRD&vgnextrefresh=1&ttl=86400000&lang=en_GB&page=3 (webpage about mediterranean plants). Accessed 9 Sept 2016

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Chapter 13
Conclusions and Recommendations

Roeland Samson

While critically reviewing the current knowledge on the role of urban trees and forests in cities, it becomes clear that trees, from a single street tree to an urban forest, provide an abundance of in environmental ecosystem services – and almost inevitably, cause some disservices as well.

The urban environment is becoming a major ecosystem type in Europe and in the world. In some densely populated regions, cities are even coming to dominate the landscape. However, it is important for us to consider that cities are extraordinarily complex, with a heterogeneous structure and huge variety of activities. They are the site of intense flows of energy and matter, amplified temperature extremes and decreased soil water availability, and often unique habitats – both above ground in streets and parks, and underground in sewage or utility systems. Recognition of the city as a full-fledged ecosystem leads citizens to realize that even our built environment is part of our nature, and that it is vulnerable and should be taken care of.

This in itself is an important reason to bring nature, and trees, into the city. But going beyond this, people can obtain an enormous range of very tangible benefits from natural amenities within cities. As the world's population becomes increasingly urbanized – and increasingly isolated from nature – interaction with a diversity of life forms in urban green spaces can give city dwellers a sense of relief and escape from urban life. So making nature an integral and significant part of the city allows it to become a more attractive, pleasant and healthy place to live.

At the same time, open space is – and will remain – a very scarce commodity in most cities. So in contrast with ecosystems where vegetation develops spontaneously, the introduction of trees in urban environments is an action which requires a clear planning strategy, considering in detail the services to be delivered from these

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trees. Depending on the local needs, this might be microclimate regulation, non-timber forest products or air pollution mitigation. Therefore a well-grounded understanding of the processes involved, and of the tree characteristics that are crucial to the complex web of services and disservices provided, is a prerequisite for making well-informed decisions on which tree species to plant and promote in a given place. Species used to create shade, for example, might at the same time aggravate local air pollution – and therefore detailed knowledge of the ES-related attributes of these species can be critical.

This section has surveyed the indispensable knowledge needed to support the selection of appropriate tree species in the form of a broad overview and a practical tool, the species-specific catalog (Table 12.1). In actual practice, the provision of services by trees will also depend on local meteorological and urban architectural conditions, which means that this knowledge of species attributes should be combined with model simulations to come to well-defined and supported choices. Atmospheric models have the capacity to deliver spatial and temporal fields of several weather and air quality variables and to anticipate, in a quantitative way, the effect of different urban planning options and different ES on urban climate, urban air quality and human comfort and health. They can, therefore, be used to diagnose the current urban condition in relation to ES, to study temporal trends, and to forecast the impact of urban development scenarios and strategies.

It is evident that if we want our urban trees to work for us, we need to take care of them and give them the appreciation they deserve. Soils are often compacted and polluted, growing spaces are too confined, and soil water is often scarcely available. Trees need to breathe, as they are living organisms – and only with enough water they will keep their stomata open to remove gaseous air pollutants. On the other hand, trees alone are not the solution to all of our environmental problems: they will not eliminate the sources of global climate change or filter out all of our urban air pollutants. But along with other source-related measures, like reigning in our dependence on fossil fuels and keeping polluting traffic out of city centers, they can certainly play a decisive role in mitigating these threats.

Although trees represent the most prominent component of the urban vegetation, they are complemented by other types of green infrastructure. Urban forest parks, with a high density of canopy coverage combined with green and permeable ground cover, can store more carbon in the soil than areas with only sporadic single trees. Along with the choice of vegetation type, appropriate management of UGI also plays a major role – not only for increasing carbon storage, but also for maintaining the health and longevity of the trees themselves, and in turn the benefits they afford. A wide, complementary and diverse array of species can reduce the risk of catastrophic loss if one or more of these predominant species were to succumb.

Summarizing the state-of-art knowledge on the environmental ecosystem services that urban trees provide shows that there are still gaps to be filled, for instance on the interaction of species with air pollutants, and the way that trees influence and depend on urban soils. But more basic knowledge is also lacking, as most knowledge on trees was until now gathered for trees growing in non-urban conditions. How do trees grow in cities? What is their leaf area index, leaf area density and leaf

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dynamic? How does pollution influence the physiology, including stomatal opening, of trees in urban environments? How do trees react to these artificial 'city desert' conditions (sometimes having very high temperatures, combined with very dry soils), and what does it mean for their performance? Even as research findings and experience continue to accumulate, we see this section as a key stepping stone to bettering our understanding of the use of trees in urban environments – as there can be little doubt that healthy and viable urban forests are critical to future urban living.

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Part II
Socio-Cultural Services Provided by Urban Forests and Green Infrastructure

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Chapter 14
Introduction: Socio-cultural Services of Urban Forests and Green Infrastructure

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The socio-cultural services and benefits provided by urban forests and green infrastructure are wide ranging and very important for urban populations in terms of contributing to their quality of life and quality of place. This section focuses specifically on these important socio-cultural services and benefits, drawing on both qualitative and quantitative data.

The first chapter explores issues of social and environmental justice with a particular focus on who is not accessing and gaining benefits from green infrastructure. Particular sections of society such as the income deprived, the disabled, and ethnic minority groups may not have the same access to green infrastructure that more affluent sections of society enjoy, and they may also face exposure to more environmental risks. The chapter outlines the wide range of benefits that can be delivered by socio-cultural services, drawing on evidence from survey data to highlight that some social groups are under-represented in having access to and gaining benefit from green infrastructure. It surveys a range of policies, programmes and grassroots actions from different European countries which enable and encourage a greater diversity of people – including under-represented groups – to access and enjoy the benefits of urban green spaces.

The accessibility of urban green infrastructure is relevant not just for the life of local residents, but also for the experience of visitors to the city. The second chapter explores the issue of tourism in detail, through a cross-cultural and comparative survey of 16 major European cities in eight countries. The aim of the survey was to explore tourists' use, practices and behaviours with regard to urban green amenities, and to assess their importance in terms of the different aims of tourists' visits. Even though the term 'green infrastructure' was not widely understood by respondents and in fact was unfamiliar, they nevertheless felt that green areas were important for

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a city and influenced their choice of cities to visit. Green infrastructure and historical sites can often be closely integrated, and people visiting cities often make the most of their experience by taking advantage of accessible parks and natural attractions in the vicinity.

The final chapter in this section focuses on the health and well-being benefits of urban forests and green infrastructure, as an increasing body of evidence has accumulated in the past two decades on this topic. There are potential benefits in terms of mental well-being, with the concept of 'restoration' suggesting that contact with nature can rejuvenate people and offer relief from stress and fatigue, and that physical activity can be enabled by green areas within the city. There are a number of mechanisms which illustrate how green infrastructure can contribute to health and well-being, though there is much debate about these issues and further evidence is undoubtedly needed. Health professionals are also starting to take note of the health benefits of nature, with an increase in the use of 'green prescriptions' as a means to prevent ill health or treat illnesses such as heart disease.

In conclusion, this section outlines the importance of socio-cultural ecosystem services for human well-being, and for all sections of society.

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Chapter 15
Social and Environmental Justice: Diversity in Access to and Benefits from Urban Green Infrastructure – Examples from Europe

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15.1 Introduction

Urban forests (UF) and green infrastructure (GI) – including trees that are not only in woodlands, but also on streets, along streams, in parks, and on roofs – provide important ecosystem services for urban and peri-urban populations. By allowing for urban living in pleasant and healthy surroundings, breaking up the paved and impermeable built environment, and providing space for recreation (Fig. 15.1), urban

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Fig. 15.1 Children playing on play equipment in Nice (Photo: Liz O'Brien)

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greening facilitates a wide variety of well-being benefits (Panagopoulos et al. 2016). Access to urban GI, whether by living on a green residential street or having an urban park nearby to walk the dog, can contribute to mental well-being, stimulate social connections and foster active lifestyles that help combat obesity-related diseases and premature death (O'Brien and Morris 2013; Koohsari et al. 2015; Coen and Ross 2006). However, particular sections of society such as the income deprived, the disabled, and ethnic minority groups may not have the same access to these amenities that more affluent sections of society enjoy, and they may also face exposure to more environmental risks. To explore and describe these issues, researchers have turned to the perspective of socio-environmental justice (Hughey et al. 2016).

This chapter will explore the issues of social and demographic distribution of access to and use of UF and GI. It will identify the benefits derived from cultural ecosystem service provision, to provide some illustration of which sections of society, in a range of different European Countries, indeed benefit from access to urban GI (as well as wider peri-urban and rural GI) and which sections of society do not have this opportunity. The chapter will then go on to provide examples of policies and interventions that are leading to action in these different countries, to enable those parts of society who are under-represented to have access to and gain benefits from GI[1].

This work is situated within the wider context of socio-environmental justice in relation to engagement with nature, which combines concepts from social as well as environmental justice (Kabisch and Haase 2014):

> *Social justice refers to the principles, values and belief that every individual and group is entitled to fair and equal treatment, which is necessary for the achievement of a society in which all people have equal access to rights, not only under law, but in all aspects of life, and all people get an impartial share of the benefits as well as carry a fair share of the responsibilities of society.*
>
> – United Nations, Department of Social and Economic Affairs (2009)

According to this view, people should have the same right to fair and equal treatment regardless of their status or background. Environmental justice is a broad concept with a number of elements. It can include distributive justice, which focuses on the distribution of environmental burdens as well as benefits irrespective of race, income, or socio-economic status (Schwarte and Adebowale 2007). Environmental burdens can include pollution, hazards and risks associated with industry and transport or natural disasters. Environmental benefits can include access to high quality built and natural environments, but also benefits from other ecosystem services (including improved air quality, protection against floods or improved health). It can also include procedural justice, which concerns the fairness and transparency of processes through which decisions are made and often has a specific focus on environmental law. Evidence suggests that low-income communities can suffer from a range of environmental disamenities including intensification of the urban heat

[1] For the rest of the chapter we will primarily use the term 'green infrastructure' (GI), noting that Urban Forests are a key component of this and some of the surveys we draw on are of forested areas.

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island, noise pollution, poor air quality and exposure to toxic facilities as well as restricted access to environmental goods and services (Evans and Kantrowitz 2002; Jerrett et al. 2001; Walker et al. 2005; Lucas et al. 2004; Bolte et al. 2011)

Both social and environmental justice are sensitive to power issues (e.g. who determines who is allowed to cause pollution, and who will suffer from it), focus on communities or groups rather than on individuals, and tend to adopt a holistic approach to analysing and addressing problems and reforms. Adebowale (2003, cited in Lucas et al. 2004) has a broad approach to defining environmental justice, including:

1. A fair share to natural resources (distributional justice)
2. The right not to suffer disproportionately from environmental policies, regulations or laws
3. The right to environmental information and participation in decision making (procedural justice)

Given the high population density in many urban areas and the concentration of inequalities, and their combined impact on human health and well-being, the uneven accessibility of urban GI has become recognized as an environmental justice issue (Wolch et al. 2014). Case study research in the United States and in European cities shows that many immigrant communities have less access to urban green space in their vicinity than the general population (Germann-Chiari and Seeland 2004; Pham et al. 2012). Several studies mention the role of the qualities provided by GI, in terms of access to space for activities and facilities for attracting a diverse range of the population (Anguelovski and Alier 2014; Wolch et al. 2014; Kabisch and Haase 2014). This suggests there is a need to take account of the cultural preferences of residents (including different age groups) that are served by green amenities in their vicinity. Low (2013) raises the issue of *interactional justice*, meaning that people should be able to interact safely and freely, regardless of age and cultural or ethnic background. By including not only access, but also the preferred and actual use of GI, the focus on equitable distribution of GI is broadened.

This discussion begins by: (1) outlining the wide range of benefits from cultural ecosystem services people can gain from contact with GI across urban and peri-urban areas, drawing on existing evidence. We will then: (2) draw on evidence from survey data at national, regional and local levels to illustrate who is accessing and benefiting from GI, how this access is distributed across different social groups, and which groups are potentially under-represented. The final section of the chapter will: (3) focus on policies, planning and projects occurring in different countries that are aimed at targeting under-represented groups and encouraging a greater diversity of people to access and enjoy GI. The chapter will finish by outlining some important conclusions and identifying directions for further research.

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15.2 Evidence of the Links Between Green Infrastructure and Cultural Ecosystem Service Benefits

There is an increasing body of literature that illustrates the wide range of benefits of engaging with GI, and the services that ecosystems offer in support of experiences which are beneficial to people's well-being (Roy et al. 2012; Saraiva et al. 2014; Madureira et al. 2015; O'Brien et al. 2016a, b; De Vreese et al. 2016). The evidence increasingly focuses on how the interactions between people and GI and the physical practices that take place in these spaces can result in the realization of positive experiences (ecosystem services), with a secondary focus on negative experiences (ecosystem disservices – see Chap. 9). A wide range of benefits (e.g. educational and recreational opportunities, benefits to human health and well-being, creating a sense of place or a local identity, increased social cohesion, pleasant sensory experiences) can be gained from engaging with GI (Berte and Panagopoulos 2014; Moreno-Jiménez et al. 2016; see also Chap. 16 on the role of GI in tourism, and Chap. 17 on the health benefits of GI). As Schroeder (2012) puts it, "such experiences serve as significant sources of meaning and happiness in people's lives, and lead to strong emotional attachments to the places where they occur". Recent ecosystem services classification frameworks, such as the Common International Classification of Ecosystem Services (CICES 2015; Haines-Young and Potschin 2013), provide useful conceptions of these services. Church et al. (2014) specified a more detailed framework specifically for cultural ecosystem services and benefits. Socio-economically disadvantaged groups can gain benefits from GI. Mitchell et al. (2015), in a large study of thirty-four European countries, explored mental well-being, socioeconomic status and access to greenspace. They found that socio-economic inequalities were reduced in neighbourhoods with good access to greenspace and argue for equigenic environments (i.e. places that can reduce health inequalities). Ward Thompson et al. (2012), in a small exploratory study in a deprived area of Scotland, looked not only at self-reported stress but also took salivary cortisol samples to assess objective signs of stress – and identified a significant relationship with the quantity of greenspace, suggesting that natural environments are associated with stress reduction for deprived sections of the population. Peters et al. (2016), in a qualitative study with immigrants in Poland, the Netherlands, Germany and the United States, found that visits to urban parks could help build social connections and develop a sense of place for immigrants in the new places they lived.

O'Brien et al. (2016b) identified a wide range of benefits in a review that drew on evidence from different European countries (Table 15.1), and suggested how these benefits fit into the Church et al. (2014) and CICES classification schemes. The seven sub-categories outlined in Table 15.1 are the benefits identified by a wide range of publics and stakeholders in different studies across Europe. Learning can be gained through knowledge being passed from generation to generation (e.g mother to daughter during outdoor play or school education in outdoor classes), or from learning new knowledge by participating in an organized activity such as a

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Table 15.1 The cultural ecosystem service benefits identified by and adapted here from O'Brien et al. (2016a, b)[a]

Overarching category	**Well-being benefits of cultural ecosystem services**						
CICES (common classification of ecosystem services)	Physical and experiential interactions			Spiritual, symbolic and other interactions with biota, ecosystems and land/seascapes			
	Intellectual and representative interactions						
Church et al. (2014) Cultural ecosystem benefits	Capabilities			Experiences			Identities
O'Brien et al (2016b) High level category	Learning	Health	Economic	Social connections	Connection to nature and benefits of urban GI	Sensory experiences	Cultural and Symbolic
Benefit types	Ecological knowledge	Physical movement and activity	Real estate value	Social inclusion	Wildlife, plant and animal diversity	Attractiveness	Spiritual experience
	Participation in planning and design	Escape and freedom	Tourism	Social contact	Nature in the city	Beauty	Local identity
	Education and learning	Enjoyment and fun		Social benefit	Mix of trees and meadows	Aesthetics	
		Relaxation			Open landscape	Arousal	Past-future continuity

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		Revitalized			Water	Atmosphere	Historical continuity
		Restoration			Nearby nature	Natural grandeur	Contributing meaningfully
		Self esteem			Nature/ecological connection	Fresh air	Satisfaction
		Refreshed			Diverse spaces	Mysterious	Security
		Feeling at peace			Favourite places	Screening from traffic	Sense of freedom
		Calm/quiet			Quality of place	Shelter	Structure and routine
		Confidence			Forest	Green view	Inspiration
					Land regeneration	Complex	Cultural importance
						Sounds and smells	Place attachment
							Heritage

[a]This study drew on 56 different studies from over 15 different countries**.** Well-being acts as an overarching category that encompasses seven sub-categories (e.g. health, learning) developed by the researchers. The text in each category represents the specific words used in the research papers and reports reviewed

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fungi foray or from learning new skills while undertaking conservation work. Tangible health benefits can be realized by undertaking physical activity in green spaces, passing by them as part of daily life, or even looking at them through the window (Ulrich 1984), and this includes the mental health benefits to be gained from relaxing and de-stressing (Korpela and Ylen 2007; White et al. 2013). Economic benefits were also mentioned (albeit less often than other benefits), for example in terms how GI can contribute to the economic vitality of local communities by boosting tourism. Social connections can be realized from accessing GI with friends and family, or by joining organized activities where there is an opportunity to meet new people (Kazmierczak 2013) – such as health walks or conservation volunteering (O'Brien et al. 2011). Connection to nature benefits people by enabling them to interact with flora and fauna, which allows them to observe changes in the seasons and to enjoy varied and diverse spaces. Pleasant sensory experiences were also identified, and although focusing on visual aesthetics, this could also include smells, touch, and feelings of security from being sheltered by trees and thermal comfort under heat stress conditions. GI can engender symbolic benefit by becoming a part of people's local community identity and a place they become attached to (Figs. 15.2, 15.3 and 15.4). The benefit of land regeneration was mentioned in relation to the creation of new nature spaces on brownfield land (e.g. land previously used for industry or commercial purposes) that could then be used by local communities (O'Brien and Morris 2013). What Table 15.1 illustrates is the wide and varied nature of benefits people gain from urban green infrastructure – but these benefits will not be realized if people live in communities with little or poor quality GI, if their rights of access to it are limited, or if their engagement with it is hindered by social, personal and economic barriers.

15.3 Access to and Accessibility of GI

It is important to distinguish between legal rights to access GI for recreation and leisure, and the concept of *accessibility*, which concerns issues that have to do with whether people have the ability – or perceive they have the ability – to access GI. For example, there may be a legal right of access to a park or other site; however, if people do not have a car and there is no public transport, they may not be able to physically reach it. It is also possible that sections of society may not realize what their legal rights of access are and may not know which places they can visit, or they may not have the confidence to visit such sites. Some of these and other barriers to access are outlined below.

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Fig. 15.2 Green wall in London (Photo: Liz O'Brien)

15.3.1 Legal Rights of Access

Elands et al. (2010) have documented the legal rights of access to forests and other natural spaces in general (in both urban and rural settings) across European countries. These differ between limited access to private forests in Mediterranean and Eastern European countries and an 'everyman' right of access (allowing responsible access to private land as well public land) in most Nordic countries and Switzerland. Access rights depend on ownership (public/private), recreational activities undertaken (e.g. non-motorized and motorized), land use type (e.g. forest, open fields, coastline), time (daytime, night), distance (to residential buildings), and size (of forest/nature area). Table 15.2 below gives a brief overview of legal rights of access in several European countries. Some of these countries have 'everyman's right' access to publically owned forests

Fig. 15.3 GI in Turin (Source: Liz O'Brien)

Fig. 15.4 Enjoying GI on the edge of Glasgow (Photo: Forestry Commission)

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Table 15.2 Legal rights of access in selected European countries

Country	Everyman's right	Roads and trails only	Private landowner defines or allows access rights
Finland	X		
Sweden	X		
Norway	X		
Latvia	X		
Switzerland	X		
Belgium		X	
Scotland	X		
England		X	X
Wales		X	X
Ireland		X	
Denmark		X	
Turkey		X	
Estonia	X		

It should be noted, however, that even private GI could have important benefits for (deprived) communities. Ecosystem services (ES) provided by urban GI are not limited to those supplied when actively using the green area itself. Seeing urban green from a distance can have a positive impact on mental health and well-being. Shade supplied by privately owned trees provides similar service levels as trees on public land (Lafortezza et al. 2009, 2013). Even though countries may have open access rights, there may still be sections of society that access nature less than others due to a range of physical, social and economic barriers.

15.4 Barriers to Accessing GI

Specific sections of society may face barriers to accessing GI. Research in Britain, for example (Morris et al. 2011), shows that the benefits gained from accessing forests are not evenly distributed across different sections of society. Minority groups, the disabled, older age groups and those of lower socio-economic status (SES) do not use GI to the same extent as other groups nor gain the wide range of benefits identified in Table 15.1. A range of evidence suggests that the following issues are important and that multiple factors may come together to act as barriers to people accessing GI.

15.4.1 Distance to and Distribution of GI

The distribution of GI, particularly forests, can have a significant impact on accessibility and is closely linked to concepts of distributive justice. Forests, and in particular urban woodlands, are the most visited parts of Danish nature (Jensen 2014).

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However forest cover is low (14%) and highly fragmented, particularly in an urban context where forests of less than two hectares in size account for 50% of all forest patches. In the UK, forest cover is also low (13%) and for some people, forests are too far away to use. Recent surveys in England show that there has been an increase in visits to nature near towns and cities, with fewer visits being made to the countryside (Natural England 2015). About 21% of the inhabitants of Flanders (Northern Belgium) have no access to green areas within walking distance (Simoens et al. 2014). In Flemish cities, this rises to one third of the inhabitants (Van Herzele and Wiedemann 2003; Simoens et al. 2014). In Turkey, urban forests have been established up to 40 km away from city centres. Only half of the urban forests are within walking distance to the city, 80% are accessible by public transport and about one fifth can only be reached by private vehicle (Atmiş and Günşen 2015). The distances between urban forests and residential areas and the lack of accessibility limit the number of users.

In the Netherlands, a model has been developed to evaluate the correspondence between the demand for and supply of opportunities for recreational walks in a natural environment. According to the model, especially in socio-economically deprived urban neighbourhoods the supply of such opportunities within 2.5 km falls behind the demand. On average, these neighbourhoods have only 68% of the needed supply available to them, compared to 82% for the wealthiest urban neighbourhoods and 97% for deprived neighbourhoods in non-urban municipalities. Also the scenic quality of the nearby countryside has been shown to be lower for these deprived urban neighbourhoods. Similar figures have been observed for urban neighbourhoods with a high proportion of people with a non-Western ethnic origin (Li 2015). In another study, calculated shortages have been shown to be related to the frequency of going for a walk. On average, people living in a neighbourhood with a large shortage (< 50% of what is required) take 20% fewer recreational walks (De Vries et al. 2014).

15.4.2 Large Road Infrastructure

A study in Denmark of large transport infrastructure acting as a barrier to outdoor recreation concluded that ring roads at the edge of towns and urban areas and especially roundabouts impair recreational access from the city to the countryside (Kaae et al. 1998). Research on the use of forests in Britain suggests that crossing large busy roads can act as a deterrent to accessing these spaces, particularly for families with children (Morris et al. 2011). Similar conclusions have been made for the use of urban GI in Flanders (Van Herzele and Wiedemann 2003).

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15.4.3 Lack of (Adequate) Recreational Infrastructure and Quality of the Greenspace

Recreational infrastructure consisting of a network of greenways, recreational roads, paths, tracks and trails is essential for enabling accessibility in many countries (Højring 2002; Olafsson 2012). In Denmark and Belgium however, the agricultural structural development with amalgamation of fields and abandonment of farm roads has in some areas reduced the accessibility of the landscape significantly (Caspersen 2011; Højring 2002). Belgian recreational users of the outdoors state a lack of well-equipped tracks and sites for their activities (Bomans et al. 2010). In Ireland, lands that are legally accessible (e.g. Coillte lands) may have no facilities, such as car parks, which act as a disincentive to use. A similar issue is found in Britain, as the provision of recreational infrastructure differs across forests and wider GI. The Forestry Commission that manages the public forest estate in England focuses its infrastructure spending on 'destination sites' that are big enough to accommodate large numbers of visitors (Molteno, et al. 2012), a similar approach (but extended to well-known and heavily visited sites) is followed by the Flemish Agency for Nature and Forests in Belgium. Disabled groups and older people suggest that a lack of facilities such as toilets, benches, and suitable pathways can act as barriers to accessing nature in Britain (Morris et al. 2011); however for other groups abundant recreational infrastructure can have a negative impact on nature experiences (Abildtrup et al. 2013). Evidence from Latvia suggested that accessibility to recreational sites is limited and that some urban forests are still often unsuitable for frequent recreation (Jankovska et al. 2013). A survey in Turkey (Atmiş et al. 2015) highlighted that recreational infrastructure such as signposts, benches, pergolas, and rain shelters are insufficiently available and if available are often damaged due to misuse. About half the participants in the survey indicated that the low quality of facilities and services negatively impacts the frequency of their forest visits, and only 34% of the users were satisfied with the management of urban parks and facilities (Atmiş et al. 2015).

15.4.4 Information and Knowledge

Due to the complexity of rules regarding rights of access and what is or is not allowed, a lack of knowledge can act as a barrier to some users. This problem is highlighted in a study showing that the Danish general population has a poor awareness of some of the rules for public access; e.g. only 45% of the population knows that it is legal to walk on private dirt roads and only 29% know it is legal to cycle on them (Jensen 1998). In England, a lack of information about what forest sites are accessible and what facilities they have is seen as a barrier to access (Morris et al. 2011). Some focus group respondents in England, when talking about access to GI felt a lack of confidence in knowing where they were allowed to go (i.e. legal right

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of access) and what to expect when they got there in terms of facilities such as toilets and footpaths (O'Brien 2006). The existence, location and recreational offer of Turkish urban forests is unknown to many residents of neighbourhoods that are not adjacent to the urban forests (Atmiş et al. 2015). Studying the visibility of urban forests in the media, Atmiş et al. (2015) revealed that only 40 (67%) of 60 occurrences in the national media on forests were on urban forest services, and 10 of the remaining 20 news clips were crime related.

15.4.5 Cultural Norms

Nine percent of respondents in Jensen's (2014) study in Denmark can be characterized as 'non-visitors' to nature areas (outside cities), and the proportion of these is especially high among adults with a non-Western background. This study also has shown that in relative terms, more citizens with ethnic minority backgrounds have a dislike or fear of different wildlife species – and this has prevented visits to natural areas and inhibited their familiarity with Danish nature (Jensen 2010). A recent case study of adolescents' outdoor recreation habits in Denmark (Gentin 2015) highlighted three of the most common reasons for not visiting green areas: a lack of time, a lack of desire to do so, and perceived boredom outdoors. Seeland et al. (2009) showed differences between native Swiss and immigrant youngsters in terms of their use of Swiss forests, but found that both groups are using parks and playgrounds to a similar degree.

Another reason for low use is the mismatch between the design and qualities of the greenspace and the infrastructure, equipment and activities looked for by these minority groups (Kabisch and Haase 2014; Wolch et al. 2014). Urban GI are mainly designed, built and managed by experts in a professional capacity, who do not always take into account the preferences of population groups living close to the area. This may also include a lack of attention to the wishes of the elderly, impaired, families with children, school groups, sport clubs, etc. Planning and managing urban GI in a participatory way with the (intended) users can help to overcome this barrier (Seeland et al. 2009; Kabisch and Haase 2014). Regulations should also take cultural norms into account; for example, picnic fires and barbecues were initially not allowed in Turkish urban forests. But as barbecuing is an important activity in Turkish outdoor culture, visitors preferred to use others recreation areas instead of urban forests, and the 2013 revised urban forestry regulation allowed this upon request of the visitors. With this amendment, a step forward was taken in adapting urban forest use in Turkey to the preferences of the population (Atmiş 2016).

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Fig. 15.5 Burnt out car in a Scottish woodland (Photo: Liz O'Brien)

15.4.6 Safety and Confidence Issues

Urban green areas can sometimes have negative connotations as unsafe places (Fig. 15.5). As mentioned above, 17 out of 60 Turkish news reports on urban forests in the national media were found to be crime-related (Atmiş et al. 2015). Seventeen other news items on urban forest services contained negative news such as urban forests turning into ruins, being opened to construction, or causing friction between municipalities (Atmiş et al. 2015). Women in Britain can have concerns about safety, and often visit woodlands in the company of others or with dogs. Women focus group participants in England talked about being 'flashed' (men exposing themselves) as teenagers (O'Brien and Morris 2013). Other focus group work in Britain found that respondents recalled high profile news coverage of bodies buried in woodlands and that such stories remain in people's memories, often for a long time, affecting their perceptions of woodlands (O'Brien and Morris 2013). Forests have been found to be under-used by females compared to males due to security concerns in Ireland, as well (Coillte and The Irish Sports Council 2005).

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15.5 Surveys on the Distribution of Access to and Benefits from GI

Members of the European COST Action FP1204 on urban forests and green infrastructure were asked to submit relevant surveys from their home countries, resulting in relevant data submitted for a total of thirteen countries. It is important to note that this sample is not representative of the entire population, but rather illustrates some key issues regarding access to GI across Europe. The surveys were primarily undertaken at a national level, and examined who is accessing GI. The UK and Belgium submitted several national/regional surveys which together covered the national area, while three others (Ireland, Greece and Turkey) supplied surveys at a regional/local level describing access to particular sites in specific regions. The national level surveys generally examined access to GI across urban and rural areas, though it was possible to draw out key results associated with urban GI when the evidence was available. In general the surveys record visits to GI, the frequency of those visits, and the benefits obtained, and sometimes they identify barriers to access which limit visits by particular social groups. The number of different socio-demographic variables for which data were collected varies between surveys (Table 15.3), ranging from just two (Belgian regional surveys) to eight (Wales, UK).

15.6 Experiences from Different European Countries

There is a growing recognition that social and economic disadvantage and exclusion have ethnic and age-related dimensions, and recently more emphasis has been placed on the connection between the provision of public recreation facilities and the promotion of social and racial integration (Ravenscroft and Markwell 2000). Table 15.4 identifies the social groups that either under-use or experience difficulty accessing GI in different countries, identifying some significant commonalities and differences. Surveys in eight countries identify people of lower socio-economic status (SES) as visiting GI less often or not at all compared to other groups. Although the surveys do not state specific reasons for this, existing evidence suggests that lower SES may lead to a lack of means to visit GI as the cost of a private vehicle or even public transport is too great. For some of this group, low aspirations and a lack of familiarity with accessing GI mean travel outside of their immediate area is limited and this may lead to a lack of access (O'Brien and Morris 2013). Older groups, 65 years of age or more (and a little as 45 years in the urban park survey in Turkey) are recorded as visiting less or not at all in eight countries (Oguz 2000). The reasons for this may include limited physical mobility, and concerns about the availability of facilities such as toilets and benches. The types of surveys drawn on here do not necessarily provide a full picture of the social distribution of access to GI. For example, not all of the surveys gather data on key socio-demographics. Also a large-scale survey in England shows that men and women visit nature in more or less

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Table 15.3 Surveys of recreational use of GI at national/regional/local level in a range of European countries and the key socio-demographic variables included

Country	National/Regional/Local (N/R/L)	Ethnic status	Education	Gender	Age	Working status/ Socio- economic status (SES)/ income	Disability	Car ownership	Low income or deprivation
UK (Scotland)	N	Yes	No	Yes	Yes	Yes	Yes	Yes	Yes
UK (Wales)	N	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes
UK (England)	N	Yes	No	Yes	Yes	Yes	Yes	Yes	Yes
Switzerland	N	Yes	Yes	Yes	Yes	Yes	No	No	No
Finland	N	No	Yes	Yes	Yes	Yes	No	Yes	Yes
Belgium (Flanders)	N/R	No	No	Yes	Yes	No	No	No	No
Belgium (Wallonia)	N/R	No	No	Yes	Yes	No	No	No	No
Belgium (Brussels)	R	No	Yes	Yes	Yes	Yes	No	No	
Latvia	N	No	Yes	Yes	Yes	Yes	No	No	No
Denmark***	N	Yes	Yes	Yes	Yes	Yes	No	Yes	Yes
Netherlands*	N	Yes	Yes	Yes	Yes	Yes	No	No**	Yes
Greece	L	?	?	?	Yes	?	Yes	?	?
Turkey	L/R	No	Yes	Yes	Yes	Yes	No	No	No
Spain	L	No	Yes	Yes	Yes	Yes	No	No	No
Portugal	L	No	Yes	Yes	Yes	Yes	Yes	Yes	No
Ireland	L/R	No	No	Yes	Yes	Yes	No	No	No

*Primarily asks about leisure activity, with type of environment as follow-up question (not spatially explicit)
**Per trip the main transport mode is asked about, which can be by car (this does not necessarily indicate possession and vice versa)
***The Danish survey was analyzed for forest access specifically and then for all GI; in Table 15.4 it has been separated to cover both forests and GI use

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Table 15.4 Social groups that either under-use or experience difficulties in accessing GI, based on a limited sample of surveys in different European countries

Country	Regions	Scale (National, Regional, Local)	Forests/ broader GI focus	Older age groups	Younger age groups	Minority ethnic groups	Less education	Lower socio economic status	Less green neighbour-hoods	Disability	Large city/ urban areas	Higher income	Females	Without access to a car
Belgium	Brussels	Local	GI		X			X						
	Flanders	Regional	GI	X				X						
	Wallonia	Regional	GI	X	X									
Denmark		National	Forest		X			X			X			X
		National	GI			X					X			X
Finland		National	GI	X				X						
Switzerland		National	Forest		X		X							
UK	England	National	GI	X		X		X		X	X			
	Wales	National	GI	X			X			X				X
	Scotland	National	GI					X						X
Netherlands		National	GI			X		X	X		X			
Latvia		National	Forest	X						X				X
Greece		Local	GI	X					X	X				

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Ireland		Regional/ Local	Forest	X	X			X			X		X	
Turkey	Black sea region	Regional	Urban Forest	X				X						
	Ankara	Local	Urban Park	X								X	X	
Spain		Regional	Urban Park	X				X		X				X
Portugal		Local	Urban gardens and parks			X								
Total				Identified in 11 surveys but data from 8 countries	Identified in 5 surveys but data from 4 countries	4	2	Identified in 10 surveys from 8 countries	2	Identified in 5 surveys but data from 4 countries	4 surveys in 4 countries	1	2	Identified in 5 surveys from 4 countries

Note that in some countries data are drawn from more than one survey (Danish data come from a single survey but are analyzed separately for GI and forests)

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equal numbers; however more detailed research has illustrated that women often visit GI with friends and family or when walking the dog, rather than alone, due to concerns about safety (O'Brien 2006; Morris et al. 2011).

Some country surveys provide more in-depth information for particular sections of the population (Neuvonen and Sievänen 2011). For example, a report on the 2009–2012 England survey data focused on specific social groups to explore differences in access to the natural environment. The report looked at the black and minority ethnic (BME) population, the disabled, the urban deprived (i.e. residents of areas within the bottom 10% of the Index of Multiple Deprivation[2]), those of lower SES (i.e. semi-skilled and unskilled workers and the long term unemployed) and older people aged 65+. It found that all of these groups visited nature less on average than the wider population. It found that out of these five groups, the elderly and disabled visit the natural environment more frequently and have more positive attitudes towards it than the other three groups. The BME and urban deprived populations are the least likely of the five groups to visit, and were also found to have less positive attitudes toward nature. For those who visit more frequently and have positive attitudes to nature, this seems to be connected to the emotional experience of enjoying wildlife and scenery at favourite places – while those who visit less participate in activities (like playing with children, exercising and socializing) that are often associated with nature, but which also might also be carried out in other types of environments (Burt et al. 2013). Sixty eight percent of visits for these groups were taken within two miles of people's starting point, which is probably linked to the fact that 64% of these trips are made on foot. Over five years of the survey to date, there has been a 17% increase in visits to nature spaces such as parks in towns and cities (Natural England 2015). Between March 2013 and February 2014, visits to green spaces in towns and cities were higher than visits to the countryside (1.36 vs. 1.31 billion visits, respectively).

In the city of Kalamaria, Greece, residents rated GI as important, and were satisfied with many of the characteristics studied – suggesting that management 'keep up the good work' in terms of accessibility, cleanliness and plant care. However residents were dissatisfied with a range of aspects related to aesthetic design, number and size of green areas, sports facilities, safety measures for children and facilities for people with disabilities, which were also rated as important (Karanikola et al. 2016). In Latvia, a national level survey examining the use of forests for recreation activities found that those over 65 years of age and with disabilities, those living in rural areas, and those not owning a car had lower accessibility to forests for recreation. The survey found that limitations to accessing forests for recreation include the reliance on public transport, poor basic infrastructure at recreation forests, and exclusion of people with disabilities due to a lack of supporting infrastructure. It was also found that the urban dwellers of the metropolitan area of Riga/Pieriga

[2] The English Index of Multiple Deprivation measures relative deprivation and is based on indicators that cover key areas such as income, education, health, housing, environment, employment and crime (Department for Communities and Local Government <CitationRef CitationID="CR27" >2015</Citation Ref>).

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travel further for recreational activities than those in rural regions. Lack of access to GI can be an indicator of lower SES, poor accessibility and unsatisfactory environmental quality of nearby forests (Jankovska et al. 2013). Riga, which is the capital of Latvia and has more than 56% GI cover, was found to suffer from poor basic infrastructure for accessibility. Urban inhabitants there preferred inexpensive and short visits for physical recreational activities.

15.7 Planning, Policies, Projects and Grassroots Action That Can Enable Engagement with GI by Diverse Groups

From existing literature and the small sample of surveys outlined above, it is evident that not all groups within society are accessing and benefiting from engagement with urban GI. However, there are a number of ways in which currently under-represented groups can be enabled and encouraged to benefit from GI through a variety of approaches. These include:

- policies that establish an overall framework for access to GI at a national or regional level
- spatial planning approaches that identify potential locations for new GI in order to improve its distribution across urban areas
- projects that are specifically organized and targeted to enable or encourage people to access urban GI
- grassroots actions, i.e. bottom-up initiatives that address specific community needs or interests

15.8 Policy and Planning

In many countries, policies regarding GI and outdoor recreation follow the principle that these amenities should be 'provided for all'. In practice, however, this may not result in all sections of society taking part. In England, the Natural Environment White Paper (HM Government 2011) has a specific section on reconnecting people and nature which emphasizes that everyone should have fair access to a good quality natural environment (distributional justice). As discussed above, this is important because minority groups often have disproportionately poor access to GI, and in turn greater exposure to health-related problems. In fact many urban parks were created not only because of their potential to protect the various ecosystem services provided, but also to bring recreational opportunities to socio-economically disadvantaged communities in urban areas (Byrne et al. 2009, 2010; Santucci et al. 2014).

Urban forests and parks are important components of the GI of many European countries and equal access is an important policy for environmental justice. At a national policy level within Denmark, the 'Naturplan Danmark' (Ministry of the Environment 2014) stipulates that "all groups in society should have the chance to use nature – and benefit from it." It goes on to suggest that everyone should have

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easy access to outdoor recreation in Denmark. The focus is on the provision of opportunities, though it is the responsibility of various user-groups to make the most of them. As discussed below, for example, the Danish Ministry of Environment in 2015 allocated over one million Euros to a social nature grant scheme that will create more and better opportunities for nature and outdoor experiences for the most socially vulnerable groups within society, giving them the chance to have a more active outdoor life.

The Flemish Government has an ambitious plan to open 1,000 extra hectares of accessible green space around the Brussels Agglomeration by 2019. Facilitating nature experiences is one of the key objectives of the Flemish Agency for Nature and Forest. One of the specific policies is focused on the younger generation, providing 'Play Zones' for children. Children can freely play and roam in these areas in nature and the forest, without having to stay on the trails. Another example, focused on changing the distribution of forests to benefit more deprived groups, is shown by the case of Vestskoven (the West Forest) in Copenhagen. This new urban forest (1,500 ha) is located in the socially deprived western part of Copenhagen, and was afforested in the 1960s as an outcome of national and local policy focused on distributional justice. Today the West Forest acts as a green wedge, providing multiple nature experiences for the urban population with a total of 325,000 annual visits undertaken in 1997 (Jensen 2003).

In terms of spatial planning, standards have been developed that can act as a guide to the amount and size of GI near to where people live, i.e. focusing on distributive justice. For example in the United Kingdom the Accessible Natural Greenspace Standard (Angst) was developed in the early 1990s, and uses existing evidence to specify the maximum distances people should travel to GI. The standard recommends that everyone, wherever they live, should have accessible natural greenspace:

- of at least 2 hectares in size, no more than 300 metres (5 minutes walk) from home;
- at least one accessible 20 hectare site within two kilometre of home;
- one accessible 100 hectare site within five kilometres of home; and
- one accessible 500 hectare site within ten kilometres of home; plus
- a minimum of one hectare of statutory Local Nature Reserves per thousand population (*Natural England* 2010).

In the Netherlands, the government recommends 75 square meters of urban green space per dwelling as a guideline. The Netherlands Environmental Assessment Agency (PBL Wageningen UR 2010) added that this public green space should be available within 500 meters from the dwelling, though not all cities meet this recommendation. For example, in 2006 the average for Amsterdam was 38 square meters per dwelling (van den Bosch et al. 2015). The city of Berlin aims to have six square metres of urban green space per person (Senatsverwaltung für Stadtentwicklung und Umwelt 2013) and Leipzig in eastern Germany aims to have ten metres per person (City of Leipzig 2003). Kabisch and Haase (2014) in a study of urban green spaces in Berlin found that the highly dense areas of the city, where

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immigrants were over-represented, had disproportionately less green space. In Belgium, Van Herzele and Wiedemann (2003) suggests residential areas should have green (walls, pocket parks, street trees) within 150 metres of each home, and a larger neighbourhood green space within 400 metres. These guidelines have been used in the Flemish Regional Ecosystem Assessment to assess the available green space for Flemish citizens (Simoens et al. 2014).

Although not statutory requirements, these guidelines can provide useful information and guidance for decision makers and greenspace planners. A World Health Organization expert group suggests the development of a health indicator for cities such as 'square meters of greenspace per capita' to reflect social and environmental equity (WHO Expert Group, 2012). More recently, based on research commissioned by WHO Europe, Annerstedt van den Bosch et al. (2015) proposed a different type of guideline: having an urban green area of at least one hectare in size within a distance of 300 meters. However, there is a danger that meeting the guidelines can become a goal in itself without consideration being given to how this contributes to the ultimate goal of improving the quality of life of citizens.

15.9 Targeted Projects and Programmes

Targeted projects can be used to encourage and enable those who visit nature less to benefit from access. Danish examples include recent projects in 2015 funded by the private Nordea foundation. These examples include projects focused on urban greening and community gardens in urban and social deprived housing areas. Furthermore, the foundation has donated 1 million Euros to a project called: 'Nature Experiences across Cultures'. The project starts from the position that young people's use of nature is in decline and that this trend is particularly pronounced among young people of ethnic backgrounds other than Danish. The project includes a training programme and a campaign in which young bilingual teachers learn how to utilize natural sites. The aim is to educate 400 'nature ambassadors' who, by leading recreational activities in nature, are planned to reach up to 10,000 young people (Nordea Foundation 2016).

The Dutch 'District Approach' targeted the 40 most deprived districts in the Netherlands, with the aim of improving their livability. Among these districts, which are situated in 18 large cities, 24 did address green space as a part of their locally tailored approach. Although these particular districts did not show more favourable changes in the trend of physical activity and general health than the others (Droomers et al. 2016), the fact that other types of interventions were taking place at the same time in all forty districts makes it hard to draw firm conclusions.

An example supported by the government in Finland is a national program known as KKI (*Kunnossa kaiken ikää*, or 'Keep fit for all ages'), which promotes exercise for all populations groups and also encourages visits to GI sites. "The KKI program promotes the development of everyday environments in order to support people's physical activity. Actions and methods of development which

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enhance physical activity for health benefits include community planning, land use planning, improvement of access and conditions for walking and bicycling, close to home sites for physical exercise, and close to home recreational areas and nature areas." The KKI program finances projects which enhance physical activity, particularly among people who are physically inactive (KKI program, http://www.kkiohjelma.fi).

A partnership initiative set up in England called 'Neighbourhoods Green' aims to raise awareness of the importance of open and green space for those residents who live in social housing[3] (Fig. 15.6). The partnership started in 2003 and a number of projects are underway, such as the Medina Housing Association working with Growing Ideas (a small company delivering community education and training) to install raised vegetable beds in communal areas of low-income households (Neighbourhoods Green 2016). Kabisch and Haase (2014) refer to the example of a park developed on the old airport in Berlin-Tempelhof. The new park aimed to increase the low greenspace provision in the neighbourhood. In a survey of users they found that immigrants and older users who were well represented in the surrounding area did not visit the site as much as other groups. A lack of trees and facilities for sitting and socializing were given as some of the reasons for these groups to visit less. The planners of the new park aimed for it to be for everybody;

Fig. 15.6 A community event to plant trees and clear rubbish from Peabody Hill Wood, which is situated between two social housing estates in Inner London (Photo: Liz O'Brien)

[3] Social housing is let at low rents for those on low incomes.

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however providing a space is not enough. There needs to be an understanding of the needs of different groups and what might attract them to the new greenspace as well as understanding some of the barriers that may prevent this. Box 15.1 illustrates a specific initiative in Scotland.

Box 15.1 The Woodlands in and Around Towns Initiative Run by Forestry Commission Scotland

Name of intervention: Woodlands in and around Towns (WIAT) led by Forestry Commission Scotland

Aim/objective

WIAT tackles the barriers that prevent people from visiting and benefiting from woodlands regularly. The programme focuses on the location, accessibility and management of urban woodlands, to encourage more use by local people and thereby improving their quality of life.

What happened?

The programme has been running in Scotland since 2005. The programme makes improvements to existing woodlands, creates new woodlands and then through community engagement and specific activities encourages use of woodlands by local communities, particularly in more deprived areas. A grant scheme (called the Challenge Fund) has been associated with the programme, offering financial support for managing urban woodlands if they are located within a kilometre of a settlement with a population of over 2,000 people (Forestry Commission Scotland 2016). WIAT is now in its fourth phase and represents a major investment of over £50 million and a priority initiative.

Outcomes

A published study (Ambrose-Oji et al. 2014) revealed that overall visits to WIAT woodlands increased by over 20%, with visitors coming from some of Scotland's most deprived communities. The value of recreation and health benefits was calculated at around £14 million per year.

Lessons learned

Funding was critical to increase woodland access and change patterns of visiting behaviour, as well as community engagement. More information is available at the WIAT web site:

http://scotland.forestry.gov.uk/supporting/strategy-policy-guidance/communities/woods-in-and-around-towns-wiat

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15.10 Grassroots Action

The role of urban agriculture (Fig. 15.7) and urban allotment gardening to increase city resilience has become more important recently for many reasons. Urban allotments have ecological, cultural, social and socio-economic value. They can be popular among more deprived populations and older people because they allow contact with nature and can sometimes provide economic benefits from the cultivation of land. However, a study in Stockholm's allotment gardens showed that recreation, education, cultural activities, health benefits, being outdoors and social cohesion are at least as important to allotment users as the garden produce (Barthel et al. 2010). The recent increase of allotments in many European cities, especially in southern Europe, has been part of a response to a sense of global crisis, attesting to the resilience of people living in cities. Bottom-up grassroots action has been taking place in recent years in relation to urban allotment gardening (Ioannou et al. 2016). An example of this is the Agros Farm in Hellinikon in Greater Athens, which was started in 2011 by a group of activists to prevent privatization of the former Hellinikon aiport. In Milan, Italy, a group of organisers of community gardens came together after a public event in 2010 and developed a network to share information through events and workshops, and it advises citizens who want to create a community garden. A project in Germany (Okotop Heerdt) in the Dusseldorf-Heerdt district started when a group of activists came together to discuss improvements in local playgrounds and public green spaces. After a number of years the group took part in setting up a new land use plan for a brownfield site, and after four years the city council agreed to the plan being implemented (Ioannou et al. 2016). Todmorden in England developed the 'incredible edible' concept using community

Fig. 15.7 Social housing and urban gardening in Denmark (Photo: Anett Sällsäter Christiansen)

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spaces around the town to grow fruit, herbs and vegetables. This has led to the development in 2012 of the 'Incredible Edible Network' to inspire new groups in other locations to grow food in community spaces (http://incredibleediblenetwork.org.uk). Box 15.2 outlines an intervention in Barcelona.

Sometimes the utilization of underused or brownfield land for community access is enabled on a temporary basis. For example, among several projects in the UK surveyed by Jones and Baines (2006) was an initiative providing access to land in Warrington, where a factory had previously been and where some woodland and tree planting was allowed on the site for 5 years until new housing was developed. In Barcelona, the temporary use of vacant land was allowed for a community allot-

Box 15.2 Casc Antic Barcelona Grassroots Action

Name of the intervention: Beyond a livable and green neighbourhood: Casc Antic of Barcelona

Aim/objective

During the past 15 years the Casc Antic, a traditionally low-income and immigrant neighbourhood in Barcelona, has been the site of community-based mobilization with the aim of revitalizing abandoned areas and improving local environmental conditions.

What happened?

Casc Antic is a place where the community, over a number of years, has organised the revitalization of degraded and abandoned spaces into playgrounds and a community garden (Anguelovski 2013). In one instance buildings were demolished to make way for apartments and a car park; however, when the space remained empty for two years local activists took it over and named it the 'Hole of Shame' – creating in its place a community garden, green space and football/basketball courts. The organization of residents and their supporters is situated within a broader context of urban political and socio-economic change – the transformation of the urban economy into a decentralized, global and technology-focused system, accompanied by rising socio-economic inequality and displacement in inner city areas.

Asserting control, sovereignty and transgression in Barcelona

This activism illustrates how, despite the fragile socioeconomic conditions of their community and the vulnerable situation of many families, the residents of historically marginalised neighbourhoods can proactively work to improve local living conditions and build broad support around them. Data was collected via interviews in the Casc Antic with 45 participants and focused on the process that initially led activists to mobilize the neighbourhood, and how they viewed the space.

(continued)

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Box 15.2 (continued)

Outcomes

Activists decided to mobilize by self-organizing to rebuild the area around the 'Forat' and foster parallel projects related to public space enhancement, healthy food production, green jobs and neighbourhood rehabilitation. The activists used their social-environmental projects and advocacy as tools to fight against broader development processes in their neighbourhood and in Barcelona as a whole. Conflict arose with the municipality over the appropriation of the space by the local community, but after three years the plan to build a car park was scrapped – and the views of residents were taken into account when the municipality permanently rebuilt the area with space for community gardens, sports courts and planted trees (Anguelovski 2013).

Lessons learned

Environmental initiatives can function as commons – preserving spaces and strengthening new types of democracy. Planning practice and change can emerge from the neighbourhood itself through bottom-up processes.

ment, and in the city of Ghent (Belgium) the use of temporary public spaces for urban farming is included in the local food strategy as a means to stimulate sustainable and short-chain food production (Crivits et al. 2016).

Urban areas are often characterized by dynamic land use, derelict infrastructure or empty urban space (e.g. for speculative reasons). Natural succession can result in new urban GI, which may prove valuable for people with limited access to green areas to use as semi-public green space or for 'guerrilla gardening'[4]. Frequent and prolonged use by the public leads to public appropriation of the site and communalization (as opposed to privatization) of the site. New development by private owners impacting this semi-public greenspace can lead to conflicts with the public. Similar are semi-public or shared greenspaces such as private land intentionally opened to the public or where public access or use is tolerated, such as in the case of permissible access in England. Another issue is privatization of public land. Atmiş et al. (2007) documented how since 1983 approximately 150,000 ha of urban forest have been allocated to the tourist industry in the Turkish regions of Marmara, the Aegean, and the Mediterranean. Tourism investors have built tourist facilities such as hotels, holiday villages, golf courses, and sports facilities in these allocated lands and closed the forest off for people living around the forest.

[4] Guerilla gardening refers to gardening on land the gardeners do not have legal rights of access to, e.g. an abandoned site, private land etc.

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Box 15.3 outlines an approach in Ballymun, Ireland, a deprived area where the community can join together to donate a tree and contribute to the future of their local area. It specifically gives agency (i.e. what type of trees do we put in and where?) to local residents during the physical reorganization of their neighbourhood. A sustained mediated effort was made to reach out to local schools, youth groups and households.

Box 15.3 Ballymun, Ireland

Name of intervention: Amaptocare (A Map to Care) commissioned by Dublin City Council

Aim/objective

The aim was to invert the routine of social housing and institutional urbanism by encouraging residents to make a public, financial investment in their own area, and thus exercise agency with regard to their immediate environment. With an emphasis on public authorship and ownership of public space, the local residents, as well as people from other areas, were invited to donate (i.e. purchase) a tree for Ballymun and thereby contribute to the future prosperity, beauty and greening of the area (Fig. 15.8).

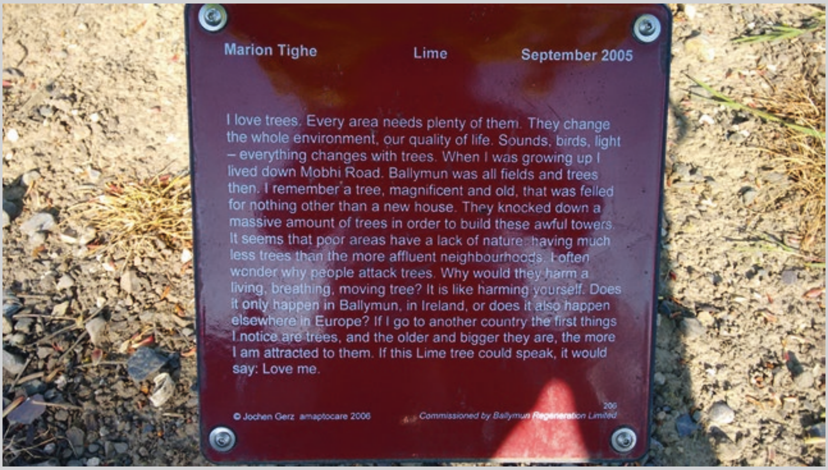

Fig. 15.8 Inscription on tree bought by local resident in Ireland – see Box 15.3 (Source: M. Brennan)

(continued)

Box 15.3 (continued)

What happened?

Over an 18-month period, each of the 637 donors met with an artist and were asked the question "If this tree could speak, what should it say for you?" Their responses were then printed in white text on a red enamel lectern beside their tree. Donors could select from 15 species of indigenous trees including Rowan, Oak and Birch. Donations ranged from €50-€250 and Dublin City Council, which was also proceeding with a landscaping tree-planting scheme for the neighbourhood, matched the value of each donation. This enabled trees of good size and girth to be bought and planted through the program.

Outcomes

Stage one was completed, with 637 people having donated trees. In the second phase of the project, it is planned that each of the donors' names will be engraved into the granite surface of the new Civic Plaza. The plaza will include the installation of a glass map of the new layout of Ballymun (24 x 24 m) that will include the location of each donated tree.

Lessons learned

By giving local people both agency and a financial stake in the transformation of their area, public buy-in to the regeneration was increased.

http://www.publicart.ie/main/directory/directory/view/amaptocare1/e6847767fbe38b14ea478aaa27662af3/

15.11 Conclusions

This chapter illustrates that while GI can provide a wide range of benefits, not all sections of society are equally able to access GI and gain these benefits. This can be a social and environmental justice issue due to the distribution of GI, with less and poorer quality GI in more deprived areas – an issue of distributive justice. There are also potential procedural justice issues with some sections of society being less likely to be included in decision making about the development, creation and improvement of GI areas. The benefits of GI are numerous and all sections of society need to be able to gain these regardless of age, gender, ethnicity or socio-economic status.

UN Sustainable Development Goal 11 is focused on 'making cities and human settlements inclusive, safe, resilient and sustainable' and has a proposed sub-goal (11.7): "By 2030, provide universal access to safe, inclusive and accessible green and public spaces, particularly for women and children, older persons and persons with disabilities." (Sustainable Development Knowledge Platform, UN n.d.; United

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Nations Department of Economic and Social Affairs n.d.). Greater access as outlined in this goal can also contribute to reducing health inequalities (see also Mitchell et al. 2015).

The range of examples presented here illustrates that efforts are being made to reach out to currently non-participating groups, either through policy and planning, targeted approaches or via grassroots action. A crucial aspect to this is understanding the needs and perspectives of diverse groups. Land owners and site managers should consider how they can design interventions that will attract the under-represented, and take approaches such as engaging directly with communities to encourage their use of green amenities, and in the process improving the maintenance of natural sites in deprived areas which may suffer from multiple problems of vandalism and littering. It is not enough to create or improve an urban green space expecting residents to visit. Rather, understanding diverse community needs and involving them in decision making is key to enabling use and potentially creating a sense of ownership of the solutions that might enable that use.

At the same time, bringing more green into the city may paradoxically result in the impairment of access for deprived groups in the longer term. The greening of neighbourhoods make them better and more attractive places to live, which sometimes results in higher housing costs – and which in the mid-term can drive out the very communities that the greening was aimed at (Bunce 2009; Haase and Rink 2015). This eco-gentrification process illustrates the delicate balance that planners and managers need to find, in order to ensure that the beneficiaries of such improvements are those who most need it.

Working in partnerships can be an important approach to enabling and encouraging wider sections of society to benefit from GI. There are examples of traditional land management organizations and the environmental sector working with the health and education sectors to develop projects and interventions that reach vulnerable groups such as immigrant communities, women and older people (Kloek 2015; Cook 2016; O'Brien et al. 2016a, b; Tabbush 2008). Potentially, an increasing focus on public health coupled with an increasing body of research on the benefits of urban greening will provide opportunities for further innovative approaches to engaging people with GI. Reaching out to non-users and infrequent users will be particularly important.

15.11.1 Recommendations

- More survey data are needed to identify who accesses and gains benefits from GI and who does not, particularly in urban and peri-urban areas.
- Research is needed to understand the barriers that those not accessing and benefiting from GI face and to explore to what extent these are related to social and environmental justice issues.
- Targeted interventions and programmes can be used to reach specific groups that are currently excluded. The ongoing monitoring and evaluation of these initiatives is critical, however, for learning lessons on what works and what does not.

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- There needs to be a greater focus by organizations that design, create and manage GI on social and environmental justice issues, recognizing that some benefit more from access to good quality GI and have more GI near to where they live than others.
- Many existing surveys do not capture data concerning certain aspects of GI such as green roofs, walls and corridors. However, these are important components of GI and can add to the quality of life of urban citizens and visitors to an area.
- Planners should take account of social and environmental justice issues in terms of the geographic distribution of GI across urban areas.
- Research is needed that focuses on the challenges arising from climate change, such as thermal stress during heat waves for socio-economically disadvantaged communities in urban areas.
- Local governments must acquire new knowledge to manage diverse and multicultural cities with ageing populations.
- Transdisciplinary research for GI management should provide better information, evaluation methods and decision-making tools for future oriented actions that could enhance social and environmental justice.
- Solutions should arise from a dialogue-oriented consulting process, co-creation of knowledge and co-design of solutions with inclusion of a broad range of stakeholders and the development of new concepts for the involvement of the public (Fig. 15.9).

Fig. 15.9 Urban allotment in Milan (Photo: T. Panagopoulos)

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References

Abildtrup J, Garcia S, Olsen SB, Stenger A (2013) Spatial preference heterogeneity in forest recreation. Ecol Econ 92:67–77

Ambrose-Oji B, Saraev V, Peace A, Connolley T, Stewart A, Chetcuti J, Edwards D (2014) An evaluation of the WIAT Challenge Fund: changing use patterns, the value of recreation and health benefits, and lessons learned. Forest Research report to Forestry Commission Scotland, Roslin

Anguelovski I (2013) Beyond a livable and green neighborhood: asserting control, sovereignty and transgression in the Casc Antic of Barcelona. Int J Urban Reg Res 37(3):1012–1034

Anguelovski I, Alier JM (2014) The 'environmentalism of the poor' revisited: territory and place in disconnected glocal struggles. Ecol Econ 102:167–176

Annerstedt van den Bosch M, Mudu P, Uscila V, Barrdahl M, Kulinkina A, Staatsen B, Swart W, Kruize H, Zurlyte I, Egorov AI (2015) Development of an urban green space indicator and the public health rationale. Scand J Public Health 44(2):1–9

Atmiş E (2016) Development of urban forest governance in Turkey. Urban Forestry and Urban Greening. 19(2016):158–166. doi:10.1016/j.ufug.2016.06.018

Atmiş E, Günşen HB (2015) An underestimated value in urban life: urban forests. I. International urban studies congress, April 16–17, 2015. Eskişehir, Turkey, pp 246–265

Atmiş E, Özden S, Lise W (2007) Urbanization pressures on the natural forests in Turkey: an overview. Urban Forestry and Urban Greening 6(2):83–92

Atmiş E, Günşen HB, Özkazanç NK, Artar M, Çinis F (2015) A forestry service that cannot reach urban people: urban forests. In: XIV World Forestry Congress, 7–11 September 2015. Durban, South Africa

Barthel S, Folke C, Colding J (2010) Social–ecological memory in urban gardens—retaining the capacity for management of ecosystem services. Glob Environ Chang 20(2):255–265. doi:10.1016/j.gloenvcha.2010.01.001

Berte E, Panagopoulos T (2014) Enhancing city resilience to climate change by means of ecosystem services improvement: a SWOT analysis for the city of Faro, Portugal. Int J Urban Sustain Dev 6:241–253

Bolte G, Pauli A, Hornberg C (2011) Environmental justice: social disparities in environmental exposures and health: Overview. Enc Environ Health 2:459–470

Bomans K, Steenbergen T, Dewalheyns V, Leinfelder H, Gullink H (2010) Underrated transformations in the open space – the case of an urbanised and multifunctional area. Landsc Urban Plan 94(3-4):196–205

Bunce S (2009) Developing sustainability: sustainability policy and gentrification on Toronto's Waterfront. Local Environ 14(7):651–667

Burt J, Stewart D, Preston S, Costley T (2013) Monitor of Engagement with the Natural Environment Survey (2009–2012): difference in access to the natural environment between social groups within the adult English population. Natural England Data Reports, Number 003

Byrne J, Wolch J, Zhang J (2009) Planning for environmental justice in an urban national park. J Environ Plan Manag 52:365–392

Byrne J, Sipe N, Searle G (2010) Green around the gills? The challenge of density for urban greenspace planning in SEQ. Australian Planner 47(3):162–177

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Caspersen OH (2011) Udviklingen i markveje 1954–2010. Videnblade Planlægning og Friluftsliv, 6.1–59. Skov & Landskab, KU

Church A, Fish R, Haines Young R, Mourato S, Tratalos J, Stapleton L, Willis C, Coates P, Gibbons S, Leyshon C, Postchin M, Ravenscroft N, Sanchis-Guarner R, Winter M, Kenter J (2014) UK national ecosystem assessment follow-on. Work package report 5: cultural ecosystem services and indicators. UNEP-WCMC, LWEC, UK

CICES (2015) Version 4.3 towards a common classification of ecosystem services. CICES http://cices.eu/. Accessed 2 Nov 2015

City of Leipzig (2003) Environmental aims and standards for the city of Leipzig. Umweltqualitätsziele und – standards für die Stadt Leipzig

Coen SE, Ross NA (2006) Exploring the material basis for health: characteristics of parks in montreal neighbourhoods with contrasting health outcomes. Health and Place 12:361–371

Coillte and The Irish Sports Council (2005) Economic value of trails and forest recreation in the Republic of Ireland

Cook M (2016) How woodlands and forests enhance mental wellbeing. The J Dementia Care 24(3):20–23

Crivits M, Prové C, Block T, Dessein J (2016) Four perspectives of sustainability applied to the local food strategy of Ghent (Belgium): need for a cycle of democratic participation? Sustainability 8(1):55. doi:10.3390/su8010055

De Vreese R, Leys M, Dendoncker N, Van Herzele A, Fontaine C (2016) Images of Nature as a boundary object in social and integrated ecosystem services assessments. Reflections from a Belgian case study. Submitted to Ecosystem Services

De Vries S, Goossen M, de Knegt B (2014) Groene recreatie in de woonomgeving. In: de Knegt B (ed) Graadmeter diensten van natuur; vraag, aanbod, gebruik en trend van goederen en diensten van ecosystemen in Nederland, WOt-technical report 13. Wettelijke Onderzoekstaken Natuur & Milieu, Wageningen

Department of Communities and Local Government (2015) The English Indices of Deprivation 2015. DCLG, London. https://www.gov.uk/government/uploads/system/uploads/attachment_data/file/465791/English_Indices_of_Deprivation_2015_-_Statistical_Release.pdf. Accessed 10 Nov 2015

Droomers M, Jongeneel-Grimen B, Kramer D, de Vries S, Kremers S, Bruggink JW, Stronks K (2016) The impact of intervening in green space in Dutch deprived neighbourhoods on physical activity and general health: results from the quasi-experimental URBAN40 study. J Epidemiol Community Health 70(2):147–154

Elands B, Bell S, Blok J, Colson V, Curl S, Berit C, Kaae VLG (2010) Atlantic Region. In: Pröbstl U, Wirth V, Elands B, Bell S (eds) Management of recreation and nature based Tourism in European forests. Springer, Berlin/Heidelberg http://link.springer.com/chapter/10.1007/978-3-642-03145-8_2, pp 11–47

Evans GW, Kantrowitz E (2002) Socioeconomic status and health: the potential role of environmental risk exposure. Annu Rev Public Health 23:303–331

Forestry Commission Scotland (2016) Woods in and around towns http://scotland.forestry.gov.uk/supporting/strategy-policy-guidance/communities/woods-in-and-around-towns-wiat

Gentin S (2015) Outdoor recreation and ethnicity – seen in a Danish adolescent perspective. IGN PhD thesis, June 2015. Department of Geosciences and Natural Resource Management, University of Copenhagen, Frederiksberg. p 179

Germann-Chiari C, Seeland K (2004) Are urban green spaces optimally distributed to act as places for social integration? Results of a Geographical Information System (GIS) Approach for Urban Forestry Research 6:3–13

Haase A, Rink D (2015) Inner-city transformation between reurbanisation and gentrification: Leipzig, Eastern Germany. Geografie 120(2):226–250

Haines-Young R, and Potschin M (2013) Common International Classification of Ecosystem Services (CICES): Consultation on Version 4, August-December 2012. *EEA Framework Contract No* EEA/IEA/09/003

liz.obrien@forestry.gsi.gov.uk

HM Government (2011) The natural choice: securing the value of nature. The Stationary Office, Norwich

Højring K (2002) The right to roam the countryside—law and reality concerning public access to the landscape in Denmark. Landsc Urban Plan 59(1):29–41

Hughey SM, Walsemann KM, Child S, Powers A, Reed JA, Kaczynski AT (2016) Using an environmental justice approach to examine the relationships between park availability and quality indicators, neighborhood disadvantage, and racial/ethnic composition. Landsc Urban Plan 148:159–169

Ioannou B, Noran N, Sondermann M, Certoma C, Hardman M (2016) Grassroots gardening movements: towards cooperative forms of green urban development? In: Bell S, Fox-Kamper R, Keshavarz N, Benson M, Caputo S, Noori S, Voigt A (eds) Urban allotment gardens in Europe. Earthscan, London

Jankovska I, Donis J, Straupe I, Panagopoulos T, Kupfere L (2013) Assessment of forest recreation accessibility in Latvia. Fresenius Environ Bull 22:2145–2151

Jensen FS (1998) Friluftsliv i det åbne land 1994/95. Forskningscentret for Skov & Landskab. Forest and Landscape Research; Nr. 25.Kaae, B.C., Skov-Petersen, H. og Larsen, K.S. (1998). Større trafikanlæg som barrierer for rekreativ brug af landskabet. Park- og Landskabsserien 17/1998. Forskningscenteret for Skov & Landskab, Miljø- og Energiministeriet

Jensen FS (2003) Friluftsliv i 592 skove og andre naturområder. Skovbrugsserien; Nr. 32, Skov & Landskab, Københavns Universitet

Jensen FS (2010) Does wildlife encourage or discourage outdoor recreation participation among different ethnic groups in the Danish society, in: Poster Session Presented at XXIII IUFRO World Congress, Seoul, Sydkorea

Jensen FS (2014) Friluftsliv i landskabet 2008 (1–9), Videnblade Planlægning og Friluftsliv 6.1–83 to 9.1–91, Department of Geosciences & Natural Ressource Management, University of Copenhagen

Jerrett M, Burnett RT, Kanaroglou P, Eyles J, Finkelstein N, Giovis C, Brook JR (2001) A GIS–environmental justice analysis of particulate air pollution in Hamilton, Canada. Environ Plan A 33:955–973

Jones N, Baines C (2006) Land in limbo: the interim use of temporarily vacant urban open space. Report for Cabe Space, London

Kaae BC, Skov-Petersen H, Larsen KS (1998) Større trafikanlæg som barrierer for rekreativ brug af landskabet. Park- og Landskabsserien, nr. 17-1998, Forskningscenteret for Skov & Landskab, Hørsholm 1998, 165 pp

Kabisch N, Haase D (2014) Green justice or just green? Provision of urban green spaces in Berlin, Germany. Landsc Urban Plan 122:129–139. doi:10.1016/j.landurbplan.2013.11.016

Karanikola P, Tampakis S, Panagopoulos T, Karipidou-Kanari A (2016) Perceptions and expectations of urban green infrastructure in the municipality of Kalamaria, Greece. Manag Environ Qual 27(3) (in press)

Kazmierczak A (2013) The contribution of local parks to neighbourhood social ties. Landsc Urban Plan 109:31–44

Kloek M (2015) Colourful green: immigrants' and non immigrants' recreational use of greenspace and their perceptions of nature. PhD thesis. Wageningen University, Wageningen, Netherlands.

Koohsari MJ, Mavoa S, Villianueva K, Sugiyama T, Badland H, Kaczynski AT, Giles-Corti B (2015) Public open space, physical activity, urban design and public health: concepts, methods and research agenda. Health & Place 33:75–82

Korpela KM, Ylen M (2007) Perceived health is associated with visiting natural favourite places in the vicinity. Health and Place 13:138–151

Lafortezza R, Carrus G, Sanesi G, Davies C (2009) Benefits and well-being perceived by people visiting green spaces in periods of heat stress. Urban Forestry and Urban Greening 8:97–108

Lafortezza R, Davies C, Sanesi G, Konijnendijk CC (2013) Green infrastructure as a tool to support spatial planning in European urban regions. iForest 6:102–108

liz.obrien@forestry.gsi.gov.uk

Li Y (2015) Exploring the accessibility of green space by socio-economic status and ethnicity; an environmental justice investigation in the Netherlands. Internship report. Alterra, Wageningen (The Netherlands)

Low S (2013) Public space and diversity: distributive, procedural and interactional justice for parks. In: Young G, Stevenson D (eds) The Ashgate research companion to planning and culture. Ashgate Publishing, Surrey, pp 295–310

Lucas K, Walker G, Eames M, Fay H, Poustie M (2004) Environment and Social Justice: Rapid Research and Evidence Review Policy Studies Institute

Madureira H, Nunes F, Oliveria JV, Cormier L (2015) Urban residents beliefs concerning green space benefits in four cities in France and Portugal. Urban Forestry and Urban Greening 14:56–64

Ministry of the Environment (2014) Naturplan Danmark. København. http://naturstyrelsen.dk/naturbeskyttelse/national-naturbeskyttelse/naturplan-danmark/. Assessed 25 Nov 2015

Mitchell R, Richardson E, Shortt N, Pearce J (2015) Neighbourhood environment and socioeconomic inequalities in mental wellbeing. Am J Prev Med 49:80–84

Molteno S, Morris J, O'Brien L (2012) Public access to woodlands and forests: a rapid evidence review. Forest Research, Farnham

Moreno-Jiménez A, Cañada-Torrecilla R, Vidal-Domínguez M, Palacios-García A, Martínez-Suárez P (2016) Assessing environmental justice through potential exposure to air pollution: a socio-spatial analysis in Madrid and Barcelona. Spain Geoforum 69:117–131

Morris J, O'Brien L, Ambrose-Oji B, Lawrence A, Carter C (2011) Access for all? Barriers to accessing woodlands and forests in Britain. Local Environ 16:375–396

Natural England (2010) Nature nearby: accessible natural greenspace guidance. Natural England, Peterborough

Natural England (2015) Monitor of engagement with the natural environment. The national survey on people and the natural environment. Annual report from 2013–14 survey. Natural England, Peterborough

Neighbourhoods Green (2016) Neighbourhoods green: improving the green spaces for social housing http://www.neighbourhoodsgreen.org.uk/home Accessed 5 Feb 2016

Neuvonen M, Sievanen T (2011) Recreational statistics 2010. http:www.metla.fi/metinfo/monikaytto/lvvi/en/tietoa-ulkoilusta-en.htm. Accessed 22 Oct 2015

Nordea Foundation (2016) Naturoplevelser på tværs af kulturer https://nordeafonden.dk/team-green-naturoplevelser-paa-tvaers-af-kulturer. Accessed 14 Jan 2016

O'Brien E (2006) Social housing and greenspace: a case study in inner London. Forestry 79:535–549

O'Brien L, Morris J (2013) Well-being for all? The social distribution of benefits gained from woodlands and forests in Britain. Local Environ 19(4):356–383

O'Brien L, Ambrose-Oji B, Waite S (2016a) Learning on the move: green exercise for children and young people. In: Barton J, Bragg R, Wood C, Pretty J (eds) Green exercise: linking nature, health and wellbeing. Earthscan, London

O'Brien L, De Vreese R, Kern M, Sievänen T, Stojanova B, Atmis E (2016b) in press. Cultural ecosystem benefits of urban and peri-urban green infrastructure in different European Countries. Urban Forestry and Urban Greening

O'Brien L, Burls A, Townsend M, Ebden M (2011) Volunteering with nature as a way of enabling people to re-integrate into society. Perspect Public Health 131:71–81

Oguz D (2000) User surveys of Ankara's urban parks. Landsc Urban Plan 52(2-3):165–171

Olafsson AS (2012) GIS-based recreation experience mapping. Development, validation and implementation. Forest & Landscape Research 56-2012. Forest & Landscape Denmark, Frederiksberg

Panagopoulos T, Duque JAG, Dan MB (2016) Urban planning with respect to environmental quality and human well-being. Environ Pollut 208:137–144

PBL Wageningen UR (2010) Beschikbaarheid groen in de stad, 2000 - 2006 (indicator 0299, versie 06, 20 mei 2010). www.compendiumvoordeleefomgeving.nl. CBS, Den Haag; Planbureau

liz.obrien@forestry.gsi.gov.uk

voor de Leefomgeving, Den Haag/Bilthoven en Wageningen UR, Wageningen. Accessed 25 Nov 2015

Peters K, Stodolska M, Horolets M (2016) The role of natural environments in developing a sense of belonging: a comparative study of immigrants in the U.S., Poland, the Netherlands and Germany. Urban For Urban Green 17:63–70

Pham TTH, Apparicio P, Séguin AM, Landry S, Gagnon M (2012) Spatial distribution of vegetation in Montreal: an uneven distribution or environmental inequity? Landsc Urban Plan 107(3):214–224

Ravenscroft N, Markwell S (2000) Ethnicity and the integration and exclusion of young people through urban park and recreation provision. Manag Leis 5:135–150

Roy S, Byrne J, Pickering C (2012) A systematic quantitative review of urban tree benefits, costs and assessment methods across cities in different climatic zones. Urban Forestry and Urban Greening 11:351–363

Santucci D, Floyd M, Bocarro J, Henderson K (2014) Visitor services staff perceptions of strategies to encourage diversity at two urban National Parks. J Park Recreat Adm 32:15–28

Saraiva MG, Almeida AF, Figueiredo LV (2014) Outstanding urban trees: which cultural services towards urban residents? A survey in Lisbon. Proceedings of the International Conference 'Urban Trees Research Conference, Trees, People and the Built Environment II, University of Birmingham, UK

Schroeder HW (2012) Giving voice to the experiential value of natural environments. The Humanistic Psychologist 40(2):136–152

Schwarte P, Adebowale M (2007) Environmental justice and race equality in the European Union. Capacity Global, London

Seeland K, Dübendorfer S, Hansmann R (2009) Making friends in Zurich's urban forests and parks: the role of public green space for social inclusion of youths from different cultures. Forest Policy Econ 11:10–17

Senatsverwaltung für Stadtentwicklung und Umwelt (2013) (Urban Green) Urbane Grünflächen. Retrieved from: http://www.stadtentwicklung.berlin.de/umwelt/stadtgruen/gruenanlagen/index.shtml Accessed 22 Nov 2015

Simoens I, Thoonen M, Meiresonne L, Van Daele T (2014) Hoofdstuk 26 – Ecosysteemdienst groene ruimte voor buitenactiviteiten (Chapter 26 – Ecosystem Service "Green Area for outdoor activities"). In: Stevens M, Demolder H, Jacobs S, Michiels H, Schnieders S, Spanhove T, Thoonen M, Van Gossum P, Van Reeth W, Peymen J (eds) (2015). Flanders Regional Ecosystem Assessment – State and Trends of Ecosystems and their Services in Flanders. Key Findings of the Technical Report. Rapporten van het Instituut voor Natuur- en Bosonderzoek 2015 (INBO.M.2015.8820574). Instituut voor Natuur- en Bosonderzoek, Brussel

Sustainable Development Knowledge Platform (n.d.) Open working group proposal for sustainable development goals https://sustainabledevelopment.un.org/focussdgs.html Accessed 10 Oct 2015

Tabbush P (2008) Maulden Faith Woodland: an investigation. Report for the Forestry Commission, Forest Research Farnham

Ulrich RS (1984) View through a window may influence recovery from surgery. Science 224:420–421

United Nations Department of Economic and Social Affairs (2009) Creating an inclusive society: practical strategies to promote social integration. http://www.un.org/esa/socdev/egms/docs/2009/Ghana/inclusive-society.pdf. Accessed 15 Nov 2015

United Nations Department of Economic and Social Affairs (n.d.) Open working group proposal for sustainable development goals. https://sustainabledevelopment.un.org/focussdgs.html Accessed 5 Jan 2016

van den Bosch MA, Mudu P, Uscila V, Barrdahl M, Kulinkina A, Staatsen B, Egorov AI (2015) Development of an urban green space indicator and the public health rationale. Scand J Public Health. doi:10.1177/1403494815615444

liz.obrien@forestry.gsi.gov.uk

Van Herzele A, Wiedemann T (2003) A monitoring tool for the provision of accessible and attractive urban green spaces. Landsc Urban Plan 63(2):109–126

Walker G, Mitchell G, Fairburn J, Smith G (2005) Industrial pollution and social deprivation: evidence and complexity in evaluating and responding to environmental inequality. Local Environ 10:361–377

Ward Thompson C, Roe J, Aspinall P, Mitchell R, Clow A, Miller D (2012) More green space is linked to less stress in deprived communities: evidence from salivary cortisol patterns. Landsc Urban Plan 105:221–229

White MP, Alcock I, Wheeler BW, Depledge MH (2013) Would you be happier living in a greener urban area? A fixed-effects analysis of panel data. Psychol Sci 24:920–928

Wolch JR, Byrne J, Newell JP (2014) Urban green space, public health, and environmental justice: the challenge of making cities 'just green enough'. Landsc Urban Plan 125:234–244

World Health Organisation (2012) Health indicators of sustainable cities in the context of the Rio+20 UN conference on sustainable development. Initial findings from a WHO expert consultation 17–18th May 2012. http://www.who.int/hia/green_economy/indicators_cities.pdf Accessed 10 Jan 2016

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Chapter 16
Recreational Use of Urban Green Infrastructure: The Tourist's Perspective

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16.1 Introduction

When we think of cities as tourist destinations, we do not just think of cafes and restaurants, cathedrals and monuments, museums and theatres – but also of tree-lined boulevards, great palace parks, beautiful botanic gardens, shady riverside embankments and intimate squares with spreading trees. In other words, the landscape of great cities includes, and is often determined by, the green spaces – or, as termed here – the urban green infrastructure (UGI). Such places offer so much – a stroll along the Champs Elysees in Paris, wandering through Hyde Park in London, sitting in Parc Güell in Barcelona, a jog along the river Po in Turin – these are just

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a few examples of how important green areas are to the tourism experience as well as for the local residents. In fact they can be as much a part of the brand image, the unique selling point and the *Genius loci* of the city as the other landmarks. Some key green elements are also integral parts of the status of UNESCO World Heritage Sites and great parks, old and new, and form living works of art which are in many ways as valuable as famous landscape paintings. The advent of cheap air travel has enabled large numbers of people to take short breaks to some of the best European cities all year round, to experience spring in Paris, summer in Riga, autumn in London and Christmas in Vienna. The seasonality of a city is emphasised by its vegetation: spring flowers, summer blooms, autumn leaves and snow-frosted leafless trees, in a world where people's experience of seasons threatens to disappear in many cities.

While current international tourism trends carve out new territories, they are simultaneously re-informing older and more established patterns, creating further opportunities for niche tourism development, catering to existing and emerging special-interest and alternative tourism products (Hall et al. 2014; UNWTO 2011; Hall and Page 2006). Such a proliferation and multiplication of tourism products goes hand-in-hand with the growth and prospects of lifestyle-, leisure- and wellness-oriented Western ways of life which affect tourism and, more generally, recreational markets (Chang and Huang 2014; Huijbens 2014; Iso-Ahola 1982). In the context of the current emphasis on greening European economies, nature-based solutions are at the forefront of these trends – including new ways of incorporating open green and blue spaces into urban life (UNWTO and UNEP 2011).

Urban tourism is at the forefront of these developments, by virtue of its nature as an ever-transforming and multi-layered set of recreational experiences, offering the potential for an endless series of combinations in the supply sector of tourism products, services, amenities, infrastructures, activities and experiences (Selby 2012; UNWTO 2011; Crouch 1999; Page 1995; Urry 1995). Urban tourism acquires a

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Fig. 16.1 View of Mytiline, the capital town of Lesvos Island, with the Castle in the background: a cultural attraction, incidentally discovered by tourists who tend to select the island as a pilgrimage, holiday or educational tourism destination (Source: https://upload.wikimedia.org/wikipedia/commons/e/e5/Mytilene_2010-04-03.jpg)

multitude of forms and caters to a wide variety of special-interest niches, including cultural tourism, shopping, nightlife and sight-seeing. Each one of these types of urban tourism offers a variety of ways in which various forms of green infrastructure may enhance, compliment, support, or improve the tourist experience – and vice versa.

As noted above, although most common and established forms and variations of urban tourism tend to neglect or under-promote the use and enjoyment of urban green areas, these often become an indispensable part of the tourism experience, either consciously or spontaneously, intentionally or accidentally, in the course of the visit (Terkenli 1996). On the basis of widely acknowledged UGI benefits shown to enrich urban life and experience, these are also expected to contribute to the urban leisure experience of visitors and tourists, albeit in different ways, with varying results and implications (MEA 2005; Kaplan and Kaplan 1989). Urban destinations cater to tourists' needs, preferences and aspirations in different ways according to factors such as the culture, location, climate and season (Fig. 16.1). Urban green tourism is just emerging as a field of scientific inquiry, offering many opportunities for investigation, lending itself to the formulation of a wide range of research questions. It is now providing useful findings, pointers and directions of practical benefit to practitioners, policy-makers and other professionals engaged in the development, promotion and provision of urban tourism and recreation products and amenities.

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Much evidence already exists about the uses of and the value placed on green infrastructure by local residents in urban settings around Europe (Berte and Panagopoulos 2014). However, there is little which specifically address use by tourists, or which attempts to do so cross-culturally. Most research on UGI use by visitors refers to selected European cases, which represent a limited selection of the types of UGI available for urban recreation. A gap exists in the understanding of how such uses are connected and relate to various forms of tourism (e.g. conventional, special-interest, alternative, etc.) (Tyrväinen et al. 2007; Madureira et al. 2015).

In this chapter we aim to clarify and then begin to address this research gap, by offering a glimpse of some trends in the use of UGI by tourists in 16 major European cities, based on an exploratory survey in eight countries (The Czech Republic, Greece, Latvia, Lithuania, Portugal, Serbia, Slovakia and the UK). The objective of this cross-cultural and comparative study was to assess and interpret tourists' practice, use and behaviour vis-à-vis UGI in the destination towns or cities. Before we get to that, however, it is worth reviewing the current state of knowledge on the benefits of UGI for local residents, who may enjoy activities that are also pursued by visitors. While the experience of UGI has numerous important aspects and dimensions, including user perceptions, understandings, preferences or emotions, we focus here on the actual uses of UGI – first by local residents, and then by tourists in the course of their visits to destination cities.

16.2 Urban Green Infrastructure and Its Role Within the City Landscape

Urban green elements (urban woodlands, parks, green corridors, roadside alleés, allotment gardens, cemeteries and other open public spaces) represent urban recreational amenities that have been deeply valued over time. The cultivation and maintenance of natural areas has a long tradition in European cities (Cekule 2010), and the use of forest gardens for food or paradise gardens for pleasure can be traced back to the very advent of civilization (McConnell 2003; Turner 2005). After the industrial revolution and the massive urbanization which followed in the nineteenth century, urban green-space recreation became a genuine phenomenon of European bourgeois culture (Tyrväinen et al. 2005). With increasing urbanization and a growing demand for and pressures on urban green areas during the twentieth century, green space planning and management became more established parts of municipal activity (Konijnendijk and Randrup 2004).

The roles of urban green space differ between European towns and cities due to their different environmental and socio-cultural backgrounds. The forest culture of northern Europe in the eastern Baltic countries and Fennoscandia are rather similar, in that the forest is a significant element of everyday life, it is important in national economies, and is a major element of the landscape (Tyrväinen et al. 2006; Bell 2008). In this respect, the recreational and aesthetic benefits of the urban forest are traditionally important (Gunnarsson and Øhrstroom 2007; Chen and Jim 2008)

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Fig. 16.2 Oak park in Kaunas city, Lithuania (Photo: Lina Straigyte)

Fig. 16.3 A panoramic view of the city of Riga, where UGI is integral to the life of the residents (Source: https://momenti.lv/pictures/1180/momenti-Anita-Austvika-AAR_2375%20copy.jpg)

(Figs. 16.2 and 16.3), and differ from those in central Europe where land conversion processes have been profound. In Latvia as in other countries of northern Europe, the human footprint on nature throughout the twentieth century and the alienation between people and nature has less impact than in other European cases (Jankovska

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et al. 2014). We can compare this with countries in the north-west of Europe where forests were cleared, where industrial cities often lacked green spaces and where nineteenth century parks were founded to overcome this.

Urban areas include green spaces which range from tiny city parks to extensive woodland landscapes, and from rounded spots to linear greenways and river corridors (Forman 2008). Recent research has highlighted the benefits of UGI to its users, in numerous case studies from European and North American cities (see Chap. 15). Such resources have the potential for significantly improving the quality of the urban environment and the well-being of residents. Trees and forests are prominent components of the landscape in most urban areas, providing a wide range of recreational and outdoor leisure opportunities from bird-watching and berry-picking to children's play and biking (Ward Thompson 2004) (see Figs. 16.2 and 16.9).

16.3 Benefits of Urban Green Infrastructure for Urban Residents

Reduced stress and improved physical health for urban residents have been associated with the presence of urban trees and forests (see Chap. 17). Studies have shown that landscapes with trees and vegetation produce more relaxed physiological states in people than landscapes that lack these natural features, while promoting ecological stability by providing habitats for wildlife, conserving soil, and enhancing biodiversity. Urban forests also have pronounced educational value by representing nature and natural processes in cities and towns, and they have often been used as testing and teaching areas. Urban parks, green corridors, greenways, and open green spaces are also of strategic importance for the quality of life of our increasingly urbanized society (Chiesura 2004); there is general agreement that they are essential for liveable and sustainable cities and towns (Konijnendijk et al. 2013). However, managing recreation sites requires strategic land planning, because of fluctuations in budgets, numbers of people entering, and even types of recreation requested and provided (Dwyer et al. 1992; Konijnendijk and Randrup 2004; Forman 2008).

UGI provides aesthetically attractive surroundings, increased enjoyment of everyday life and a greater sense of meaningful connection between people and the natural environment. However, past planning and management efforts have not always been as effective as they might have, because planners and managers have underestimated the potential benefits that UGI can provide and have not understood the planning and management efforts needed to provide those benefits, particularly the linkages between benefits and characteristics of the urban forest and its management (Dwyer et al. 1992; Gudurić et al. 2011). Moreover, over the years, there have been many attempts to place precise economic value on environmental amenities, including UGI. Although wood production from urban forests is not highly prioritized at the European level, these resources are crucial in countries like Latvia,

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where Riga municipal forests play a considerable economic role (Donis 2001). In addition, urban green areas may also provide non-timber forest products such as mushrooms and berries (see Chap. 7).

The systematic assessment of recreational and other non-market benefits of UGI is essential in order to incorporate the positive externalities of forests into policy and planning decision-making, including those for promoting tourism. One way to assess monetary values of non-market commodities is *contingent valuation*. This economic approach has usually valued forest amenities based on 'willingness to pay' criteria: e.g. *hedonic pricing* attempts to place a cash value on landscape elements by estimating the value of amenity benefits from the costs and prices of related market transactions (Ward Thompson 2004). Studies in Denmark and Finland have shown, for example, the positive impact of nearby forests on house prices (Konijnendijk and Randrup 2004). However, recent research in both Europe and North America has suggested that a combination of monetary and non-monetary approaches to valuation needs to be adopted in environmental decision-making (Ward Thompson 2004). It is highly likely that such studies would also identify significant benefits associated with tourism spending if the role of UGI in tourist experience and destination choice could be sufficiently understood – which so far is not the case.

Urban green spaces, as core components of UGI, may hold different values for people depending on their varying social, cultural, environmental and economic contexts. Tyrväinen et al. (2006) highlighted the fact that recreational and aesthetic benefits of urban forests are traditionally important, especially in the Nordic countries, because the forest is a major element of the landscape, the national economy, and people's everyday lives. The concept of local ecological knowledge (Berkes et al. 2000) illustrates the similarities in environmental perception of local people in Finland and Latvia, because both countries hold a long tradition of living close to nature in rural conditions, where the use of natural resources for livelihood and recreation purposes has resulted in laypeople acquiring a deep knowledge of nature (Yli-Pelkonen and Kohl 2005). Therefore the forest plays a significant role in local traditions, and is represented in a variety of social-economical, psychological and perceptual demands and requirements. Similarly, other studies confirm the importance of physical components (distance and accessibility), site facilities (parking, boardwalks, viewpoints, playground and sports facilities, trails and picnic areas) and environmental qualities (Bell 2008).

Monitoring and analysis of the flow of visitors to recreational areas is one of the indicators of their social functioning (Jankovska et al. 2013). Nowadays, urban forests and parks in or around large cities serve as areas for recreation and entertainment, as well as space for biodiversity to compensate for the built parts of the city. Urban forests can provide an experience of nature in the middle of urban life. They are important to people through symbolizing personal, local, community and cultural meanings (Fig. 16.4). They provide aesthetic enjoyment, educational opportunities and create a pleasant environment for different outdoor activities. In particular, old woodlands with large trees may provide urban people with the opportunity to recover from daily stress, revive memories and regain confidence (Fig. 16.9).

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Fig. 16.4 The castle of Trencin in Slovakia located in a park on a forested hill overlooking the city (Source: http://mormonhistoricsites.org/trencin-slovakia-memorial)

It is important to assess people's beliefs about the functions of urban green spaces, as their opinions may generate conflicts between residents, planners and managers (Jankovska et al. 2010; Eriksson et al. 2012; Madureira et al. 2015). In addition, assessing various perceptions of stakeholders is important, since they sometimes have different goals for the use of these areas (Gudurić et al. 2011; Živojinović and Wolfslehner 2015). This multi-dimensional understanding of UGI can improve urban planning, vegetation management, urban sustainability, allocation of financial resources and, most importantly, human well-being in cities (Dobbs et al. 2011), for locals and tourists alike.

16.4 Identifying the Research Gaps

UGI therefore serves users' needs, whether they are local inhabitants or visiting tourists. Konijnendijk et al. (2013), for instance, reviewing the benefits of urban parks, consider the following major benefits as having the highest impact to society: positive impacts of parks and park use on human health and well-being, social cohesion and identity, tourism, real estate prices, biodiversity, air quality and carbon sequestration, water management and cooling of urban areas. Greenways of high recreational, visual and historical value also tend to attract tourists (Fábos 1995).

Several studies examine users' perceptions, attachments, motives, preferences, practices, and behaviours, and the factors influencing their visits to urban forests.

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Mapping research priorities for green space in the UK, mentioned the lack of baseline data on people's use of parks and other green space as a first cross-cutting theme that needed to be addressed by future research. This includes basic research concerning who does and does not use green space, categorized by social group, age group, gender, ethnic group and patterns of use over time and in relation to age/life stage. However, such knowledge has of yet to be adequately developed with regard to tourist uses of green space. A lot of information has also been accumulated empirically by landscape architects in order to offer optimal planning, design and management solutions at particular sites for specific types of outdoor recreation (Bell 2008), but little is known about the interactions between the structural characteristics of the recreational site and recreation patterns in particular.

In sociological research, attention has been paid to the link between visitor characteristics and their behaviour regarding recreational activities. A study by James et al. (2009), aimed at creating an integrated understanding of green space in the European built environment, suggested a range of research questions that need further addressing, such as: 1) what are personal and social influences that result in greater use of urban green spaces? and 2) what are the necessary quantities, qualities and configurations of urban green space that contribute to their regular use such that different segments of society with changing socio-demographic characteristics may gain benefits? Schipperijn et al. (2010), reviewing studies on the use of green space published in the past 10 years, found three main groups of such uses:

- studies focusing on the use of one specific green space;
- studies focusing on regional or national samples of a particular type of green space, e.g. forests or national parks;
- studies dealing with the use of all types of green space close to respondents' home in one or more cities or neighbourhoods.

They also identified studies with a focus on the use of all types of green space; their general conclusion was that several studies report significant differences in the use of green space for different population segments (Schipperijn et al. 2010) – that is, differences and variability in recreational uses of UGI that need to be further explored in various cases of tourism.

16.5 Urban Green Spaces and Tourism

The topic of how urban parks impact tourism has not been given much attention in the scientific literature, at least not since the year 2000. Konijnendijk et al. (2013) concluded that there are some indications that parks have tourism benefits, but the strength of the evidence is weak due to the very small number of studies as well as the quality of those studies. However, several authors mention that green spaces can play an important role in attracting tourists to urban areas, by enhancing the attractiveness of the city and as a complement to other urban attractions (Majumdar et al. 2011). Aesthetic, historical and recreational values of urban parks also increase the

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Fig. 16.5 In the city of Faro, Portugal, the downtown historical area is surrounded by green infrastructure and the Ria Formosa natural park that increase the attractiveness of the city and promote it as a tourist destination (Photo: Thomas Panagopoulos)

attractiveness of the city and are used to promote it as a tourist destination (Fig. 16.5), thus generating employment and revenues (Chiesura 2004). A study by Hansmann et al. (2016) also shows that tourism is one of the objectives of urban forest partnerships that are becoming increasingly popular around Europe. Not only do urban parks provide recreational settings to local residents, but also visitors from out-of-town will very likely use these green spaces. In some cases, such as especially high-profile parks like Central Park in New York City, these spaces are major tourist attractions in their own right (Konijnendijk et al. 2013).

In the USA, city planners and urban forest managers constantly monitor the condition of their urban forests. A study by Andrada and Deng in Washington, D.C. (2010) provided feedback on how visitors prefer urban forests to be structured and showed that most visitors were familiar with the benefits of having urban forests as tourist destinations to enhance visitor enjoyment. Visitors commented that the greenery of the city was impressive, and that the city should maintain and even expand the areas allocated for urban forests. In terms of their preferences regarding the appearance of urban forests in the city, visitors placed almost equal importance on plant variety, planting pattern, colour, and growth. However, they tended to prefer urban forest elements to be scattered throughout the city with more types of plants, more colour, and a less manicured appearance. These findings provide managers with a clearer picture of what visitors like and enjoy while spending time in the city. Thus, these attributes should be carefully considered in plans to establish, maintain, or improve urban forests (Andrada and Deng 2010).

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Fig. 16.6 The castle of Bratislava, a must-visit site for tourists in the capital of Slovakia, is surrounded by urban green infrastructure (Photo: Thomas Panagopoulos)

Most urban tourists consider a wide variety of factors when they plan and visit cities, and the role and significance of UGI in their experience acquires variable forms and weights depending on the tourism product offered and even the size of the urban destination. Bigger cities tend to offer a greater variety of UGI possibilities with a wider range of recreational opportunities, while smaller urban centres (towns and cities) are usually connected to specific special-interest or alternative forms of tourism. In the latter case, the connection between tourism and UGI tends to be selective and specific, since it usually is related to the features which attract visitors there in the first place. Whether intended or not, some UGI uses in European tourist destination cities are integral to the tourist visit, while others are more-or-less incidental to the overall tourism experience (Fig. 16.6). For instance, UGI may play a much more central role in small urban wellness and thermal spa destinations (e.g. Lednice, Brno in the Czech Republic), or even in pilgrimage destinations (e.g. Fatima in Portugal – see Wiltshier 2009), than in destinations more strictly connected with cultural and nightlife attractions (Riga, Latvia and Bratislava, Slovakia).

In concluding this review, we can see that there is plenty we need to know in order to maximise the values and benefits to be obtained from urban green infrastructure by tourists, as well as the income generated by tourists as a result of visiting cities where UGI is an integral part of what gives the visit its purpose. This leads us to the second part of the chapter, where we present our survey of 16 cities in eight

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Fig. 16.7 View on Petrovaradin Fortress in Novi Sad, situated on the right bank of the Danube River. The fortress is one of the main visited green areas in the city. Its urban surroundings are also rich in green infrastructure elements (Source: http://goexcursion.net/images/excursions/5433a873a416704410720576/5.jpg)

European countries (Fig. 16.7). While this is exploratory study not intended to provide a complete picture of UGI and tourism in Europe, it does give a glimpse of what is happening and offers useful guidance for future research.

16.6 Survey Results: Urban Green Infrastructure and Tourism Benefits

This cross-cultural comparative study took place during the spring and summer of 2015, with the aim of collecting and analysing data on tourists' uses of UGI, at an exploratory level (indicative trends), across Europe. Its main objective was to understand and assess the ways that tourists use and profit from experiencing UGI in the cities they visit, as reflected in the selected cases. For this purpose, an interview questionnaire was used to assess and interpret tourists' practice/use/behaviour vis-à-vis UGI, in the cities or towns they visited. This was part of a broader survey, which also aimed to assess tourists' perceptions, understandings, preferences and affective associations with UGI – in addition to their actual use, practices and experiences. The questionnaire survey took place among tourists/users of UGI in the following countries and cities (one large and one mid-sized): The Czech Republic (Kromeriz and Brno), Greece (Athens and Mytiline), Latvia (Riga and Jelgava),

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Fig. 16.8 Map of case study sites of interview survey (Source: Lina Straigyte)

Lithuania (Birštonas and Kaunas), Portugal (Lisbon and Faro), Slovakia (Trencin and Bratislava), Serbia (Belgrade and Novi Sad) and the United Kingdom (London and Southampton) – see Fig. 16.8.

The selection of case studies followed a roughly comparative geographical logic, covering Mediterranean, Northern, North-Western and Central European countries. Cities were selected according to three criteria: a) all are urban tourism destinations, with some presence of UGI; b) there is roughly a 1/10 population ratio between the two cities in each country (or at least they are of significantly different urban rank size; and c) the geographical distance between the two cities is small. For the smaller urban centres (towns), an effort was made to find cases with some type of alternative or special-interest tourist attraction related in some way to the use of UGI. The characteristics of case study cities are summarized in Table 16.1.

The questionnaire combined closed (yes/no, multiple-choice or Likert scale evaluation) and open-ended questions to investigate the various dimensions of respondents' views and, particularly, to ensure that accurate information was obtained (Tomićević 2005). It included 28 questions, divided into five sections:

1. Perception questions
2. Psychological and preferences questions
3. Behaviour and activities questions
4. General questions related to how tourists use GI in the city, what kinds of GI tourists like, how tourists prefer to use GI (open-ended questions), and to what extent GI plays a role in tourists' choice of cities to visit (rating on a scale from 'very much' to 'not at all').

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Table 16.1 Characteristics of the case study cities

City (country)	Population (thousands)	Sample size (number of tourists by origin)				Main forms of tourism	Main UGI types
		Total	Foreign country	Neighbouring country	Domestic		
Brno (CZ)	378	54	26	28	0	Exhibition/congress, cultural	Forests, landscape greenery, green areas, parks
Kromeriz (CZ)	29	51	20	31	0	Cultural	Lawns, gardens, flowerbeds, woody plant areas
Athens (GR)	3828	50	50	0	0	Urban, cultural, archaeological, congress/conference	Parks, public open spaces/squares, roadside verges, cemeteries, church yards
Mytiline[b] (GR)	38	50	46	0	0	Urban, cultural, pilgrimage, educational, food	Parks, squares, public green spaces, private gardens, coastline and roadside trees/vegetation
Riga[a] (LV)	696	50	45	2	2	Cultural, sports, spa/health, business	Forests, parks, squares, green spaces, roadside/riverside trees, private courtyards, cemeteries
Jelgava[a] (LV)	63	50	42	5	2	Cultural, natural resources, festival	Forests, parks, squares, green spaces, roadside/riverside trees, private courtyards, cemeteries
Kaunas City[a] (LI)	299	50	38	11	0	Urban	Parks, public squares, forest
Birstonas (LI)	2.5	50	26	24	0	Health	Forest park, urban forest, riverside promenade
Lisbon(PT)	2700	51	47	2	1	Cultural, conference, business, cruise	Forests, parks, horticulture allotments, gardens
Faro[b] (PT)	43	49	37	2	7	Sea-sun, natural and cultural heritage	Public green space, natural parks, sand-dune islands

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Belgrade (SR)	1659	50	25	25	0	Cultural, business/event, urban	Parks, public green areas, squares, street-side and river-bank vegetation, lawns
Novi Sad (SR)	342	50	27	23	0	Cultural, natural resource, event	Parks, public green areas, squares, street-side and river-bank vegetation
Bratislava (SK)	433	53	18	35	0	Cultural, congress/ exhibition, business, sports	Forests, parks, remnants of natural vegetation, roadside verges, cemeteries
Tencin (SK)	56	51	21	30	0	Spa, cultural, winter sports, rural agro-	Public parks, green areas of housing estates, forests, tree-lined alleys, cemeteries, private gardens
London (UK)	8600	50	34	0	16	Urban, cultural, business, arts/entertainment, shopping, higher education	Parks, open spaces, railroad/road/ waterways-side vegetation/trees, nature conservation areas, children's play areas, gardens
Southampton (UK)	231	50	36	0	14	Urban, cultural, natural resource, education	Parks, green spaces, natural/ semi-natural green spaces, sport courts, allotments, cemeteries, amenity green spaces

[a]one resoponse is missing for tourist origin
[b]four responses are missing for tourist origin

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5. Biographical information (socio-economic status, age-group, marital status, educational level, profession, and household income category) and questions related to travel experience (accompanying travelers, distance travelled, and country of origin).

The research hypotheses were as follows:

1. Unless a city is a destination of a special-interest or alternative form of tourism related to UGI, tourists do not explicitly include UGI in their tourism planning.
2. When planning more conventional forms of urban tourism, tourists are not much influenced in their destination choice by the presence of UGI. Nevertheless, they find it important once they visit and, to the degree that they use it, generally have a positive attitude towards it. Normally, they do not initially intend to use UGI during their visit but do so incidentally.
3. In the cases of conventional urban tourism, the shorter the distance of the trip, the lower the family income and the higher the number of accompanying children, the greater the likelihood of incorporating UGI into tourists' travel plans.

About 50 questionnaires were completed for each case study city, totalling approximately 100 respondents per country. Mainly foreign tourists were interviewed, though many of these came from neighbouring countries; in some cases domestic tourists were included as well (see Table 16.1). The data were collected in face-to-face interviews, and the analysis used both descriptive statistics and correlation methods. We combined the results of different questions to derive four main indices: *Interest in UGI*, *Intention using UGI*, *Willingness to pay for UGI* and *Socio Economic Status*.

16.6.1 Characteristics of the Sample

In terms of gender, the ratio of male and female respondents was almost equal, and most belonged to the age category of 25–45 years (37%), followed by the youngest cohort of the sample (those under 25, with 32%). The age group of 45–66 was represented with 19% of the sample and that of over 66 with 12%. There is only a slight difference between the categories of respondents who were married or partnered (46%) and those who were single (45%), with the remaining respondents belonging to the category 'married with children'. In terms of education, more than a half of the sample held university degrees (57%), while 10% of the respondents also had post-graduate or PhD education.

In terms of income level more than a half of all respondents belonged to the category of low income and below average income (in total 65%); followed by average income (20%), and above average or high income (together about 10%). Since this was a sensitive question, responses were not obtained from nearly 5% of the sample. It must also be noted that this question was adapted to local circumstances; thus, the amount of money assigned to different categories was different from country to country.

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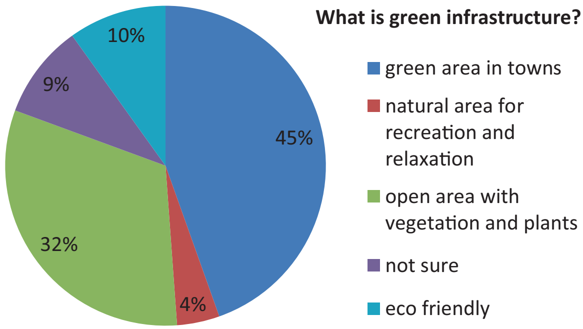

Fig. 16.9 Responses to the question 'What is green infrastructure?'

The survey results aimed to test the research assumptions and provide a cross-cultural comparison of tourists' uses and intentions to use UGI, framed by other aspects of their visit (understanding of UGI and purpose of travel) in order to put the former in context. Most respondents selected 'pleasure' as the purpose of their travel (87%), while for 10% it was business travel. When asked what their status during this trip was, 14% said that they had travelled alone and 34% as a couple, while the rest had travelled in some sort of a group (with children, friends, family, etc.).

When asked why they chose to visit this specific city, different and very nuanced answers were obtained, ranging from sightseeing, cultural amenities, unique history, visits to family, friend and relatives and business related (such as study visits, attending a conference, or work). Many of the cities were visited because they are: "calm, small cities", "nice to relax in", or because of their specific attractions, such as spas. Others were mainly visited as capital cities. Cities in the Mediterranean region were mainly visited for purposes of holiday-making.

The types of activities that tourists had planned to undertake were also varied, ranging from city tours, shopping and chilling out to more specific ones, such as guided photo tours, specific sports' activities, visiting specific exhibitions or concerts. In many cases, tasting and enjoying local food was mentioned as an important activity.

16.6.2 Understanding of UGI

The question "What is green infrastructure?" (Fig. 16.9) elicited a variety of answers, with most referring to 'green areas in towns' (45%) or 'open areas with vegetation and plants' (32%). Some 10% of respondents quoted the concept of eco-friendliness, and a similar proportion were not sure what UGI is. Together with those who did not even provide an answer, this gave an indication that many respondents are not actually familiar with the concept.

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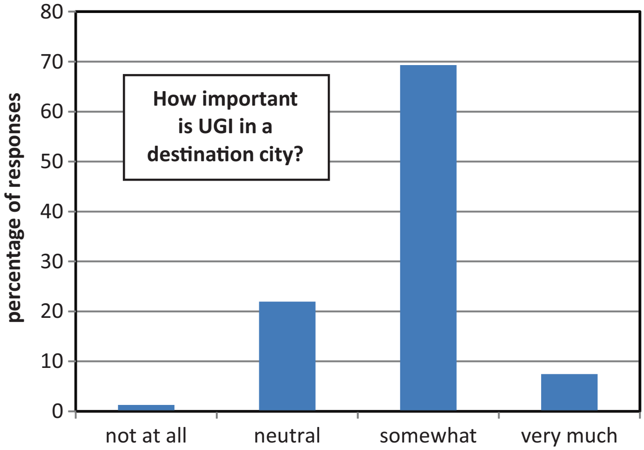

Fig. 16.10 The perceived importance of UGI in a city to be visited

16.6.3 Intentions and Uses of UGI

Regardless of respondents' exact understanding of the term, UGI was largely seen as important, with more than two-thirds of the respondents referring to UGI as somewhat important, and a small but significant portion (7%) considering it very important, to the visited city (Fig. 16.10). The perceived importance and understanding of UGI were also reflected in questions related to tourists' actual use of UGI and their intentions to use it in the cities they visit. In Fig. 16.11 we can see that most of the interviewees declared that they use UGI for walking (70%) but less so for other activities, and they also intended to visit parks (72%) more than other categories of UGI. In connection with their understanding of the term, this finding suggests that they identify UGI mainly with parks.

The results also indicated that during their trip the majority of respondents planned to spend 1–2 hours in UGI of selected cities (50%), followed by those who intended to spend 2–5 hours (23%), and 5–10 hours (11%). Just 16% responded that they would spend only a few minutes there. Thus, UGI appears to represent an important component of urban areas visited by tourists (Fig. 16.12).

16.6.4 Relation of Socio-demographic Aspects to Intentions and Uses of UGI

We looked in more detail at country differences in terms of tourists' ' *Interest in UGI', 'Intention to use UGI', 'Willingness to pay for UGI' and 'Socio-economic status – SES'*, by applying one-way analysis of variance (ANOVA). All four scores are significant ($p<0.05$), meaning that countries of tourist destination in our survey

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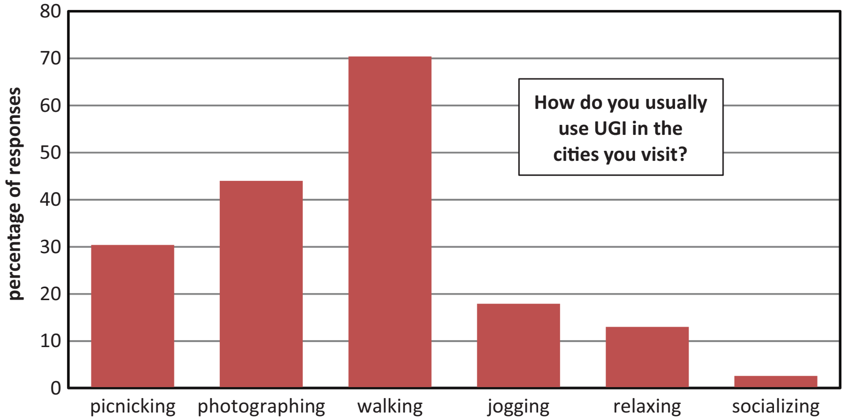


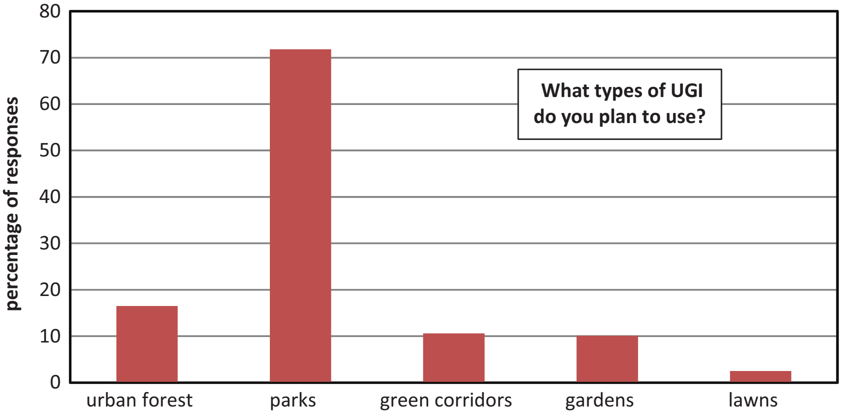
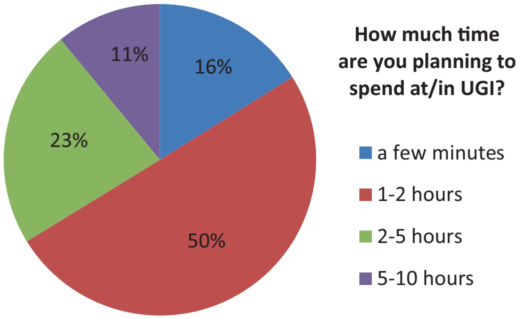


Fig. 16.11 Usual use of UGI (*top*), and type of UGI intended to be used in the visited city (*bottom*)

Fig. 16.12 Amount of time respondents planned to spend at/in UGI in visited city



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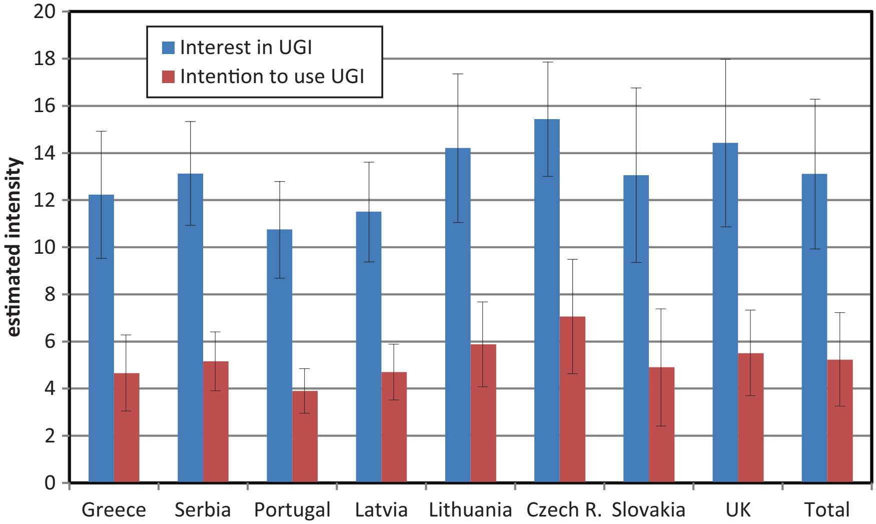

Fig. 16.13 Descriptive (arithmetic means) for all analysed scores related to indices 'Interest in UGI' and 'Intention to use UGI'

differ on all 4 indices. Looking at the countries separately (Fig. 16.13), it can be deduced that interest in UGI is greatest in The Czech Republic (intensity score of 15.44) and smallest in Portugal (10.76). Furthermore, the intention to use UGI seems to be highest in The Czech Republic (7.06) and lowest in Portugal (3.89). Willingness to pay for UGI was very low in all countries, with highest mean values in Lithuania (intensity score of 0.79) and lowest in Slovakia (−.94).

We next ran correlations between the question of importance of UGI to a city and the aforementioned indices, in order to test the respondents' perceived importance of UGI for tourism. For this purpose, we applied Pearson correlation coefficients with significance at (<0.05) and considered weak if the coefficient is between 0 and 0.3, moderate between 0.4 and 0.6, and strong above 0.7. Positive correlation means direct proportionality (if one score is higher, the other one is higher too), while negative correlation means reverse proportionality (if one score is higher, then the other one is lower).

In Table 16.2, the results show positive moderate correlations between intention and interest in UGI (r = 0.520, N = 806, p = 0.000), meaning that the more one is interested in UGI, the higher the intention to use it. Other correlations were also positive, but weak, i.e. if one has more interest in UGI, one will tend to pay for them (r = 0.138, N = 804, p = 0.000). Also, if one shows a higher intention to use UGI one will be more willing to pay for it, but this relationship is also weak (r = 0.089, N = 802, p = 0.012). Finally, the higher the socio economic status, the more one is willing to pay for use of UGI, but this correlation also appears to be weak (r = 0.174, N = 804, p = 0.000).

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Table 16.2 Correlation between analysed indices

		Intention to use UGI	Willingness to pay for UGI	SES
Interest in UGI	Pearson Correlation	**.520[b]**	**.138[b]**	−.025
	Sig. (2-tailed)	**.000**	**.000**	.475
	N	**806**	**804**	808
Intention to use UGI	Pearson Correlation		**.089[*]**	−.032
	Sig. (2-tailed)		**.012**	.366
	N		**802**	806
Willingness to pay for UGI	Pearson Correlation			**.174[b]**
	Sig. (2-tailed)			**.000**
	N			**804**
Importance of UGI to a city	Pearson Correlation	−.021	**.168[b]**	**.194[b]**
	Sig. (2-tailed)	.550	**.000**	**.000**
	N	779	**775**	**779**

[*] one response is missing for tourist origin
[**] four responses are missing for tourist origin

The results for importance of UGI to a city are also significant and positively correlated, but at a low intensity, as related to socio-economic status ($r = 0.194$, $N = 779$, $p = 0.000$) and willingness to pay for UGI ($r = 0.168$, $N = 775$, $p = 0.000$), showing that tourists who find UGI more important and have higher socio-economic status will tend to be more willing to pay for the use of UGI (Table 16.2). However, other factors as well, such as how tourists travel (alone or with other parties), accessibility and available time to spend in UGI, may influence this trend, once there is willingness to pay for UGI in the first place.

Differences between tourist categories based on who they travelled with on the proposed indices, were obtained through the application of one-way analysis of variance (ANOVA), and all appeared to be significant (<0.05). These results show the highest interest in using UGI by those who travelled with friends, followed by those travelling with children and family, and the lowest by travelling couples. The intention to use UGI was apparently higher among those travelling with friends than among all other categories of tourists, which showed a lower intention to use UGI and did not differ among themselves. Willingness to pay for UGI showed very interesting results, according to which those tourists traveling with children and families quoted the highest willingness to pay for use of UGI, while those travelling in a group indicated the lowest willingness to pay for UGI. Other groups, such as those travelling alone, as a couple, or with friends were somewhere in between.

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16.7 Final Remarks

Although most of the tourists interviewed in the surveyed cities were visiting mainly for pleasure, UGI seemed to play an important role in their plans to visit the specific city even when their main purpose of travel was business – irrespective of the other activities they were planning to take part in. Tourists visiting Northern and Central European cities showed more interest in UGI than tourists visiting Southern European cities, and the same was true regarding the intention to visit UGI, which appeared to be lowest in Southern Europe.

Results of the study revealed that many tourists are unfamiliar with the concept of 'green infrastructure' and that the term is ambiguously used and understood. Tourists mostly identified UGI as parks, and less often as green corridors or urban forests; some interpreted UGI as flower boxes or cycle paths for tourists, and some considered it as a concept connoting eco-friendliness. The majority of our survey participants seemed to enjoy visiting green spaces such as large parks or urban forests, mostly for light physical activity or relaxation (Fig. 16.14), and also to explore the culture and society of the destination city. The fact that most large green spaces in our study area were located near important heritage sites in the visited cities provided an indirect opportunity for tourists to include UGI in their visiting plans. Moreover, taking into consideration that UGI tends to be connected with public spaces/amenities and attractive city landscapes, this connectivity could be enhanced

Fig. 16.14 Taking time to relax and people-watch in Russell Square – one of the finest public spaces in London, designed by Humphry Repton, the famous 18th-century English landscape designer (Source: Forestry Commission, UK)

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by further investigation and investment in the linkages between UGI and social/cultural activities in such areas.

The majority of the respondents stated that UGI is very important to a city and that it influenced their choice to visit a specific city. At the same time, when it came to their personal circumstances, they stated that UGI was not their main preference for sightseeing when choosing a certain city as their travel destination. However, green infrastructure and historical sites often go hand in hand, such that tourists do not visit one without also visiting the other. In all the surveyed cities, it was observed that most tourists were visiting UGI and spending time in activities like walking, picnicking and taking photographs, without the latter being their initial intention when deciding to visit this particular city. Nevertheless, tourists tended to acknowledge the importance of green spaces to the cities; they were mainly planning to visit parks, but not actually paying attention to what particular type of UGI they were visiting – which is not surprising, since these typological distinctions are mainly devices used by green space professionals. Tourists seem to care about UGI in these cities and the majority planned to visit UGI for more than an hour; for most of them, however, this was not the main reason of their trip.

Finally, no significant correlations emerged between the socio-economic status of the visitors and their willingness to pay for UGI services, nor between the city's geographic location and the willingness of tourists to pay for UGI services. The intention to use UGI was highest among tourists travelling with friends, who also expressed the lowest willingness to pay for such UGI services – while families showed a pronounced willingness to pay, but a low intention to visit in the first place.

The results of the survey, which may be considered as an exploratory pilot project rather than a representative sample of European cities, cannot provide any definitive answers. However, it helps to formulate more useful questions and to suggest further research with a clearer focus. Such research, asking a similar or expanded range of questions to a larger sample of tourists, may prove to be very helpful to local and regional authorities in the planning and management of an urban tourist destination's green infrastructure.

Examples of certain cities, famous for and recognised by their distinctive green areas (e.g. the Bois de Boulogne and Bois de Vincennes of Paris, New York's Central Park, etc.), illustrate how UGI can play a significant role in building a city brand or image, and thus in attracting tourist visits (Konijnendijk 2008). However, more comprehensive and cross-sectoral approaches must be adopted by city actors, in this regard, in most cities. Additional and more in-depth research on the measures, methods and interventions in UGI to be undertaken by UGI managers would be valuable for the enhancement of a city's UGI usefulness and its attractiveness to tourists. Public perception surveys aimed at further investigating tourists' perceptions, preferences and uses of UGI, in various contexts and at different urban scales, could enable green infrastructure managers to identify preferred management alternatives and to put this information to better use, in future urban planning and tourism development projects worldwide.

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References

Andrada II R, Deng J (2010) Enjoying green cities: assessing visitors' attitudes and preferences for urban forests in Washington, DC. In: Proceedings of the 2010 Northeastern Recreation Research Symposium GTR-NRS-P-94, pp 168–174

Bell S (2008) Design for outdoor recreation. Taylor & Francis, London

Berkes F, Colding J, Folke C (2000) Rediscovery of traditional ecological knowledge as adaptive management. Ecol Appl 10:1251–1262

Berte E, Panagopoulos T (2014) Enhancing city resilience to climate change by means of ecosystem services improvement: a SWOT analysis for the city of Faro, Portugal. Intern J Urban Sustain Dev 6:241–253. doi:10.1080/19463138.2014.953536

Cekule M (2010) Rīgas telpiskās struktūras analīze, izmantojot ģeogrāfiskās informācijas sistēmas (Riga's city spatial strukture analyse based on geographical information system). Doctoral thesis, University of Latvia, Riga, Latvia (in Latvian)

Chang TC, Huang S (2014) Urban tourism and the experience economy. In: Lew AA, Hall CM, Williams AM (eds) The wiley-blackwell companion to tourism. Wiley Blackwell, Oxford

Chen WC, Jim CY (2008) Assessment and valuation of the ecosystem services provided by urban forests. In: Carreiro MM, Song YC, Wu J (eds) Ecology, planning, and management of urban forests. International perspectives. Springer, New York, pp 53–83

Chiesura A (2004) The role of urban parks for the sustainable city. Landsc Urban Plan 68(1):129–138. doi:10.1016/j.landurbplan.2003.08.003

Crouch D (ed) (1999) Leisure/tourism geographies: practices and geographical knowledge. Routledge, London

Dobbs C, Escobedo FJ, Zipperer WC (2011) A framework for developing urban forest ecosystem services and goods indicators. Landsc Urban Plan 99:196–206

Donis J (2001) Urban forestry in Latvia: status, policy, management research. In: Urban forestry in the Nordic and Baltic countries – urban forests under transition. Proceedings from an international seminar on urban forestry in Kaunas, Lithuania. Randrup TB, Gustavsson R, Christophersen T (eds) Skov& Landskab Report 9. Hoersholm: Skov& Landskab, pp 19–23

Dwyer JF, McPherson GE, Schroeder HW, Rowntree RA (1992) Assessing benefits and costs of the urban forest. J Arboric 18(5):227–234

Eriksson L, Nordlund A, Olsson O, Westin K (2012) Beliefs about urban fringe forests among urban residents in Sweden. Urban For Urban Green 11:321–328

Fábos JG (1995) Introduction and overview: the greenway movement, uses and potentials of greenways. Landsc Urban Plan 33:1–13

Forman RTT (2008) Urban regions. ecology and planning beyond the city. Cambridge University Press, Cambridge

Gudurić I, Tomićević J, Konijnendijk CC (2011) A comparative perspective of urban forestry in Belgrade, Serbia and Freiburg, Germany. Urban For Urban Green 10:335–342

Gunnarsson G, Øhrstroom HE (2007) Noise and well-being in urban residential environments: the potential role of perceived availability to nearby green areas. Landsc Urban Plan 83:115–126

Hall CM, Page SJ (2006) The geography of tourism and recreation: environment. Place and space. Routledge, London

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Hall CM, Williams AM, Lew AA (2014) Tourism: conceptualizations, disciplinarity, institutions, and issues. In: Lew AA, Hall CM, Williams AM (eds) The Wiley-Blackwell companion to tourism. Wiley Blackwell, Oxford
Hansmann R, Whitehead I, Krajter Ostoić S, Živojinović I, Stojanovska M, Jones N, Bernasconi A, Benamar S, Lelieveld C, Barstad J (2016) Partnerships for urban forestry and green infrastructure delivering services to people and the environment: a review on what they are and aim to achieve. Southeast Eur For 7(1). doi:10.15177/seefor.16-09
Huijbens E (2014) Natural wellness. The case of Icelandic wilderness landscapes for health and wellness tourism. In: Smith M, Puczkó L (eds) Health, tourism and hospitality: spas. Wellness and Medical Travel. Routledge, London, pp 413–416
Iso-Ahola SE (1982) Toward a social psychological theory of tourism motivation: a rejoinder. Ann Tour Res 9(2):256–261
James P, Tzoulas K, Adams MD, Barber A, Box J, Breuste J, Elmqvist T, Frith M, Gordon C, Greening KL, Handley J, Haworth S, Kazmierczak AE, Johnston M, Korpela K, Moretti M, Niemelä J, Pauleit S, Roe MH, Sadler JP, Thompson WC (2009) Towards an integrated understanding of green space in the European built environment. Urban For Urban Green 8:65–75
Jankovska I, Straupe I, Panagopoulos T (2010) Professionals awareness in promotion of conservation and management of urban forests as green infrastructure of Riga, Latvia. WSEAS Trans Environ Dev 6:614–623
Jankovska I, Donis J, Straupe I, Panagopoulos T, Kupfere L (2013) Assessment of the forest recreation accessibility in Latvia. Fresenius Environ Bull 22(7B):2145–2151
Jankovska I, Straupe I, Brumelis G, Donis J, Kupfere L (2014) Urban forests of Riga, Latvia – pressures, naturalness, attitudes and management. Balt For 20(2):342–351
Kaplan R, Kaplan S (1989) The experience of nature. A psychological perspective. Cambridge University Press, Cambridge
Konijnendijk CC (2008) The forest and the city: the cultural landscape of urban woodland. Springer, Berlin
Konijnendijk CC, Randrup TB (2004) Urban forestry. In: Burley J, Evans J, Youngquist JA (eds) Encyclopedia of Forest sciences. Elsevier, Amsterdam, pp 471–478
Konijnendijk CC, Annerstedt M, Busse Nielsen A, Maruthaveeran S (2013) Benefits of urban parks a systematic review. International Federation of Parks and Recreation Administration, Copenhagen/Alnarp, pp 1–70
Madureira H, Nunes F, Oliveira JV, Cormier L, Madureira T (2015) Urban residents' beliefs concerning green space benefits in four cities in France and Portugal. Urban For Urban Green 14:56–64
Majumdar S, Deng J, Zhang Y, Pierskalla C (2011) Using contingent valuation to estimate the willingness of tourists to pay for urban forests: a study in Savannah, Georgia. Urban For Urban Green 10(4):275–280
McConnell DJ (2003) The forest farms of kandy: and other gardens of complete design. Ashgate, Aldershot
Millennium Ecosystem Assessment (MEA) (2005) Ecosystems and human well-being: current state and trends. Island Press, Washington, DC
Page S (1995) Urban tourism. Routledge, London
Schipperijn J, Ekholm O, Stigsdotter UK, Toftager M, Bentsen P, Kamper-Jørgensen F, Randrup TB (2010) Factors influencing the use of green space: results from a danish national representative survey. Landsc Urban Plan 95:130–137
Selby M (2012) Geographies of tourism and the city. In: Wilson J (ed) The routledge handbook of tourism geographies. Routledge, London, pp 232–239
Terkenli TS (1996) The cultural landscape: geographical perspectives. Papazissis Publications, Athens (in Greek)
Tomićević J (2005) Towards participatory management: linking people, resources and management. A socio-economic study of Tara National Park. Culterra, Schriftenreihe des Instituts für Landespflege der Albert-Ludwigs-Universität Freiburg, Heft 43, Freiburg

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Turner T (2005) Garden history: philosophy and design 2000 BC–2000 AD. Spon Press, New York

Tyrväinen L, Pauleit S, Seeland K, de Vries S (2005) Benefits and uses of urban forests and trees. In: Konijnendijk C, Nilsson K, Randrup T, Schipperijn J (eds) Urban forests and trees. Springer, Berlin, pp 81–114

Tyrväinen L, Gustavsson R, Konijnendijk C, Ode A (2006) Visualization and landscape laboratories in planning, design and management of urban woodlands. Forest Policy Econ 8:811–823

Tyrväinen L, Mäkinen K, Schipperijn J (2007) Tools for mapping social values of urban woodlands and other green areas. Landsc Urban Plan 79:5–19

UNWTO (2011) Tourism Trends 2030: Global Overview. UNWTO General Assembly, 19th Session, Gyeongju, Republic of Korea, 10 Oct 2011, UNWTO, Madrid

UNWTO & UNEP (2011) Tourism: investing in the green economy. In: Towards a green economy. United Nations Environmental Programme, Geneva, pp 409–447

Urry J (1995) Consuming places. Routledge, London

Ward Thompson C (2004) Forest amenity planning approaches. In: Burley J, Evans J, Youngquist JA (eds) Encyclopedia of forest sciences. Elsevier, Amsterdam, pp 478–486

Wiltshier P (2009) A review of "Religious" tourism and pilgrimage management. J Sustain Tour 17:408–409

Yli-Pelkonen V, Kohl J (2005) The role of local ecological knowledge in sustainable urban planning: perspectives from Finland. Available at http://ejournal.nbii.org/archives/vol1iss1/0410-007.yli-pelkonen.pdf Accessed 20 Sept 2016

Živojinović I, Wolfslehner B (2015) Perceptions of urban forestry stakeholders about climate change adaptation – A Q-method application in Serbia. Urban For Urban Green 14:1079–1087

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Chapter 17
The Role and Value of Urban Forests and Green Infrastructure in Promoting Human Health and Wellbeing

Giuseppe Carrus, Payam Dadvand, and Giovanni Sanesi

17.1 Overview of the State-of-the-Art

Research from many different disciplines – including environmental psychology, urban forestry, human ecology, human geography, landscape architecture, and environmental epidemiology – has consistently highlighted the tendency of human beings to prefer scenes and settings where there is a substantial presence of natural elements, such as plants, trees and water (e.g., Purcell et al. 2001; Van den Berg et al. 2007). According to a shared view in the scientific community, such a preference can be explained through an evolutionary mechanism, which has selected the human capacity of appreciating those elements in their life settings that make an environment more suitable for survival, providing food, shelter from predators, and better survival conditions, in general. This vision has come to be known as the "biophilia hypothesis" (e.g., Kellert and Wilson 1993).

In the last two decades, with an increasing emphasis on the potential benefits of people-nature relationships, a growing body of literature on this topic has investigated the role of natural place experience for promoting human health – and indeed,

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natural environments such as urban forests have been consistently identified as ideal settings for the promotion of human health and wellbeing (e.g., Hartig et al. 2011; Dadvand et al. 2016).

In current research, the concept of *restorative environments* offers an interesting perspective for understanding the beneficial effects of contact with nature in human life. The idea of restorative environments presumes the recovery function of interacting with nature, implying that specific environments more than others offer the possibility of relaxing, clearing one's minds, and taking some distance from ordinary aspects of life. Therefore, in this view, restorative environments are those that promote, and not only permit, the recovery of psycho-physical resources used to meet the demands of everyday life tasks (Hartig 2004).

The seminal study by Ulrich (1984), demonstrating the positive effects of visual contact with nature on the speed of post-surgical recovery, is frequently cited as a cornerstone for this field of inquiry. Frumkin (2001) also discussed the potential health benefits of contact with natural settings, and suggested considering these empirical research findings in interventions for improving human health and quality of life in everyday settings. Later, Hartig and Cooper-Marcus (2006) analyzed the potential influence of healing gardens for improving patients' experiences in health care settings. Likewise, de Vries et al. (2003) suggested that living close to green spaces is positively associated with different health indicators, and this relationship is even stronger for specific groups of residents, such as housewives and the elderly. Milligan and Bingley (2007) also discussed the importance of childhood woodland experiences in strengthening personal resources to cope with young adulthood problems, thereby promoting mental health. Korpela and Ylén (2007) clearly pointed out that people tend to choose favourite natural places to achieve self-regulation goals, and these choices, in turn, are linked to perceived personal health.

Large-scale epidemiological studies have also pointed in the same direction, suggesting how the availability of accessible components of green infrastructure (GI) in a residential context is a strong factor for overcoming income-based health inequalities (e.g., Mitchell and Popham 2008; see also Nieuwenhuijsen et al. 2014).

Frequenting urban forests and other components of GI during the course of daily life has also been associated with the promotion of subjective wellbeing (e.g., Lafortezza et al. 2009) and the recovery of cognitive executive functions (e.g., Berman et al. 2008). In particular, recent findings suggest that GI with a higher degree of 'naturalness' and biodiversity are perceived as more restorative and have a stronger association with subjective wellbeing (e.g., Carrus et al. 2015a, b). Finally, more recent studies also suggest that staying in touch with nature has a positive influence on cognitive, behavioural, and emotional development, interpersonal relations, and promoting positive social behaviour and altruism in children and adults (e.g., Taylor et al. 2002; Guéguen and Stefan 2014; Carrus et al. 2015a, b; Amoly et al. 2015; Dadvand et al. 2015a).

On the whole, a considerable amount of studies have highlighted the benefits of people-nature relationships. This seems to be even more important in urban settings, where stressful situations and heavy psychological demands for residents are more likely to come into conflict with the pursuit of urban sustainability (van den Berg et al. 2007).

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17.2 Perceived General Health and Wellbeing (Observational Studies)

It is beyond the scope of this chapter to provide a comprehensive review of the literature on the beneficial effects of contact with nature for human health, wellbeing and quality of life (for more extensive reviews, see, for example, de Vries et al. 2003; Maller et al. 2006; Van den Berg et al. 2007; and Mensah et al. 2016). Rather, we will summarize here the basic assumptions and major milestones of research in this field, as it has evolved for more than three decades. The curative properties of nature for human health are shared in common sense knowledge and reflected in popular thinking, religious beliefs, visual arts and shared narratives across many different cultures. The first widely cited seminal study to support this assumption was published by Roger Ulrich in 1984, and showed that patients with a view of nature from their hospital window experienced faster recovery from surgery than patients viewing a concrete hospital courtyard. This finding was later corroborated by similar results demonstrating how contact with nature (either actual or visual) may help reduce stress (e.g., Ulrich et al. 1991), replenish cognitive functions (e.g., Hartig et al. 1991; Berman et al. 2008), and positively affect perceived general health (e.g., Korpela and Ylén 2007), subjective wellbeing (e.g., Lafortezza et al. 2009; Carrus et al. 2015a, b) and quality of life (e.g., Mensah et al. 2016). Taken together, this body of evidence offers valid arguments to advocate for a more substantial presence of natural settings within healthcare facilities (e.g., Hartig and Cooper-Marcus 2006).

17.3 Green Infrastructure and Mental Health

Improving mental health is one of the better-known effects of contact with components of GI. During the past two decades, an accumulated body of evidence has given rise to the ‘attention restoration theory’, which proposes that contact with nature and its inherently delightful stimuli could modestly invoke indirect (i.e., effortless) attention and, in time, minimize the need for directed attention that together could restore the directed attention mechanisms (Kaplan and Kaplan 1989; Kaplan 1995; Berman et al. 2008). The majority of evidence in support of the ‘attention restoration theory’ involves experimental studies focusing mainly on the short-term restorative effects of contact with nature. These studies have shown that walking/exercising in GI or watching images/footages of GI could not only improve attention and other cognitive functions in healthy individuals, but also mitigate the symptoms of disorders, such as attention-deficit hyperactivity disorder (ADHD) in affected children (Pearson and Craig 2014). Stress relief is another short-term effect of contact with components of GI, which has been widely reported by experimental studies (Pearson and Craig 2014). Such contact has been shown to reduce both psychological indicators of stress as well as its physical markers, for example, cortisol level, heart rate, and blood pressure.

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Aside from short-term effects, a growing body of observational evidence has associated contact with green spaces with long-term improvements in mental health status. The findings of a recent systematic review on the beneficial impacts of long-term residential exposure to GI on mental health are suggestive of improvements in self-perceived general mental health and lower risk of stress, anxiety and mood disorders in adults, and behavioural and emotional problems in children (Gascon et al. 2015). Recently, long-term exposure to green spaces has also been associated with enhanced cognitive development (including working memory and attention) in children (Dadvand et al. 2015a). Given the short- and long-term benefits in both adults and children, GI can play an important role in improving the mental health of urban dwellers.

17.4 Green Infrastructure and Physical Health

A growing body of evidence has associated contact with different components of GI to improved physical health status. A recent systematic review and meta-analysis of available studies on the association between residential exposure to green space and mortality has reported a decrease in all-cause and cardiovascular mortality associated with higher residential greenness (Gascon et al. 2016). This exposure has also been associated with a reduction in the risk of a wide range of morbidities. For example, higher greenness surrounding homes or the presence of GI in the vicinity of the residential address has been shown to reduce risk of cardiovascular conditions, diabetes, obesity, and musculoskeletal complaints in adults (Maas et al. 2009a, b; Lachowycz and Jones 2011). In children, surrounding residential greenness and proximity to GI have been associated with lower risk of obesity (e.g. Dadvand et al. 2014); however, the available evidence on such an association is inconsistent.

Further to reducing physical morbidity and mortality, components of GI have also been reported to improve pregnancy outcomes. Higher greenness surrounding the residence of pregnant women has been associated with higher birth weight (Dzhambov et al. 2014) and larger head circumference (Dadvand et al. 2012a). GI exposure has also been reported to reduce the risk of preterm birth (Grazuleviciene et al. 2015; Laurent et al. 2013); however, such an impact has not been supported by other studies (Dadvand et al. 2012b; Agay-Shay et al. 2014).

The available evidence on the association of exposure to GI and allergic rhinitis, aeroallergen sensitization, and asthma, particularly in children, is inconsistent. While some studies have reported higher risk of allergic conditions and exacerbation of asthma in children in relation to this exposure (DellaValle et al. 2012; Lovasi et al. 2013; Fuertes et al. 2016), others have shown no or even protective effects (Lovasi et al. 2008; Maas et al. 2009a, b; Hanski et al. 2012; Pilat et al. 2012).

To summarize, the available body of evidence supports a beneficial impact of contact with GI on mortality, morbidity (especially non-communicable diseases), and pregnancy outcomes. However, the findings for the association between this contact and asthma and allergic conditions are still inconsistent.

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17.5 Mechanisms Underlying the Health Effects of Components of Green Infrastructure

An accumulating body of evidence has associated exposure to GI with improved physical and mental health; however, the potential mechanisms underlying such associations are yet to be established. Stress relief resulting from visual access or visits to GI has been suggested to be one of the pathways through which GI exerts beneficial effects, given that psychological stress has been linked to increased risk of a wide range of chronic conditions (Bowler et al. 2010). Enhancing social contact and cohesion is another potential mechanism underlying the health benefits of GI, as improved social contact and cohesion have been associated with improved health status (Maas et al. 2009a, b; Dadvand et al. 2016). Components of GI have also been reported, although not consistently, to promote physical activity, which itself, has been increasingly associated with lower risk of a wide range of adverse health conditions (Bowler et al. 2010; Dadvand et al. 2016). Moreover, urban forests have been shown to mitigate the urban heat island effect (Phelan et al. 2015) and reduce exposure to traffic-related air pollution (Dadvand et al. 2012c, b) and noise (Gidlöf-Gunnarsson and Öhrström 2007). Exposure to these environmental hazards has been associated with a wide range of detrimental health effects. A growing body of evidence is also suggestive of the immunoregulatory properties of exposure to environmental microbiota (Rook 2013; Rook et al. 2013), which in turn has been associated with a range of health outcomes, such as brain development (Rook 2013; Rook et al. 2013). Therefore, the ability of GI to enhance and enrich immunoregulation-inducing microbial input from the environment (Rook 2013) could be another potential mechanism underlying the observed associations between green space exposure and health. Further studies are required to confirm the aforementioned mediatory roles of GI in health benefits and to shed light on other potential, yet currently unknown, mediators.

17.6 The Socio-cultural Benefits of Green Infrastructure: Migrant Inclusion and Other Positive Social Outcomes

International and national migration is a topic of considerable and growing interest. In recent years, these phenomena have reached dramatic proportions in the context of southern Europe due to conflicts and the global change impacts that are affecting the Northern Africa and Western Asia. Many studies and extensive research during the last few years have focused on migrants' adaptation to different cultures across different settings (e.g., de Leeuw and van Wichelen 2012). Yet, the literature still has several gaps in regards to urban forestry and green infrastructure as a tool for supporting migrants' adaptation or social inclusion.

The current literature on this topic focuses mainly on gardening (i.e., community gardening), which can play an important role in preserving migrants' cultural identity and establishing a space for socializing and interacting both with people of the hosting country and those of other cultures (Fig. 17.1). Community gardens as a place for

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Fig. 17.1 Social allotments of different types, sizes and structures can improve social inclusion. (**a**) The Stadtteilgarten Schillerkiez community gardens are located on the site of Berlin's abandoned Tempelhof Airport. Since the airport closed in 2008, the local authorities have supported a number of temporary experimental projects and installations. These gardens are free, open to the public and provide a friendly space to meet people in a very informal way, and at the same time, grow vegetables. (**b**) The social allotments in Parco Nord Milano: the first 35 gardens inside the park were equipped and regulated in the late '1980s, according to a strategy of revitalization of the areas closest to the city, for the elderly, with a specific design philosophy and management approach. These gardens have created, over time, a highly loyal relationship between the park and its users, through a participatory process involving elderly people in the maintenance of a portion of the park. The individual plots are fenced and allocated to the elderly by yearly public calls. The area is open to the public and passable, so that everyone can enjoy the landscape

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social relations and food production for self-subsistence are a fairly common experience in countries such as in Argentina, Australia, Canada, Germany, Portugal, the United States and the United Kingdom, where immigration is a common phenomenon (Agustina and Beilin 2012; Cabannes and Raposo 2013; Harris et al. 2014). In Germany, the history of a particularly successful community garden is the 'Intercultural Gardens Network', coordinated by the Stiftung Interkultur (Intercultural Foundation). Within these gardens fences are rarely erected; migrants have large common areas equipped with a fireplace and sometimes a glasshouse for growing winter vegetables. Women migrants especially use the common areas for socializing, eating and drinking together, and for inviting guests hosted by the city (www.http://anstiftung.de/english).

In addition, GI can provide elective spaces for multicultural meetings and sharing different experiences. Urban forests can increase affinity among users as well as interpersonal contact and empathy, acting as 'temporary communities', especially by allowing for leisure activities or in association with multisensory experiences (Neal et al. 2015). Canadian studies have analyzed how, by accessing different components of GI in natural settings within Montreal, migrants were able to minimize the effects of inadequate housing, strengthen social cohesion and reduce emotional stress (Hordyk et al. 2015).

17.7 Experiences of Green Strategies for Solving Health Problems

In the last decade, the interest of the scientific community in the positive effects of GI on human health has determined the proliferation of initiatives and national strategies that promote this relationship. Although frequently established by foundations, these strategies are often supported by national health services; their aims mainly concern preventive measures against some non-infectious diseases (e.g., cardiovascular, obesity, diabetes) linked to sedentary lifestyles. In other cases, the aim is to foster social inclusion. Frequently, such strategies are multi-purpose.

Among the many national strategies that might be mentioned, the so-called 'health walks' as a preventive tool are present in many states and widely supported by public health services or health-related organizations, for example, in the US, Australia and the UK. 'America Walks' (www.americawalks.org) is a non-profit organization sponsored, inter alia, by some health prevention institutions committed to mobilizing individuals to increase walking and walkability in America and to promoting physically, mentally and economically healthy neighborhoods. 'Heart Foundation Walking', an Australian charity, aims to make regular physical activity enjoyable and easy (www.walking.heartfoundation.org.au). In England, 'Walking for Health' is the largest network of health walks that helps people across the country to have a more active lifestyle (www.walkingforhealth.org.uk). This charity organizes groups of walks in different urban areas, preferably urban forests, providing volunteer assistance. It also promotes, through a more active lifestyle, an opportunity for a social dimension for some marginalized people (e.g., the elderly, cancer affected, etc.). Furthermore, the interest in promoting physical activity in a green

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Fig. 17.2 Urban forests are among the most favoured places for citizens to practice physical activities: (**a**) gym exercises in China, and (**b**) runners in Europe

urban setting has prompted the State of Mississippi in the US to authorize the city of Pascagoula to use food tax revenue to implement a comprehensive parks and recreation master plan (Winterfeld 2014).

Community gardens have been conceived to couple physical activity, nutrition and socialization in order to achieve a holistic approach for improving quality of life

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Fig. 17.3 Urban forests and other components of GI are places for meeting, relaxing and socializing. Here, different age groups in different social, cultural and economic contexts can easily integrate and have positive interactions in their daily lives

(Figs. 17.2 and 17.3). In the US, since 1988, the California Healthy Cities and Communities (CHCC) program has been supporting communities to establish community gardens using a collaborative approach (Twiss et al. 2003). More recently, in Europe, a Life+ project has supported six organizations representing five major European cities to share practices and build community gardens together. This project, called EU'GO, aims to promote community gardens as a tool to work on different themes: social cohesion, intercultural and intergenerational dialogue and promotion of healthy lifestyles (www.http://otesha-gardens.eu).

17.8 Green Prescription

The term 'green prescription' has come into use over the last decade, especially in reference to physical practices implemented in the outdoor environment to counter some non-infectious diseases (e.g., cardiovascular, obesity). Thanks to some epidemiological studies at the beginning of the new millennium and the 'vitamin G' project (where 'G' stands for green), relationships between GI and health were empirically verified, and preliminary insights into mechanisms explaining these relationships were suggested (Groenewegen et al. 2012).

As discussed in the previous paragraph, walks are the main physical activity that may be included in the context of 'green prescription', as walking programs appear

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to have positive outcomes. Walks in GI, expressed in terms of frequency and duration, are associated not only with more positive physical effects but also with less perceived stress and depression (Marselle et al. 2013). In addition, the World Health Organization (2010) has promoted a sort of 'green prescription' which suggests that each adult perform at least 150 minutes of moderate-intensity aerobic activity (walking, gardening, etc.) throughout the week. These ideas, however, are not exempt from criticism. In the current perspective, as reported by Carpenter (2013), the 'nature on prescription' approach is often evidenced within a positivist, reductionist paradigm, thus reducing nature to a 'dose' with 'measurable mental and physical effects.' In a 'green prescription' perspective it is necessary, however, to rethink the planning of GI and to consider various indicators (e.g., Gallup-Healthways Wellbeing Index) that can support urban regeneration programs (Larson et al. 2016).

The typology of natural environments used for a group walk could have an effect on human wellbeing. Certainly, an individual's perceptions can play a crucial role (Korpela et al. 2008; Bell et al. 2014), but further research is needed to shed more light on the causal relationships involved (Schipperijn et al. 2013).

17.9 Concluding Remarks

In this chapter we have highlighted how theories and empirical studies from different disciplines in the last three decades have converged in suggesting that human beings can significantly benefit from staying in touch with natural elements in their daily lives in terms of general psychological wellbeing, quality of life and mental and physical health. Outcomes such as stress reduction, improved cognitive executive functioning, reduced risk of mood disorders and anxiety, reduced mortality, reduced risk of a wide range of morbidities (e.g., cardiovascular conditions, diabetes, obesity, and musculoskeletal complaints) and improved pregnancy outcomes (e.g., higher birth weight, larger head circumference, lower risk of preterm birth) have all been associated with various indicators of contact with natural settings in daily life experiences. However, findings of this kind are not always consistent and warrant further investigation.

In addition to health and wellbeing outcomes, more recent research has also suggested an association between contact with urban nature and various environmental, social and societal outcomes. Many factors can be identified as potential mechanisms acting together with positive health outcomes in making the presence of GI a major source of urban quality of life. Among the factors worth mentioning is the role of urban forests and green infrastructure in mitigating the urban heat island effect, reducing traffic-related air pollution and noise, strengthening social cohesion, favouring social behaviour and altruism, and helping to create more socially inclusive communities in today's multicultural society.

Despite the consistent body of literature addressing the outcomes of people-nature relationships in present-day societies, more studies are needed to clarify the mechanisms involved in the positive association between contact with nature and

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human health and wellbeing, to establish the mechanisms underlying such an association, and to corroborate more recent findings that also highlight the social and societal benefits of green infrastructures. Finally, a topic that certainly deserves more investigation is the potential contribution of GI in reducing our carbon footprint by helping the transition toward sustainable lifestyle changes among individuals, groups and communities in society.

References

Agay-Shay K, Peled A, Crespo AV, Peretz C, Amitai Y et al (2014) Green spaces and adverse pregnancy outcomes. Occup Environ Med 71:562–569

Agustina I, Beilin R (2012) Community gardens: space for interactions and adaptations. Procedia Soc Behav Sci 36:439–448

Amoly E, Dadvand P, Forns J, López-Vicente M, Basagaña X, Julvez J, Alvarez-Pedrerol M, Nieuwenhuijsen MJ, Sunyer J (2015) Green and blue spaces and behavioral development in Barcelona schoolchildren: the BREATHE Project. Environ Health Perspect 122(12):1351–1358

Bell SL, Phoenix C, Lovell R, Wheeler BW (2014) Greenspace, health and wellbeing: making space for individual agency. Health Place 30:287–292

Berman MG, Jonides J, Kaplan S (2008) The cognitive benefits of interacting with nature. Psychol Sci 19:1207–1212

Bowler D, Buyung-Ali L, Knight T, Pullin A (2010) A systematic review of evidence for the added benefits to health of exposure to natural environments. BMC Public Health 10:456

Cabannes Y, Raposo I (2013) Peri-urban agriculture, social inclusion of migrant population and Right to the City Practices in Lisbon and London. City 17(2):235–250

Carpenter M (2013) From 'healthful exercise' to 'nature on prescription': the politics of urban green spaces and walking for health. Landsc Urban Plan 118:120–127

Carrus G, Scopelliti M, Lafortezza R, Colangelo G, Ferrini F, Salbitano F, Agrimi M, Portoghesi L, Semenzato P, Sanesi G (2015a) Go greener, feel better? The positive effects of biodiversity on the wellbeing of individuals visiting urban and peri-urban green areas. Landsc Urban Plan 134:221–228

Carrus G, Passiatore Y, Pirchio S, Scopelliti M (2015b) Contact with nature in educational settings might help cognitive functioning and promote positive social behavior. Psyecology 6:191–212

Dadvand P, Sunyer J, Basagaña X, Ballester F, Lertxundi A et al (2012a) Surrounding greenness and pregnancy outcomes in four Spanish birth cohorts. Environ Health Perspect 120:1481–1487

Dadvand P, de Nazelle A, Figueras F, Basagaña X, Sue J et al (2012b) Green space, health inequality and pregnancy. Environ Int 40:110–115

Dadvand P, de Nazelle A, Triguero-Mas M, Schembari A, Cirach M, Amoly E et al (2012c) Surrounding greenness and exposure to air pollution during pregnancy: an analysis of personal monitoring data. Environ Health Perspect 120(9):1286–1290

Dadvand P, Villanueva CM, Font-Ribera L, Martinez D, Basagaña X et al (2014) Risks and benefits of green spaces for children: a cross-sectional study of associations with sedentary behavior, obesity, asthma, and allergy. Environ Health Perspect 122:1329–1325

Dadvand P, Nieuwenhuijsen MJ, Esnaola M, Forns J, Basagaña X et al (2015a) Green spaces and cognitive development in primary schoolchildren. Proc Natl Acad Sci U S A 112:7937–7942

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Dadvand P, Rivas I, Basagaña X, Alvarez-Pedrerol M, Su J, De Castro PM et al (2015b) The association between greenness and traffic-related air pollution at schools. Sci Total Environ 523:59–63

Dadvand P, Bartoll X, Basagaña X, Dalmau-Bueno A, Martinez D, Ambros A et al (2016) Green spaces and general health: roles of mental health status, social support, and physical activity. Environ Int 91:161–167

de Leeuw M, van Wichelen S (2012) Civilizing migrants: integration, culture and citizenship. Eur J Cult Stud 15(2):195–210

de Vries S, Verheij RA, Groenewegen PP, Spreeuwenberg P (2003) Natural environments – healthy environments? An exploratory analysis on the relationship between greenspace and health. Environ Plann A 35(10):1717–1731

DellaValle CT, Triche EW, Leaderer BP, Bell ML (2012) Effects of ambient pollen concentrations on frequency and severity of asthma symptoms among asthmatic children. Epidemiology 23:55–63

Dzhambov AM, Dimitrova DD, Dimitrakova ED (2014) Association between residential greenness and birth weight: systematic review and meta-analysis. Urban For Urban Green 13:621–629

Frumkin H (2001) Beyond toxicity. Human health and the natural environment. Am J Prev Med 20(3):234–240

Fuertes E, Markevych I, Bowatte G, Gruzieva O, Gehring U et al (2016) Residential greenness is differentially associated with childhood allergic rhinitis and aeroallergen sensitization in seven birth cohorts. Allergy. doi:10.1111/all.12915: n/a-n/a

Gascon M, Triguero-Mas M, Martínez D, Dadvand P, Forns J et al (2015) Mental health benefits of long-term exposure to residential green and blue spaces: a systematic review. Int J Environ Res Public Health 12:4354–4379

Gascon M, Triguero-Mas M, Martínez D, Dadvand P, Rojas-Rueda D et al (2016) Residential green spaces and mortality: a systematic review. Environ Int 86:60–67

Gidlöf-Gunnarsson A, Öhrström E (2007) Noise and well-being in urban residential environments: the potential role of perceived availability to nearby green areas. Landsc Urban Plan 83(2):115–126

Grazuleviciene R, Danileviciute A, Dedele A, Vencloviene J, Andrusaityte S et al (2015) Surrounding greenness, proximity to city parks and pregnancy outcomes in Kaunas cohort study. Int J Hyg Environ Health 218:358–365

Groenewegen PP, van den Berg AE, Maas J, Verheij RA, de Vries S (2012) Is a green residential environment better for health? If so, why? Ann Assoc Am Geogr 102(5):996–1003

Guéguen N, Stefan J (2014) "Green altruism" short immersion in natural green environments and helping behavior. Environ Behav 48(2):324–342

Hanski I, von Hertzen L, Fyhrquist N, Koskinen K, Torppa K et al (2012) Environmental biodiversity, human microbiota, and allergy are interrelated. Proc Natl Acad Sci U S A 109:8334–8339

Harris N, Minniss FR, Somerset S (2014) Refugees connecting with a new country through community food gardening. Int J Environ Res Public Health 2014(11):9202–9216

Hartig T (2004) Restorative environments. In: Spielberger C (ed) Encyclopaedia of applied psychology, vol 3. Elsevier/Academic, San Diego, pp 273–278

Hartig T, Cooper-Marcus C (2006) Healing gardens-places for nature in health care. Lancet 368:S36–S37

Hartig T, Mang M, Evans GW (1991) Restorative effects of natural environment experiences. Environ Behav 23(1):3–26

Hartig T, van den Berg AE, Hagerhall CM, Tomalak M, Bauer N, Hansmann R, Ojala A, Syngollitou E, Carrus G, van Herzele A, Bell S, Camilleri Podesta MT, Waaseth G (2011) Health benefits of nature experience: psychological, social and cultural processes. In: Nilsson K et al (eds) Forests, trees and human health. Berlin, Springer Science, pp 127–168

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Hordyk SR, Hanley J, Richard E (2015) "Nature is there; its free": urban green space and the social determinants of health of immigrant families. Health Place 34:74–82

Kaplan S (1995) The restorative benefits of nature: toward an integrative framework. J Environ Psychol 15:169–182

Kaplan R, Kaplan S (1989) The experience of nature: a psychological perspective. Cambridge University Press, New York

Kellert SR, Wilson EO (1993) The biophilia hypothesis. Island Press, Washington, DC

Korpela KM, Ylén M (2007) Perceived health is associated with visiting natural favourite places in the vicinity. Health Place 13:148–151

Korpela KM, Ylen M, Tyrvainen L, Silvennoinen H (2008) Determinants of restorative experiences in everyday favorite places. Health Place 14:636–652

Lachowycz K, Jones AP (2011) Greenspace and obesity: a systematic review of the evidence. Obes Rev 12:e183–e189

Lafortezza R, Carrus G, Sanesi G, Davies C (2009) Benefits and well-being perceived by people visiting green spaces in periods of heat stress. Urban For Urban Green 2:97–108

Larson LR, Jennings V, Cloutier SA (2016) Public parks and wellbeing in urban areas of the United States. PLoS One 11(4):e0153211

Laurent O, Wu J, Li L, Milesi C (2013) Green spaces and pregnancy outcomes in Southern California. Health Place 24:190–195

Lovasi GS, Quinn JW, Neckerman KM, Perzanowski MS, Rundle A (2008) Children living in areas with more street trees have lower prevalence of asthma. J Epidemiol Community Health 62:647–649

Lovasi GS, O'Neil-Dunne JPM, Lu JWT, Sheehan D, Perzanowski MS et al (2013) Urban tree canopy and asthma, wheeze, rhinitis, and allergic sensitization to tree pollen in a New York City Birth Cohort. Environ Health Perspect 121(4):494–500

Maas J, Verheij RA, de Vries S, Spreeuwenberg P, Schellevis FG et al (2009a) Morbidity is related to a green living environment. J Epidemiol Community Health 63:967–973

Maas J, Van Dillen SME, Verheij RA, Groenewegen PP (2009b) Social contacts as a possible mechanism behind the relation between green space and health. Health Place 15(2):586–595

Maller C, Townsend M, Pryor A, Brown P, St Leger L (2006) Healthy nature healthy people: 'contact with nature'as an upstream health promotion intervention for populations. Health Promot Int 21(1):45–54

Marselle MR, Irvine KN, Warber SL (2013) Walking for well-being: are group walks in certain types of natural environments better for well-being than group walks in urban environments? Int J Environ Res Public Health 10:5603–5628

Mensah CA, Andres L, Perera U, Roji A (2016) Enhancing quality of life through the lens of green spaces: a systematic review approach. Int J Wellbeing 6(1):142–163

Milligan C, Bingley A (2007) Restorative places or scary places? The impact of woodland on the mental well-being of young adults. Health Place 13:799–811

Mitchell R, Popham F (2008) Effect of exposure to natural environment on health inequalities: an observational population study. Lancet 372:1655–1660

Neal S, Bennett K, Jones H, Cochrane A, Mohan G (2015) Multiculture and public parks: researching super-diversity and attachment in public green space. Popul Space Place 21:463–475

Nieuwenhuijsen MJ, Kruize H, Gidlow C, Andrusaityte S, Antó JM, Basagaña X et al (2014) Positive health effects of the natural outdoor environment in typical populations in different regions in Europe (PHENOTYPE): a study programme protocol. BMJ Open 4:e004951. doi:10.1136/bmjopen-2014-004951

Pearson DG, Craig T (2014) The great outdoors? Exploring the mental health benefits of natural environments. Front Psychol 5:1178

Phelan PE, Kaloush K, Miner M, Golden J, Phelan B, Silva H et al (2015) Urban heat Island: mechanisms, implications, and possible remedies. Annu Rev Environ Resour 40(1):285–307

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Pilat MA, McFarland A, Snelgrove A, Collins K, Waliczek TM et al (2012) The effect of tree cover and vegetation on incidence of childhood asthma in metropolitan statistical areas of Texas. HortTechnology 22:631–637

Purcell T, Peron E, Berto R (2001) Why do preferences differ between scene types? Environ Behav 33:93–106

Rook GAW (2013) Regulation of the immune system by biodiversity from the natural environment: an ecosystem service essential to health. Proc Natl Acad Sci U S A 110(46):18360–18367

Rook GAW, Lowry CA, Raison CL (2013) Microbial 'old friends', immunoregulation and stress resilience. Evol Med Public Health 1:46–64

Schipperijn J, Bentsen P, Jens Troelsen J, Toftager M, Stigsdotter UK (2013) Associations between physical activity and characteristics of urban green space. Urban For Urban Green 12:109–116

Taylor AF, Kuo FE, Sullivan WC (2002) Views of nature and self-discipline: evidence from inner city children. J Environ Psychol 22:49–63

Twiss J, Dickinson J, Duma S, Kleinman T, Paulsen H, Rilveria L (2003) Community gardens: lessons learned from California healthy cities and communities. Am J Public Health 93(9):1435–1438

Ulrich R (1984) View through a window may influence recovery. Science 224(4647):224–225

Ulrich RS, Simons RF, Losito BD, Fiorito E, Miles MA, Zelson M (1991) Stress recovery during exposure to natural and urban environments. J Environ Psychol 11(3):201–230

Van den Berg A, Hartig T, Staats H (2007) Preference for nature in urbanized societies: stress, restoration, and the pursuit of sustainability. J Soc Issues 63:79–96

WHO (2010) Global recommendations on physical activity for health. P. 58. Switzerland. ISBN 978 92 4 159 997 9

Winterfeld A (2014) State actions to reduce and prevent childhood obesity in schools and communities. National Conference of State Legislatures, p 50

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Part III
Economic Benefits and Governance of Urban Forests in a Green Infrastructure Approach

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Chapter 18
Introduction: Governance and Economic Valuation

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This section examines the policy motivations which come into play when local actors promote urban green infrastructure (UGI) within the context of broader environmental objectives. A fundamental component of UGI is the creation or enhancement of biophysical green resources within cities, such as urban parks, urban forests, and species-rich open spaces. Green infrastructure, however, is a *contested* term – and the approaches taken to promote it are greatly influenced by political strategy and policy context. If certain aspects of environmental policy making are prioritized over others, there is the risk that the role of biophysical green resources in UGI delivery may become ambiguous or under-prioritized.

The first chapter in this section investigates the impact of the European Green Capital Award (EGCA) on the governance of UGI in European cities which have been recognized as being the most environmentally sustainable and green. The EGCA falls under a broader category of "soft policy tools" used by the EU to encourage self-steering or network governance of environmental management and regulation at the local level, as opposed to top-down decision making. The authors' findings, showing a distinct shift toward the prioritization of "green growth" and short-term economic targets in the EGCA, bring into question the prioritization of biophysical urban green resources in EU UGI governance.

The second chapter explores the role and significance of partnerships in urban forestry and green infrastructure governance, with a specific focus on the emerging role of the Third Sector (such as NGOs and voluntary organizations) in the delivery

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of urban forestry (UF) within the context of regional green infrastructure (GI). In particular, the strengths and weaknesses of Third Sector approaches is evaluated against traditional public and private sector models. Optimal scenarios are proposed for the role of the Third Sector with respect to other GI delivery agents. Success factors for partnerships discussed in previous research are reviewed and considerations for the evaluation of partnerships are outlined.

The third and final chapter for this section explores the critical role of the economic valuation of the benefits of urban trees and related green infrastructure (GI) to assist with best management practices in urban greening, planning and management. This discussion is combined with an analysis of strategies and outcomes of completed studies using various valuation methods. These examples offer the reader an accessible insight into the "Value of Valuing," and show how actual outcomes can encourage a greater emphasis on – and accommodation of – the important and critical aspect of urban life that is represented by the Urban Forest.

Examining these different aspects of urban green governance should significantly inform the EU's assessment of the role of urban forests and other biophysical GI in European cities. Current calls for "Nature-Based Solutions" to achieving climate resilience necessitate enhanced strategic integration of biophysical UGI into all spatial planning processes at the local, national and trans-national level. Local actors play a significant role in current EU environmental governance schemes, and this role will continue to grow as urban climate mitigation necessitates local solutions to global challenges. In this sense, there is a dire need to integrate biophysical UGI solutions into all EU environmental programming and financing work to build in capacity for cross-border, inter-regional and trans-national cooperation to nature-based climate resilience.

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Chapter 19
Challenges to Governing Urban Green Infrastructure in Europe – The Case of the European Green Capital Award

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19.1 Introduction

19.1.1 Green Infrastructure as a Response to the Challenges of Urbanization in Europe

As highlighted in previous chapters, urban areas are home to the majority of people in Europe. According to the European Environment Agency, about three quarters of the population now lives in cities and towns – and by the year 2020, this proportion is expected to reach 80% (EEA 2006). One of the consequences of rapid urbanization is a diminishing area of green spaces such as parks, forests and gardens, as well as blue spaces like lakes, rivers and wetlands (Nuissl et al. 2009; Kabisch et al. 2015). This decrease in green infrastructure (GI) can severely impact local ecosystems, reducing their capacity to provide essential services ranging from the management

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of storm water to the moderation of thermal stress (Larondelle et al. 2014; Alavipanah et al. 2015; Kabisch 2015). Urban populations may in turn face a deteriorated quality of life, as they increasingly depend on urban GI for social and environmental benefits (James et al. 2009; Roy et al. 2012; Konijnendijk et al. 2013). Climate change and extreme weather events accentuate these challenges, and threaten the economic vitality of European urban areas (European Commision 2013a, b, c).

Even as urbanization poses these ecological, social and economic challenges, cities are also acknowledged as a critical element in pursuing environmental sustainability and resilience (EEA 2006; European Green Capital Award 2010a). Thus the European Union has enhanced its focus on sustainable urban development, and a prominent part of its approach to improving the livability of cities is to promote comprehensive networks of urban green infrastructure (European Commision 2013a).

Urban GI is seen by policy makers as one of the most efficient and cost effective measures to combat new and emerging urban environmental challenges – such as climate change (European Commision 2013b), storm water management, and biodiversity conservation (European Commision 2014a). The establishment of a comprehensive network of urban GI supports European environmental policy, according to which a majority of cities in the EU will have a resource efficient, green and competitive low-carbon economy by 2020 (European Commision 2014b). EU policy in fact points to sustainable green cities as the cornerstone of current and future European economic growth (European Commision 2010).

The implementation and enhancement of green infrastructure is strongly supported in key policy areas, such as regional development, disaster risk management, agriculture/forestry and the environment – with a recent emphasis on mitigating and adaptating to global climate change. The EC's 7th Environmental Action Programme, which is intended to guide European environmental policy until 2020, identifies three key objectives (European Commision 2014b):

- to protect, conserve and enhance the Union's natural capital
- to turn the Union into a resource-efficient, green, and competitive low-carbon economy
- to safeguard the Union's citizens from environment-related pressures and risks to health and well-being

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and two horizontal priority objectives:

- to make the Union's cities more sustainable
- to help the Union address international environmental and climate challenges more effectively[1].

EU policies related to GI focus on two main concerns: one is climate change, and the other is biodiversity. In its strategy on adapting to climate change, the EU encourages member states to develop comprehensive adaptation strategies on a voluntary basis, with the goal of "*mainstreaming adaptation into urban land use planning, building layouts and natural resource management*" (European Commision 2013b:6). Important steps forward are the establishment of *Climate-ADAPT*[2] (the European Climate Adaptation Platform), and *Mayors-ADAPT*[3] (the Covenant of Mayors Initiative on Climate Change Adaptation). Biodiversity protection (European Commision 2011) is promoted through the establishment of the EU-level network of green areas known as NATURA 2000, which is a central component in the effort to arrest biodiversity loss by 2020. Furthermore, forests are seen as an especially important element of GI – since, according to the new EU Forest Strategy (European Commision 2013c), they host *"an enormous variety of biodiversity"* and provide many other ecosystem services. The overarching strategy labeled *EC, 2010* does not refer to GI directly, but it encourages sustainable growth that is achievable through "*promoting a more resource efficient, greener and more competitive economy*" (European Commision 2010).

Urban GI is thus a clear delivery mechanism for the social and environmental benefits that are sought after by the EU in smart and sustainable urban growth – and a fundamental component of urban green infrastructure is the delivery, management and enhancement of biophysical green resources such as urban parks, urban woodlands, and species-rich open spaces (Werquin et al. 2005; Benedict and McMahon 2006; Tratalos et al. 2007; Young 2010; Mell 2013). These are specifically considered to be some of the most effective strategies for counteracting problems associated with increased urbanization and climate change (Kabisch 2015).

However, the way that urban GI is planned and delivered can vary widely – and it is decisively influenced by political strategy and policy context (Mell 2013; Roe and Mell 2013). For example, population growth in cities often shifts the focus from open-space amenities to urban densification (Fuller and Gaston 2009; Kabisch 2015) – and efforts to properly develop and maintain such amenities are further strained by shrinking municipal budgets (Chiesura 2004; Gulsrud et al. 2013). Paradoxically, the long-term ecosystemic benefits of urban greening are becoming more and more apparent with intensifying climate change due in part to land-use and land cover changes (Niemelä et al. 2010) – but these very changes make investment in green space more challenging in the short term. Ultimately, there is political

[1] http://ec.europa.eu/environment/action-programme/

[2] http://climate-adapt.eea.europa.eu/

[3] http://mayors-adapt.eu/

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ambiguity about what role biophysical green resources play in urban GI planning (Gulsrud et al. 2013). In this sense, policy tools used to craft and implement urban greening policy take on a special role of importance.

19.1.2 EGCA and Its Role in EU Environmental Governance

One EU policy tool being used to govern urban GI delivery and management is the European Green Capital Award (EGCA). The EGCA is a relatively new program driven by the European Commission, initiated in 2006 when the leaders of 15 European municipalities and the Association of Estonian cities signed the *Tallinn Memorandum*.[4] By establishing competitive criteria and awarding the title of "European Green Capital" to a different city each year, their goal was to encourage cities to craft greener and more environmentally sustainable urban development plans that could serve as role models in the future – and these criteria specifically included the integration of urban green infrastructure. The winning cities to date include Stockholm (2010), Hamburg (2011), Vitoria-Gasteiz (2012), Nantes (2013), Copenhagen (2014), Bristol (2015), Ljubljana (2016) and Essen (2017).

The award is given to cities that are judged to be consistent in achieving high environmental standards, and committed to ambitious goals in terms of the improvement of living environments. Applicant cities are assessed according to 12 environmental indicators: *climate change and adaptation, local transport, green urban areas incorporating sustainable land use, nature and biodiversity, ambient air quality, quality of the acoustic environment, waste production and management, water management, waste water treatment, eco-innovation and sustainable employment, energy performance, and integrated environmental management*. For each indicator, applicants must describe the present situation, the measures implemented in the past five to ten years, short- and long-term objectives for the future and proposed approaches to achieve these, and a set of documents and verifiable evidence supporting these claims.

The evaluation process is two-tier: first, a panel of internationally recognized experts assesses the information provided by the cities and determines a list of finalists. Short-listed cities are then invited to present their action plans and communication strategies in front of a jury which includes representatives from the EC, DG Environment, the European Parliament, the ENVI Committee, the Committee of the Region, the European Environmental Agency, ICLEI, the European Environmental Bureau, and the Covenant of Mayors Office. Based on these presentations, the jury decides on the winner.

The EGCA falls under a broader category of "soft" policy tools used by the EU to encourage self-steering or "network governance" of environmental management and regulation at the local level. Such tools are are typically voluntary, which means that member states have no obligation to implement them, and stand in contrast to a

[4] http://ec.europa.eu/environment/europeangreencapital/about-the-award/

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more traditional governance model of top-down decision making (Zuidema and De Roo 2009; Torfing et al. 2012). Environmental network governance refers to citizen involvement in collective action toward goals such as awareness raising, capacity building, systems of peer review, the exchange of best practices, and the encouragement of green development strategies – as is the case with the EGCA (Jordan and Tosun 2012).

The EGCA is designed to bring recognition each year to a particular European city that has demonstrated efforts to improve the urban environment, and winning cities are branded as having an exemplary ability to monitor and reduce environmental impact through very specific local policy regulations and strategies (Wurzel et al. 2013). This "green city branding" is intended to spur urban competition around investment in environmental sustainability, including GI, while raising awareness about environmentally resilient cities (European Green Capital Award 2015a). By branding and celebrating selected European cities for their environmental performance, the EU aims to steer the evaluation, delivery and development of urban GI policy and the urban sustainable development agenda as a whole.

A question arises, though, regarding the extent to which the EFCA is effectively achieving these goals: in other words, is there a discrepancy between theory and practice?

Only limited attention has been paid to the EGCA's role as a soft tool of pan-European urban sustainability and urban GI governance. Understanding how this award impacts urban environmental policy and the delivery of GI is important, because the choice and application of different policy instruments, tools, and techniques arguably constitute the very essence of governing (Hood 2007; Jordan et al. 2013). The EGCA has the potential to form powerful policy networks, determining the nuts and bolts of local policy strategies, budget allocations, and overall policy-making priorities underlying the delivery of urban GI (Sabatier 1988; Jenkins-Smith and Sabatier 1994). Green city brands like the EGCA essentially *prioritize certain environmental qualities over others*, making some environmental policies highly visible while rendering others invisible (Kornberger and Carter 2010). The exclusion of certain aspects of environmental policy making and urban GI delivery can influence decision-making power, and thereby resource allocation. In this sense, green city branding through the EGCA is an agenda-setting tool establishing political and cultural norms (Kingdon 1994; Govers and Go 2003). Ultimately, policy instruments like the EGCA matter because they are a main link between steering at the EU level and policy impacts and outcomes at the local level (Jordan et al. 2013: 310).

Our objective here is to analyze and discuss the ways in which the EGCA impacts urban GI delivery and governance through green agenda setting and green discourse formation. Specifically, we consider what the role of GI delivery is within EGCA, which aspects are prioritized, and how discourses of winning cities establish best practices in GI delivery management. If certain aspects of environmental policy making are prioritized over others in the EGCA, there is the risk (as highlighted by Mills, 2013) that the role of biophysical green resources becomes ambiguous or under-prioritized. Closer evaluation of the EGCA can contribute to a broader understanding of what "green" really means in green city branding, and how network

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governance tools such as the EGCA contribute to EU environmental governance. Such scrutiny can facilitate multilevel policy learning around GI governance, by developing a common understanding of the meaningful contributions that support better cities at the European level.

19.2 Conceptualizing Urban GI Governance and Policy Tools

Governance theory examines the dispersal of policy making powers amongst a wide-range of actors and networks, specifically looking at the increasing importance of horizontal decision making or self-steering with and without the help of hierarchical government agencies (Wurzel et al. 2013: 4).

Environmental governance in particular can be understood as the collective multi-level steering of decision-making involved in the control and management of the environment and natural resources across the trans-national, member state and local levels (Hooghe and Marks 2001; Jordan and Lenschow 2010; Wurzel et al. 2010).

The EU and its member states comprise a system of multilevel governance and as such depend on a variety of governance networks and policy tools to implement its directives (Hooghe and Marks 2003). Every member state is impacted by EU membership, but there is no uniform environmental governance – and as such there is no single uniform model of policy at the national, regional or city level (Jordan and Tosun 2012). This is in part due to the subsidiarity principle, whereby the EU is limited in establishing environmental policies controlling environmental issues at the member state or local level (Knill and Liefferink 2007). It is also due to the increasing complexity of urban environmental issues such as climate change adaptation, that often demand locally-sourced and horizontally-governed solutions (Zuidema and De Roo 2009; Kern 2014; Wurzel et al. 2013).

As part of environmental governance, the planning and implementation of urban green infrastructure (UGI) is promoted through EU policies that seek to mainstream it as a tool which underlines the values and benefits of nature (European Commision 2013a, b, c). While national authorities at the member state level play a large role in developing strategies and political visions for green infrastructure development, regional and local governments are often responsible for the spatial planning and delivery of UGI (European Environmental Agency 2011).

In the context of EU environmental governance in general, and UGI in partucular, the boundaries between different levels of government have become blurred. In this blurring, the "competencies" between local, national and European authorities have shifted not only "upwards" to the EU but also "downwards" from nation states to regions and cities (Kern 2014). Regarding governance of UGI, EU policy directives are often aimed not only at member state federal governments, but also at regional and local authorities where UGI policy is implemented and managed.

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In this multi-level policy arena, cities frequently are governing their UGI horizontally, without the directives of the national government – networking and sharing policy knowledge regarding the establishment and management of their UGI. This dynamic multilevel policy arena provides an opening for innovative policy goals and steering instruments to deliver and govern UGI.

This subsequent shift from top-down environmental regulation to environmental governance in the EU has been accompanied by new policy tools to deliver UGI, what Wurzel et al. (2013) refer to as "suasive" instruments: soft policy tools aimed at encouraging regulatory bodies such as city governments to comply with environmental standards through informational measures and voluntary agreements. The EGCA is such a policy tool.

19.2.1 Operationalizing UGI Governance and Policy Tools

Shifts in EU environmental governance, such as the use of suasive policy tools like the EGCA to deliver and govern the widespread establishment of UGI in European cities, occur within what Arnouts et al. (2012) and others term "governance arrangements." Governance arrangements depict the temporary stabilization of the content and organization of a particular policy domain such as urban environmental sustainability in the EU. We use the term governance arrangements to reflect the multilevel governance dimension of EU urban environmental policy and situate the EGCA within the urban environmental sustainability policy domain. This domain is steered horizontally by cities themselves, under stipulations provided by the EU. As policy tools such as the EGCA are introduced by the EU to city officials, shifts within the urban environmental sustainability policy domain occur. Figure 19.1 illustrates the four dimensions of a governance arrangement, depicting how they are interwoven and how a shift in one dimension imposes a shift on all other dimensions (Arts et al. 2006). It is this change or potential for change that calls for analysis.

Our particular focus here is the shift in policy programming and discourses brought about by the use of the EGCA to deliver UGI. Policy programming refers to the specific indicators and policy measures used to define winning cities in the EGCA, including dominant aspects of UGI (Arts et al. 2006). Discourses in this context refer to the ideas and narratives of the actors involved in the EGCA cities, and how their values and defnitions of problems and solutions are defined (Hajer 1995; Arts et al. 2006;). In Fig. 19.1, policy programming and discourses represent one of the four governance-related dimensions.

Attempts to measure and operationalize the effectiveness of governance often focus on indicators measuring performance and overall public sector activities (Knack et al. 2003). But Torfing et al. (2012) argue that these indicators ignore the essence of governance, which lies in *goal-setting* and *process* attributes. Collective goal setting is important for the studying of governance, because collective goals constitute the standards by which the outcomes of policy-making are judged. The collective goal setting established through the EGCA is important to examine

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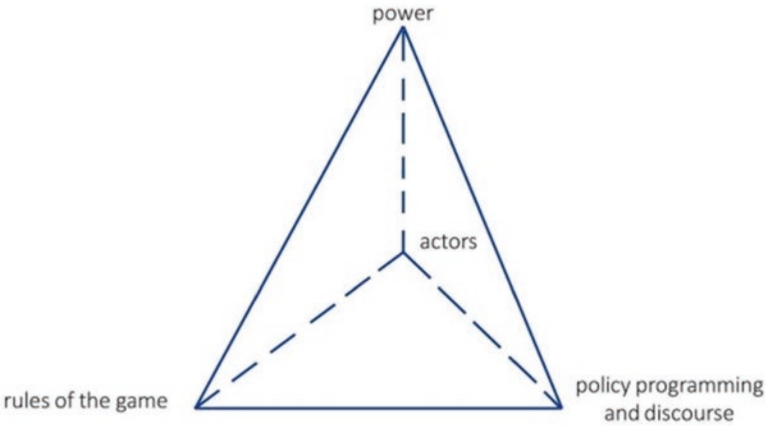

Fig. 19.1 A governance arrangement visualized as a four-dimensional space (Liefferink 2006)

because the environmental standards and dominant aspects of UGI outlined by the award dictate the measures that local authorities perform to. By establishing an environmental agenda to measure and regulate UGI delivery through broader urban sustainability indicators, the EGCA could determine the nuts and bolts of urban environmental policies, including which outcomes or aspects of UGI are favored over others.

Shifts in discourse matter as well, because storylines unify policy networks and shape interactions between participants (Sabatier 1988; Hajer 1993, 1995; Torfing and Sørensen 2014). Policy networks, or advocacy coalitions, subscribe to specific sets of "normative and causal" beliefs about how environmental regulation works – including the efficacy of policy instruments (Jenkins-Smith and Sabatier 1994). A policy tool such as the EGCA has the potential to reconfigure the EU urban environmental sustainability policy domain as it allocates resources to "winning" municipalities that perform well in environmental management, as judged by the EU. The network of winning cities establishes precedence in urban sustainability performance, setting a discourse about how a successful European city should implement and manage UGI, including which actors should be involved in the implementation and which aspects of UGI should be prioritized over others. Torfing et al. (2012) argue that governance networks are stabilized by policy discourses that provide standards by which the problem context is understood and defined. Over time, a "hegemonic discourse" is formed and the concepts supported in the dominant discourse become institutionalized. As a network governance steering tool, the EGCA could impact the governance of European UGI and broader urban sustainability schemes through the development of institutionalized discourses or policy narratives packaged as "best practices."

A final perspective that governance theory helps us operationalize is the concept of green city "branding." Articulated through a governance lens, green city branding is an agenda-setting tool establishing political and cultural narratives. The discourses that are formulated through the EGCA best practices, and the policy

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programs that are established through the EGCA indicators, establish a broader understanding of how "green" is understood in the EGCA and what types of green resources are actually delivered through the award.

19.3 Case Study Analysis Methods

In order to get a sense of how urban green infrastructure is prioritized within a larger "green" agenda, we examine the case of the EGCA and how its priorities have evolved over time. We focus on the way that UGI features have been emphasized, both in the declared criteria for success and in the green narratives of the winning cities, during the first seven EGCA cycles from 2010 to 2016. The first step of analysis focuses on the award's indicators and the relative weight given to UGI, and the second step focuses on the formulation of "best practice" discourse in each award cycle.

Multiple sources of data have been used to analyze this case. The policy tool's evolution was monitored using documentary evidence published by the EGCA for each award cycle, including the application material submitted by each winning city, the technical assessment synopses and jury reports, and the EGCA good practice and benchmarking reports. All of these documents are publicly available on the EGCA website (http://ec.europa.eu/environment/europeangreencapital), and they provide a transparent description of the EU-established criteria by which all cities applying for the award have been judged. Additionally, media content such as political speeches by EU and municipal officials have been analyzed to gain critical insight into how these actors shape the environmental discourse and present their cities as green capitals (YouTube, European Green Capital Award 2015c). EGCA documents, speeches and media have been triangulated with peer-reviewed articles written about the EU, the EGCA, and other green city awards and brands in the fields of urban planning, urban green space governance, environmental governance, and neoliberal governance. All data collected have been analyzed qualitatively to examine how UGI is represented in the EGCA indicators and winning city green discourses and best practices.

This case study does not pursue causal links between the EGCA and its long-term impacts on UGI planning and implementation in the winning cities. Rather, it seeks to illustrate the principle of "literal replication" (Yin 1994) by analyzing inter-annual patterns and shifts in UGI governance arrangements crafted by the EGCA. Since "green infrastructure" itself is a contested term (Lennon 2014) with a broad range of associated definitions and typologies (Benedict and McMahon 2006; Young et al. 2014; Mell 2013; Davies et al. 2006), we examine these trends over time using a classification of different types of UGI that adhere to a number of different definitions. Following Roe and Mell (2013), and as illustrated in Fig. 19.2, UGI typology may be characterized as being composed of "ecologically and visibly green resources" (Type 1) and as "humanly engineered infrastructure composed of sustainable elements" (Type 2). According to this model, an integrated typology (Type 3) could focus on the delivery of visibly greener environments that provide

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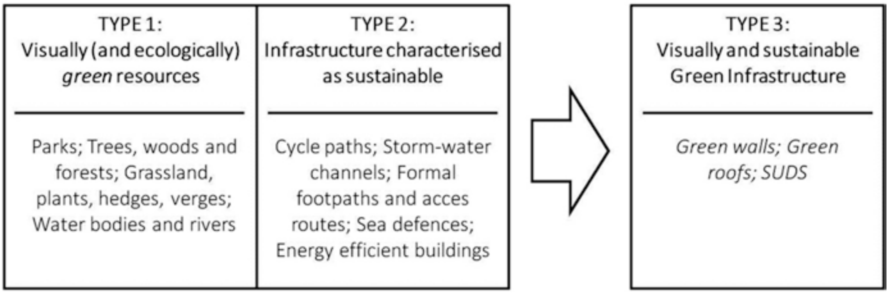

Fig. 19.2 Green infrastructure characteristic typology from Mell (2013)

ecological and social benefit above and beyond functional change, addressing the desire for more sustainable and multi-functional landscapes (Mell 2013). Given this broad spread of typologies associated with green infrastructure and what Mell (2013) calls the “strategic subjectivity” surrounding the implementation and delivery of UGI, it is important to gauge which characteristics of UGI are prioritized by the award.

These typologies are helpful in terms of measuring to what extent UGI is represented in the EGCA indicators, and what types of UGI characteristics are in focus. We measure UGI representation in the EGCA through these typologies by examining the award indicators in each award cycle with an emphasis on (1) the UGI aspects emphasized in the award indicators, (2) the shifting nature of the award indicators over time, and (3) the relative weight assessed to UGI-related features, compared to other features.

Discourses in this context refer to the ideas and narratives of the actors involved in the EGCA and how their values and definitions of problems and solutions are defined (Hajer 1995; Arts et al. 2006). Green discourses in the EGCA documents, political speeches and media sources are analyzed based on their storylines, assumptions, symbols and metaphors (Krajter Ostoić and Konijnendijk van den Bosch 2015). In this sense our analysis identifies how environmental problems are presented and structured in the EGCA and which solutions or best practices are offered to manage and solve these problems (Hajer and Versteeg 2005). This analysis situates UGI delivery through the EGCA in a historical, cultural and political context (Krajter Ostoić and Konijnendijk van den Bosch 2015).

19.4 Findings: Green Infrastructure in the EGCA

19.4.1 Policy Programming

A review of the indicators in the seven EGCA cycles from 2010 to 2016 reveals a strong, all-be-it shifting, focus on UGI characteristics. As shown in Table 19.1, some of the indicators (such as “environmental management” or “eco-innovation”)

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Table 19.1 An overview of EGCA indicators with focus on UGI

Year	2010/2011	2012/2013	2014	2015	2016
City	Stockholm/Hamburg	Vitoria-Gasteiz/Nantes	Copenhagen	Bristol	Ljubljana
Indicator 1	Local contribution to global climate change[b]	Local contribution to global climate change[b]	Local contribution to global climate change[b]	Local contribution to global climate change[b]	Climate change: mitigation and adaptation[b]
Indicator 2	Local mobility and transport[b]	Local transport[b]	Local transport[b]	Local transport[b]	Local transport[b]
Indicator 3	Availability of green areas open to the public[a]	Green urban areas[a]	Green urban areas with sustainable use[c]	Green urban areas with sustainable use[c]	Green urban areas incorporating sustainable land use[c]
Indicator 4	Quality of local ambient air[b]	Quality of local ambient air[b]	Quality of local ambient air[b]	Quality of local ambient air[b]	Ambient air quality[b]
Indicator 5	Noise pollution[d]	Noise pollution[d]	Noise pollution[d]	Quality of acoustic environment[d]	Quality of acoustic environment[d]
Indicator 6	Waste production and management[d]	Waste production and management[d]	Waste production and management[d]	Waste production and management[d]	Waste production and management[d]
Indicator 7	Water consumption[d]	Water consumption[d]	Water consumption[d]	Water consumption[d]	Water consumption[d]
Indicator 8	Waste water management[b]	Waste water management[b]	Waste water management[b]	Waste water management[b]	Waste water management[b]
Indicator 9	Sustainable management of local authority[d]	Environmental management of municipality[d]	Environmental management of municipality[d]	Environmental management of municipality[d]	Sustainable management of the local authority[d]
Indicator 10	Sustainable land use[a]	Sustainable land use[a]	Eco-innovation and employment[d]	Eco-innovation and employment[d]	Eco-innovation and employment[d]
Indicator 11	Dissemination programme[d]	Nature and biodiversity[a]	Nature and biodiversity[a]	Nature and biodiversity[a]	Nature and biodiversity[a]
Indicator 12	N/A	Dissemination programme[d]	Energy performance[b]	Energy performance[b]	Energy performance[b]

UGI Typology:
[a]Type 1
[b]Type 2
[c]New Type
[d]Non-UGI

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relate indirectly to UGI, and more than half focus *directly* on aspects of UGI according to Mell's (2013) classification. These *direct* UGI indicators are mentioned in Table 19.1 as either Type I, Type II or "NewType".

In Table 19.1 it can be seen that the number of indicators directly focused on UGI increased slightly over the period, from 6 indicators in 2010 to 7 indicators in 2016. At the same time, however, the total number of indicators increased from 10 to 12 – such that the proportion of indicators defined as being UGI-focused did not rise between the initial cycle and the latest one.

A closer review of the UGI typologies represented in the indicators of each EGCA award cycle reveals a mixed-focus on Type 1 UGI characteristics, i.e. those pertaining specifically to biophysically green resources, and Type 2 characteristics, which pertain to a broader agenda of sustainability (Mell 2013). One indicator in the EGCA focuses on New Types of UGI characteristics, or visually and sustainably green infrastructure. Table 19.1 shows a shift from the earliest award cycles (2010–2013), which had a mixed focus on both Type 1 and Type 2 UGI characteristics, to the most recent award cycles (2014–2016) in which a more predominant focus on Type 2 UGI characteristics can be seen.

In the initial award cycle, 2 out of 10 (or 20%) of the indicators focused on Type 1 UGI characteristics, and 40% focused on Type 2 characteristics. By 2016 only 1 out of 12 (or 8%) of award indicators focused on Type 1 characteristics, whereas 5 out of 12 (or 42%) focused on Type 2 UGI characteristics. Thus a subtle but significant shift in emphasis can be seen, by which the specifically biophysical green attributes of UGI – whose benefits arguably transcend their valuation in terms of an immediate return on investment – have been gradually de-emphasized in the award indicators. Instead there is an increased focus on the more short-term "deliverables" of UGI, such as economic stimulation and green job creation.

Another way to understand this shift away from Type 1 UGI characteristics is by focusing on changes in several key UGI indicator titles and content shifts over time. The role of urban green spaces and natural areas (Type 1 UGI characteristics) within the EGCA is arguably called into question by its declining weight in the award indicators, while the role of "sustainably" engineered infrastructure is given an increasingly pronounced role. In considering this trend, a number of specific points seen in Table 19.1 can be instructive:

- In progressing from the 2010/2011 to the 2012/2013 award cycles, **Indicator 3** (originally titled "Availability of green areas open to the public") was renamed "Green urban areas." This shift is not accompanied by changes in indicator criteria. Also **Indicator 11**, "Nature and Biodiversity," was added to the award indicators, providing an increased focus on ecological green resources including Natura2000 sites and is closely aligned with the EU 2020 Biodiversity strategy (2010a).
- From the 2012/2013 to the 2014 award cycles, **Indicator 3** underwent another change – shifting titles to "Green urban areas incorporating sustainable use." This shift in title accompanied a merger with the former Indicator 10, "Sustainable land use," and combined two former Type 1 UGI indicators into a "New Type" of

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UGI indicator. The indicator criteria shifted from a singular focus on accessibility to public green spaces, to include an emphasis on demonstrating how public urban green spaces and rehabilitated brownfields contribute to increased quality of life as well as local ecosystem services (EGCA 2012a, 2014a). **Indicator 12**, entitled "Energy performance," was added to the award criteria, providing an increased focus on sustainably engineered infrastructure or Type 2 UGI characteristics – emphasizing the importance of energy efficient buildings, district heating, and municipal renewable energy strategies. **Indicator 10**, "Eco-innovation and sustainable employment," does not fall under one of the three UGI typologies but it does represent an important outcome of successful UGI planning and delivery, green growth. This indicator emphasizes innovations that address resource efficiency and the creation of green jobs (EGCA 2012a, 2014a).

- From the 2014 to the 2016 award cycle, **Indicator 3** "Green urban areas incorporating sustainable use" has an increased focus on measuring the quality of urban green and blue areas *in addition to* investments in green infrastructure such as SUDS and green roofs (EGCA 2014a, 2015a, 2016a). **Indicator 11** "Nature and Biodiversity" sharpens its focus on guidelines to meeting Target 2 of the EU biodiversity strategy, stipulating that by 2020 ecosystems and their services will be maintained and enhanced by establishing green infrastructure and by restoring at least 15% of degraded ecosystems (EGCA 2014a, 2015a, 2016a).
- There is an increased sophistication and strategic focus in the Type 2 UGI characteristic **indicators (1,2,4,8,12)** as the criteria focus on how the indicators meet a city's overall environmental vision based on governance arrangements, political support, budget allocation and stakeholder involvement (EGCA 2014a, 2015a, 2016a).

In sum, the changes in indicator titles and criteria over time indicate a shift in focus from Type 1 to Type 2 UGI indicators, and emphasize the latter's role in supporting a city's overall environmental vision in the policy programming of the EGCA. It appears, then, that local authorities competing for the EGCA are predominantly performing to Type 2 UGI measures.

19.4.2 Discourse and Best Practice

An analysis of the discourses of the winning EGCA cities from the 2010–2016 award cycles reveals that "green" takes on various and often conflicting meanings.

As summarized in Table 19.2, the messages conveyed by these cities are dominated by an approach which defines urban sustainability through the lens of green growth and eco-innovation. In all, five of the seven winning cities – Stockholm, Hamburg, Vitoria-Gasteiz, Copenhagen, and Bristol – emphasize their commitment to the green economy (Table 19.2). Stockholm's allegiance to green growth takes its departure in the city's well developed IT structure, which "attracts knowledge intensive companies… and cleantech" (EGCA 2010b). Hamburg and Vitoria-Gasteiz

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Table 19.2 Discourses of the winning EGCA cities

Year/City	Dominant storyline	What makes a successful city? (normative views)	How is urban sustainability understood? (causal views)	Which aspects of UGI are prioritized in the solution? (solution definition)
2010 Stockholm	The clean city	Urban nature	Smart technologies and innovative solutions define a sustainable city	Cleaner water
	The connected city	Knowledge-intensive companies		Integrated water system
	The climate smart city			Green areas
2011 Hamburg	Environmental protection creates jobs	Public – private partnerships	Urban centers are the source of ecological, social and economic challenges but they are also a critical part of the solution to environmental sustainability and urban resilience	Tree planting
	Economy and ecology are not adversaries			Biophysical urban greening
				Mobility projects
	Environmental protection generates knowledge			Improved water protection
				Hamburg renewable energy cluster
	Environmental quality creates quality of life			The Climate Action Plan
				Rain infrastructure adaptation
2012 Vitoria-Gasteiz	An alternative and green growth solution to urban development in the crisis	Compact, diverse, and mid-sized city	Cities have the power to change current trends, and can be the catalysts to achieve a more sustainable society	Tree planting
		Political consensus, technical work, public commitment		Multi-level governance
				Flooding prevention program
				Bike lanes and traffic calming measures
2013 Nantes	From an industrial city towards an cometropolis	Long-term development, realized collectively and founded on good-quality public services, social cohesion and valuing natural assets	The challenge is to guarantee both the quality of life and sustainable land use. Local people also have a say in the provision and orientation of essential services, such as water, and in city planning and land use.	Uniting the town with its rivers and countryside
				'Eco-quarter'
				'Urban ecology' principles
				Reduction in energy consumption
				District heating
				Wind and solar electricity-generation facilities

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2014 Copenhagen	Public-private partnerships for green growth. Sharing knowledge, visions and ambitions while learning from other cities.	It is possible to combine growth and an increasing quality of life while reducing carbon emissions and meeting environmental challenges. Requires partnerships across businesses and public institutions, and a great deal of involvement from citizens.	More than two thirds of Europeans live in towns and cities. This places major cities at the heart of the many environmental challenges facing us today, such as polluted air and water and climate change.	Improve access to recreational areas
				Tree planting
				Carbon neutral energy production
				Reduce water consumption
				Green mobility
2015 Bristol	Bristol is a vibrant and multi-cultural city and is leading the way with bottom-up, community-based initiatives.	A city that is good for children is surely good for us all!	Europe's urban societies face many environmental challenges and sustainable, low-carbon living is vital to the future of our cities and our people.	Climate change mitigation efforts
				Mobility projects
				Wildlife network
				Air quality monitoring
				Multifunctional GI network
				Energy conservation
2016 Ljubljana	Raising environmental awareness amongst its citizens	We intensely connect with other stakeholders, encourage active dialogue with our citizens, promote sustainable development, share good practices, learn from the best and implement best solutions.	Old models of governing have been unsuccessful and sustainable development is an attractive and acceptable way to move forward in democracy building and integrated urban governance.	Climate change mitigation efforts
				Mobility projects
				Biodiversity conservation strategy
				Air quality monitoring
				Nature management plan
				Water treatment plant
				Renewable energy

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focus directly on the concept of green growth, linking environmental protection and sustainable development with economic opportunity as illustrated by Hamburg's slogan for the 2011 EGCA award cycle, "Green is growth. Don't miss your chance." Vitoria-Gasteiz calls its approach to urban development "an alternative and green growth solution to urban development in the crisis" (EGCA 2012b). Copenhagen emphasizes the need for public-private partnerships for green growth in their slogan, "Sharing Copenhagen," "Green, smart and carbon-neutral city by 2025." Bristol makes its claim to being the UK's greenest city based on, "innovation, learning and leadership." Each of these cities points to the problem context of cities being responsible for environmental problems as well as having the power to "change current trends, and… be the catalysts to achieve a more sustainable society" (EGCA 2012b). The popular solution to this problem is sustainable economic growth. The green discourses tell a story of environmental protection, economic innovation and urban growth working hand-in-hand. The dominant brand of the EGCA winning cities is an economic discourse.

An alternative discourse about successful urban development in the face of urban pollution and blight is the eco-metropolis or biophilic city narrative told by Nantes, winner of the 2012 EGCA cycle. Nantes is a self-described post-industrial city striving to become an "eco-metropolis" by placing its ecological heritage at the center of its sustainable urban development strategy. Nantes is actively uniting the town with its rivers and countryside – the blue and the green – through controlled development and the active participation of citizens (EGCA 2013a). Nantes is the only EGCA winning city that explicitly builds social justice initiatives into its eco-metropolis strategy to address the ability of those with lower income to maintain their residence in a quickly gentrifying and economically competitive urban environment (EGCA 2013a, b). Nantes' urban development discourse presents a holistic approach to greening the city with a multifunctional focus on ecosystem services in both an ecological and social sense. Other cities like Hamburg, Bristol, and Ljubljana tie the eco-metropolis discourse to quality of life (Table 19.2).

Copenhagen also calls itself an eco-metropolis, but presents a very different version of a sustainable city in its green city discourse. Being an eco-metropolis involves carbon neutrality, energy efficiency and public-private partnerships to stimulate and finance eco-innovation. In contrast to Nantes, Copenagen presents a very limited biophilic urban profile, referring to its blue and green network in a purely urban context while Nantes also integrates its urban and peri-urban UGI (Table 19.2). Additionally, while Nantes' eco-metropolis discourse is about preserving the ecological heritage of the city by expanding urban green spaces, Copenhagen mentions the city's need to improve recreational access to urban green speaces but does not provide policy solutions (Table 19.2).

EGCA winning city narratives support measures of sustainability and specific "green" solutions to environmental problems. An analysis of the best practices of the EGCA winning cities reflects a stong focus on sustainably engineered infrastructure (Type 2 UGI characteristics) to promote carbon neutrality, regenerative energy schemes and climate protection. Hamburg in its 2011 winning EGCA bid set out to establish a renewable energy cluster in the city as a network to achieve

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regenerative energy and climate protection goals (EGCA 2011). Vitoria-Gasteiz, in cooperation with the Basque government, invested 21.5 million Euro in 2012 to prevent flooding in the city (EGCA 2012c). Nantes has constructed an "eco-quarter" to demonstrate its commitment to sustainable urban development. The eco-quarter includes gardens, leisure spaces and workshops, designed to incorporate "state-of-the-art approaches to construction, collective transportation, recycling and renewable energy including rainwater collection, reuse of topsoil and natural water treatment systems (EGCA 2013a). This project represents a microcosm of Nantes' innovative and creative vision of sustainable urban living. Copenhagen has committed to energy production through the exclusive use of carbon-neutral district heating in addition to wind and biomass electricity to meet its aim of being a carbon-neutral city by 2025 (EGCA 2014b). Bristol is actively working to increase the number of cyclists and public transit users by the end of 2015 (EGCA 2015b) and Ljubljana aims to achieve a 25% share of renewable energy consumption by 2020 (EGCA 2016b). It is strikingly apparent that stimulating the economy and creating green jobs are popular solutions to environmental problems in the EGCA winning cities.

Only select cities approach environmental problem-solving through urban greening. Bristol, Ljubljana and Hamburg are among the EGCA winning cities that make prominent efforts to keep a strong ecological perspective in their green narratives and solutions. Bristol currently works with a green infrastructure planning perspective that shapes land-use decisions and developments (EGCA 2015b). The city is currently aiming to integrate 27% of the city into a wildlife network, including areas such as cemeteries and allotments as well as previously developed land. Ljubljana is also using its opportunity as the winner of the 2016 EGCA cycle to develop management plans and a biodiversity strategy for the three-quarters of the city area that is covered by green space (EGCA 2016b). Hamburg perhaps outshines all the other winning EGCA cities with its initiative to cover a stretch of urban motorway with a 25-hectare green lid, with the aim of reducing noise and carbon pollution and increasing the connectivity of the city's already extensive green network (EGCA 2011). Additionally, Hamburg will continue developing its already extensive green space and waterfront network to emphasize the role of urban green spaces in protecting the urban climate and ecology.

Several best practices are continued from year to year by multiple winning cities. A review of the best practices through the multiple cycles of the award demonstrates that those practices which are "passed on" through the network of winning cities are heavily focused on Type 2 characteristics of UGI or sustainably engineered infrastructure (Table 19.1). Mobility projects such as expanding bicycle lanes have been completed by or aim to be completed by six out of the seven winning cities. Regenerative energy and climate protection projects are also undertaken by six of the winning cities, and eco-quarters or climate districts have been constructed or aim to be constructed by four of those cities. Rehabilitation of brownfield sites for new urban developments is replicated in six cities. Ecological practices (Type 1 UGI characteristics) have also been replicated throughout the winning cities network, but to a much lesser extent. Tree planting campaigns have been carried out in three of the seven cities, with varying success. While Vitoria-Gasteiz aims to plant 250,000

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trees through support of a public-private partnership, Copenhagen has planted 3,600 trees, 217 of which were adopted by local citizens – and Hamburg planted 2,600 road trees with citizen support and donations (EGCA 2010c, 2012d, 2014c). The concept of a blue and green open space network is replicated in five out of the seven cities.

19.5 Discussion and Conclusion: Lessons for a Green Urban Future

The EGCA aims to encourage a more intergrated and sustainable approach to urban management, as outlined in the EC's Thematic Strategy on the Urban Environment (EU 2006). An approach to urban planning, design and management that is strongly grounded in UGI can support the aims of the EGCA by encouraging a holistic and multi-functional approach to urban environmental sustainability. Research reveals, however, that while the EGCA as a policy tool draws on elements of green infrastructure in its approach, it has come to prioritize Type 2 UGI characteristics (Mell 2013) over Type 1 elements, thus de-emphasizing the role of actual biophysical green resources within the city.

This is reflected in the discourses of the winning EGCA cities, which trumpet that the highest value of a green city is green economic growth and eco-innovation. This view is encouraged by EGCA in its "best practice" guidelines, which enthusiastically promote sustainable infrastructure that creates green jobs. It could be argued, therefore, that the EGCA is steering the delivery and management of UGI in a limited and largely one-dimensional direction that is only partially supportive of the multi-functional and holistic planning principles advocated by a GI approach to urban planning, design and management. This suggests that the EGCA as a policy tool falls short of the overarching EU policy goal of supporting sustainable development in all EU Directives and Communications, as well as the mainstream GI principles laid out in the 2006 Sustainable Development Directive and the 2013 EU GI Strategy (European Commision 2013a; Pallemaerts 2013).

The EU has a reputation for promoting progressive environmental policies, but some difficulties seem to exist in implementing sustainable development and GI planning principles in a multi-level governance system founded on economic growth and energy security (Jordan and Adelle 2013). EU environmental regulation originated in the 1960s as a 'cleverly designed' trade policy that responded to trade inequity between European regions (Knill and Liefferink 2007; Jordan and Adelle 2013). Since the 1970s, the EU has been setting global standards for environmental policy, the most recent having a strong emphasis on sustainable development (Knill and Liefferink 2007). Since the economic crisis of 2008 however, there has been a noticable decline in interest amongst EU leaders in long-term, overarching policy objectives such as sustainable development (Pallemaerts 2013). This trend is clearly represented in the EC, 2010 Growth Strategy, released in 2010, which reduced the

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environmental dimension of sustainability to energy and resource efficiency. This low-carbon strategy relies on 'an industrial policy for green growth' to assist the EU's industrial base in overcoming the financial crisis, and places little weight on the value of biophysical resources in providing natural capital (European Commision 2014b). This trend supports the apparent shift that has taken place in the EGCA's indicators since its inception, as it leans toward a more narrow and technocratic vision of eco-efficiency. Despite the EU's stated ambitions to mainstream a GI approach to land-use planning in all their environmental policies (European Commision 2013a), the most recent evolution of the EU's policy discourse places the delivery and management of biophysical urban resources in something of an ambiguous and under-prioritised position.

The shifts we have observed in the steering of UGI delivery and management in the EGCA can thus be contextualised within the EU's multi-level environmental governance arrangements (Arnouts et al. 2012). Whereas the self-steering delivery of UGI by cities constitutes a shift in the urban environmental sustainability domain, the dominant trend towards eco-efficiency and green growth indicates an overall shift in EU environmental governance arrangements.

Given the hierarchical nature of the EU, it is perhaps not suprising that network governance policy tools such as the EGCA are somewhat limited in their capacity to achieve self-steering and horizontal governance. It is noteworthy that in spite of the perceived limitations of the EGCA, winners of the award are performing in diverse and multi-functional ways, delivering biophysical UGI through innovative and impressive policies and partnerships. The EGCA continues to promote a diverse green city agenda, albeit focused on green growth, eco-innovation and quality of life as the dominant green city political and cultural norms.

Governance arrangements are always susceptible to change, and are influenced by what Arts et al. (2006) call 'shock events', such as the post-2008 financial crisis. The reverberations of this crisis are easily detected in the EGCA winning city discourses, as nearly all of the cities rally around the green promise of eco-innovation and sustainable growth. These winning cities are establishing a policy network based upon a specific set of normative and causal beliefs about how environmental regulation works. By marginalizing biophysical resources in their delivery of UGI, they are challenging one of the core principles of a GI approach to urban planning, design and management.

Paradoxically, green city brands such as the EGCA suggest that we can have it all – environmental sustainability, economic growth, reductions in environmental externalities and increases in environmental benefits, such as tree planting campaigns (Kruegger and Gibbs 2007). A different perspective can be drawn, however, that suggests that green city brands as *suasive* policy tools can actually narrow the scope and definition of a green city. Such a perspective chimes with other studies of green city brands, which are shown to focus upon entrepreneurial urban development schemes where ideas such as ecological greening campaigns that are not measured and ascribed a social-economic value do not rise to the top of the agenda, and thus are not championed or funded (Gulsrud et al. 2013). In other words, by promoting

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a standardized definition of what it means to be green, alternative interpretations tend to be discouraged (Goulden et al. 2015).

In spite of this, the green city agenda is developing as a global discourse, being replicated in a similar fashion by cities across the world (Gulsrud and Ooi 2015). Singapore's government-sponsored Centre for Livable Cities, for example, acts as a consultant to developing cities in Asia and Africa, who look to Singapore for clean and green solutions to urban development and expansion (Centre for Liveable Cities 2015). Even in Europe, Copenhagen promotes what it calls the 'Copenhagen Solution', selling its approach to green urban sustainability to cities as far apart as Singapore, New York and Melbourne (Copenhagen 2015).

Challenges remain, however, to the future delivery and governance of UGI in the EU, as neo-liberal green growth discourses in the European Commission continue to steer national and urban development policies. This should not preclude updating the EGCA to include a more comprehensive and focused planning approach in the award, but there does seem to be some ambivalence in current policy trends. On the one hand, the EU announced in 2015 the launch of a new green city competition – the European Green Leaf (EGL 2015). This award aims to encourage European towns and cities with populations between 20,000 and 100,000 people to commit to improving environmental outcomes through 'efforts that generate green growth and new jobs'. The award will be presented on an annual basis, in conjunction with the EGCA (EGL 2015).

On the other hand, the 2013 EC Strategy on GI (European Commision 2013a, b, c) underlines that GI can make a considerable contribution to the effective implementation of *all* policies where some or all of the desired objectives can be achieved in whole or in part through 'nature-based solutions'. In addition, the Regional Policy 2014–2020 continues to support nature and GI through financial instruments such as the European Regional Development Fund and the Cohesive Fund, which contribute to several policy objectives and deliver multiple benefits.

Do these diverse approaches leave us with a message that is merely ambivalent? Perhaps, but as Jordan et al. (2013) remind us, the green city agenda matters because it is a necessary *link* in a chain of interested players – a link between those who steer policies at a global and national level, and those who implement those policies at the most local level of all.

References

Alavipanah S, Wegmann M, Qureshi S, Weng Q, Koellner T (2015) The role of vegetation in mitigating urban land surface temperatures: a case study of Munich, Germany during warm season. Sustainability 7:4689–4706

Arnouts R, Van der Zouwen M, Arts B (2012) Analysing governance modes and shifts – governance arrangements in Dutch nature policy. Forest Policy Econ 16(1):43–50

Arts B, Leroy P, van Tatenhoven J (2006) Political modernisation and policy arrangements: a framework for understanding environmental policy change. Public Org Rev 6(1):93–106

liz.obrien@forestry.gsi.gov.uk

Benedict MA, McMahon ET (2006) Green Infrastructure: linking landscapes and communities, 2nd edn. Island Press, Washington, DC
Centre for Liveable Cities (2015) Available at http://www.clc.gov.sg/
Chiesura A (2004) The role of urban parks for the sustainable city. Landscape and. Urban Plann 68(1):129–138
Copenhagen (2015) Copenhagen solutions for sustainable cities: state of Green and Copenhagen CLeantech Cluster. Available at http://kk.sites.itera.dk/apps/kk_pub2/pdf/1353_58936BnEKE.pdf
Davis C et al (2006) Green infrastructure planning guide project: final report. NECF, Annefield Plain
EU Council (2006) Renewed EU sustainable development strategy. Available at http://www.eeb.org/?LinkServID=D251F7FC-9997-D51C-7F05CB5A872C33BD&showMeta=0
European Commision (2010) European Commission, Europe 2020: a strategy for smart, sustainable and inclusive growth. COM(2010) 2020 final. Available at http://www.elgpn.eu/elgpndb/fileserver/files/39
European Commision (2011) Our life insurance, our natural capital: an EU biodiversity strategy to 2020. COM(2011) 244 final
European Commision (2013a) Green Infrastructure (GI) — enhancing Europe's Natural Capital. COM(2013) 249 final. Available at http://eur-lex.europa.eu/legal-content/EN/TXT/?uri=CELEX:52013DC0249
European Commision (2013b) EU Strategy on adaptation to climate change. COM(2013) 216 final. Avialble at http://ec.europa.eu/clima/policies/adaptation/what/docs/com_2013_216_en.pdf
European Commision (2013c) A new EU forest strategy: for forests and the forest-based sector. COM(2013) 659 final. Available at: http://ec.europa.eu/agriculture/forest/strategy/communication_en.pdf
European Commision (2014a) An introduction to EU Cohesion Policy: 2014-2020. Available at http://ec.europa.eu/regional_policy/sources/docgener/informat/basic/basic_2014_en.pdf
European Commision (2014b) General union environment action programme to 2020: living well, within the limits of our planet. Available at http://bookshop.europa.eu/en/general-union-environment-action-programme-to-2020-pbKH0113833/
European Environmental Agency (2006) Environmental statement. Available at http://www.eea.europa.eu/publications/report_2006_0707_150910
European Environmental Agency (2011) Green dnfrastructure and territorial cohesion. Available at http://www.eea.europa.eu/publications/green-infrastructure-and-territorial-cohesion
European Green Capital Award (2010a) Measuring urban sustainability: analysis of the European Green Capital Award 2010 & 2011 application round. Accessed December 2014 at: http://ec.europa.eu/environment/europeangreencapital/wp-content/uploads/2013/02/egc_analysis2010-2011.pdf
European Green Capital Award (2010b) Final report: Stockholm the first European Green Capital. Available at http://ec.europa.eu/environment/europeangreencapital/wp-content/uploads/2011/04/Stockholm-Final-Report.pdf
European Green Capital Award (2010c) Catalogue of best practice urban sustainability – learning from the Best. Available at http://ec.europa.eu/environment/europeangreencapital/wp-content/uploads/2013/02/egc_bpcatalogue_2010-2011.pdf
European Green Capital Award (2011) Hamburg – European Green Capital final report. Available at http://ec.europa.eu/environment/europeangreencapital/wp-content/uploads/2011/04/Doku-Umwelthauptstadt-engl-web.pdf
European Green Capital Award (2012a) The expert panel's evaluation work & final recommendations for the European Green Capital Award of 2012 and 2013. Available at http://ec.europa.eu/environment/europeangreencapital/wp-content/uploads/2011/05/Evaluation-Panel-Report-Award-Cycle-2012-2013.pdf

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European Green Capital Award (2012b) Vitoria-Gasteiz 2012 European Green Capital final report. Available at http://ec.europa.eu/environment/europeangreencapital/wp-content/uploads/2011/04/VG-Green-Conclusiones.pdf

European Green Capital Award (2012c) Vitoria-Gasteiz – European Green Capital 2012. Available at https://www.youtube.com/watch?v=26o8HXRW0uQ

European Green Capital Award (2012d) Environmental best practice & benchmarking report. Available at http://ec.europa.eu/environment/europeangreencapital/wp-content/uploads/2011/06/Environmental-Best-Practice-Benchmarking-Report-Award-Cycle-2012-2013.pdf

European Green Capital Award (2013a) A review of 2013: Nantes European Green Capital. Available at http://ec.europa.eu/environment/europeangreencapital/wp-content/uploads/2011/04/bilan_nantes_green_capital_EN.pdf

European Green Capital Award (2013b) Award Handover Ceremony, 2013. Available at https://www.youtube.com/watch?v=2NUioVYklYk

European Green Capital Award (2014a) Expert evaluation panel – synopsis technical assessment report. European Green Capital Award 2014. Available at http://sharingcopenhagen.dk/media/26830/Synopsis-Technical-Assessment-Report.pdf

European Green Capital Award (2014b) Copenhagen insights – sharing urban learnings. Available at https://www.youtube.com/watch?v=G1aPa19hRqE

European Green Capital Award (2014c) Good practice report European Green Capital 2014. Available at http://ec.europa.eu/environment/europeangreencapital/wp-content/uploads/2011/04/MDR0763Rp00013_Good-Practice_Final2.pdf

European Green Capital Award (2015a) Expert evaluation panel – synopsis technical assessment report. European Green Capital Award 2015. Available at http://ec.europa.eu/environment/europeangreencapital/wp-content/uploads/2013/02/Synopsis-EGCA-2015-Technical-Assessment-Report.pdf

European Green Capital Award (2015b) Bristol application. Available at http://ec.europa.eu/environment/europeangreencapital/winning-cities/2015-bristol/bristol-application/index.html

European Green Capital Award (2015c) Youtube site. Available at https://www.youtube.com/user/EGCwebteam

European Green Capital Award (2016a) Expert evaluation panel – synopsis technical assessment report. European Green Capital Award 2016. Available at http://ec.europa.eu/environment/europeangreencapital/wp-content/uploads/2013/02/EGCA-2016-Technical-Assessment-Synopsis-Report_F01.pdf

European Green Capital Award (2016b) Lublijana application. Available at http://ec.europa.eu/environment/europeangreencapital/winning-cities/2016-ljubljana/ljubljana-2016-application/index.html

European Green Leaf Award (EGLA) (2015) Available at http://ec.europa.eu/environment/europeangreencapital/europeangreenleaf/

Fuller RA, Gaston KJ (2009) The scaling of green space coverage in European cities. Biol Lett 5(3):352–355

Goulden S, Garb Y, Erell E, Pearlmutter D (2015) Green building standards as socio-technical actors in municipal environmental policy. Build Res Inf. doi:10.1080/09613218.2015.1116844

Govers R, Go F (2003) Deconstructing destination image in the information age. Inform Technol Tour 6(1):13–29

Gulsrud NM, Ooi CS (2015) Manufacturing green consensus: urban greenspace governance in Singapore. In: Sandberg A, Bardekjian A, Butt S (eds) Urban forests, trees, and green space: a political ecology perspective. Routledge, New York, pp 77–92

Gulsrud N, Gooding S, Konijnendijk CC (2013) Green space branding in Denmark in an era of neoliberal governance. Urban For Urban Green 12(3):330–337

Hajer M (1993) Discourse coalitions and the institutionalization of practice: the case of acid rain in Great Britain. In: Fischer F, Forrester J (eds) The argumentative turn in policy analysis and planning. Duke University Press, Durham, pp 43–76

Hajer MA (1995) The politics of environmental discourse: ecological modernization and the policy process. Clardon Press, Oxford

liz.obrien@forestry.gsi.gov.uk

Hajer M, Versteeg W (2005) A decade of discourse analysis of environmental politics: achievements, challenges, perspectives. J Environ Policy Plan 7(3):175–184
Hood C (2007) Intellectual obsolescense and intellectual makeovers: reflections on the tools of government after two decades. Governance 20(1):127–144
Hooghe L, Marks G (2001) Governance and European integration. Rowman & Littlefield Publishers Inc, Oxford
Hooghe L, Marks G (2003) Unraveling the central state, but how? Types of multi-level governance. Am Polit Sci Rev 97(2):233–243
James P, Tzoulas K, Adams MD, Barber A, Box J, Breuste J, Elmqvist T, Frith M, Gordon C, Greening KL, Handley J, Haworth S, Kazmierczak AE, Johnston M, Korpela K, Moretti M, Niemelä J, Pauleit S, Roe MH, Sadler JP, Ward Thompson C (2009) Towards an integrated understanding of green space in the European built environment. Urban For Urban Green 8(2):65–75
Jenkins-Smith HC, Sabatier PA (1994) Evaluating the advocacy coalition framework. J Public Policy 14(2):175–203
Jordan A, Adelle C (2013) Environmental policy in the EU – actors, institutions and processes, 3rd edn. Earthscan from Routhledge, London
Jordan A, Lenschow A (2010) Environmental policy integration: a state of the art review. Environ Policy Gov 20:147–158
Jordan A, Tosun J (2012) Policy implementation. In: Jordan A, Adelle C (eds) Environmental policy in the EU: actors institutions and processes. Earthscan from Routledge, London/New York, pp 247–266
Jordan A, Benson D, Wurzel RKW, Zito A (2013) Governing with multiple instruments? In: Jordan A, Adelle C (eds) Environmental policy in the EU: actors institutions and processes. Earthscan from Routledge, London/New York, pp 309–325
Kabisch N (2015) Ecosystem service implementation and governance challenges in urban green space planning – the case of Berlin, Germany. Land Use Policy 42:557–567
Kabisch N, Qureshi S, Haase D (2015) Human–environment interactions in urban green spaces — a systematic review of contemporary issues and prospects for future research. Environ Impact Assess Rev 50:25–34
Kern K (2014) Climate governance in the European Union Multilevel system: the role of cities. In: Weibust I, Meadowcroft J (eds) Multilevel environmental governance managing water and climate change in Europe and North America. Edward Elgar Publishing, Cheltenham/Northampton, pp 111–130
Kingdon J (1994) Agendas, ideas, and policy change, 2nd edn. HarperCollins, New York
Knack S, Kugler M, Manning N (2003) Second-generation governance indicators. Int Rev Adm Sci 69(3):345–364
Knill C, Liefferink D (2007) Environmental politics in the European Union. Melbourne University Press, Manchester
Konijnendijk CC, Annerstedt M, Nielsen AB, Maruthaveeran S (2013) Benefits of urban parks a systematic review. The International Federation of Parks and Recreation Administration-IFPRA, Copenhagen
Kornberger M, Carter C (2010) Manufacturing competition: how accounting practices shape strategy making in cities. Account Audit Account J 23(3):325–349
Krajter Ostoić S, Konijnendijk van den Bosch CC (2015) Exploring global scientific discourses on urban forestry. Urban For Urban Green 14(1):129–138
Kruegger R, Gibbs D (2007) The sustainable development paradox: urban political economy in the United States and Europe. The Guilford Press, New York
Larondelle N, Haase D, Kabisch N (2014) Mapping the diversity of regulating ecosystem services in European cities. Glob Environ Chang 26:119–129
Lennon M (2014) Green infrastructure and planning policy: a critical assessment. Local Environ Int J Justice Sustain. doi:10.1080/13549839.2014.880411

liz.obrien@forestry.gsi.gov.uk

Liefferink D (2006) The dynamics of policy arrangements: turning round the tetrahedron. In: Arts B, Leroy P (eds) Institutional dynamics in environmental governance. Springer, Dordrecht, pp 45–68

Mell IC (2013) Can you tell a green field from a cold steel rail? Examining the "green" of Green Infrastructure development. Local Environ Int JJustice Sustain 18(2):152–166

Niemelä J, Saarela SR, Söderman T, Kopperoinen L, Yli-Pelkonen V, Väre S, Kotze DJ (2010) Using the ecosystem services approach for better planning and conservation of urban green spaces: a Finland case study. Biodivers Conserv 19(11):3225–3243

Nuissl H, Haase D, Lanzendorf M, Wittmer H (2009) Environmental impact assessment of urban land use transitions– a context-sensitive approach. Land Use Policy 26(2):414–424

Pallemaerts M (2013) Developing more sustainably? In: Jordan A, Adelle C (eds) Environmental policy in the EU: actors institutions and processes. Earthscan from Routledge, London/New York, pp 309–325

Roe M, Mell I (2013) Negotiating value and priorities: evaluating the demands of green infrastructure development. J Environ Plan Manag 56(5):650–673

Roy S, Byrne J, Pickering C (2012) A systematic quantitative review of urban tree benefits, costs, and assessment methods across cities in different climatic zones. Urban For Urban Green 11(4):351–363

Sabatier PA (1988) An advocacy coalition framework of policy change and the role of policy-oriented learning therein. Policy Sci 21:129–168

Torfing J, Sørensen E (2014) The European debate on governance networks: towards a new and viable paradigm? Polic Soc 33:329–344

Torfing J, Peters BG, Pierre J, Sørensen E (2012) Interactive governance: advancing the paradigm. Oxford University Press, Oxford

Tratalos J, Fuller RA, Warren PH, Davies RG, Gaston KJ (2007) Urban form, biodiversity potential and ecosystem services. Landsc Urban Plan 83(4):308–317

Werquin AC, Duhem B, Lindholm G, Oppermann B, Pauleit S, Tjallingii S (eds) (2005) Green structure and urban planning. Final report, COST Action C11, European Commission, Brussels. Available at http://www.cost.eu/media/publications/05-37-Green-Structure-and-Urban-Planning-Final-Report

Wurzel RKW, Zito AR, Jordan AJ (2013) Environmental governance in Europe. A comparative analysis of new environmental policy instruments. Edward Elgar Publishing, Inc., Cheltenham

Yin RK (1994) Case study research: design and methods. In: Applied social research method series, vol 5, 2nd edn. Sage Publications, Beverly Hills

Young OR (2010) Emergent patterns in international environmental governance. The MIT Press, Cambridge

Young R, Zanders J, Lieberknecht K, Fassman-Beck E (2014) A comprehensive typology for mainstreaming urban green infrastructure. J Hydrol 519:2571–2583

Zuidema C, De Roo G (2009) Towards liveable cities: progress in the European Union urban environmental agenda. Eur Plan Stud 17(9):1405–1419

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Chapter 20
The Role of Partnerships and the Third Sector in the Development and Delivery of Urban Forestry and Green Infrastructure

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This chapter describes the role and significance of partnerships in urban forestry and green infrastructure governance. Special focus is given to the emerging role of the Third Sector, including voluntary or not-for-profit organisations, non-governmental organisations (NGOs), charities and social enterprises, in delivery of urban forestry (UF) within the context of regional green infrastructure (GI). We will

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examine partnership approaches adopted in Scotland, UK, and consider to what extent they can be applied as models within the wider European context, where the management and implementation of GI has traditionally been implemented by public authorities on a top-down basis. In particular, the strengths and weaknesses of Third Sector approaches will be evaluated against traditional public and private sector models. Optimal scenarios will be proposed for the role of the Third Sector with respect to other GI delivery agents. Success factors for partnerships discussed in previous research are reviewed, and considerations for the evaluation of partnerships are outlined.

20.1 Partnerships as a Mechanism for Planning, Delivery and Management of Urban Forestry and Green Infrastructure

Partnerships are becoming of greater importance in the context of urban forestry policy (Pütz et al. 2015), and represent an effective approach towards the participatory planning and management of green infrastructure and urban forestry (GI/UF). Such partnerships place a strong emphasis on the delivery of ecosystem services related to GI/UF, often within the wider context of sustainable development objectives (Konijnendijk et al. 2006).

In partnerships, two or more stakeholders co-operate and contribute resources to facilitate the delivery of predetermined outcomes. Stakeholders might include, for example, local authorities, government agencies, community groups, land owners, NGOs and private sector developers. Partnerships can create effective synergies between these stakeholders which combine the resources and ideas of contributing partners. Disputes can therefore be reduced or avoided since potential conflicts of interest can be identified at an early stage and resolved through open dialogue and transparent decision making processes.

Partnerships can also represent cost effective solutions for providing and maintaining urban forests and GI through their ability to leverage additional resources and "in kind" support. They can effectively reduce public sector costs for UF/GI service provision through promoting community engagement, volunteering and direct action. Empowerment and inclusion of the public in planning and management of urban green space promotes greater interaction between residents and thus promotes social cohesion. It can also instil a sense of ownership and stewardship for green spaces amongst local residents. In certain cases, this can reduce local authority maintenance burdens as resident initiatives take over day to day management roles.

Partnerships have also been shown to be successful when it comes to the acquisition and leverage of additional physical and financial resources. This might be through involving landowners, acquiring donations or through mobilising public resources or income streams such as National Lottery funding. GI/UF partnerships between cities, communities, forest-owners and forest-enterprises can thus be regarded as viable mechanisms to generate income for the forest sector for the

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provision of environmental and social aspects of forestry. The importance of partnerships for providing benefits to people has been demonstrated through a broad variety of outcomes ranging from planning, establishment and management of urban green space, provision of health services or education in forest schools (Jones et al. 2005; Van Herzele et al. 2005).

20.2 Partnerships and the Context of Urban Forestry and Green Infrastructure in Scotland

Within Scotland green infrastructure is a relatively recent concept, although there is a long established tradition of urban greening and management of "countryside around towns" on the proximity of Scottish cities. In recent years, GI has become formally embedded within Scottish national planning policy through incorporation within the National Planning Framework, NPF2 (Scottish Government 2009a). In particular, NPF2 specifies the creation of the *Central Scotland Green Network* (CSGN 2011) as one of a number of key national developments (Fig. 20.1). This in turn cascades down through planning policy into the creation of City region development plans and ultimately into local development plans.

Whilst these strategic planning processes may be relatively new in Scotland with relation to GI, the implementation of green infrastructure has been assisted by a number of existing processes and cultural factors. These include a strong established culture of public participation and volunteering, whereby the role of public agencies and local government has increasingly becoming an enabling one. These structures place a strong emphasis on multi-functionality and social return on investment in program delivery. There are consequently many established social programmes which deliver multifunctional objectives within the Scottish context.

Fig. 20.1 The Central Scotland Green Network Partnership aims to transform urban Scotland by 2050

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Fig. 20.2 Stakeholder typology for GI co-ordination and delivery

There is, however a strong urban/rural divide within Scotland. Whilst many rural communities have been at the forefront of developing grassroots community action (through, for example, community woodland groups), urban communities, particularly within deprived areas, have relied upon local authorities and voluntary organisations to take the lead role in co-ordinating greenspace action.

Central Scotland in particular faces considerable GI challenges resulting from the post-industrial legacy and from the significant housing, health and social inequalities which exist throughout the area. In these locations the physical GI resource is often limited or of poor quality and there is sometimes little sense of community ownership towards greenspaces (CSGN 2011). However, Scotland fortunately benefits from the fact that there is a strong tradition of green volunteering and Third Sector activity with significant experience of working within urban and peri-urban areas. Strong partnerships between NGOs, governmental agencies, local authorities and businesses are taking forward the GI agenda.

There is a diverse range of stakeholders involved in the coordination and delivery of green infrastructure within the Scottish context (Fig. 20.2). These include:

- Government departments and agencies,
- Third Sector NGOs, charities and social enterprises,
- Grass roots community organisations,
- Local authorities,
- Private sector developers, and
- National and Regional Development Agencies (RDAs). Although the latter were scrapped by the UK Government in 2012, a similar function is still undertaken in Scotland by Scottish Enterprise and Highlands and Islands Enterprise.

Recent policy recognises that in order to optimise the effective delivery of the multifunctional social, economic and environmental benefits of GI, it must be considered and planned at a landscape scale (European Commission 2013). This

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Fig. 20.3 Adding value through promoting community volunteering

requires the identification of new mechanisms for planning and delivery of green infrastructure on the ground. In particular it requires stakeholders, such as local authority planners and land managers, to think beyond their traditional territories and to implement measures which cut across administrative and thematic boundaries (Figs. 20.3, 20.4 and 20.5).

Co-ordinating bodies and partnerships which operate on a landscape scale are not a new concept. There are many examples which predate the establishment of green infrastructure policy; long established examples include regional and national park authorities, urban regeneration partnerships and Natura 2000 networks. More recently, regional GI partnerships which integrate strategic planning objectives with green network principles have been established to co-ordinate and deliver GI on a regional scale (Whitehead 2012). These bodies co-ordinate their programmes through strategies and action plans, the formulation of which requires a high degree of stakeholder participation. Examples of such policies and action plans include integrated habitat network (IHN) modelling, regional indicative forestry strategies, outdoor access strategies and specific green infrastructure plans.

To develop such holistic and partnership-orientated approaches to GI delivery requires methodologies which emphasise consensus building and stakeholder engagement (Whitehead 2009). However, in order to identify such potential GI delivery mechanisms, it is first necessary to consider the remit and role of individual stakeholders who might be involved in the development of wider partnerships. The

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Fig. 20.4 Delivering Social Return on Investment can bring the urban forest to life (Courtesy of Edinburgh & Lothians Greenspace Trust)

Fig. 20.5 Effective partnerships are a key factor in the establishment and delivery of Green Infrastructure (Courtesy of Lothians and Fife Green Network Partnership)

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Table 20.1 The roles and limitations of stakeholder types within GI delivery

Stake holder role in relation to GI:	Limitations:
Local authorities	
The management of public open spaces	Often limited cross boundary working
Provision of ecological advisory services to public and private landowners	Financial and political constraints
Formulation of local development plans and community plans	Spatially limited in extent and not always corresponding with landscape and ecological zones
Processing and approval of planning applications	Community consultation is often limited; speculative development can arise from a reactive approach
Developing projects and partnerships with external organisations	Projects often operate over limited time spans and are opportunistic, under-resourced or of limited geographical coverage
Community outreach	Sometimes unable to access external funding sources available to the Third Sector
National/regional economic development agencies (formerly RDAs)	
Bigger picture regional overview	No specific remit for GI or specialist land-use planning functions
Integration of economic development aspirations into GI programs	Lack of specialist knowledge of GI issues
Influential contacts with business sector, government and politicians	Environment perceived as being of low economic priority by National Economic Development Agencies
Can integrate GI into wider regional policy context	Lack of awareness and specialist knowledge means that GI concepts are not filtered down to individual clients and stakeholders
Governmental departments and agencies	
Issue policy statements and guidelines around GI topics	Remote from stakeholder groups
Provide a regulatory framework and policing role	Reactive functions do not result in new initiatives
Funding provision	Perceived by stakeholders as often being bureaucratic and slow to respond
Source of information and advice	Outputs tied to fixed funding cycles
Provide a strategic overview	Often lack flexibility and business acumen
Project development and involvement in partnerships	Often at arm's length from partnerships with decreasing input over time
Private sector	
Provide finance directly and through planning gain and mitigation process	Looking to minimise additional costs whilst maximising profit; mitigation is often ad hoc and poorly targeted
Getting things done most cost-effectively	GI component a "bolt on" extra and not considered a core area of responsibility
Dynamism and business acumen	Limited staff resource and budgets for GI projects (particularly with present economic conditions)
Job creation	Green issues perceived negatively

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Table 20.1 (continued)

Stake holder role in relation to GI:	Limitations:
Integration of GI within development	Short-term view focusing on minimum compliance; dependent upon economic swings
Project management on the ground	Lack of GI knowledge and expertise
Grass roots community action	
Encourages effective local "buy-in" and citizen participation	Representation often limited to a few predictable individuals
Maximises use of local knowledge structures and networks	Bureaucracy and reporting can be onerous for community groups
Builds capacity and empowers the community	Initial interest can decline and threaten viability
Provides long term solutions for local sustainability	Local groups can lack the professional and administrative skills required
Provides a high social return for investment	Grass roots action is often opportunistic and is not targeted strategically
Encourages local sourcing of materials, expertise and labour	Quality of outputs can vary enormously with higher rates of success in cohesive rural and peri-urban communities
Keeps control at a local level	Relies entirely upon volunteer effort
A good vehicle for partnership working	
Third sector NGOs and social enterprises	
Role as an honest broker between stakeholders and authorities	Opportunity and funding driven – often limited strategic approach
Generally perceived positively by local stakeholders	Reliant on short term funding arrangements – lack of long term core funding endangers continuity and staff retention
Able to access additional funding streams unavailable to public and private sector	Considerable competition for resources within the charitable sector
Good local contacts and networks	Staff turnover an issue
Specialist local knowledge	Onerous reporting / administration procedures consume limited resources and staff time
Adaptable and dynamic to changing policy and economic conditions	Difficult to invest time in research and project development
Deliver high social return on investment	Do not always provide the cheapest procurement option for outsourced services
Green infrastructure partnerships (comprising previous stakeholder types)	
Mediator and mentor across a diverse range of partner organisations	Small budgets and limited access to resources to showcase best practice
Source of information and knowledge through access to extensive networks	Complex and ambiguous management structures create confusion
Provision of an overview across science, policy and implementation interface	Partnership posts often short term and complex arrangements
Development of structured frameworks and action plans	Agendas sometimes sabotaged or hijacked by vested interests

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Table 20.1 (continued)

Stake holder role in relation to GI:	Limitations:
Promoting profile and awareness of GI across partners and public	Lack of statutory remit often requires extensive lead-in time for diplomacy and consensus building before actions result
Providing a strategic context for GI within wider policy and planning	Time consuming and complex to establish and maintain. Often perceived as being undemocratic by public
Neutrality	Status of partnership is often unclear or ambiguous dependent on location / hosting
Showcasing and delivery of GI best practice	Difficult to recruit and maintain suitably qualified staff with short term funding arrangements

primary role of these individual stakeholder types within GI delivery is shown in Table 20.1.

20.3 Evaluation of How the Third Sector Can Contribute to GI Initiatives

Although the term "Third Sector" is contested, it has been defined by the UK Government to signify "non-governmental organisations that are value-driven and which principally reinvest their surpluses to further social, environmental or cultural objectives. It includes voluntary and community organisations, charities, social enterprises, cooperatives and mutuals." (National Audit Office 2011). This distinguishes it from the "First" and "Second" sectors, which represent the private and public sectors respectively.

The role and composition of Third Sector organisations can be very diverse in relation to GI/UF (as shown in Table 20.2). For practical purposes, in this chapter a distinction is also made between larger and more organised Third Sector organisations such as charities and social enterprises (e.g. Greenspace Trusts, which have a wider enabling role in the delivery of GI/UF), and purely local (and often more informal) groups which might promote volunteering at an individual community or site specific level.

The Third Sector contributes to the development of GI initiatives at a variety of different levels. For example, Third Sector organisations can simply take on the role of being delivery agents for larger area-based initiatives through implementing projects on the ground or through developing education or capacity building initiatives. Alternatively the Third Sector can, in some cases, act in the dual role of both policy driver and delivery agent. The strength of the former role results from the lobbying power of the sector and its ability to influence national and local policy-making processes. Certainly, many environmental NGOS are well connected and often

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Table 20.2 Remit of third sector organisations in relation to GI

Type of organisation	Examples (from Scotland)	Remit in relation to GI
Area-based Greenspace/ groundwork Trusts	Lothians and Fife Greenspace Trust	Projects, funding, contract management, point of contact, advice provision, agent for change, skills development
	Aberdeen Greenspace Ltd.	
	Carts Greenspace	
Regional Partnerships	Lothians and Fife Green Network Partnership (LFGNP)	Co-ordination, agent for change, best practice dissemination, point of contact, mediation, policy formulation, advice
	Glasgow and Clyde Valley Green Network Partnership (GCVGNP)	
Umbrella Bodies	Community Woodland Association (CWA)	Provision of advice, best practice, knowledge-sharing, networking and lobbying
	Federation of City Farms and Community Gardens	
	Greenspace Scotland	
Local Groups	"Friends of" Groups	Project implementation, action on the ground, awareness building, mobilising volunteers, fundraising, local ownership, local lobbying
	Community Woodland Groups	
	Path Groups	
Campaigning bodies	Royal Society for the Protection of Birds (RSPB), Friends of the Earth, Sustrans	Awareness-raising at national and regional level, lobbying, best practice, contesting development applications
Special interest groups	Galgael Trust	Social inclusion, skills development, product marketing, action on the ground, adult learning
	Coachhouse Trust	
	Falkland Centre for Stewardship	

employ professional lobbyists to directly influence policy decision-making processes.

Other factors including political, economic and social connections play a contributory role in determining the ability of the Sector to directly influence and shape policy. With this in mind the picture becomes a complex one indeed whereby the GI policy agenda is both driven and influenced by the same Third Sector organisations which stand to benefit from the process. In this respect it is difficult to determine the extent to which the Third Sector is proactively shaping policy through indirect lobbying and influencing, as opposed to merely responding reactively to GI policy decisions, especially as much of this lobbying is conducted through subtle and unrecorded personal interactions.

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20.4 Types of Projects Involving Third Sector Organisations

Third Sector organisations deliver a complex range of projects, goods and services in relation to green infrastructure development. Some main outputs of the Third Sector include:

- Woodland creation and management
- Development of path networks, signage, interpretation and access infrastructure
- Creation, management and maintenance of parks and urban greenspaces
- Skills development and employment training
- Derelict land restoration programmes
- Special needs and social inclusion programmes
- Biological surveying and record keeping
- Environmental arts and education
- Lobbying and campaigning

Additionally, the range of Third Sector organisations involved in the delivery of GI is considerable, with diverse organisation roles and remits. Key roles are shown in Table 20.2.

Table 20.3 Strengths of Third Sector organisations in relation to GI

Perceived key Third Sector strengths	Key features of organisations	Examples (from Scotland)
Local accountability and responsive-ness	Often locally-based and perceived positively as non-partisan; staff are often skilled in communication and community outreach and have good local knowledge and networks	Greenspace Trusts
Ability to innovate	Organisations are generally small in size and are not constrained by the same bureaucracy affecting government agencies and departments; new working methodologies and approaches can be more easily adopted	Coachhouse Trust Galgael Wecan
Ability to access funding	Third Sector bodies are often able to access funding from a variety of sources which are unavailable to statutory bodies and government departments in the form of grants, awards and trust funds (e.g. Lottery funding, Rural Development funds etc.)	Edinburgh and Lothians Greenspace Trust (ELGT), Community Woodland Association (CWA), Local Development Trusts

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Table 20.1 (continued)

Perceived key Third Sector strengths	Key features of organisations	Examples (from Scotland)
Adoption of "social enterprise" models	Third Sector bodies are increasingly adopting business models in terms of their operation and cost recovery. This makes them efficient, streamlined and cost-effective in terms of the services they provide	Wise Group Falkland Centre
Working opportunistically	Organisations are responsive in their working practices and are therefore able to respond rapidly to opportunities and identify areas of work where there is scope for them to develop key roles	Greenspace Trusts
Social return on investment	Able to provide considerable additional social benefits through service delivery including community capacity building, employment training, social inclusion, recycling and environmental education	All of the above

Table 20.4 Weaknesses of Third Sector organisations in relation to GI

Perceived Third Sector weaknesses	Key features
Lack of overall strategic vision	Many Third Sector (TS) bodies lack strong strategic vision but instead pursue a more opportunistic funding-driven agenda
Requirement to secure ongoing funding to ensure continued operation	Unlike statutory bodies, TS organisations have to cover their costs through fund raising which can create conflicts with delivering core functions; this can make it difficult for these organisations to invest in new project development
Inefficiencies created by competition between Third Sector organisations	Like businesses, Third Sector organisations are in a state of tough competition for a limited resource pool for GI projects
Inequalities in the distribution of core funding across the spectrum of NGOs responsible for GI projects	Government funds are not always dispersed equitably across Third Sector organisations delivering GI programmes; this can lead to over/under provision in certain areas and can create conflicts
Public concern about charitable organisations	There is a belief amongst the public that some charities' support costs are unnecessarily high; most feel that charitable donations should go directly to projects and not to organisational running and staff costs
General economic situation	The current tough economic climate affects charitable and Third Sector organisations as much as the public and private sectors; with generally less disposable income available, organisations have to be innovative and dynamic to survive

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20.5 Identification of Strengths and Weaknesses of Third Sector-Based Delivery Systems with Reference to Examples in Scotland

The perceived benefits of Third Sector contribution to green infrastructure provision are illustrated in Table 20.3.

In contrast to this, a number of disadvantages of the Third Sector in GI network development can be identified, as summarized in Table 20.4.

20.6 An Evaluation of What Conditions Favour Third Sector Involvement in GI Initiatives

It is clear that there is a strong potential role for the Third Sector to play in the planning, co-ordination and delivery of GI initiatives (Scottish Government 2009b). However, the realisation and delivery of this is currently not being achieved as effectively or equitably as it might, across the full range of geographical and policy areas.

In order to maximise effectiveness of the Sector, certain key conditions need to be satisfied. Most important of all is the requirement for sympathetic government policies and incentives which favour the creation and development of Third Sector organisations (and which encourage these to play a role in the delivery and development of green infrastructure). The following situations appear to create the appropriate conditions for the sector to flourish:

- The government prioritizes community engagement and Social Return on Investment policies
- Government bodies are overloaded or constrained in their remit through high levels of state bureaucracy
- Decentralised funding structures allow the Third Sector to tap into varied funding opportunities
- Neo-liberalist economic policies have encouraged market driven outsourcing of services
- An established culture of volunteering and community action exists

20.6.1 Governmental Community Engagement and Social Return on Investment Policies

Traditionally, local government administrations have undertaken the development of local plans through a largely top-down process whereby planning objectives have been identified by professionals, with only limited input from stakeholders and local communities.

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In recent years top-down, paternalistic approaches have given way to new community planning-based models. These models seek to involve local people as equal partners in the identification of priorities and subsequent development of action plans. Through this planning process, convoluted as it may be, government and stakeholders aim to work together in partnership to secure mutual benefits.

In response to this, opportunities have been created for Third Sector organisations to become proactively involved in the delivery of local services, on behalf of (and in partnership with) local authorities and communities. At the same time, local authorities have come under increasing financial pressure with a consequent reduction in core service provision. An expanded role for the Third Sector is therefore potentially an attractive option to local authorities who are increasingly looking to outsource functions whilst maximising social return on investment. Third Sector organisations, subject to their ability to leverage external funding, fit this role perfectly.

Increasingly, decentralisation and outsourcing of public service provision is in response to a number of core national and devolved UK government priorities. At a UK Government level, the "Big Society" concept formed part of the legislative programme for the 2010–2015 Conservative-Liberal Democrat Coalition Government. The stated aim was to create a climate that empowered local people and communities to enable a "Big Society" that would take power away from politicians and give it to people. This concept applied to domestic policy in England only, and was devolved in other parts of the UK (HM Government Cabinet Office 2010).

In Scotland, the *Local Government in Scotland Act* of 2003 provides guidance for community planning. The Act places a duty on local authorities to "initiate and facilitate community planning in their respective areas (Scottish Government 2003).

In 2009 the UK Government Cabinet Office, in association with the Scottish Government, launched a best practice guide to Social Return on Investment (SROI). SROI was widely promoted as a mechanism for measuring value and improved wellbeing by incorporating social, environmental and economic costs and benefits. SROI was specifically designed to help charities and social enterprises compete for public service delivery contracts.

This was made clear in the SROI Guidance, which stated that *"While many Third Sector organisations have a powerful story to tell, the social and environmental value of the impact being made is often underplayed. As we face tough economic times, it is now more important than ever that we allow for better recognition of those who create social and environmental value, leading to more efficient movement of resources to the right people, in the right place, at the right time"*. The SROI guide provided a framework for measuring and accounting for this broader concept of value; it sought to reduce inequality and environmental degradation and improve wellbeing by incorporating social, environmental and economic costs and benefits (SROI Network 2012).

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20.7 Linking Public and Private Interests with the Third Sector

20.7.1 Partnership Models and Success Factors

Models of partnership working provide effective planning tools for ensuring integration of divergent interests. Partnerships take on varied forms and deliver widely different outputs. Examples of the roles which partnerships adopt include:

(i) Simple forums/steering groups – including, for example, estuary management forums, access forums and GI initiative steering groups
(ii) Best practice project delivery – whereby more formal partnership arrangements allow a group of organisations to work together to deliver GI on the ground; this can be from a local scale through to transnational or European initiatives
(iii) Corporate social responsibility programmes – schemes which aim to engage the business sector working alongside Third Sector organisations to deliver GI (e.g. Scottish Forest Alliance)

Partnership models provide an excellent mechanism for the public and private sectors to engage constructively with the Third Sector for mutual benefit and added value in GI delivery. Critical success factors for successful partnerships have been identified by Jones et al. (2005) and Baerlocher et al. (2015) and include:

- The combination of skills and other resources of the involved parties
- Clearly defined aims

Table 20.5 Attributes of successful partnership structures

Partnership attribute	Impact when not applied
A clear vision	Partnership lacks direction
Efficient flow of information across the partnership	Some partners are excluded and become mistrustful of hidden agendas
Efficient decision making processes based on consensus	Partnership becomes dominated by a few vocal players
Experienced steering group and executive with devolved responsibility	Time is wasted through communication problems and inefficient micro management
Adequate and assured funding streams	Implementation will be slow; key personnel will lack confidence and move on
Appropriate representation, influence and effective networks	Partnership will have little influence over key players and will therefore be ineffective
Respected expertise and specialist knowledge	Partnership will not have credibility with stakeholders
Effective strategies and action planning processes	Action and resources will not be targeted where appropriate
Free from manipulation by vested interests	Stakeholders will be alienated and not participate
Simple, clear management structures	Executives will waste time on unnecessary bureaucracy and capacity to deliver core functions will be reduced

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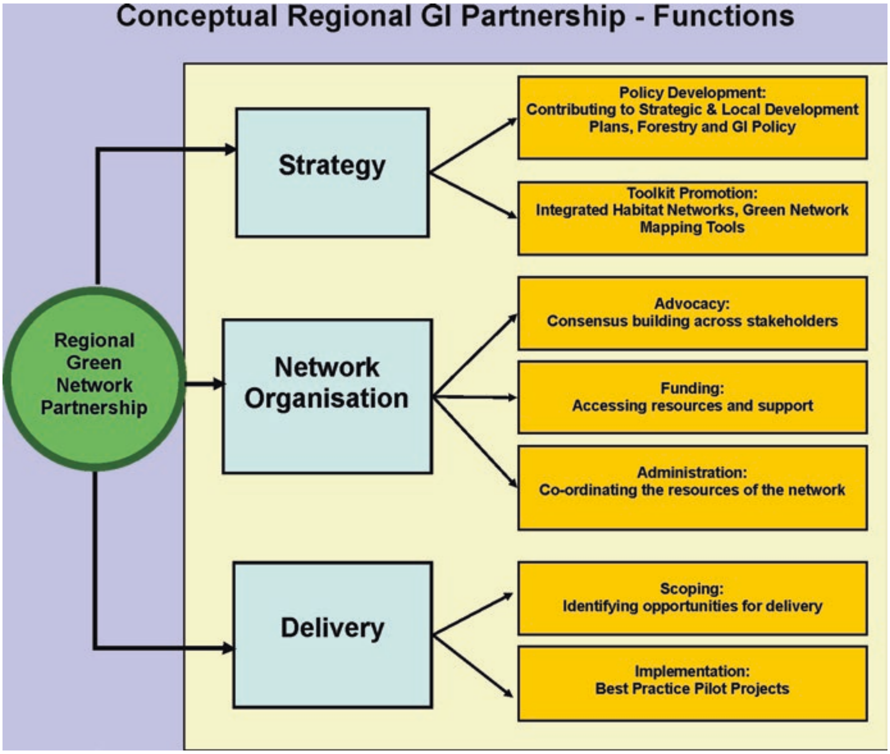

Fig. 20.6 Conceptual regional GI partnership functions

- Motivation of the partners involved
- Clear mutual benefits for the partners
- Efficiency and adaptability
- Formation of a distinct identity
- The ability for cross-sector, interdisciplinary thinking
- Strong leadership
- Ability to act/action competence

A list including further possible success factors and critical challenges which can arise if these factors are absent is provided in Table 20.5. It shows that participation, collaboration and partnerships in urban forestry face critical challenges.

Conflicting goals, lack of trust, fluctuating levels of engagement and rivalry between partners can have detrimental impacts on partnerships (Jones et al. 2005; Van Herzele et al. 2005). Furthermore, the long-term continuation of partnerships can be threatened if the initial high levels of enthusiasm and engagement are not sustained.

Partnerships may also create social exclusion if participation has been restricted or if conflicts lead to the exclusion or withdrawal of some partners. It is therefore important to facilitate an open dialogue which encourages the free flow of information within a neutral environment. This dialogue should emphasise effective knowl-

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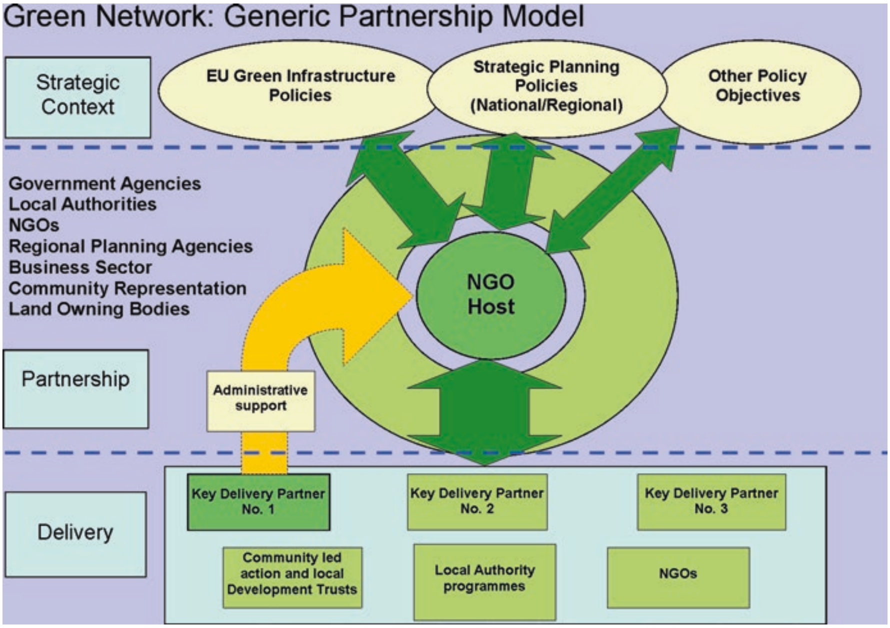

Fig. 20.7 Green network: generic partnership model

edge sharing and should seek to achieve mutually acceptable outcomes which should strengthen partnerships.

Public policies and support for partnerships therefore needs to be designed with a view towards developing sustainable processes and outcomes. This requires a long-term perspective which should promote socially inclusive partnership structures which integrate ecological, economic and social aspects of sustainability (Bernasconi et al. 2014a, b; Hansmann et al. 2012).

From the perspective of taking forward future GI planning and delivery, it is useful to consider how conceptual models might be developed to identify the form, function and structure of GI partnerships operating at the various spatial scales. Figures 20.6 and 20.7 illustrate conceptual models which might operate most successfully at an individual City-region level. These illustrate clearly three main functions of GI partnerships (based on the model of the Lothians and Fife Green Network Partnership) and combine strategy, delivery and partnership development functions within one clear structure.

Figure 20.7 shows the potential role for Third Sector organisations to act as a host for GI partnership structures and in so doing, to effectively bridge the strategy/delivery interface through providing an effective hub for partnership working. This structure should include partners drawn from government agencies, local authorities, NGOs, regional planning agencies, land owning bodies, businesses and local community representatives.

Whilst it is helpful to propose generic models for GI development, a note of caution must be sounded to ensure that such models are adapted to local cultural situations and circumstances rather than being applied universally in their basic form. A

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Fig. 20.8 The Scottish model of partnership, focusing on local stakeholder action, can potentially be replicated in other geographical regions of Europe

model which functions well within the Scottish context might not necessarily fit the very different organisational and administrative structures in other European countries (Fig. 20.8).

20.7.2 Evaluation of Partnerships

The identification of success factors and critical challenges in programme delivery begs the obvious question of how success is actually defined in the context of urban forestry partnerships. What criteria can effectively be used to evaluate the quality

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and success of the process and outcomes of partnerships and how can such criteria be assessed?

Since evaluations need reference to a framework, it would seem practical to consider the evaluation of processes and outcomes within the wider context of sustainability. Evaluation systems should consider the perspectives of stakeholders, both within the partnership and additionally external individuals and organizations who might be indirectly impacted. The latter is particularly important since stakeholders who are not directly involved in the partnership process may bear either positive or negative consequences resulting from the actions of the partnership.

Thus a multi-perspective and multi-criteria evaluation approach covering partnership processes and outcomes in relation to aspects of sustainability within a framework for collaborative governance is required. The criteria for evaluation should include objective environmental criteria (e.g. size of forested area, number of trees, species composition, biodiversity, ecosystem services such as noise reduction and air cleaning) as well as social sustainability criteria such as social inclusion, social learning, democratic processes, mutual acceptance of decisions, fairness, transparency, economic effects and resilience (Krütli et al. 2012; Lockwood 2010; Stauffacher et al. 2012).

As a starting point for evaluation, factors including motivation, organisational structure, implementation mechanisms and ongoing review should all be considered as important topics for incorporation. The partnership attributes listed in Table 20.5 might be considered as suitable headings for developing more detailed partnership evaluation mechanisms.

20.8 Relevance and Application of Scottish Urban Forestry and GI Experiences Within the European Context

One of the aims of this chapter is to assess the potential for applying Scottish GI partnership approaches to other European situations. The GI experience in other European countries varies considerably from Scotland, with differing expertise and methodologies in operation.

Whilst Scotland has favoured multi-sector partnership approaches which link social and environmental objectives, the approach adopted in many Central European countries such as Germany, Switzerland, Austria and France has been a more top-down one, which has been largely driven by the public sector. In these countries, woodlands are generally the responsibility of individual forest owners, who must adhere to management rules which are defined and regulated by the public sector, either through the federal state or through local authorities. In these instances, the resources are managed generally by professional foresters, acting on behalf of the landowners, with a primary focus upon economic aspects of the woodlands. In areas with specific management objectives such as leisure and recreation, education, natural heritage or nature protection, woodlands may be managed by

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professionals drawn from other disciplines (such as ecologists, wildlife biologists or environmental education specialists). In these cases, the forest is managed as an ecological asset, which can, in addition, provide social and ecological services.

Within Eastern and Southern European, there are noticeably fewer participative programmes than in the rest of Europe. Provision of social benefits within urban woodlands in these countries is usually limited to top-down approaches. These are dominated by decisions made by national agencies and are characterised by a low level of communication and participation from other stakeholders (Zivojinovic and Wolfslehner 2015).

However, this situation has been changing in many of these countries, with the emergence of democratic regimes. The existence and involvement of local community action groups and NGOs is currently on the increase, though there still remains considerable room for further development (Gudurić et al. 2011). Potential social benefits of urban woodlands and GI have not yet been fully realised in these locations, mainly because urban forestry has not been recognised as a discipline in its own right and at the same time very traditional forestry practices persist (Krajter Ostoić et al. 2015; Gudurić et al. 2011).

Activities of the Third Sector as a partner in GI are usually characterised through its involvement in response to specific threats to green infrastructure. Recently, there have been conflicts and citizen protests in a number of cities relating to perceived and actual threats to urban forests and green spaces. These have been extensively covered by the media. Each of these protests involved the creation of citizens' groups or NGOs, which became the lead partner in negotiation with the city authorities and green space managers (e.g. Šimpraga 2011; Radiosarajevo 2015; H-ALTER 2010).

The success of these responses varies. As an example of major changes to urban forest and green spaces, the protected area of the 'Medvednica' Nature Park in the city of Zagreb has recently been reduced by around 5000 ha due to the impact of urbanisation (Croatian Parliament 2009). This resulted in significant public protest. Another example from the city of Belgrade in Serbia is protection of the 'Zvezdarska Suma' Forest Park. This was the result of a long battle between the city administration and the building lobby, which envisaged the expansion of commercial developments within the forest park area. A citizens group named 'Protect Zvezdara Forest' is still working on the promotion of green spaces as a multi-functional asset and aims to integrate the diverse range of ecosystem service functions which contribute to citizens' satisfaction and environmental quality (Zvezdarska 2015).

With regard to these shortcomings, a stronger, more strategic involvement of the Third Sector, complemented by concerted grass-roots community action (as shown in the Scottish examples) could add diversity and value to the role of urban woodlands within other European countries. Increasing opportunities for stakeholder involvement will further highlight the point that urban forest policy should no longer be considered to be the exclusive preserve of top-down style management authorities. As the result of a strong welfare system in many Western European countries, there are currently fewer socially orientated NGOs than in the UK; however workers' welfare associations, schools, sport clubs, public health organisations

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and local groups could be seen as potential partners in a new model of participative forestry. It is likely that the Third Sector as a whole will become an increasingly important component of the economy within Europe (Anheier 2002).

There are some positive examples of projects which illustrate a broader and more holistic understanding of urban forestry principles within the European context. The city of Leipzig, for example, has used 'Urbane Wälder' (Burckhardt et al. 2008) as a low-cost approach of maintaining public open spaces within neighbourhoods characterised by decreasing population and reduced building stock. The project 'Urwald vor den Toren der Stadt' near Saarbrücken (Lohrberg and Timpe 2005) similarly assessed the potential of an urban forest as the catalyst for sustainable regional development.

In Germany, the 'Emscher Landschaftspark' 2010 master plan stresses a new role for the urban woodland within the economic renewal of the Ruhr area. Importantly, this is the latest strategic plan within a longer term visionary programme for the Emscher Landschaftspark which has been underway since the late 1980s. This is in stark contrast to many UK initiatives which have tended to be short-lived, limiting their effectiveness to deliver longer-term sustainable development outcomes. However, similar long-term concepts were also pioneered in England at around the same time, although on a smaller scale and with fewer resources. The Black Country urban forest was the first UK example of a partnership programme which used planted woodland and natural regeneration to tackle brownfield land as a measure to promote economic regeneration (Black Country Urban Forestry Unit 1995).

The decline of heavy industries presents further opportunities which require new, innovative approaches to forest management on former brownfield sites where woodlands have developed on an ad-hoc basis through natural succession processes. Consequently, a holistic approach to urban forestry is needed in these localities to ensure that regenerating woodland areas provide accessible, attractive assets for local communities (Lohrberg 2011).

There is also scope for learning through sharing knowledge and experiences with projects from rural parts of the European continent. Landcare Trusts, for example, under the umbrella of the Deutsche Verband für Landschaftspflege (DVL) have become an established mechanism for managing cultural landscapes as partnerships between landscape conservation organisations, biological stations and individual landowners in recent years (Basora et al. 2013). In terms of general methodology and overall structure, there are some close synergies with the Scottish partnership approaches to GI implementation.

20.9 Conclusions

This chapter has introduced the role of the various stakeholders in the delivery of green infrastructure provision, particularly within the context of Third Sector participation. From the preceding discussion it is clear that the role and influence of the

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Sector varies considerably between European countries and regions. Generally, however, the Third Sector is of much greater significance for GI delivery within the Scottish (and general UK) context than in other countries, where traditionally the public sector has taken a more active role in the process of GI development.

This need not necessarily remain the case, however. In a climate of diminishing resources from central government, the Third Sector partnership model could become an established cost effective approach which could be successfully replicated in new geographical regions. Whilst partnership structures form a mechanism which is becoming increasingly significant for GI planning and delivery, there remain many unanswered questions which will require further detailed research and evaluation. These include the question of whether methodologies might be applied universally across different geographical and cultural contexts (e.g. rural to urban and across national boundaries).

In addition, GI partnership models successfully address "top-down" strategic approaches but leave questions as to how "bottom-up" action and citizen participation can best be integrated within these GI partnership structures. The role of spatial scale in terms of stakeholder composition is also a crucial question, since an entirely different series of actors will be required depending on whether a project involves working at a neighbourhood level or across a City-region.

It will also be necessary to consider how networking and knowledge-sharing can best be promoted, particularly within the Central, Southern and Eastern European context where GI activity is generally managed at the municipality or state level and without the same level of participation from national agencies as occurs in the UK.

We also need to consider just what measures, incentives and resources are required to encourage greater levels of Third Sector involvement and citizen participation. Finally, there is the more fundamental question as to whether Third Sector-based models are necessarily the most desirable or appropriate way forward in all situations.

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References

Anheier HK (2002) The third sector in Europe: five theses, Civil society working paper 12. http://eprints.lse.ac.uk/29051/1/CSWP12.pdf. Accessed 23 Dec 2015

Baerlocher B, Bernasconi A, Kern M, Mühlethaler U (2015) Sustainability and governance in urban forests. The Swiss case of neighbourwoods – SUNWoods – and its embedding in new ways of analysing urban woodland management. ICF proceeding paper In: Johnston M (ed) Trees, people and the built environment II. Urban trees research conference, University of Birmingham

Basora X, Mitchell B, O'Neill C, Sabaté X (2013) Caring together for nature, manual on land stewardship as a tool to promote social involvement with the natural environment in Europe, Landlife http://www.cenlr.org/sites/www.cenlr.org/files//users/Nathalie%20Hiessler/landlife/documents/European_manual_LS.pdf. Accessed 23 Dec 2015

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Bernasconi A, Gubsch M, Hasspacher B, Iseli R, Stillhard J (2014a) Präzisierung Basis-Indikatoren Nachhaltigkeitskontrolle Wald. Im Auftrag des Bundesamtes für Umwelt. 57 S

Bernasconi A, Brang P, Schneider O (2014b) Wie Waldfachleute die Nachhaltigkeit der Waldnutzung in der Schweiz einschätzen. Schweizerische Zeitschrift für Forstwesen 165(3):68–73

Black Country Urban Forestry Unit (1995) The black country urban forest – a strategy for its development

Burckhardt DI, Dietrich R, Hoffmann H, Leschner J, Lohmann K, Schoder F, Schultz A (2008) Urbane Wälder. In: Heft 63 der Schriftenreihe des Bundesamtes für Naturschutz. Bad Godesberg, Bonn

Croatian Parliament (2009) Zakon o izmjenama zakona o proglašenju zapadnog dijela Medvenice parkom prirode (Law on changes of law on establishment of nature park Medvednica). Narodne Novine 25/2009. http://narodne-novine.nn.hr/clanci/sluzbeni/2009_02_25_537.html. Accessed 22 July 2015

CSGN (2011) Bringing change to life, the vision. CSGN partnership board

European Commission (2013) Green Infrastructure (GI) (COM (2013) 249 final). http://eur-lex.europa.eu/LexUriServ/LexUriServ.do?uri=CELEX:52013 DC0249:EN:NOT. Accessed 23 Dec 2015

Gudurić I, Tomićević J, Konijnendijk CC (2011) A comparative perspective of urban forestry in Belgrade, Serbia and Freiburg, Germany. Urban Forestry & Urban Greening 10:335–342

H-ALTER (2010) Pravo na Beograd (Right to Beograd). http://h-alter.org/vijesti/pravo-na-beograd. Accessed 15 July 2015

Hansmann R, Mieg HA, Frischknecht P (2012) Principal sustainability components: empirical analysis of synergies between the three pillars of sustainability. International Journal of Sustainable Development and World Ecology 19(5):451–459

HM Government Cabinet Office (2010) The coalition: our programme for government. http://webarchive.nationalarchives.gov.uk/20100919110641/http://programmeforgovernment.hmg.gov.uk. Accessed 23 Dec 2015

Jones N, Collins K, Vaughan J, Benedikz T, Brosnan J (2005) The role of partnerships in urban forestry. In: Konijnendijk CD, Nilsson K, Randrup TB, Schipperijn J (eds) Urban forests and trees: a reference book. Springer, Berlin, pp 187–205

Konijnendijk C C, Ricard R M, Kenney A, Randrup T B (2006) Defining urban forestry – a comparative perspective of North America and Europe. In: Urban forestry & urban greening 4(3–4): 93–103. http://curis.ku.dk/ws/files/10982352/Konijnendijk_et_al_-_Defining_urban_forestry_-_a_comparative_perspective_of_North_America_and_Europe.pdf. Accessed 23 Dec 2015

Krajter Ostoić S, Konijnendijk van den Bosch C, Dijana Vuletić, Stevanov M, Živojinović I, Mutabdžija-Bećirović S, Lazarević J, Stojanova B, Blagojević D, Stojanovska M, Nevenić R, Pezdevšek Malovrh Š (2015) Citizen satisfaction with urban forests and green space: results from selected Southeast European cities. In: Urban forestry and urban greening (in press)

Krütli P, Stauffacher M, Pedolin D, Moser C, Scholz RW (2012) The process matters – fairness in repository siting for nuclear waste. Social Justice Research 25(1):79–101

Lockwood M (2010) Good governance for terrestrial protected areas: a framework, principles and performance outcomes. Journal of Environmental Management 91:754–766

Lohrberg F (2011) Wald als Qualität für Stadt: Ideen und Experimente. In: Machule & Usadel: Grün-Natur und Stadt-Struktur: Entwicklungstrategien bei der Planung und Gestaltung von städtischen Freiräumen. Societäts-Verlag. Frankfurt 2011, ISBN 978–3797312655. http://www.la.rwth-aachen.de/Forschung/PDF/wald%20als%20qualitaet.pdf. Accessed 23 Dec 2015

Lohrberg F, Timpe A (2005) Sich der Stadt zuwenden. In: ForstZeitung, Heft 10/2005. http://www.lohrberg.de/f-lohrberg-a-timpe-sich-der-stadt-zuwenden/. Accessed 23 Dec 2015

National Audit Office (2011) Successful commissioning toolkit, glossary of terms. https://www.nao.org.uk/successful-commissioning/glossary-of-terms/#T. Accessed 5 Jan 2016

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Pütz M, Schmid S, Bernasconi A, Wolf B (2015) Urban forestry: definition, trends und Folgerungen für die Waldakteure in der Schweiz. Schweiz. Z. Forstwes. 166(4):230–237

Radiosarajevo BA (2015) Novo okupljanje protiv uništavanja zelenih površina (New protest against devastation of green space). http://radiosarajevo.ba/novost/83686/novo-okupljanje-protiv-unistavanja-zelenih-povrsina. Accessed 16 July 2015

Scottish Government (2003) Local government in Scotland Act 2003 – guidance for community planning. http://www.scotland.gov.uk/Publications/2004/04/19168/35271. Accessed 24 Nov 2015

Scottish Government (2009a) National planning framework for Scotland 2, Scottish government, pp 126–127. http://www.scotland.gov.uk/Resource/Doc/278232/0083591.pdf. Accessed 21 Dec 2015

Scottish Government (2009b) The evidence base for third sector policy in Scotland: a review of selected recent literature. http://www.scotland.gov.uk/Resource/Doc/288502/0088238.pdf. Accessed 15 Dec 2015

Šimpraga S (2011) Zagreb, javni prostor (Zagreb, public space). Porfirogenet, Zagreb, pp 512

SROI Network (2012) A guide to social return on investment. http://socialvalueuk.org/what-is-sroi/the-sroi-guide. Accessed 15 Dec 2015

Stauffacher M, Krütli P, Flüeler T, Scholz RW (2012) Learning from the transdisciplinary case study approach: a functional-dynamic approach to collaboration among diverse actors in applied energy settings. In: Spreng DT, Flüeler TH, Goldblatt DL, Minsch J (eds) Tackling long-term global energy problems: the contribution of social sciences. Springer, Berlin, pp 227–245

Van Herzele A, Collins K, Tyrväinen L (2005) Involving people in urban forestry – a discussion of participatory practices throughout Europe. In: Konijnendijk CD, Nilsson K, Randrup TB, Schipperijn J (eds) Urban forests and trees: a reference book. Springer, Berlin, pp 207–225

Whitehead I (2009) Facilitating stakeholder participation in development of a forest habitat network within the Edinburgh and South East Scotland (SESPlan) strategic development plan area. In: Ecological networks: science and practice. Proceedings of the 16th IALE (UK) conference, Edinburgh University, 2009. http://iale.org.uk/node/71. Accessed 29 Nov 2015

Whitehead I (2012) Implementing the Central Scotland Green Network: developing best practice within the Edinburgh City Region. In: Implementation of landscape ecological knowledge in European urban practice, Bavarian Academy for Nature Conservation and Landscape Management (ANL). http://www.bestellen.bayern.de/application/applstarter?APPL=STMUG&DIR=stmug&ACTIONxSETVAL(artdtl.htm,APGxNODENR:1273,AARTxNR:anl_lsb_0098,USERxBODYURL:artdtl.htm,KATALOG:StMUG,AKATxNAME:StMUG,ALLE:x)=X. Accessed 10 Dec 2015

Zivojinovic I, Wolfslehner B (2015) Perceptions of urban forestry stakeholders on climate change adaptation – a Q-method application in Serbia. Urban Forestry and Urban Greening 14:1079–1087

Zvezdarska S (2015) Zaštitimo Zvezdarsku šumu. Punim plućima! http://zvezdarskasuma.blogspot.co.il/. Retrieved September 8th 2015

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Chapter 21
The Value of Valuing: Recognising the Benefits of the Urban Forest

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Nature's economy shall be the base for our own, for it is immutable, but ours is secondary. An economist without knowledge of nature is therefore like a physicist without knowledge of mathematics.

(Carl Linnaeus, in 'Linnaeus: Nature and Nation', as translated by Lisbet Koerner)

21.1 Introduction

The urban forest (UF) is made up of urban trees and other green infrastructure (GI). It plays a critical role in the planning, design and management of established and emerging urban areas. It provides extensive ecosystem services (ES), i.e. the green infrastructure services directly valued by humans (Costanza et al. 1997) which

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include environmental, socio-cultural, public health and economic benefits (MEA 2005).

There is an increasing interest in both the measurement of ES and in placing an economic value on the multiple benefits associated with GI. This momentum is triggered in part by the European Union Biodiversity Strategy's Target 2, which has determined that from 2020 onwards the following goals will be met:

- ecosystems and their services will be maintained and enhanced by including green infrastructure in spatial planning
- at least 15% of degraded ecosystems will be restored

One of the ways to meet these targets is defined in Action 5 of the Strategy, where member states are requested to:

- map and assess the state of ecosystems and their services by 2014
- assess the economic value of such services
- promote the recognition of their economic worth into accounting and reporting systems across Europe (European Commission 2011)

Economic valuation can be an important part of the management of the urban forest, helping to ensure that it is maintained, protected and enhanced (McPherson 2007; Sunderland et al. 2012). In particular, it is the economic valuation of UF and GI benefits which can most readily be incorporated into the planning and decision-making process, in order to prioritise different project proposals and justify the relative allocation of funds for urban greening.

This discussion is combined with an in-depth analysis of different valuation strategies, and a number of completed valuation case studies using various methodologies: Ribnjak Park in Zagreb, Croatia; the city of Barcelona, Spain; and Wirral Waters and Torbay, both in the UK. These examples offer the reader an accessible insight into the "value of valuing," and into ways in which anticipated outcomes can encourage a greater commitment to the cultivation of urban forests and related green infrastructure.

21.2 What Is Value?

The Oxford English dictionary describes value as *"The regard that something is held to deserve; the importance, worth, or usefulness of something."*

People create and judge value on the basis of their perceptions, education and culture, i.e. the prism through which they view the world. These values may be defined in the abstract, or quantified using instruments such as economic valuation methodologies. The economic value of a multi-faceted resource, such as the urban forest, can be considered equal to the net benefit which that system provides to society (Freeman et al. 1992).

Economists may try to ascribe a monetary value to trees and natural capital based on the many services or benefits they provide (both tangible and intangible),

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in order to encourage more informed decision making – whereas an artist may contemplate only what he or she considers to be the essential intangible qualities, conceptualising value in terms of cultural or spiritual importance in a more subjective way.

> *The tree which moves some to tears of joy is, in the eyes of others, only a green thing that stands in the way. Some see nature all ridicule and deformity...and some scarce see nature at all. But to the eyes of the man of imagination, nature is imagination itself.* (William Blake, Poet and painter)

21.3 Why Value Urban Trees?

The reasons for economic valuation are varied. They include:

- development of strategies for funding of urban trees
- demonstration of the benefits of urban trees and how much these represent in monetary terms
- development and evaluation of programmes for managing urban trees
- calculation of potential losses caused by pests and diseases
- protection of trees during construction
- calculation of claims for compensation when trees are cut down or pruned unlawfully

Economic valuation can also be used for assessing the cost-effectiveness of alternative investment and management options for increasing the extent of the UF. This can be done by juxtaposing the public demand for green areas on one hand, and the cost of the required investment for meeting that demand on the other. However, it should be recognised that economically-deprived communities are often located where the need for enhanced urban greening is greatest, and these same communities are often the least able to articulate the case for investment.

Economic appraisal can also be used to highlight the benefits lost by reducing the abundance and quality of urban green areas. This should improve policy-makers' understanding of current and long-term values which the urban forest and related GI bring to a city (Tyrväinen et al. 2003).

Valuing the primary components of an urban forest – its urban trees – can assist with a *best management practices* (BMP) approach to accommodating their essential needs. This can enhance the ES benefits afforded by the urban forest and related GI, which comprise a valuable source of *natural capital* (Hawken et al. 1999). This is indicated by several significant international policy documents (MEA 2005; TEEB 2010) and the foundations of IPBES (Intergovernmental Platform on Biodiversity and Ecosystem Services), ESP (Ecosystem Services Partnership), and DIVERSITAS (Integrating Biodiversity Science for Human Wellbeing).

People may object to putting an economic value on trees. However, in many instances the valuation is based on the services provided by the tree, and not the tree

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itself. It is important that practitioners understand exactly what is being valued, and how to articulate the results effectively to other stakeholders and decision-makers.

> *People in suburbia see trees differently than foresters do. They cherish every one. It is useless to speak of the probability that a certain tree will die when the treeis in someone's backyard You are talking about a personal asset, a friend, a monument, not about board feet of lumber.* (Roger Swain, Horticulturalist and Environmental TV presenter, USA)

Uncomfortable as the idea of 'putting a price tag on nature' may feel, there is an increasing *need* to establish and communicate the value and benefits of the urban forest and its network of trees and green-spaces, rather than just its costs. As the world becomes increasingly urban, land is at a premium and there is growing pressure to develop and capitalise on every square metre. It is therefore essential to be able to determine what the urban forest can provide in the way of human wellbeing. The ability to demonstrate its significance is informing the philosophy of ecosystem valuation (ESV) and is expanding the definition from mere monetary expressions to urban multifunctional landscape economics.

21.4 Economic Valuation: The Methodologies and Their Variables

Over the past 100 years, numerous economic valuation methodologies for trees have been developed (Cullen 2007) and reviewed (Watson 2002; Sarajevs 2011; Riera et al. 2012) so the concept is not new. Economic valuation is understood here as a process by which economic analysis is used to allocate a monetary value to a given entity (which may be a service or benefit, or an actual physical asset).

Clear objectives are important in helping to determine what exactly is going to be valued and which type of method should be used to value it. Because many ES typically have no market price, a measure of their value can only be obtained through "non-market" valuation techniques**.**

There are several methods for developing a fair and reasonable estimate of the value of individual and small groups of trees. These include "amenity tree" valuation methods (such as the *Helliwell System, CTLA, CAVAT* and *VAT03*), which place a monetary value on the visual amenity provided by individual trees and/or woodlands, and valuation toolkits centred on the income or benefit transfer approach, such as i-Tree Eco and GI-Val.

The *Helliwell System* was first advocated by Rodney Helliwell in 1967 (Helliwell 1967) and is endorsed by the Tree Council and the Arboricultural Association (UK). Details of the method were set out in the Arboricultural Association's 2008 Guidance Note 4: *Visual Amenity Valuation of Trees and Woodlands (the Helliwell System)*. The Helliwell method has been commonly used as the basis for compensation claims where trees have been lost or damaged.

The Council of Tree and Landscape Appraisers (*CTLA*) has developed a suite of assessment methods aimed at the determination of asset values and amenity values

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of trees. It is the most sophisticated in the extent to which it takes account of other published research and guidance, and has long been used in the USA.

Capital Asset Value for Amenity Trees (*CAVAT*) has been developed by Chris Neilan and the London Tree Officers Association. The published guidance (Neilan 2009) emphasises that the method can ‘only be used by arboriculturists who have received relevant training, and who have appropriate skills and experience’.

The *VAT03* method (Randrup 2005) is tailored particularly to the trees and climate of Denmark.

While the *CTLA* method uses a depreciated replacement cost (DRC) approach and is accredited by the Royal Institute of Chartered Surveyors (RICS) in the UK, *Helliwell* and *CAVAT* are more open to interpretation (Watson 2002). This is largely due to the visual assessment nature (and practitioner interpretation, thus potential bias and subjectivity) inherent in these latter systems. Moreover, *CAVAT*, in particular, is likely to lead to higher values than the two other methods reviewed here and has been criticised by some practitioners for not reflecting depreciation adequately. Similar approaches have also been adopted elsewhere in the world, for example *STEM* (Standard Tree Evaluation Method) in New Zealand, *Swiss-Modified* in Italy, *German method* in Germany and *Norma Granada* in Spain.

Conversely, the “ecosystem function-oriented” valuation toolkits (*i-Tree Eco* and *GI-Val*) tend to produce estimates from actual measurements of the tree structure and published environmental data, so are far less subjective and more readily comparable.

i-Tree Eco is an ecosystem services-based method, developed in the USA. It is designed to use field data derived from complete inventories of urban trees or randomly selected plots of trees, linked to a suite of published environmental data. It can generate data on a range of ecosystem services benefits and can also be used for planning future management of urban trees.

GI-Val is an Excel-based toolkit, developed in the UK. It identifies quantitative and qualitative data for 11 benefits derived from trees and also other GI elements such as grassland, green roofs and water bodies. Data for any green infrastructure intervention can be input to produce “gross value added” (GVA), property value and wider economic benefit information that can be used for a wide range of purposes. *GI-Val* uses ready published data and can source information from aerial photographs but it does not require detailed work in the field.

These toolkits are still fairly new in Europe and have higher levels of complexity. Despite this, they have been used to great effect and they have the advantage to local communities of being freely available. Furthermore, the ecosystem function-based approach allows for targeted studies, for example where the issue of air pollution may be more important in one geographical area and storm water attenuation in another. This has the advantage of being able to deliver key messages to different stakeholders in the urban forest.

De Groot et al. (2002) have provided a comprehensive and consistent overview of 23 functions, (goods and services) provided by natural and semi-natural ecosystems and have described their linkages with available valuation methods. Based on a synthesis study by Costanza et al. (1997), they explain that for each ecosystem

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function, several different valuation methods can usually be adopted, even if one or two methods are most commonly used. In particular, there seems to be a relationship between the main type of function and the preferred valuation method (Pascual and Muradian 2010; Mavsar et al. 2014; Hanley et al. 2001; Bateman et al. 2009): "regulation functions are mainly valued through indirect market valuation techniques (notably *avoided cost* and *replacement cost*), habitat functions mainly through direct market pricing (i.e. money donated for conservation purposes), production functions through direct market pricing and *factor income* methods, and information functions mainly through *contingent valuation* (cultural and spiritual information), *hedonic pricing* (aesthetic information) and *market pricing* (recreation, tourism and science)."

Commonalities, however, do exist in all economic valuation approaches. Cullen (2007) describes any valuation as having four basic characteristics:

- It is an estimate or expression of value
- It is a systematic process
- It is an aid to decision makers or an answer to a question
- It may be independent and impartial or an advocacy tool.

From the urban forest and natural capital perspective, the process of valuing has gone through a considerable evolution. Initially only single ecosystem services were valued, often in direct comparison with hard engineering solutions (e.g. protecting a watershed in comparison with building a water filtration plant). It has also been realised that some ecosystem services cannot be evaluated or can only be valued from an isolated perspective. The interconnectedness of environmental systems means that they usually deliver on more than one ES function; ecosystems are communities consisting of abiotic and biotic components, interacting in association. Given that understanding, it is critical to try to value the specific ecosystem, e.g. the urban forest, in its entirety.

> *That land is a community is the basic concept of ecology, but that land is to be loved and respected is an extension of ethics… We abuse land because we regard it as a commodity belonging to us. When we see land as a community to which we belong, we may begin to use it with love and respect.* (Aldo Leopold, Author, philosopher and environmentalist)

21.5 Case Studies

Four valuation case studies have been selected from across Europe. These have been chosen to illustrate different project types and the application of different valuation methodologies, as well as different outcomes and motivations for valuation. As part of the research for these case studies, the authors contacted professionals in a number of different countries with a simple questionnaire, the condensed responses of which are included in Fig. 21.1.

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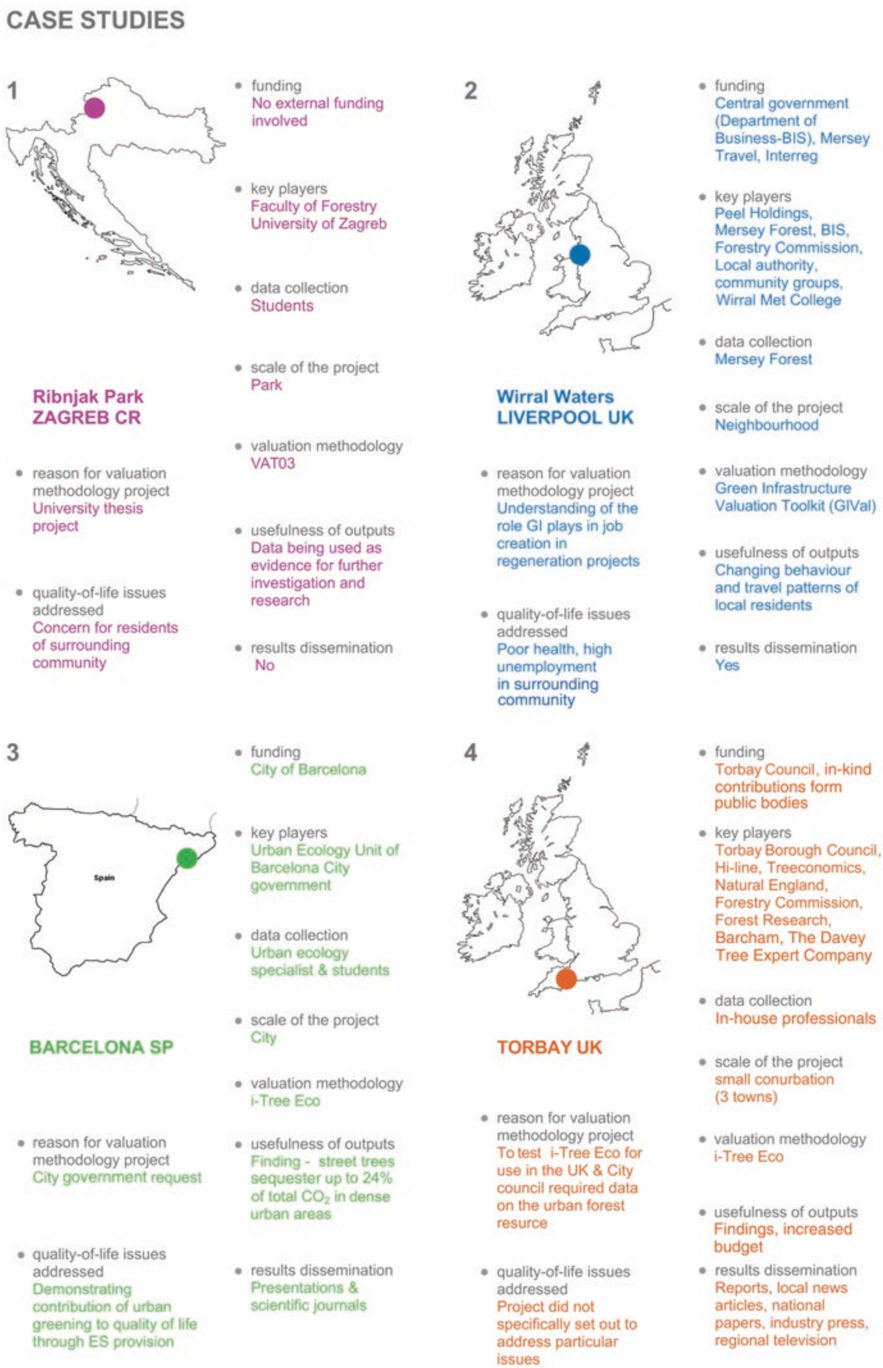

Fig. 21.1 Summary of the four valuation case studies (Source: Petar Vranic)

CASE STUDY 1
Typology: Research
Location: Ribnjak Park, Zagreb, Croatia (2015)
Scale: 4 hectare urban park
Valuation tool used: *VAT03*
The "value of valuing": Raising awareness through dissemination of results

Ribnjak Park is located in the old town of Croatia's capital, Zagreb. The 4 hectare park is surrounded by a busy road and tram route with heavy traffic, within an area of high population density. As a green area within the old town, the park is of considerable historical importance and is considered a valuable amenity by the local residents. There is an active children's playground and the park is popular with local dog walkers and also with tourists. Landscape architecture plans, which were prepared in 1946, are still intact today and include some modern Croatian sculptures (Fig. 21.2).

In the research, 20 randomly selected individual trees from all parts of the park were chosen, and the basic physical and aesthetic characteristics of the trees were measured or estimated. The value of all measured trees was then determined according to the *VAT03* method, on the basis of the following indicators: size, age, aesthetics, location, shape and other special features.

Plane trees were found to have the highest value among all the sampled species.

The case study was presented at the IUFRO Green conference 2014 in Zagreb and subsequently published in the SEEFOR Journal.

Bottom line: The average estimated amenity value of one tree in Ribnjak Park is €542, with a total value of €10,850 for all selected and measured trees.

Fig. 21.2 View of Ribnjak Park (Photo: Maria Beatrice Andreucci)

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CASE STUDY 2
Typology: Investment
Location: Wirral Waters, Liverpool City Region, United Kingdom (2015)
Scale: 220 hectare neighbourhood
Valuation tool used: *GI-Val*
The "value of valuing": Contributed to urban regeneration with €2.5 million of investment in green infrastructure; Post-occupancy health benefits evaluation; Improved image and perception of the neighbourhood; Potential investment partners identified

Wirral Waters is a long term, mixed-use regeneration project within the former dockland areas of Birkenhead in the Liverpool city region. This is a severely deprived neighbourhood, with particularly poor health and life expectancy statistics. Wirral Waters is one of the most extensive regeneration projects in the UK, covering 200 ha (Fig. 21.3).

The valuation project carried out an indicative economic assessment of the proposed improvements to the green infrastructure of the area using the *GI-Val* tool. The toolkit identified increased property value and job creation as the major wider economic benefits.

Having completed "phase one" of the green infrastructure improvements in 2015, post-occupancy evaluation showed that the new green routes had increased walking and cycling in the area significantly. This has a health benefit as people are more active, and also a pollution mitigation effect due to less car travel. Local residents also highlighted the improved image and perception of the neighbourhood.

The site developer has referred to "trees leading to jobs," claiming that green infrastructure interventions have been a significant factor in enabling the commercial development at Wirral Waters.

Bottom line: Contribution to gross value added (GVA) through increased profit, reduced costs, salary etc. of €14.3 m; Other economic benefits (health and pollution mitigation) €19.9 m.

Fig. 21.3 View of Wirral Waters (Source: Liverpool City Region – http://liverpoolcityregion.uk/)

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CASE STUDY 3
Typology: Research
Location: Barcelona, Spain (2009)
Scale: 101 km2 city
Valuation tool used: i-Tree Eco
The "value of valuing": Scientific contribution through publication of environmental benefits of economic valuation; Awareness; Model of governance

The scale of the study was determined by the Barcelona City Government and the *Centre de Recerca Ecològica i Aplicacions Forestals* (CREAF). The partners agreed to perform the study at the municipal (whole city) scale (Fig. 21.4).

The study area of 101 km^2 included Barcelona and the Collserola peri-urban forest, a total of 1,419,823 trees, covering 2535 hectares (25.2% of Barcelona's total area including Collserola). The whole area was classified into different land uses using aerial photography. Urban land uses were defined using the third edition of the Ecologic Map of Barcelona, which was adapted for the study by merging the 29 land uses into eight categories.

The study indicated that 200,000 new trees could be planted in Barcelona's UF and intensively used areas without buildings.

Bottom line: Barcelona's trees and shrubs were found to have filtered 305.6 tonnes of pollution[1] from the air. From an economic point of view, this service was valued at €1,115,908 a year. Trees were also estimated to sequester 5.422 tonnes of carbon, worth approximately € 412,000 a year.

Fig. 21.4 View of Barcelona (Photo: Maria Beatrice Andreucci)

[1] The pollutants measured for both Barcelona and Torbay with i-Tree Eco model are: PM-10, carbon monoxide, nitrogen dioxide, sulphur dioxide, and ozone.

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CASE STUDY 4
Typology: i-Tree Eco model testing
Location: Torbay, United Kingdom (2011)
Scale: 63.75 km2 small conurbation (Torbay is made up of the towns of Torquay, Paignton and Brixham)
Valuation tool used: i-Tree Eco
The "value of valuing": Economic valuation of environmental benefits, scientific contribution; Results dissemination; Model of governance; i-Tree testing led to a €32,000 increase in the tree planting budget in the year of study and again in 2013

The Borough of Torbay is a small coastal conurbation in the south-west of England. It covers 63.75 km^2 and includes both urban and rural areas (Fig. 21.5).

Set up in 2010, a public/private partnership was formed to pilot the *i-Tree Eco* model, using Torbay's urban forest resources to establish the UK benchmark for applying the system elsewhere. *Treeconomics* carried out the survey in the Borough of Torbay, working alongside Forest Research, Natural England and the Tree Officers at Torbay Council.

Torbay has approximately 11.8% forest cover made up of around 818,000 trees at a density of 128 trees/ha. Using collected field data, the i-Tree Eco model and existing scientific literature, the value of Torbay's urban forest was estimated. The study used a random sampling approach to the urban forest and measured 241 plots across the entire project area.

Bottom line: Torbay's trees represent an estimated structural asset worth over €333 million and provide €1,789,900 in ecosystem services annually. An estimated 98,100 tonnes (approximately 15.4 tonnes/ha) of carbon is stored in Torbay's trees, with an additional gross carbon sequestration rate of 4,279 tonnes carbon per year, (approximately 671 kg /ha/year). This equates to €6,076,400 in storage and €205,640 in annual sequestration. 50 tonnes of pollutants are removed every year, with an annual estimated value of €1,584,000.

Fig. 21.5 View of Torbay (Photo: Kenton Rogers)

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21.6 Discussion

The valuing process is an important one. Traditionally, open spaces and natural resources have been assessed subjectively, with a simple recognition that a healthy natural environment creates healthy human beings. With increasing urbanisation and disassociation from the natural environment, society needs a new way in which to be made aware of the importance of the urban forest and green infrastructure in our towns and cities. In a highly commercialised world where economic considerations are so central to decision making, that importance is currently best expressed using the language of monetary value.

By expressing in monetary terms the services and benefits provided by trees, practitioners, managers and community groups can offer quantitative evidence upon which decision-makers can base their investment choices for creating maintaining, or restoring green spaces. This in turn informs planners' land-use decisions, landscape architects' project designs, arborists' tree maintenance practices and urban foresters' management procedures and guidelines. Such evidence can be used to maintain current levels of investment in an historic park, to argue for increased or improved areas of green space in a new development, or for the adoption of an all-encompassing strategic overview – which too often is sorely lacking. Concrete examples of the ways that valuation-based evidence can be leveraged in the real world are shown in the four case studies presented here.

The **Ribnjak Park** study used the "amenity tree" valuation approach. Although this type of method does not take into account ecosystem services, it is more familiar to practitioners and relatively quick and easy to undertake. While such methods have been used successfully for compensation where trees have been damaged, and are part of a tree manager's toolbox, there are wider uncertainties posed by experts and researchers around what exactly the 'amenity' valuation is, e.g. structural value or replacement cost, when compared with the wider sphere of ecosystem services valuation. Although in 2015 the results had yet to be presented to the decision-making bodies in the City of Zagreb (being a doctoral research thesis), project collaborators were planning to use the study as an evidence base to support national and international funding. This would then be used to further research and disseminate information around the value of green spaces in the City of Zagreb.

The **Wirral Waters** case study fully expressed the idea of 'getting more from trees' and the *GI-Val* toolkit specifically identified relevant economic benefits. At a time when resources are limited, the stakeholders here appreciated the need to extract maximum return from the investment. The Wirral Waters Investment Fund (a Tax Increment Fund model) was established, with a direct benefit to the Enterprise Zone (EZ) where the project is located, because the local authority has been able to retain 100% of the income from new property taxes that come from new building projects in the EZ. A proportion of the fund has been allocated to 'Environmental Improvements' and GI. This has already ensured that tree planting and GI investments continue to grow.

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Using *i-Tree Eco*, the city of **Barcelona** has not only been able to assign monetary values for the environmental services of its urban forest, but also obtained detailed information on the urban forest structure. As with Wirral Waters, the study had educational (as well as management) value, as the starting point for other related investigations on ES provided by urban vegetation. The Barcelona information has demonstrated the need to modify the management of urban greening, to considerably increase the vegetation surface (through green roofs, green walls, etc.), to evaluate the suitability of selected species, to increase urban soil permeability and to establish systems that avoid invasive species proliferation in natural areas of the city. The Barcelona city government continues to work on these and other urban forest issues. Currently, further studies are being developed to evaluate the ecosystems services provided by historic gardens and parks, and also by the trees of two districts of Barcelona.

In **Torbay**, the *i-Tree* testing led to a €32,000 increase in the tree planting budget in the year of study and then again in 2013 when the data on urban forest structure was used to demonstrate the potential threat of *Chalara* dieback of ash *(Hymenoscyphus fraxineus).* The values presented in this study represent only a portion of the total value of the urban forest of Torbay because not all the benefits have been evaluated. Trees confer many other benefits, such as reduced energy costs for cooling and heating, visual amenity, human health, tourism, ecological benefits, and other provisioning and regulating services such as timber and natural hazard mitigation (De Groot et al. 2010) and these remain unquantified.

21.7 Lessons Learned

> *As guardians of the good earth, trees stand silent sentry over our planet, strengthening our soil, creating the air we breathe, enriching our lives with their natural splendor. When we protect and nurture our trees, we protect and nurture ourselves.* (Mario Cuomo, Governor, State of New York, 1993 official statement)

There is plenty of evidence that unless a resource such as a street tree, park or entire urban forest is measured then it is unlikely to be managed effectively. Similarly with valuation, if no value is calculated for a resource, service or object, then managers and practitioners have little option but to ascribe a purely nominal value to the asset or even to regard it as a liability.

As the world becomes increasingly urban, green space is needed to improve human health and wellbeing. As the tools and methods described within this chapter illustrate, the effective valuing of a resource is able to ascribe important monetary figures and therefore to facilitate cost-benefit analyses (CBA). It also helps in the achievement of a deeper understanding of the processes and services that natural systems provide. This will help in creating urban forests that deliver benefits where they are most needed.

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There are many reasons for adopting a valuing approach and a growing number of examples demonstrate this using different methods and scales. In summary, the principal lessons learned and messages from the authors are:

- ES valuation implementation and its resulting outputs offer valuable contributions to CBA that can provide decision-makers with support for increased urban forest and related GI funding and for a *best management practices* (BMP) approach to management strategies; evidence-based outputs can also be used to encourage public utilities to fund tree planting initiatives
- While none of the systems considered is able to comprehensively quantify biodiversity or socio/cultural benefits, quality-of-life value can be inferred
- As with other aspects of urban forestry management, the basis for ES data needs to be supported with a standardised, conceptual language. This will help to facilitate global research and sustainable decisions which can be shared more readily with academics, practitioners and other interested parties, thus offering further support for valuing for the resulting outcomes
- The process of expressing an economic value for ecosystem services generally provides opportunities for scientific observation and specific measurement. Practitioners and decision-makers alike should take advantage of the increased appreciation of the urban forest that this can provide
- Instrumental values, such as monetary costs, are fundamentally anthropocentric in nature and for that reason economic and ecological measures of value may at times conflict with one another
- A key goal of the economic valuation of ES functions is the development of consistent support from a very broad and growing membership of individuals and organisations which recognise the benefits and value of urban trees and green open spaces
- There is clearly no one single ‘correct’ set of concepts, methods or techniques to address the importance of economic valuation, and while scientific findings and practical projects break some new ground and address the economic valuation issues in interesting new ways, it is clear that much additional work still remains to be done

21.8 Conclusions

Within the European Union, the concept of multi-functionality is used to emphasise the many services which the urban forest and other green infrastructure provide (MEA 2005). As a result, the urban forest is valued less for the production of goods, and rather more in the context of natural resource protection, spaces for recreation and leisure, education and wellbeing, and cultural and heritage landscapes (i.e. ecosystem services).

The recently emerging “green infrastructure” approach is characterised by the recognition of the full range of economic, social, cultural and environmental

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functions and benefits. The economic implications, in particular, are increasingly focusing the attention of researchers, policy makers and practitioners on new perspectives which mirror the needs and claims of the growing population of urban dwellers.

Landscape architects, planners, and other practitioners have started to incorporate metrics and performance standards as an emerging part of best practice, mostly in North America and Europe, but also elsewhere in the world. Numerous theoretical and technical tools have been developed to understand different economic valuation aspects, adapting methodologies and designing new frameworks, especially in the emerging research area of the landscape economy.

Better understanding of economic values, associated with design and management strategies and practices, opportunity costs and ecosystem functions and services, enables decision makers to successfully engage in trade-off analysis and to identify the potential benefits and losses associated with specific urban landscape governance models.

As the extensive literature on ecosystem service valuation shows, each economic valuation method has its strengths and weaknesses and for each ecosystem function several valuation methods can usually be used in combination. For all types of ecosystem functions it is possible, in principle, to arrive at a monetary estimation of human preferences for the availability and maintenance of the related ecosystem services. However, ecosystem services values are context-specific, as the importance of an ecosystem (such as an urban forest) varies according to local conditions.

Economic valuation can have different types of uses: decisive, technical, or informative. In any case, it should be considered an important tool for integrated cost-benefit analysis and for balanced decision-making. Both of these are essential for the sustainable use and conservation of natural resources, and their many goods and services, in the built environment.

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Further Resources

The resources listed below provide links to the tools and projects.

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Tools

GI-Val – www.bit.ly/givaluationtoolkit
i-Tree – www.itreetools.org
AVAT – www.ltoa.org.uk/resources/cavat
Heliwell – www.trees.org.uk/Help-Advice/Public/What-is-the-Helliwell-system

Projects (including those reviewed but not included as case studies)

Barcelona –www.pdffiller.com/46886281-Ecological-Services-of-Urban-Forest-in-Barcelona-i-Tree-
Cost Action 45 – www.cost.eu/COST_Actions/fps/E45
Oakville – www.oakville.ca/residents/trees
Sidmouth Arboretum – http://www.sidmoutharboretum.org.uk
Torbay – www.treeconomics.co.uk/projects/torbays-urban-forest-assessing-urban-forest-effects-and-values
Wirral Waters – www.wirralwaters.co.uk

References

Bateman I, Brouwer R, Cranford M, Hime S, Ozdemiroglu E, Phang Z, Provins A (2009) Valuing environmental impacts: practical guidelines for the use of value transfer in policy and project appraisal. Value Transfer Guidelines. Eftec, London
Beljan K, Posavec S, Jerčić K (2015) Economic valuation of urban trees: Ribnjak Park case study, Zagreb. SEEFOR (South-east European forestry) 6(1):119–127
Chaparro L, Terradas J (2009) Ecological services of urban forest in Barcelona. Institut Municipal de Parcs i Jardins Ajuntament de Barcelona, Àrea de Medi Ambient
Costanza R, d'Arge R, De Groot R, Farber S, Grasso M, Hannon B, Limburg K, Naeem S, O'Neill RV, Paruelo J (1997) The value of the world's ecosystem services and natural capital. Ecol Econ 25(1):3–15
Cullen S (2007) Putting a value on trees—CTLA guidance and methods. Arbitr J 30(1):21–43. doi:10.1080/03071375.2007.9747475
De Groot RS, Wilson MA, Boumans RM (2002) A typology for the classification, description and valuation of ecosystem functions, goods and services. Ecol Econ 41(3):393–408
De Groot RS, Alkemade R, Braat L, Hein L, Willemen L (2010) Challenges in integrating the concept of ecosystem services and values in landscape planning, management and decision making. Ecol Complex 7(3):260–272
European Commission (2011) Our life insurance, our natural capital: an EU Biodiversity Strategy to 2020. Compr Ther 2011:244
Freeman AM, Camino V, Boucher F, Ehrlich P, Ehrlich A, Pachauri R, Brockett CD, Cornia G, Jolly R, Stewart F (1992) The measurement of environmental and resource values: theory and methods, vol GTZ-1574. Resources for the Future, Washington, DC
Hanley N, Shogren JF, White B (2001) Introduction to environmental economics. Oxford University Press, New York

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Hawken P, Lovins AB, Lovins LH (1999) Natural capitalism: the next industrial revolution. Earthscan, New York

Helliwell D (1967) The amenity value of trees and woodlands. Arboricult Assoc J 1(5):128–131

Mavsar R, Herreros F, Varela E, Fabrice G (2014) Methods and tools for socio-economic assessment of goods and services provided by Mediterranean forest ecosystems. Optimising the production of goods and services by Mediterranean forests in a context of global changes. EFIMED, CTFC, Barcelona

McPherson EG (2007) Benefit-based tree valuation. Arboricult Urban For 33(1):1–11

MEA (2005) Ecosystems and human well-being, vol 5. Island Press, Washington, DC

Neilan C (2009) CAVAT (capital asset value for amenity trees) full method: user's guide. London Tree Officers' Association, London

Pascual U, Muradian R (2010) The economics of valuing ecosystem services and biodiversity. In: Sukhdev P (ed) The economics of ecosystems and biodiversity: ecological and economic foundations. Earthscan, London, pp 1–133

Randrup TB (2005) Development of a Danish model for plant appraisal. J Arboric 31(3):114–123

Riera P, Signorello G, Thiene M, Mahieu P-A, Navrud S, Kaval P, Rulleau B, Mavsar R, Madureira L, Meyerhoff J, Elsasser P, Notaro S, De Salvo M, Giergiczny M, Dragoi S (2012) Non-market valuation of forest goods and services: good practice guidelines. J For Eco 18(4):259–270. doi:10.1016/j.jfe.2012.07.001

Sarajevs V (2011) Street tree valuation systems. Forestry Commission, Roslin

Sunderland T, Rogers K, Coish N (2012) What proportion of the costs of urban trees can be justified by the carbon sequestration and air-quality benefits they provide? Arbitr J 34(2):62–82. doi:10.1080/03071375.2012.701416

TEEB (2010) The economics of ecosystems and biodiversity: mainstreaming the economics of nature: a synthesis of the approach, conclusions and recommendations of TEEB. UNEP/Earthprint, London/Washington, DC

Tyrväinen L, Silvennoinen H, Kolehmainen O (2003) Ecological and aesthetic values in urban forest management. Urban For Urban Green 1(3):135–149

Watson G (2002) Comparing formula methods of tree appraisal. J Arboric 28(1):11–18

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Part IV
Summary

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Chapter 22
Tying It All Together

Rocío Alonso del Amo and Giovanni Sanesi

In a dynamic environmental, economic and social context characterized by progressive urbanization and the growing effects of global climate change, the planning and management of urban green infrastructure play a crucial role in maintaining liveable cities. Urban forests form the backbone of a city's green infrastructure, and together with other natural components of the urban environment, they provide Ecosystem Services (ES) that are essential to the local population.

Any plan for Urban Forestry and Green Infrastructure needs to define clear goals, that aim to improve the quality of the services delivered and consider how these objectives can be achieved in practice. Goals such as urban heat island mitigation, reduction of air pollutants, or mediation of storm water can be effectively achieved through an increase in tree canopy cover, green spaces and pervious surfaces. These indicators, as well as the accessibility of green spaces, are now commonly used criteria in urban planning. The actual planning of a city's green network, however, takes place at a number of very different scales: at a strategic level, it may cover the entire metropolitan area or city-region, and at a more 'operational' level it will focus on individual urban districts and green spaces. In the case of a streetscape, for example, planning can be articulated at the level of individual trees, considering their maintenance or replacement within the context of the larger strategic plan – and always considering the recommendations of practitioners.

The development of such plans requires a broad range of skills, and a multidisciplinary approach – as well as a series of connections and synergies with other plans that normally exist at the urban scale, relating to such things as mobility, waste

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management, water resources, energy supply, or the prevention of soil sealing. As Ugolini et al. (2015) recently wrote, "The establishment and management of green infrastructure in cities require the involvement of a complex network of stakeholder groups, who may differ sharply from one another in their expectations and approaches. Bridging the communication gaps between them is essential for creating and maintaining urban green spaces and expressing their full potential and multi-functionality."

From this perspective, the involvement of active citizens and the third sector at different stages of planning and maintenance is crucial. Public participation is essential throughout the governance process, and its effectiveness relies on robust education and training programs. The participation of citizens in the planning process almost inevitably means a more vigorous promotion of local landscape features, more affection for single trees, and better use of green areas – which all lead to measurable health and social benefits. While the role of trees in cities is increasingly promoted by the European Community and individual member states, it is not sufficiently understood by urban planners and the general public. In this lies the importance of the message that has been emphasized throughout the chapters of this book – that the environmental, social and economic benefits provided by urban trees are an expression of tangible value.

This final section ties together these diverse aspects of the value provided by urban forests and green infrastructure. The first chapter takes a broad view of the ecosystem services that these resources provide, and considers the linkages between the different ways that they benefit people and the environment. Finally, the second chapter concludes by providing a practitioner's perspective on how these valuable services can be best delivered in practice.

Reference

Ugolini F, Massetti L, Sanesi G, Pearlmutter D (2015) Knowledge transfer between stakeholders in the field of urban forestry and green infrastructure: results of a European survey. Land Use Policy 49:365–381

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Chapter 23
Linking the Environmental, Social and Economic Aspects of Urban Forestry and Green Infrastructure

Nerys Jones and Clive Davies

23.1 Introduction

Green infrastructure planning has become a pre-eminent vehicle for discussion and delivery of strategic green space management, especially in urban areas. However, "green infrastructure" is a contested term, with definitions varying among different stakeholders, countries and continents. Nevertheless, there are a number of common themes – including *connectivity*, *multifunctionality* and the delivery and continuing maintenance of *ecosystem services*. The "urban forest" – meaning all the trees within and around urban areas, whether individually, in groups or in woodlands – forms a key part of this green infrastructure in cities. This chapter explores the relationship between the urban forest and green infrastructure, and analyses some of the links between the environmental, social and economic benefits that they generate.

23.2 The Complexity of the Urban Forest

The typology of green infrastructure is varied, but it generally consists of significantly more than the tree and woodland domain alone. For example, in some urban areas the water environment is especially important, whilst in others grasslands and

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parks will dominate. Nevertheless, the tree and shrub cover of an area is highly likely to be a significant element of green infrastructure in almost all situations. It is especially important when planning for green infrastructure to remember that the whole is greater than the sum of the parts. For this reason, green infrastructure and urban forests can be particularly effective when considered at a strategic scale.

An implication of this strategic approach is that green infrastructure should be embedded in a hierarchy of planning policies and documents. This is particularly the case in instances where there are multiple planning levels, such as the district, city or metropolitan region level. For instance, at a local level it may be considered at street scale or in neighbourhood master-planning. At a metropolitan level, it may be considered at the urban river catchment scale or as the spatial framework for natural shelter and air quality improvement. It is important to ensure that policy links are forged from the very local through to the regional scale and consequently that green infrastructure strategies are 'nested' through all the planning documents at all these levels if the strategic benefits of green infrastructure are to be fully realised.

This hierarchal approach is highly advantageous when considering the tree and woodland domain of green infrastructure. In a densely built central business district it is likely that individual trees will dominate, whereas in the urban periphery community woodland, wooded corridors and trees in domestic gardens may well be present, and further out, extensive forests will be located in the peri-urban area. These peri-urban forests may well be managed principally as ecological or commercial enterprises, but because of their location, they are almost always a major resource for recreation as well.

One aspect of urban forestry that is especially pertinent to the green infrastructure approach is to consider all of the trees in an urban area collectively. Urban trees and shrubs will exist in a variety of settings such as woodlands, parklands, roadsides, gardens and nature areas. All too often these urban trees tend to be considered individually – but the essence of the holistic approach is to consider them as a "canopy" across the urban area. A given urban area will almost certainly have some districts where the canopy appears closed and others where there are notable gaps. Green infrastructure planning can assist urban forestry by seeking to infill those areas of the urban canopy which are relatively short of trees.

The preparation of green infrastructure strategies also presents an opportunity to embed urban forestry into wider municipal planning. This is especially so in urban areas where tree cover is historically low and where, as a consequence, urban forestry may have been overlooked. Where urban tree cover is already high, the woodland and tree domain may be the major typology of local green infrastructure. In this situation trees and woodlands deliver a wide spectrum of ecosystem services. It is important to ensure that this is recognised in local green infrastructure planning documents. A key element for incorporating urban forestry in green infrastructure strategies is for municipalities to ensure that relevant professionals such as tree officers, arborists, landscape architects and foresters are included in the work teams appointed to prepare such strategies. If these professions are poorly represented

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locally then it is likely that urban forestry will be undervalued in terms of its contribution to local green infrastructure. If there are no urban forestry professionals operating in the area, then this is a role that could be performed by a suitably experienced volunteer, by a community organisation, or by an independent consultant appointed to act as an urban forest advocate.

The European Commission has emphasised a broad range of challenges facing society: unsustainable urbanisation and a related decline in human health, the degradation and loss of natural capital and ecosystem services (clean air, water and soil), and climate change – including an alarming increase in the scale and frequency of extreme weather and natural disasters (www.ec.europa.eu/research/environment/index.cfm?pg=nbs). The EC has also promoted a growing awareness that nature can help provide viable solutions to these challenges if the properties of natural ecosystems are deployed in a 'smart' way. Such "nature-based solutions" (NBS) are designed to bring more natural features and processes into cities, and at the same time support economic growth, create jobs and enhance human health and well-being.

Green infrastructure is a significant deliverer of nature-based solutions. This applies to trees and woodlands in particular. For example, it has long been known that urban trees can help reduce air pollution by intercepting microscopic particulates arising from fuel combustion in the built environment. Trees also provide notable cooling in urban districts that are at risk from excessively high temperatures. In some cases, non-tree elements of green infrastructure such as green roofs, swales and rainwater retention wetlands can deliver nature-based solutions more rapidly than trees. However, they tend to require a high level of maintenance and they may need regular renewal. In contrast, while the creation of a functioning urban tree canopy may take much longer to achieve, it is likely to last for generations. Because of its scale it also has a more readily appreciated visual impact on the image of a city.

Whilst many of the obvious elements of green infrastructure such as public parks, nature areas and tree-lined streets are largely in the public domain, it is generally the case that a great deal of an urban area's green infrastructure is to be found on privately owned land. In European cities a notable quantity of urban green infrastructure is incorporated into gardens surrounding private dwellings spread across large residential districts (Fig. 23.1). Planning for green infrastructure on private land poses a number of challenges. For example, planning systems generally do not extend to the management of private land except for permissions for new buildings and, in some countries, the legal protection of individual trees. Hence this element of green infrastructure planning has to be essentially voluntary. It may be helpful to provide encouragement and incentives to private landowners to manage their land in a way that is complementary to the management of land in public ownership. One way to achieve this is to enable partner organisations in the voluntary sector to perform a role as green infrastructure advocates. Voluntary organisations are able to engage with communities and residents without the constraints that local municipalities sometimes experience. Historically, two aspects of green infrastructure that

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Fig. 23.1 Domestic gardens and street trees are important elements of green infrastructure (Photo: Andrew Holt)

have been popular for public participation are the planting of new trees and the monitoring of tree health. For this reason, urban forestry is highly suited as a theme to motivate public participation.

23.3 Benefits and Disadvantages

The urban forest can deliver many ecosystem services across all of the four commonly understood service areas (i.e. regulating, supporting, provisioning and cultural). For example, the tree canopy's function in reducing storm water run-off is a regulating function, as is the role of wooded areas such as parklands in providing cool zones within hot cities during high temperature events. Fallen leaves form a key part of nutrient cycling in urban areas, allotments and domestic gardens provide a source of seasonal food and urban woodlands can provide a source of renewable fuel. Wooded urban environments also strongly function as cultural destinations for recreation, for ecotourism and as event spaces. Indeed, perhaps the most common cultural event of each winter season in Europe is the decoration of trees – now associated with the Christian calendar, but strongly based on ancient pre-Christian traditions.

Although the benefits of trees in urban areas significantly outweigh any problems that they may cause, it is important to recognise the potential disadvantages. Most disadvantages are locationally driven, meaning that they may be a disadvantage in one situation but an advantage in another. For example:

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- Leaf fall on unsealed surfaces is important for nutrient cycling as fungi and invertebrates break down the fallen leaves and return the nutrients to urban soils. However, leaf fall on sealed surfaces can lead to slipping hazards and blocked drains which can cost municipalities large sums in street sweeping. It can also disrupt rail travel.
- Trees and shrubs trap air-borne particulates that are produced by the combustion of fossil fuels and that are harmful to health. However, trees also generate unhealthy volatile organic compounds (VOCs) and their pollen can cause allergic reactions.
- Tree lined, traffic-free routes encourage people to walk and cycle. This has notable health benefits but, if not properly managed and patrolled, such areas may also encourage anti-social behaviour.

A critical feature of green infrastructure, including the urban forest component, is the overlap of environmental, social, health and economic benefits. This is a powerful argument in favour of green infrastructure. The creation of new assets and the management of existing ones can often meet several policy goals simultaneously. This is much more the case than with grey infrastructure interventions. In a local neighbourhood, green infrastructure will usually be responsible for the following:

- Providing environmental benefits such as flood risk management, shade and shelter, and enhanced local biodiversity
- Facilitating social benefits such as the provision of spaces for people to meet and communicate, destinations for exercise and learning, and facilities for recreation and informal sports
- Enabling economic benefits such as improved labour productivity due to green views and improved thermal comfort, enhanced property values, reduced vacancy times and higher rents.

In the past, investment in green infrastructure has often been made for a combination of purposes. For example, many urban parks were created in the nineteenth century to enhance the value of neighbouring land and property and they also became a focus for civic pride (Fig. 23.2). In addition, they offered safe green spaces with clean air where working people could relax, take exercise and improve their health. In some industrial cities, whole forests were purchased for these purposes. Allotment and leisure gardens have always existed to produce food, but they can also be rich in wildlife, a source of quiet contemplation and a stimulus to good mental health. Future investments in green infrastructure may be justified on additional grounds. For example, as climate change negatively impacts on urban resilience, cities become denser and the social divide increases. Green infrastructure can be used to moderate the impact and to create new democratic spaces where all sections of urban society can feel comfortable and meet on equal terms.

The benefits of urban forests and green infrastructure are increasingly understood, and many scientific publications provide clear evidence of this. However, in public policy there is a notable discontinuity between 'who pays' and 'who benefits'. This is perhaps best illustrated with respect to public health. Access to local

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Fig. 23.2 Many urban areas have a legacy of earlier greening projects. Mature city parks were created by people with great long-term vision (Photo: Nerys Jones)

green infrastructure is a major beneficial contributor to public health, and the impact of this on health care costs can be very positive. Despite this, budgets for the creation and management of green infrastructure and urban forests are extremely small in comparison with those for healthcare, and they are normally located within planning or recreation departments. It would be far better if resources for urban forestry and green infrastructure could be linked directly to public and private health provision.

23.4 Dynamism of the Urban Environment

Most urban areas are in a constant state of flux. Land uses change, and there is always pressure to replace "unproductive" open spaces with new built development, transport infrastructure etc. The greatest challenge is to establish a green infrastructure strategy that is robust enough to cope with such pressures. When the green infrastructure framework is physically strong it can accommodate the constantly changing land uses around it and this in turn will provide long-term environmental continuity as an effective aid to sustainable urban living.

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Fig. 23.3 Even in the most densely built urban areas there are opportunities to invest in green infrastructure. Green walls and green roofs can make valuable contributions (Photo: Maria-Beatrice Andreucci)

The trend in almost every urban area is towards ever greater densification. This makes the complementary role of greenspace increasingly important, but it also makes the competition for land use within towns and cities ever more intense (Fig. 23.3). Whilst official green spaces such as parks, public gardens and sports fields may be well protected, green infrastructure is also heavily dependent on domestic gardens, educational campuses, transport corridors, commercial estates, hospital grounds and many other categories of land use. The greatest biodiversity is frequently to be found on naturally re-colonised post-industrial sites which have been neglected ahead of future building. Development pressure puts all of these "unofficial" elements of the greenspace network at particular risk, since their vegetation is rarely protected by legislation.

There is wide-scale evidence of domestic gardens in residential neighbourhoods being lost to more intensive built development. There are more subtle changes too. In rapidly regenerating modern cities, there is a tendency for long-abandoned industrial land, with its naturally regenerated wildspace, to be made "respectable" through conversion to relatively sterile public parks and sports facilities. This may maintain a green presence in the city, but it is likely to reduce biodiversity and the rhythms of seasonal change very considerably. Urban renewal may also threaten existing green

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infrastructure as services such as public transportation and water and power supplies are upgraded or increased.

Urban renewal can also provide opportunities for increasing green infrastructure, and there is now a far greater commitment to the installation of green roofs, green walls and a more naturalistic approach to storm water storage and dispersal. These relatively modern interventions have the advantage of delivering green outcomes within a short space of time – but they can have a high entry cost and a relatively short lifespan, whereas urban forests have a comparatively long lead time, low long-term cost and long lifespan. Both are important, particularly since loss of unofficial green habitat is an all too familiar feature of economically vibrant towns and cities.

23.5 Governance

With increasing urbanisation there is more pressure than ever to justify land use in terms of employment and wealth creation. The future prospects for urban greenspace will depend upon the ability to make a convincing case for its economic value as well as the contribution it makes to the appearance of a place and the health and well-being of those who live and work there.

Unfortunately, the benefits derived from much green infrastructure can be difficult to quantify and they may take years to materialise. New trees and woods can take at least a generation before they make a large-scale contribution, and the decision-making processes in urban areas are predominantly short term. It may be true that some elements of green infrastructure such as wetlands, species-rich grasslands and food crops can deliver tangible results within a single political cycle, but the truly structural elements of green infrastructure need to be justifiable over several decades. In the great towns and cities that were shaped in the nineteenth and twentieth centuries there are many examples where policy making was based on a long-term vision. Most of the great city parks were designed and financed by people who would never see their plans grow to maturity.

There are some modern examples of such long-term commitment to substantial green infrastructure. The Emscher Landscape Park that now covers an area of 450 km^2 of the post-industrial Ruhr area in Germany is one particularly bold example. The flooding of the worked out coal pits around Leipzig is another, and the re-wilding of the Thames Estuary east of London is a third. On a smaller scale, the developers of retirement housing seem able to market the idea of a long-term commitment to well managed greenspace close to home. Prestigious gated communities also seem to recognise the added value that comes from greenspace. However, these latter examples often have the disadvantage of excluding the wider public.

Long-term success tends to be built on an optimistic vision of the future, combined with the ability to seize opportunities and to adapt to changes in political and economic circumstances. Ironically, the laudable efforts to engage the wider public in decision-making and to encourage their commitment to urban greenspace can

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yield mixed results. Popular support undoubtedly unlocks resources and strengthens political commitment. However, the move toward greater involvement and more democratic decision-making can also lead to more localised ambitions and to greater difficulty in achieving strategic success over the longer term and the wider landscape. In the end, enthusiastic public participation needs to be complemented by a well-articulated vision, strategic planning and persuasive leadership.

23.6 Conclusion

The benefits of green infrastructure are many and various. However, multifunctionality does not fit comfortably with the compartmentalised structure of most urban administrations, with short term political cycles or with the protectionist approach to individual public and private sector budgets. In order to achieve full integration and long term success for urban forestry and green infrastructure, there will have to be a far greater awareness of their potential and a shared commitment to their sustainable delivery. Promoting good practice and celebrating inspirational case studies will surely help.

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Chapter 24
Growing the Urban Forest: Our Practitioners' Perspective

Naomi Zürcher and Maria-Beatrice Andreucci

The materials of city planning are:
sky, space, trees, steel, and cement;
in that order and that hierarchy.

– Le Corbusier

In a natural forest, trees and their traditional forest associates – the living soil ecosystem as well as other flora and fauna – exist in communities – dynamic systems of mutual dependence and accommodation among the community's members.

Enter the Urban Forest – primarily consisting of urban trees and related green infrastructure (GI), but with few of the traditional community members and one very new and very dynamic associate – us.

The availability of valuation research tools combined with the pressures of urbanization and climate change have promoted an awareness of the multi-faceted value of Urban Forests. As with all valued resources, the Urban Forest and related GI require a clear, well-defined, working toolbox of Best Management Standards, Protocols and Practices that can effectively manage the urban tree and its associates.

The preceding book chapters have defined the resource and its traits, reviewed the environmental services and socio-cultural benefits provided, and surveyed and analyzed the governance practices, policies and economic valuation methodologies that would drive planning, implementation and management.

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Delivering the "goods" – those cost-effective, invaluable ecosystem services (ES) that the Urban Forest and related GI provide – requires the animation of these definitions, reviews, surveys and analyses. At the end of the day, it falls to urban planners, landscape architects, urban foresters and arborists – practitioners with an interdisciplinary grasp of urban forestry – to digest the scientific research findings and invest them in an Urban Forest Strategic Plan – a set of Best Management Practices (BMPs) based on policies, standards and tools that link planning, design, management and maintenance of the Urban Forest and related GI to maximize the health and well-being of the resource and all its associates.

Maria Beatrice Andreucci, Landscape Architect (LA), and Naomi Zurcher, Consulting Arborist/Urban Forester (CA/UF), present to you our Practitioners' perspective on how best to GROW a healthy Urban Forest that can "deliver those goods".

24.1 Environmental Services of Urban Forests

24.1.1 What Are Ecosystem Services?

CA/UF Defining what the Urban Forest can deliver, and how, requires a comprehensive understanding of its needs – that is, how the essential requirements of urban trees and their associates can be accommodated within an urban setting.

European countries that still retain extensive areas of traditional forest often believe these forested tracts will adequately address the ever-increasing environmental stresses urbanization is creating. Research paints a very different picture. While contiguous traditional forest is critical to our planet's environmental well-being, urban areas are a primary source of concentrated air and water pollution and these pollutants must be addressed at the source.

Whether the "deliverable" ES focus is environmental, health-related, economic, or socio-cultural, urban trees can only provide these important benefits if their basic, critical needs are attended to. Ecosystem services are canopy- and trunk-centric. The numerous ecosystem functions that urban trees can perform require a healthy crown that is free of pathogens, a trunk that is not affected by fungal diseases and an adequate, accessible soil volume for a viable root system, enabling the tree to mature and thrive. All too often, the planning and design aspect of management overlooks the fact that there is more to the tree than what is above ground. It is, in fact, the health of that landscape underground – the tree's root zone and the related below ground environment – that must be considered.

LA The provision of environmental services of urban forests should not be assessed only in relation to urban open spaces but also through biodiversity-related project design and implementation, integrated with buildings and other urban artificial architectures (e.g. vegetated roofs, green walls, and other integrated 'bio-devices').

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The specific contribution of those nature-based solutions to the provision of environmental services is still mostly unexplored in landscape architecture and urban design professional practice. UF and UGI configure spaces of constant evolution, specialized transition and dynamic change – "continuously evolving projects" challenging landscape architects' skills and applications.

The presence (and often dominance) of biotic components in the urban landscape design project requires higher awareness, sensitivity and "vision" from the landscape architect (LA).

24.1.2 Urban Heat Islands and Thermal Stress

CA/UF An increased focus on the landscape underground would include expanded areas of permeable surface and a tree-appropriate volume of accessible soil – strategies that grow a larger, healthier canopy, directly increasing shade and transpiration and thus reducing the urban heat island effect (UHI). Trees that do not have adequate growing conditions will not produce the healthy canopy UHI reduction relies on. Therefore, appropriate planning, design and management strategies must be implemented to increase natural permeable surfaces – specifically, open accessible soil volume. A viable strategy for curbside urban trees has been the elimination of the ubiquitous "tree pit" and the establishment of tree lawns, interrupted intermittently with smooth Belgian block pavers to facilitate pedestrian passage. Covering the open soil surrounding such plantings with an organic wood chip mulch can simulate the organic horizon found in a forest setting and help preserve soil moisture content – which enhances trees' water uptake and evapotranspiration and potentially reduces ambient temperatures.

City park construction should favor permeable surfaces over hardscape, as the extent of this permeable treed area has a decisive influence on a park's heat-mitigating potential for surrounding communities. In cities with a high UHI intensity, an assessment of existing healthy canopy cover and a focus on increasing that cover would be a prudent, cost-effective mitigation strategy. It is critical, though, that the placement of urban trees in relation to buildings and roads be well planned, giving careful consideration to air flow and air mixing resulting in reduced air temperature.

New building permitting strategies should include incentives to build with green roofs and green walls. When combined with an increase in canopy cover and natural permeable surfaces, a consequential overall reduction in UHI can be realized.

LA The progressive replacement of natural groundcovers by built surfaces due to uncontrolled urbanization, together with anthropogenic heat and insensitive open space design, constitutes the main cause of UHI formation with its consequent heat-related risks, especially for vulnerable populations.

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It is well-known that permeable surfaces such as moisture-trapping soil, along with urban trees and other vegetation, utilize a relatively large proportion of the absorbed radiation in the evapotranspiration process, releasing water vapor and lowering air temperature in their proximity. The decrease and fragmentation of large vegetated urban areas not only reduces these benefits, but also inhibits the positive atmospheric cooling due to horizontal air circulation generated by the temperature gradient between vegetated and urbanized areas (i.e. advection), which is known as the "Park Cool Island" (PCI) effect.

Among the strategies that landscape architects can effectively leverage for UHI reduction is the increase in vegetation cover, mainly in the form of urban forests and other GI. Tree canopy is of capital importance, intercepting radiation and producing shade that also contributes to reduced urban heat release. UFs maximize the multiple ecosystem benefits in controlling the temperature rises, and, together with increased surface reflectivity (i.e. higher albedo), they can significantly reduce the absorption of incident radiation compared to exposed urban areas with non-reflective and water-resistant construction materials.

24.1.3 Air Pollution

CA/UF ES deliverables can be enhanced by applying species-specific ES attributes in developing an informed and appropriate urban tree planting plan, design and management strategy, e.g. trees emitting high VOC's should not be used to create an allée over a heavily trafficked road, and trees with extremely dense canopies should not be planted adjacent to heavily trafficked roads since such canopies reduce air flow and drive pollutants downward to pedestrian levels.

In addition to the use of species-specific ES capabilities, a tree's ability to tolerate the urban conditions into which it will be planted must be the first selection consideration, e.g. many coniferous species are able to mitigate pollution year round but they have a relatively low tolerance of abiotic urban stress, resulting in long term survival issues. Additionally, current infestation or disease epidemics must be considered as well – for example, *Fraxinus* species are viable urban trees but are hosts for Asian Longhorned Beetle, Emerald Ash Borer and Chalara Dieback of Ash.

Cities play host to a great deal of unobserved wildlife, some of which is critical to human well-being. There has been extensive research on the present pollinator debacle. Declines in pollinator populations are a threat to life as we know it. Given that cities host a diverse range of pollinators, from native bees to flies to butterflies, it is important to consider the value of planting flowering urban trees for their pollinator forage services in addition to their potential allergenic disservices. Managing urban trees is a constant balancing between costs and benefits and an informed awareness of all attributes, be they services or disservices, is an essential ingredient in planning and maintaining a healthy Urban Forest.

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LA Worldwide, cities consume more than 75% of the world's energy and are responsible for 80% of global greenhouse gas emissions and pollution. Poor air quality is leading to an explosion of asthma cases and other health problems among vulnerable populations including children, the elderly, and low-income residents. According to the World Health Organization, each year bad air causes two million deaths worldwide.

Effective policies to reduce carbon emissions have so far developed slowly, and landscape architects should try to re-imagine their projects as active solutions to polluting, energivorous, and soil consumption-driven processes, promoting more resilient and adaptive designed ecologies – like UF –that also encourage active participation and conscious learning processes by the people.

By understanding the UF as a multiple-use urban landscape type, LAs can simultaneously drive sustainable urban development while offering a respite from some of its inevitable drawbacks such as traffic, noise, pollution, or the lack of democratic access to healthy green spaces.

24.1.4 Carbon Sequestration in Biomass and Soil

CA/UF Most of the trees we plant in our urban areas originate in a forest somewhere in the world. Forests are a process of succession, of evolution. Forests don't happen in a day, a week, a year. They occur over millennia, beginning with the soils they populate. Soil quality is typically changed over time periods several times longer than what is required for soil formation, which in central Europe is about 10,000 years (Flueck 2009). Forests are a sophisticated, highly-developed community of trees and all their associates – other flora, fauna and soil containing a healthy soil microbial community, providing the macro and micro nutrients that all associates in the forest community depend on, either directly, as with trees, or indirectly, as with fauna. Forests evolve in direct relationship to their environment – temperature range, the soil's pH and the availability of light and water will all dictate what is growing and where – edge or interior.

The procedures we use to plant these forest trees into our urban environment ignore all of that tree species' communal evolution, especially the soil. Permeable surfaces are at a premium in urban areas and those that do exist have invariably been compromised by engineering criteria that are, in some circumstances, applied with an unnecessarily heavy hand – e.g. compacting the open soil around a curbside tree in order to reduce potential "trip" hazards. This practice not only impedes water infiltration, filtration and retention, it also reduces the presence of a soil food web, the probability of soil aggregation and thus the soil's capabilities as a carbon sink.

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LA Applied research on environmental components through UF and GI project implementation can contribute substantially to the development of the landscape architecture discipline. The transformability of dynamic natural and semi-natural components and systems represents a challenging experimental laboratory for testing new integrative design and management models, aiming at resilient urban environments – a clear claim for mutual exchange between the science of ecology and the practice of landscape architecture and urban design.

24.1.5 Water Regulation and Purification

CA/UF Until recently, little thought was given to urban soil's potential in the management of water quality and storm water runoff. Given the pressures of climate change and related extreme weather events, we have had to expand our search for mitigating strategies and thus, we have begun to focus on the issue of increasing permeability within the urban center footprint.

Water infiltration, filtration and purification and the recharging of groundwater are entirely dependent on soil that is not only permeable but includes an organic layer and whose structure is aggregated, incorporating macro- and micro-pores. Soil, even a viable soil, does not exist in a void. It is part of a green community. Urban trees' contribution to the soil / plant association is the ability of tree roots to bind soil, reducing erosion. Most importantly, urban trees and the soils they populate are dependent on a soil profile that includes an organic horizon – leaf litter and / or composted wood chip mulch – a soil structure that supports porosity and a bulk density that enables root growth and water infiltration.

Using pervious paving materials has been considered as an option to increase permeable surfaces; however, pervious paver installation still requires soil compaction to stabilize the sub-base, thus decreasing the water infiltration potential of the soil substrate. In addition, pervious pavers do not accommodate an organic profile so the soil's food web is diminished, along with its ability to form aggregates which contain the macro- and micro-pores that support water retention. Our ability to reduce storm water runoff requires a holistic overview of the Urban Forest as a system – an ecosystem.

LA Landscape architects must attentively consider the articulated environmental benefits, deriving from managing water in the urban landscape through appropriate UF design and management. Trees intercept storm flows from adjacent paved surfaces and reduce runoff across watersheds. UFs can reduce the risk of flooding, as well as helping to allow natural processes to break down pollutants in drainage water.

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Too often growing the UF is considered only as a water-demanding and expensive city "beautification" process and no attention is paid to the essential regulating ES services it provides. This includes the ecosystem service of water purification – reducing the input of sewage and pesticides to the watershed area, soil absorption and filtration of chemicals, biotic recycling via root systems and soil microorganisms, and water quality improvement to levels that meets government standards.

In many European cities, there has been a decline in the total number of trees planted each year and the number of older trees with large spreading crowns, with smaller alternatives often chosen as replacements. Such smaller crowned trees are often easier to manage but have a reduced capacity to intercept rain. Also, growing the UF into areas at risk from surface water flooding can make a significant contribution to reducing runoff. This includes design and planting of curbside and street trees, trees in car parks, planting of banks and slopes prone to runoff and in urban parks and public gardens.

24.1.6 Soil Quality

CA/UF The removal of topsoil, combined with the use of organic-deprived soils as planting substrate and the compacting of soil in and around planted areas, sets the stage for limitations to the curbside tree's biological functions and for root elongation – forcing roots to explore minute fissures and cracks in order to break out of the proverbial coffin into which the tree has been planted, with the resulting potential for damage to the surrounding grey infrastructure. This opportunistic search may not, however, result in locating critical elements – air, water and water-soluble nutrients. The sterile nature of most urban soils greatly limits the possibility of biotic processes – a primary soil function – and thus impairs its function as an important atmospheric carbon sink. Sterile, compacted soils do not support the soil food web – the microbial life that provides water-soluble nutrients for root uptake as well as the carbon exchange that is part of all processes.

Soil erosion in the urban environment is often the result of naturally permeable areas being left bare. Forests teach us that soil is never bare. It is always covered with a vast array of living flora and organic detritus. Soils that have an organic cover – the organic horizon – are protected from erosion, promoting an environment where nutrient transfer can occur.

Management strategies that are urban soil friendly must be developed and implemented. At the very least, the extensive use of wood chip mulch in urban planted areas would cost-effectively reduce soil compaction and erosion, moderate soil temperature, increase moisture retention and infiltration rates and create the organic layer that would support biotic processes while, at the same time, decrease a carbon source by recycling carbon-rich material back into the environment.

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LA UFs must respond to complex interacting elements and systems that are above ground, adjacent, and underfoot. We have forced them to cope with difficult urban site conditions such as the low fertility, low depth and insufficient percolation rates common to urban soils. Urban trees must tolerate car abuse, contaminants, trans-national pests and non-native species invasions.

Operating within the built environment for a landscape architect often means working in degraded left-over open spaces with compacted and nutrient-poor or polluted soils. As a response, "growing an urban forest" might not begin with tree planting design, but with the restoration of urban soils, a time-consuming crucial process that significantly affects the viability, growth rates and ultimate success of the whole project.

24.1.7 Delivery of Goods

CA/UF It is essential that an expanded use of urban forestry standards and procedures be integrated into the current governance and usage of BMPs. Urban Forests and related GI need to be managed with a much greater understanding of urban abiotic stress and resulting structural changes and challenges to growth which the urban environment imposes on the living green resource.

LA Environmental risks such as the failure of climate-change mitigation and adaptation are rising up the list of worldwide concerns. It is crucial that landscape architects, together with other professionals from related disciplines, contribute flexible UF/GI designs that leverage appropriate technologies[1] (Schumacher 1973) in order to mitigate negative impacts and strengthen urban ecosystem resilience.[2]

In contemporary urban complex systems, environmental performance-oriented design and ecosystem-adaptive monitoring are crucial for cultivating dynamic vital functions and processes, replacing outmoded emphases on static structures and the illusion of critical natural capital control through simple preservation.

Urban forestry design should carefully consider the contribution that trees and forests can make to urbanites' needs in terms of environmental benefits: moderating climate, conserving energy, reducing carbon dioxide emissions, protecting water resources, improving air quality and thermal comfort, controlling rainfall runoff and flooding, lowering noise levels, harboring wildlife, and enhancing the attractiveness of cities. UF/GI planning, design and management efforts should consequently

[1] The Urban Forest can be viewed as a 'living technology', a key component of the urban green infrastructure that helps maintain a healthy environment for urban dwellers.

[2] Resilience in this context is a measure of robustness and buffering capacity of the ecosystem to changing conditions (Holling 1986).

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focus on how the Urban Forest can best meet those specific needs, particularly with respect to the linkages between environmental benefits and characteristics of the Urban Forest and its management.

24.1.8 Biodiversity

CA/UF While urban parks and woodlands have the capability to host an expansive and diverse palette of urban fauna, the individual tree's capability to support urban wildlife should not be overlooked. For many urban residents, it is that individual curbside tree that represents the Urban Forest and nature in the city and in order for wildlife diversity to be supported, the entire Urban Forest's needs must be accommodated.

LA The size of green areas and the intensity of their management are key aspects influencing urban biodiversity: landscape architects should be aware that habitat loss and isolation associated with land conversion for human activities constitute the most serious threat to the Earth's biological diversity.

24.1.9 Disservices of Urban Trees

CA/UF To evaluate the economic impact of disservices caused by the Urban Forest, managers would have to do a comprehensive cost-benefit analysis in order to compare the costs (e.g. of cleaning, repairing and maintaining sidewalks) with the economic savings provided by such benefits as reduced energy consumption and avoided investment in additional infrastructure (e.g. new power plants or storm water management facilities). Research shows benefits greatly outweigh costs, especially when the resource is managed using BMPs and the result is a healthy, viable Urban Forest.

LA Developing knowledge about ecosystem disservices should have more influence on how urban green areas are designed by landscape architects, as well as subsequently managed. The structure of the UF regulates how ecological functions occur in the built environment, determining the quantity and efficiency of ecosystem services and disservices. Moreover, spatially explicit indicators enable the detection of areas of low and high provision of ecosystem services and disservices, thus providing crucial information which should be included in any sensible urban landscape design project.

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24.1.10 The Use of Models for Estimating Ecosystem Services

CA/UF The attenuation of wind flow by urban trees should be considered as a significant urban design issue. Wind corridors and their effect on the movement of air, combined with air pollutants that are present in the flow, should dictate the design strategies used to determine which trees should be planted and the distances between those trees. As in the case of high VOC concentrations, it is important to avoid creating a closed canopy on heavily trafficked streets – where uninterrupted wind flow is needed to generate air circulation and prevent polluted air from stagnating at the pedestrian level.

LA Notwithstanding the advances in computational modeling that have been achieved during the past two decades, and their contribution to environmental analyses, embedded complexities and technicalities have prevented most landscape architecture and urban design practices from applying rigorous specific knowledge. Seeking to reproduce, through the use of computational modeling, the major processes in the atmosphere that affect the microclimate and ultimately the level of outdoor comfort, on a well-founded physical basis (i.e., the fundamental laws of fluid dynamics and thermodynamics) should be adopted as a standard tool in designing and adaptive monitoring practices.

24.1.11 Assessing the Ecosystem Services Deliverable: The Critical Role of the Urban Tree Inventory

LA Through the process of site inventory and analysis, landscape architects can determine design elements and conditions that will impact the ecosystem services delivery and the ultimate use of the urban landscape. Urban Forest design and requalification, in particular, when based on thoughtful inventory and full site analysis, can substantially improve the built environment, by creating multifunctional green infrastructure based on both the resource and the users' needs, while saving those existing features that are deemed useful and desirable for both the people and the natural capital.

The process of tree and site inventory and analysis identifies and assesses existing conditions to determine what can be worked with and what must be re-thought in order to accomplish the design proposal and reach the established goals. It is very important to carefully review existing space, UF structure, elements and on-site materials so that a beautiful, functional, and manageable landscape can be envisaged and evolve in the long-term.

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Identifying and locating all on-site vegetal elements by species, size, origin, and condition; finding out the history of the UF, how it once was used, and if such use is still relevant today, who will use the area and what functions, aesthetics and activities are to be incorporated into the ultimate landscape design, are all essential steps to be taken in any sensible landscape design process. Landscape architects, aiming to maximize users' comfort, should also map the prevailing wind directions, patterns of sun and shade, existing topography, and soil type on a site, thus identifying the different "microclimates" that exist.

The use of simulation software is widely employed nowadays by landscape architects and urban designers. Commonly used environmental design and microclimatic simulation software include "Ecotect", an environmental prediction software package developed by A. Marsh and the Square One research group, currently commercialized by Autodesk, and "ENVI-met" another leading simulation system addressing the impact of architecture and urban planning on the microclimate system (Bruse and Fleer 1998).

GIS has evolved into a tool capable of supporting established methods of site inventory and analysis, but while it is now ubiquitous in planning departments, it finds relatively limited application in practicing landscape architecture firms (Hanna and Culpepper 1998). This is mainly attributable to the fact that the reliance on GIS in its common form overemphasizes easily quantifiable attributes like land cover, elevation, and cadastral boundaries, and minimizes qualitative, yet critical attributes related to human experience and interpretation (Martin and Wing 2007).

LIM "Landscape Information Modeling" is a platform for coordinating design, budgeting, construction, and management activities. Landscape architects, consultants, contractors, and site managers share a centralized database with the end user or client, in which each component of the project —pavement, wall, water fountain, tree, and so on—has a wealth of information attached to it. Almost any sort of data relevant to a given component can be included, such as weight, dimensions, carbon sequestration capacity, even the website of the supplier. LIM takes advantage of a library of plant and landscape forms that come pre-populated with information but can also be configured based on the needs of the designer. Moreover, LIM models are increasingly cloud-based, which allows real-time collaboration within a team of consultants literally working in the same model, thus mitigating potential design conflicts. BIM (Building Information Modeling, which includes LIM) is quickly becoming the industry standard and in Europe there is now a BIM mandate on all public sector projects (European Union Public Procurement Directive – EUPPD). Landscape architects can take seriously their role as community builders by embracing LIM and related design tools, elevating their application beyond elementary inventory and analysis.

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24.2 Socio-cultural Services Provided by UF & GI

24.2.1 Social and Environmental Justice: Diversity in Access to GI

CA/UF In an Urban Forest, the goal of "inclusion" – the ability of all residents to access and benefit from the presence of the natural amenities in their neighborhoods – begins at the planning table. If the decision-making table is not inclusive, outcomes usually fall short of the "inclusion" goal.

If an Urban Forest is to truly incorporate all its human associates, informed communities must have an opportunity to present their interests and participate in planning and implementation where they live. It therefore behooves the decision makers as well as local Urban Forest managers to disseminate information, which would enable communities to make the informed decisions that would enhance the resource and thus its potential outcomes – ecosystem service benefits for all.

Whether or not a country has an "every person right of access" law, disenfranchised, minority and lower socio-economic communities may not have the physical means with which to access traditional forests or even peri-urban forest lands. Given that laws supporting or guaranteeing equal access to traditional forests, urban woodlands or other GI-related natural resources may not result in their intended realization, Urban Forest governance and management must address these inequities.

Furthermore, a review of valuation methodologies has highlighted the use of the "willingness to pay" approach to encourage government funding for planning and maintenance in certain countries. This strategy reflects a potential socio-cultural bias as to where and how Urban Forests and related GI are developed and access maintained. Funding to facilitate small community-oriented parks along with community gardens, urban allotments or other urban agriculturally-oriented resources must be undertaken with the community's direct involvement in the planning, design and development processes. Such involvement supports the implementation of social and environmental justice concepts and usually results in empowering a sense of ownership and thus the protection and preservation of the site. The development of such urban spaces may require a bit of handholding on the part of management personnel, but thoughtful and culturally sensitive input can facilitate an informed, proactive community involvement in site use and maintenance.

There is much research detailing the quality of life issues that beset urban living, and evidence suggests that many of these urban issues can be mitigated by the Urban Forest and related GI. While the environmental aspect of these benefits has been studied for some time, the equitable distribution of these benefits – including those for residents' mental and physical well-being – is only recently receiving the focus it deserves. Minority and lower socio-economic communities are all too often the very locations where polluting installations are sited, local parks are non-existent and individual trees – curbside, plazas and street malls – are few and far between,

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offering little respite from toxic contaminants, air, noise and water pollution as well as the mental balm that a green environment offers.

In such disenfranchised communities, asthma is extremely prevalent and this has all too often contributed to the decision to *not* provide such communities with adequate greening. While some urban trees do release allergens into the environment and could, at certain times of the year, contribute to asthmatic symptoms, the root causes of asthma are complex and exposure to outdoor and indoor air pollution is among its primary instigators. Creating small parks and increasing the number of individual large-canopy urban trees throughout such communities would certainly assist with the reduction of outdoor pollution exposure. Careful selection of species and species gender can reduce allergen production in asthma-prone communities.

The streets within these communities should be well-populated with curbside trees that are properly selected and planted correctly with a focus on each tree's potential longevity and well-being. The very process by which communities are part of the planning and implementation of such endeavors is enabling, and supports positive thinking among community members, enhancing health and mental well-being.

When an Urban Forest is thoughtfully planned, designed, managed and maintained for its permanent residents, that same vital dynamic that has been created will also be a draw for the visitor. PR extravaganzas that create "instant" green spaces rarely support BMPs and all too often result in a complete waste of both the living green resource as well as the taxpayer's investment.

There are vast cultural differences in the ways that different communities relate to their Urban Forest resource (one example is the role played by Feng Shui in Asian communities). Such differences must be understood and integrated into planning and design in order to develop a resource that will be embraced, enjoyed and protected by diverse communities.

LA The social and aesthetic benefits of urban green areas are generally acknowledged as key functions of open space for local residents and visitors alike; these include recreational opportunities, improvement of the home and work environment, impacts on physical and mental health, as well as cultural and historic values.

There is also an important educational role played by Urban Forests. Contact with trees, in particular for children, can help people learn about nature and natural processes in an otherwise artificial environment (Tyrväinen et al. 2005).

The "European Landscape Convention"[3] promotes the protection, management and planning of European landscapes. Reflecting long-established European identity and diversity, the landscape is our living natural and cultural heritage, be it ordinary or outstanding, urban or rural, on land or in water. The role that informed design and management of UF play is of capital importance for the conservation and valorization of those ordinary or outstanding "heritage landscapes".

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[3] http://www.mzp.cz/C1257458002F0DC7/cz/evropska_umluva_o_krajine_smlouva/$FILE/OZV_anglicky_text_EoUK_20120125.pdf

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The notion of "Landscape Democracy" is anchored in the European Landscape Convention's aspirations for civil society's democratic values. Democracy and landscape converge where landscape, whether natural or built, is recognized to be the infrastructural physical environment we inhabit – a vital support system that sustains social and cultural wellbeing of all inhabitants. The implications of democracy's relationship to UF are significant because these natural resources are tangible expressions of human society: UF have an impact on daily living and their quality affects wellbeing and social inclusion.

Both policy makers and LA/UP thus play an instrumental role in facilitating and affecting democratic processes, addressing social issues through appropriate (Schumacher 1973) design and professional ethos. Emerging socio-cultural functional needs (e.g. wellness and recreation, education, new urban agriculture, etc.) characterize today's UF, thus positively enlarging the range of design strategy options available.

In parallel, the relevance of UF design and management in terms of implications for human health and well-being results in greater social responsibilities for all practitioners involved. Involving, from the very early stages, local communities together with policy-makers, planners, landscape architects and urban foresters (i.e. a "participatory approach") translates into higher levels of identity and attachment to place (Fried 1963), as well as enhanced connection to, and engagement in, the local resource.

To attract excluded groups (minorities, elderly people, children, etc.) the LA should eliminate barriers and aim at providing equitable access to the "commons", including in the project facilities and other features able to attract the underrepresented. Engaging directly with those communities, the LA can successfully encourage use, improve the maintenance and social care of UF/urban open spaces, in areas previously characterized by problems of vandalism, scarce attachment to place, littering, discomfort, insecurity, etc.

The edge of Urban Forests, marking a distinct boundary between the built and the rural environment (i.e., an "Ecotone"), can play an important role in developing a healthy interactive relationship between the city, its people and the landscape (Høyer 2002). As an example, in the case of Sletten, in Denmark, the Urban Forest design is tailored to facilitate community fostering, via interactive open spaces, which are conceived not just as a garden but as multifunctional green infrastructure, designed for people, and the cultural and natural processes (Boris 2012). This is but one example of how Urban Forests can reconnect society and nature in places where we work and live (Konijnendijk 2008).

This ambitious set of goals calls for a paradigm shift in the way UF is designed and managed, and requires new approaches to sustainable development of the urban landscape that enable successful management of the layered connections between individual expectations, collective identity, complex natural and artificial infrastructural systems, short-term political objectives and long-term ecological processes.

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24.2.2 Recreational Use of Urban Green Infrastructure: The Tourists' Perspective

CA/UF The importance of a tourist destination is often driven by the specific city and its residents. If a city and its citizens recognize and promote local landscape features that are seen as positive attributes, tourists are likely to follow. While urban green can be a hard sell for some locations, it's quite clear that when cities adopt their Urban Forest as part of their persona, visitors flock to the offering. Central Park in New York City is the quintessential example of an Urban Forest tourist "destination" – not just for the free concerts or the John Lennon memorial "Strawberry Fields," but for the park itself and the impression of a real "people's park." While the reason tourists visit NYC would not be because Central Park is there, is visiting Central Park on most tourist's "to do" list? The answer is a definite "yes". In addition, Central Park was always a destination, even when it's benches were old and the lawns were not immaculate and the Shakespeare garden was a bit overgrown, albeit always accessible. It is a city's "identifiers" – those special attributes that are prominent in the mind of a tourist – that are the most common destinations during a visit.

A recent survey by *National Geographic* of the ten best Urban Forests in the United States offers a window into Urban Forest management strategies and the resulting enhancement of each selected city's Urban Forest resource.[4] Washington D.C., one of the cities surveyed, is interesting for the involvement of its elite "High Society" in gardening and horticulture – a phenomenon which attracts media attention, and in turn visitors. While we don't know if visitors to Urban Forests are similarly inclined in their home location, we do know that when cities invest in their green attributes for the well-being of the resource as well as their residents, the result is vibrant urban centers that tourists want to visit. It is critical, however, that policy-makers base their decisions on citizen quality-of-life, not just supporting tourist-oriented business in the hope of a trickle-down benefit to residents. Such an approach often undermines the very things that draw visitors. When the Urban Forest thrives, it creates an upbeat, positive urban environment and the resulting vibrant municipality becomes a magnet for visitors.

Cities that are green provide an atmosphere that is conducive to relaxation, calmness and enjoyment. People naturally respond to things "green"; they may do this subconsciously but respond positively they do. Visit cities like Ljubljana, Slovenia – one can't help but notice just how fresh the city feels and how vital. Its green streets are teaming with life, with residents and visitors alike enjoying the river and riverside – walking, jogging, dining, boating or just sitting on the myriad benches, taking photographs, chatting or simply relaxing. The focus Ljubljana has placed on greening the city has created an ambiénce that is unmistakable, and while it is not clear to

[4] http://tvblogs.nationalgeographic.com/2013/12/05/americas-10-best-urban-forests/

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what extent tourists flock to the city *because* of this investment, the level of enjoyment once there is palpable.

LA Since the "Grand Tour" (seventeenth–nineteenth century) the urban landscape has been at the core of cultural tourism in Europe. Rome, as an example, has always been and still is remembered by tourists as the "city of pine trees" (*Pinus pinea*). This unique landscape – *Ager Romanus*, archeology, pine-tree groves and natural reserves, all interconnected in the Rome city center – has always contributed to its success as a tourist destination. Moreover, quite recently, the re-discovery of traditional urban agriculture in diffused heritage and natural sites of Rome has also generated conceptual (identity, branding) and tangible (food, services, accommodation, etc.) benefits for visitors and residents alike.

Substantial are the benefits provided by UGI to tourists and visitors (and residents alike): cultural and social services, ecotourism and recreation, cultural values and inspirational services, and landscape and amenity values. In principle, landscape architects are well suited to the rapidly evolving challenge of tourism. Working at the interface of nature, people and architecture, they can effectively shape the character of space and the overall quality of life. High-quality landscape projects are rich in both touristic appeal and environmental protection potential.

Landscape architecture shows a long history of dealing with travel and tourism and many of the world's most visited UGI are the product of enlightened practitioners: historic Central Park in NYC, Prospect Park in Brooklyn NY, the "Emerald Necklace" in Boston (Frederick Law Olmsted 1822–1903); Parc Güell in Barcelona (Antoni Gaudì 1852–1926); Parc des Buttes-Chaumont in Paris (Jean-Charles Alphand 1817–1891); Parco Sempione in Milan (Emilio Alemagna); Avenida das Tílias, the forest and the balconies' design over the river Douro in Porto (Émile David); and contemporary Lurie Garden in Chicago (Kathryn Gustafson, Piet Oudolf, and Robert Israele); Park Ariel Sharon in Tel Aviv (Peter Latz); Promenade plantée in Paris (Jacques Vergely and Philippe Mathieux) and Queen Elizabeth Olympic Park in London (Hargreaves Associates and LDA Design) to name just a few.

Those forms of long-lasting "indirect branding" of the UGI have already proven to be particularly effective in promoting the city image and in marketing touristic offerings. At the same time, environmental concerns and economic growth are increasingly clashing in cities worldwide. The relationship between urban tourism and environmental protection, in particular, can be defined as "circular". Mass tourism substantially impacts on the quality and quantity of a city's natural capital, consuming scarce resources (soil, water, energy, etc.) and producing significant amounts of waste. At the same time, growing concentrations of people and events in urban centers can provide better opportunities to launch, finance, implement and manage GI, compared to peri-urban and rural areas.

The International Ecotourism Society defines ecotourism as "responsible travel to cities and natural areas that conserves the environment, sustains the well-being of the local people, and involves interpretation and education". Ecotourism in heritage

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cities (i.e. in most of the European cities), in particular, can provide multiple options and insight to visitors – contributing to protection and restoration efforts, training, education and information exchange, urban agriculture, etc. – fostering a significant shift in their behaviors and beliefs.

In responding to the "eco-city-tourism" challenge, landscape architects in particular should be able to provide responsible and sensible design solutions, bridging the gap between environmental conservation and business development through informed and adaptive UGI design. A wide range of possibilities for creativity and innovation is possible within the urban realm, supported by the existing valuable heritage infrastructure and financing which is more readily available in large urban centers.

24.2.3 Human Health and Well-Being

CA/UF Joni Mitchell captured not only our environmental imagination but urban reality when she wrote *Big Yellow Taxi* in 1970, with its well-known refrain "they paved paradise and put up a parking lot". Although our awareness of the value of restorative environments has been expanding for several decades, maintaining existing green spaces in immediate proximity to hospitals was underappreciated and expendable well into the 1990s.

Cities like NY have a long history of the de-mapping and sale of publicly owned parkland for non-green purposes like parking garages. Even when such decisions are actively challenged in the courts, with information on the loss of restorative health benefits introduced along with other environmental concerns, this often holds little sway over policy makers or administrators who favor the financially lucrative development of these once-green properties. Increasing concern over the far-reaching effects of relentless urbanization and climate change may be giving more credence to the research showing the positive effects of urban greening on health outcomes – especially given the economic pressure on medical institutions to shorten hospital stays.

The proximity of residence to urban trees is critical to human well-being (Fig. 24.1). While large footprint parks, urban woodlands and forests offer the best possibilities of respite from city stressors and their outcomes, e.g. cardiovascular disease and cancers, even the presence of curbside trees in an otherwise "grey" urban neighborhood can afford those residents with green stress mitigation to such a degree that an element of improved health condition prevails. As noted previously, asthma and other allergic conditions should not serve as an excuse to not plant trees in communities with a history of asthma. Rather, tree selection should be sensitive to this issue so that appropriate species are planted.

A greater availability of community gardens on publicly-owned lands would afford more communities an opportunity for greater social cohesion, as well as

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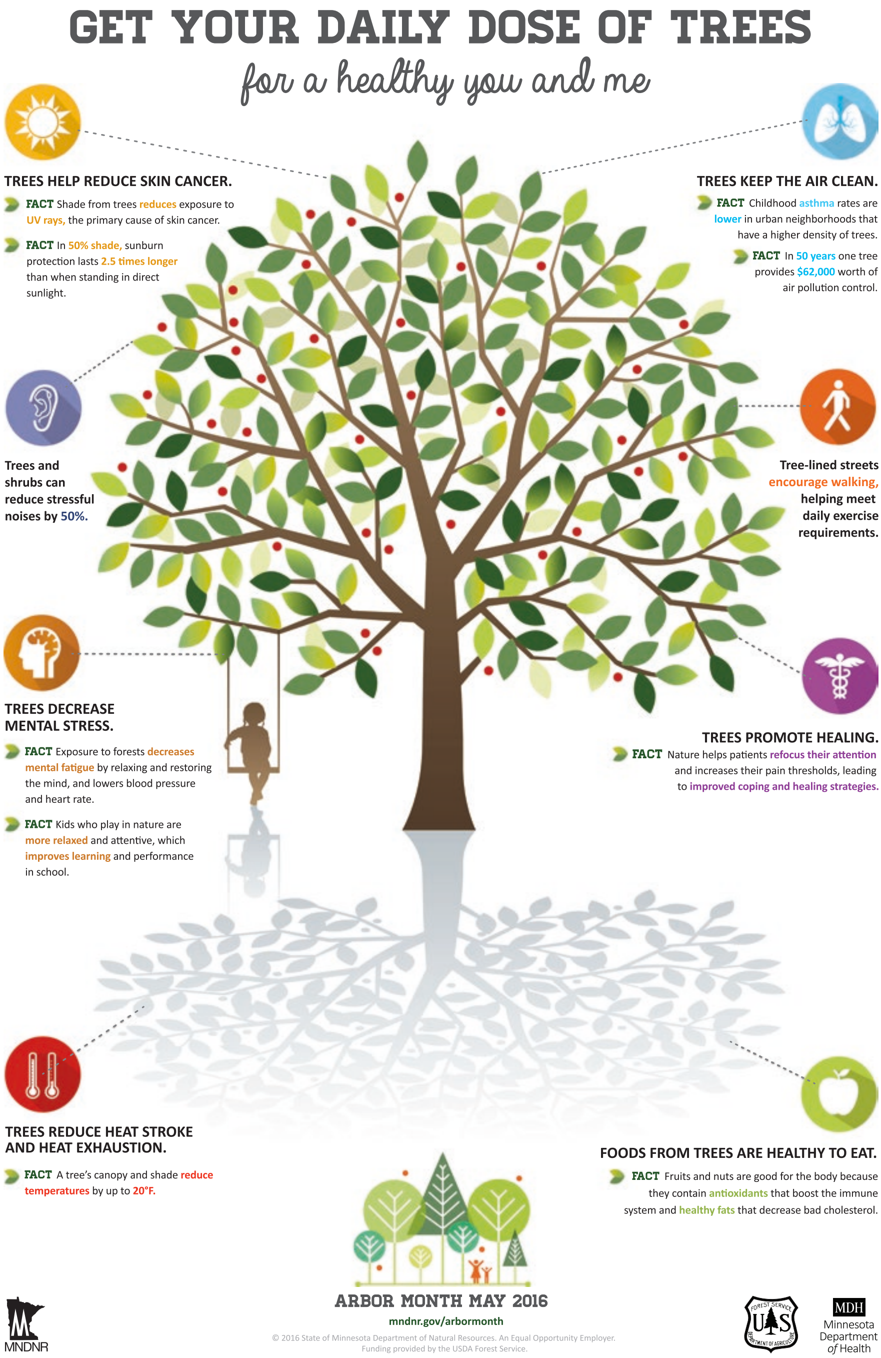

Fig. 24.1 Promotional material drawing attention to the health benefits of trees (Source: http://www.dnr.state.mn.us/arbormonth/health-benefits.html)

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increased access to fresh produce and physical activity outdoors in a green environment – all potential health benefits. While American community gardens are free of charge, allotment (UK) or Schrebergarten (German-speaking countries) gardens are normally rented. This may preclude the very people who are often the most in need of such resources from accessing them. Land that is publically owned such as parkland can support the presence of a community garden, provided there are clearly defined rules of usage. This free-of-charge access would also facilitate integration of migrants into the communities where they have settled, and serve as an entrée into the larger world of publically-owned urban green space.

An approach to increasing access to publically-owned green spaces as well as increasing the connectivity of those green spaces is the Urban Greenway – paths that are established which connect existing green spaces throughout the urban area. These paths encourage additional greening in the form of individual trees interspersed with vest-pocket parks – all linked and connected – creating a Green Ribbon that extends throughout the City or urban area, providing extensive respite from the stresses of city life and increasing opportunities for access to green walking areas for all the city's residents. Easy access to such Urban Greenways is critical, especially for those disenfranchised communities where the need to economize is ever present and opportunities to access any form of nature is limited.

LA Along with people, non-human agents in the socio-ecological world such as trees and other natural landscape artifacts contribute to human relations in numerous ways. In particular, trees possess significant forms of active agency which have usually been assumed to exist only in the human realm (Jones and Cloke 2008) and are able to stimulate affective and emotional responses from the humans who dwell amongst them – effectively contributing to the making of place via different kinds of sensorial and spiritual exchanges with human beings. Thus the tree is not just a passive recipient of human interventions; rather, it brings its own abilities and tendencies to the equation (Jones and Cloke 2002; Latour 2005).

Reclaiming a more substantial presence of natural settings within healthcare facilities is related to the alleviation of stress and the abilities of those landscapes to soothe, calm, rejuvenate and restore the patient's mental and emotional health. The main idea is to differentiate curing a disease from healing a person.

In this way, contact with nature in cities can play an important role in improving mental health of urbanites. Taylor et al. (2001) carried out empirical studies which particularly demonstrated the higher cognitive development of children who spend more time outdoors, while Kaplan (1993) demonstrated the various effects of landscape elements on workplace productivity and absenteeism.

In recent social studies regarding the cities of Uppsala, Malmö and Gothenburg, Eriksson et al. (2016) describe the importance for urbanites of natural city places (lawns, in particular) for different outdoor activities, including walking and exercising. The time citizens spent in open spaces, according to the researchers, is dependent on both design quality and weather. According to Ingegnoli and Giglio (2016)

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it is possible to demonstrate that extreme landscape degradation is damaging to human health, even in the absence of pollution.

Casotti and Salza (2016), with their experience of horticultural therapy in a child and adolescent psychiatric facility in Turin, contributed in breaking down the isolation that affects many families of different ethnic groups whose children suffer from pathologies or disabilities. The collective vegetable gardens of “Associazione Casamatte” offer different experiences of interactions and socialization in a non-judgemental context, which promotes individual communicative skills and mutual social support among cultures sharing the green spaces, as well as counteracting mistrust and isolation.

‘Nature-deficit disorder’ describes the human costs of alienation from nature, among them: diminished use of the senses, attention difficulties, and higher rates of physical and emotional illnesses. The disorder can be detected in individuals, families, and communities. The nature deficit can even change human behavior in cities, which could ultimately affect their design, since longstanding studies show a relationship between the absence, or inaccessibility, of parks and open space with high crime rates, depression, and other urban maladies. Nature healing with alternative, complementary medicine and therapies are antidotes and preventatives (Institute of Global Education 2004).

24.3 Economic Benefits and Governance of UF in a GI Approach

24.3.1 Challenges to Governing Urban GI in Europe

CA/UF The fundamental management components of the Urban Forest are the planning, design and maintenance of its constituent parts, beginning with its urban trees, wherever they reside – streets, plazas, parking lots, median strips as well as urban parks and woodlands – all biophysical green resources. Most of our pollution begins in our urban centers, and it is the individual tree that is the workhorse of the Urban Forest. It is these trees, these *individual* trees, that need to be recognized for their importance, for the work they do and for the ecosystem service benefits they contribute to an urban center’s quality-of-life.

A coherent governance policy can only be developed if there is an understanding of the Urban Forest and all its constituent parts as they exist – the Urban Forest ecosystem. Since urban tree inventories, conducted by municipalities’ urban foresters, are not accessed at the national level, a larger standardized policy has no basis on which to develop a working Urban Forest Strategic Plan. From our Practitioners’ perspective, the resource is not being governed well if the fundamental Scope of Work is missing.

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Nowhere is this more evident than the need to "PR-itize" the Urban Forest resource through such initiatives as "Million Tree Plantings" or the *European Green Capital Award* – high profile "green" initiatives which earn publicity for a city but do not necessarily address the actual requirements of the Urban Forest as an ecosystem.

LA The European Green Capital Award (EGCA) is one EU policy tool being used to govern urban GI delivery and management. The award has been given yearly since 2006 to cities that are judged to be "proactive in achieving high environmental standards, and committed to ambitious goals in terms of improvement of life quality" – and it mostly reflects a strong focus on "sustainably engineered infrastructure" to promote carbon neutrality, regenerative energy schemes and climate protection.

Explicit tree planting campaigns, however, have been carried out in just three of the last seven winning cities, with various degrees of success. Vitoria-Gasteiz (Spain) has aimed at planting 250,000 trees through support of a public-private partnership, Copenhagen (Denmark) has planted 3,600 trees, 217 of which have been "adopted" by local citizens, and Hamburg (Germany) has planted 2,600 street trees, thanks to the support and donations of local citizens. This approach seems to confirm the relatively low priority given in this "soft governance tool" to the actual Urban Forest, compared to other GI or nature-based solutions whose benefits are presented in a more clear and tangible form.

The intrinsic variability among mechanisms of urban green space governance, and in the planning, design and management of the resource across Europe, makes it difficult to produce meaningful comparative analyses and comprehensive assessments of UF and GI at the regional, national or transnational level. Although many urban participatory efforts and private-public partnerships can be considered efficient in reaching political or financial targets, the balance of power between the parties and the democratic nature of the overall process are often controversial.

Internationally accepted valuation techniques such as Cost Benefit Analysis and Contingent Valuation methodologies are not capable of capturing the multifaceted ecological, economic and social functions of the Urban Forest. While more sophisticated, and natural resource friendly, economic valuation techniques are emerging in Europe (e.g. "i-Tree"), the trade-offs among different ecosystem service benefits remain mostly unexplored. We are in fact still far from a satisfying and comprehensive scientific understanding of the multiple relationships and feedbacks among different ecosystem services. Those uncertainties and information gaps should thus be at the core of scientific research in the near future.

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24.3.2 The Role of Partnerships and the Third Sector

CA/UF Informed constituents and partners are an important resource, and in the management of the Urban Forest, they are invaluable. As increased urbanization and climate change escalate the need for sustainably managed Urban Forests, a well-developed Third Sector partnership should take on greater relevance. It is often the experience of practitioners that governments, regardless of the amount budgeted for UF and GI, cannot manage the resource without the involvement of the Third Sector and the community-at-large. Gone are the days of the strictly top-down approach as a workable management strategy.

What is absolutely critical to the urban forestry network is the appropriate level of technology transfer between urban foresters and both formal and informal Third Sector partners. What will not serve the resource or its beneficiaries are outdated management practices or governance policies. Currently proven, professionally accepted BMPs must be disseminated to all who wish to participate, be they NGO or the interested lay public. It is not only essential that all actors within the network ascribe to BMPs, a basic understanding of the underlying principles of BMPs must drive Third Sector and community participation. Neighborhood seminars and workshops on subjects useful to the individual and beneficial to the community, hosted by urban foresters and open to the public, provide excellent opportunities to share BMPs and encourage participation in all areas where the public's involvement can make a difference. Since people are such an integral component of the Urban Forest ecosystem, we must all be stewards – informed, active participants in its well-being, which is critical to its management.

Disenfranchised communities are often not included in the planning process, so there is no structured organization representing their interests – and this is often construed as a sign of a disinterested community. Outreach in such communities might require a different approach. While the standard top-down approach seldom works, non-community NGOs may also be viewed as top-down. An assessment of probable gathering places, e.g. religious centers, might afford an opportunity to identify community leaders and to stimulate an interest in participating in the planning, design and implementation of community-focused urban green spaces from the planting and care of curbside trees to providing locations for community gardens / allotments.

While urban planners and landscape architects plan and design the spaces and places which accommodate urban trees and related GI, it is the urban foresters who manage and the arborists who actually plant and maintain those installations. It is critical to the wellbeing of the Urban Forest that the full complement of UF-related professionals are at the decision-making table, implementing the policies and protocols of good governance.

One of the primary roles for the Third Sector and especially the community-at-large is as informed advocates. While cost-benefit analyses favor investing in Urban Forest management, each slice of the budget pie has many contenders. Decision-

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makers are often sensitive to constituent opinions, and the willingness of an informed citizenry to advocate for adequate urban forestry funding is fundamental to the municipality's ability to manage the resource and to the fostering of Urban Forest stewardship.

It is clear that, at the end of the day, the development and implementation of an Urban Forest Strategic Plan is essential to management oversight. Additionally, the management of publicly-held lands should remain with the municipality to avoid any improprieties. With that understanding, informed Third Sector groups and community members can participate by undertaking practical maintenance tasks that are not performed often enough but are critical to urban trees' survivability, such as mulching, irrigating or adding compost to curbside trees.

Such endeavors lend themselves to community planting / beautification days and support good stewardship practices. If the materials necessary for such endeavors cannot be provided by the municipality, the community might consider outreach to a local garden center and / or sponsorship from a neighborhood business entity, e.g. a supermarket. Local media enjoy covering such endeavors and it is also good for business.

Empowering local communities is not the same as decision-makers divesting themselves of their responsibility to their constituents. While community-based participatory planning and implementation of programs is an essential ingredient of a "taking ownership" policy, there are certain realities to the management of the Urban Forest that must be acknowledged. Urban trees are sophisticated organisms that require a BMP-based management strategy if they are to deliver the ecosystem services we know are critical to the urban dweller's well-being. Misinformed decisions can result not only in the decline of the Urban Forest resource, leading to a loss of the public's investment, but also in loss of property and even human life.

The negative experience of community trauma when Urban Forest devastation strikes can often result in beneficial partnerships leading to community empowerment and positive Urban Forest outcomes:

- The first appearance Asian Longhorned Beetle (ALB) on US soil was in 1996 in the Greenpoint/Williamsburg community of Brooklyn, NY. It was discovered not by an urban forester, but by a local resident. The subsequent community participation in addressing the infestation was critical to the outcome. Through a community-professional-government partnership, an inventory of all remaining trees was conducted and a citizen training protocol was developed in which participants were trained in basic tree identification by federal urban foresters. Joint teams of citizens and tree experts determined what spaces could be re-planted with non-host, government-provided replacement trees. This action brought together and empowered a traumatized community, forged a bond between all the participants and has helped residents of Greenpoint to continue actively assisting with the informed management of their Urban Forest (Fig. 24.2a, b).
- As ALB was found in more areas of NY City, it became clear that a citywide cadre of trained observers was needed. NYC Root Zone, a professional not-for-profit organization, collaborated with the University of Vermont in developing

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Fig. 24.2 Residents of the Greenpoint community actively assisted with the management of their threatened urban forest, through (**a**) tree inventory t-shirt for participants fosteres awareness building, (**b**) events celebrating the Greenpoint communitiy's continuing Urban Forest stewardship (**c**) trainers and trainees all became Beetle Busters, wearing the t-shirt designed to bring greater awareness about ALB throughout the City of New York, and (**d**) Botanical Gardens donated space for a city-wide Girl Scouts ALB project (Photos: Naomi Zürcher)

citizen-oriented tools – a Beetle-Buster Toolbox – to help fight the infestation. Local environmental organizations and Botanical Gardens hosted free citizen training with the help of USDA Forest Service personnel, and local Girl Scouts volunteered as well. All services from Federal agencies, professionals, Third Sector partners and public institutions were donated, in a collaborative effort to support the City's urban trees in their time of need (Fig. 24.2.c, d).

From the practitioners' perspective, the entirety of what THE Urban Forest is has not been acknowledged or well understood at the national level of most European countries – where National Forest Inventory criteria do not even consider the existence of the primary component of an Urban Forest – the individual trees that populate urban centers. Until the Urban Forest, in its entirety, attains a level of importance equal to wood-producing traditional forests, we will continue to short-change the critical management role of the urban forester, and thus the ability to "grow" the resource.

A much greater application of the extensive Urban Forest body of knowledge needs to be put into play before the benefit of a Third Party role can be realized. Presently, our European Urban Forests are not being managed to the extent that they need to be. Growing an Urban Forest is a management process. In order for the process to function, we must adopt ground-tested BMPs and incorporate them into a larger Urban Forest Strategic Plan. Only then can we delegate responsibilities for aspects of a resource that has been well defined. The public and their investment in the Urban Forest deserve the enhanced ecosystem services outcomes that growing a healthy and vital Urban Forest brings.

LA Across Europe, communities are actively reclaiming and improving urban open spaces of various kinds, including UF and other GI. Their efforts represent broader social and economic needs, and those struggles are made in a built environment more and more characterized by conflicting interests over decreasing resources.

The traditional approach of a top-down, state-led, unilateral way of steering no longer suffices. Urban green spaces – including UF – have been for too long the exclusive responsibility of municipal or regional authorities. Now, new forms of multi-level governance with multiple stakeholders, as well as new types of valuation frameworks and monitoring tools, are expanding the horizon and urging us to reconsider this model.

Effective interaction is the essence of urban social life. Social processes are important in bringing together broad drivers of change and reconciling them with specific pressures that act upon the management and multiple uses of urban green space. Within the social processes, the role of the LA is to integrate sometimes divergent viewpoints from the public sector, professionals, academics and the Third Sector. Such processes include research and knowledge transfer, different specialist practices, community involvement and participation, as well as inclusive decision-making.

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Acknowledging the community-building role of landscape architecture within the complex urban mosaic enables citizens and decision-makers alike to consider the many goods and services provided by UF and GI throughout the metropolitan area, and not just in designated parks or gardens. Appropriate design is just a starting point for "growing the UF". The geographical and social templates into which the resource might fit represent the decisive elements of an articulated system, enhancing the ability of UF to deliver ecosystem services at their best.

Local initiatives, partnerships between NGOs and businesses, and other voluntary agreements are proliferating all over Europe. Below is a short description of some recent initiatives, highlighting the integrated environmental, social and economic role played by the urban forest of Rome.

- The *Comitato Piazza Vittorio Partecipata* ("Vittorio Square Participatory Committee") initiated in 2006, and continues to lead, the effort to restore and redevelop one of the most degraded historical green spaces in central Rome. Piazza Vittorio is the largest square in Rome, and its Nicola Calipari central garden has been hosting, since 1888, a collection of trees including *Magnolia*, *Cedrus*, *Chamaerops*, and *Platanus*. After many decades of abandonment, this nineteenth-century garden is today the vibrant heart of a multi-cultural, ethnically diverse neighborhood whose citizens, associations and committees work together for its protection and management.
- The "Participatory Management Plan" of Piazza Vittorio was the product of many months of work by residents, landscape architects and related practitioners. A key step towards a more informed management of the GI is a tree inventory of the entire neighborhood, including the many individual trees populating its streets, together with an estimation of the economic value of the ecosystem services they provide using the 'benefit transfer' method (24.3a).
- Not far from the central train station, the traditional Roman bar and restaurant "Panella" has been engaging with local residents – especially with a municipal center for elderly people, located just opposite the bar's main entrance – in a "beautification" exercise aimed at decorating the via Merulana curbsides, planting colorful flowers at the base of the old *Platanus* and *Robinia* tree trunks.
- Both the restaurant's clientele and the many seniors populating the street regularly participate in the seasonal "planting days" and can now enjoy a much more agreeable setting. Local engagement in the planting of the flowerbeds has been essential for the success of the refurbishment project, and stands to benefit the individual historical *Platanus* trees as well (24.3b).
- What is called now "Parco del Centro Culturale Piazza Elsa Morante" in Rome used to be a parking lot of approximately two hectares, whose only natural elements were 31 *Pinus pinea* trees growing in the central isle of a sea of asphalt. After a 5-year participatory process, developed during several occasions of confrontation with the resident community, the urban forest has been doubled in size – with the planting of *Acer*, *Quercus* and *Ginkgo* trees in a newly created, culturally rich setting that includes an open-air theater, cinema, and co-working areas. Other GI and nature-based solutions (e.g. rain water collection and re-use systems, permeable pavements) complete the program of this contemporary regenerated urban community park (24.3c, d).

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Fig. 24.3 Recent initiatives highlighting the integrated environmental, social and economic role played by the Urban Forest of Rome: (**a**) Piazza Vittorio, (**b**) “beautification” in via Merulana, and (**c**–**d**) Piazza Elsa Morante (Photos: (**a**) and (**b**) Maria Beatrice Andreucci and (**c**–**d**) LC-Architettura)

Urban partnerships often appear to be the tentative, partially unsatisfactory results of an imperfect process in which different actors struggle realize the true potential of a place. But relationships which have been built solely around a financing vehicle and the coordination of budget expenditures – and not on the positive interplay of different needs, cultures and goals of the multiple stakeholders – are proven to fail even more consistently in delivering what is expected at the community level.

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According to a national law regulating the development of urban green spaces, (Ministero dell'Ambiente 2013), all large Italian municipalities are required to prepare an appraisal and inventory of their urban tree balance, focusing especially on monumental trees. This recent upgrade in the Italian regulatory framework confirms the importance placed on detailed urban forest databases, and on the protection of historical urban parks and gardens. According to the Italian Statistics Institute, however, only 11 of the 73 municipalities have gathered complete data accounting for new urban tree planting as well (ISTAT 2014).

From the LA perspective, the availability of quantitative and qualitative data regarding the UF is of capital importance. Without these detailed sources of information, it would be almost impossible to intervene with appropriate design (and related site management plan) in the layered urban fabric, which traditionally characterizes most European cities and towns. Notwithstanding the widespread awareness of the importance of detailed tree inventories, huge discrepancies still characterize Europe with respect to the actual use of those invaluable instruments and tools in planning, design, and collaborative management of the UF.

To what extent participatory governance models have gained prominence in political agendas across Europe, and what difference they have made for the management of UF and other GI resources, are key questions that remain to be explored. The actual results of collective stewardship, anchored by the Third Sector in particular, should increasingly capture the attention of researchers and practitioners alike.

24.3.3 The Value of Valuing: Enhancing Ecosystem Services

CA/UF Our present world of economic constraints and environmental concerns has no greater realization than in our ever-increasing and sprawling urban centers. And while Urban Forest stakeholders have understood for some time the capability of urban trees and related GI in addressing environmental issues cost-effectively, proving it in a quantifiable and well-documented way was not possible. The resource, therefore, was usually undervalued, with scant consideration for the myriad contributions to ecosystem services benefits which, by the second half of the twentieth century, "had completely disappeared from the economic production function" (Hubacek and van der Burgh 2006). As explained by Costanza et al. (1997):

> *The under-valuation of the contributions by ecosystems to welfare in public and business decision-making was partly explained by the fact that they are not adequately quantified in terms comparable with economic services and manufactured capital.*

The advent of Valuation Methodologies that can assess the Urban Forest structure and its ecosystem service functions – i.e. the potential of the Urban Forest to deliver the services, as well as the cost-benefit of delivering – has allowed these

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biological resources to be valued in monetary terms and receive economic consideration by decision-makers.

This ability to offer decision-makers evidenced-based, quantifiable data has been a boon to Urban Forest managers. Valuation Methodologies such as “i-Tree” and “GI-Val” have provided managers with functional, usable tools that are able to quantify what can be gained by investing in the resource. While the software that performs the valuation is available free of charge, there are important initial costs to implementing these methodologies.

Although different methodologies have different approaches and different outputs, they all are based on the need to assess the resource. There are various inventory strategies that would support the implementation of these methodologies, but from this Practitioner’s perspective, a complete ground-based inventory is an invaluable tool if the resource is to be sustained. In addition to an inventory, whatever data is collected must be input according to the particular strategies of the selected software. An initial investment of funds and personnel must be accommodated with budgeting – but such costs tend to be negligible when compared with the value of ecological benefits that fall outside the expected realm of “amenity” services.

These benefits encompass many aspects of sustainable urban management, and are discussed at length in the first section of this book: mitigation of atmospheric emissions (facilitating compliance with regulations), reduction of the urban heat island (with its attendant health benefits and reduced energy costs), and the increased capability of water filtration, purification and retention (avoiding expensive infrastructure), to name but a few.

Thus the entire sphere of sustainable urban management can benefit directly and indirectly from a healthy Urban Forest that has been valued for its natural capital benefits and has been funded accordingly.

LA The effective implementation of a sustainable, multi-functional urban landscape, as a result of informed decision-making, requires multi-disciplinary engagement. Stakeholders should in principle negotiate, define and launch only those projects they consider “adjusted and enhanced” both in terms of trade-offs and the balance of diversified interests.

A detailed understanding of environmental, social and economic values associated with design strategies enables LAs to engage with various stakeholders in synergy and trade-off analysis and in identifying the potential gains/losses associated with specific ecosystem services (ES) and GI patterns. For landscape architects to work with the ES concept, data and information must be provided in a form that suits their specific tasks. Applied research that depict which ES bundles are supplied – on which location, in what quantity and by which GI type – can guide the way to optimal planning, design and management of UF and other GI.

Although requests from practitioners for such information and valuation tools are considerable, ES assessments still suffer from a lack of spatial and thematic detail to account for the fine-scale nature-based solutions that supply ES in cities, close to people’s multiple needs.

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For most GI, independent measurements of the actual supply of the ES are still not available and ecological studies measuring ecosystem functions that can be used by LAs as indicators are much needed in the majority of the European urban contexts. Most economic valuation studies carried out on urban GI are restricted to one or two ES, a coarser resolution of analysis and a single vegetation type (Haase et al. 2014), but LAs, to inform their projects, need to carefully consider ES bundles and to analyse landscape performance, synergies and trade-offs implied in alternative strategies, making use of data at high spatial resolution and at different urban scales: building, street, neighbourhood, and city.

24.4 Conclusions

As presented and discussed throughout the preceding chapters, Urban Forests and related GI hold an extraordinary potential to deliver a spectrum of ecosystem services that are sorely needed in so many cities. Their value, for our personal health today and for our environmental health tomorrow, may often seem intangible. But as our knowledge, our modeling tools and our valuation methodologies continue to evolve and improve, we find the value of urban nature becoming ever more concrete.

The list of cohorts involved in Growing the Urban Forest is extensive -
from scientists and researchers at the theoretical end,
plus academics creating the bridge by teaching the theories,
to planners, landscape architects, arborists, animating and testing the theories
and Urban Foresters, maestros managing the animations and resulting BMPs
in stewardship / liaison with an informed and empowered community / Third Sector.

All cohorts are essential to the Urban Forest's growth – its survivability and sustainability. All cohorts have a crucial role to play in collaboration with all other cohorts. Imagine the outcomes that could be achieved if the cohorts, collectively, were inspired by the possibilities of such a collaboration.

The best teacher is the traditional forest. Take a walk in a forest. Leave your human baggage at the door. As you stroll along you can't help but feel the vibrant, diverse life that's all around you and you are a part of it. Now imagine if we could bring that vibrancy to the Urban Forest, creating an environment in which our urban trees and all their green associates could thrive. Imagine the benefits – quantifiable or not – such a collaboration would bring to all the non-green associates – us. What a remarkable Urban Forest that would be to call home.

By means of trees…
wildlife could be conserved, pollution decreased,
and the beauty of many landscapes enhanced.
This is the way, or at least one of the ways,
to spiritual, moral and cultural regeneration.–
– E. F. Schumacher

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References

Boris SD (2012) Urban forest and landscape infrastructure: towards a landscape architecture of open-endedness. J Landsc Archit 7(2):54–59

Bruse M, Fleer H (1998) Simulating surface-plant-air interactions inside urban environments with a three dimensional numerical model. Environ Model Software 13:373–384

Casotti C, Salza A (2016) "Orti Aperti". The experience of horticultural therapy in a child and adolescent psychiatry facility in Turin. In: Proceedings from 53nd IFLA worldwide congress, 20–22 April 2016, Turin (I)

Costanza R, d'Arge R, de Groot R, Farber S, Grasso M, Hannon B, Naeem S, Limburg K, Paruelo J, O'Neill RV, Raskin R, Sutton P, van den Belt M (1997) The value of the world's ecosystem services and natural capital. Nature 387:253–260

Eriksson F, Eriksson T, Ignatieva M (2016) Lawn as a symbol of nature in urban environment: social benefits of lawns in Sweden. In: Proceedings from 53nd IFLA Worldwide Congress, 20–22 April 2016, Turin (I)

Flueck WT (2009) Evolution of forest systems: the role of biogeochemical cycles in determining sustainable forestry practices. Ecol Soc 14(2):r4 http://www.ecologyandsociety.org/vol14/iss2/resp4/

Fried M (1963) Grieving for a lost home. In: Duhl LJ (ed) The urban condition: people and policy in the metropolis. Simon & Schuster, New York, pp 124–152

Haase D et al (2014) A quantitative review of urban ecosystem service assessments: concepts, models and implementation. Ambio 43:413–433

Hanna KC, Culpepper RB (1998) GIS in site design: new tools for design professionals. Wiley, New York

Holling CS (1986) Resilience of ecosystems; local surprise and global change. In: Clark WC, Munn RE (eds) Sustainable development of the biosphere. Cambridge University Press, Cambridge. Reprinted in: Cleveland C, Costanza R, Perrings C (eds) (1997) The development of ecological economics. Edward Elgar Publishing, Brookfields, pp 292–317

Høyer S (2002) Sven-Ingvar Andersson 2002, garden art and beyond. Exhibition catalogue. Arkitektens Forlag, Copenhagen

Hubacek K, van der Bergh J (2006) Changing concepts of land in economic theory: from single to multi-disciplinary approaches. Ecol Econ 56:5–27

Ingegnoli V, Giglio E (2016) The improving importance of landscape project to limit premature death due to environmental alterations, independently from pollution. Helps from landscape bionomics. In: Proceedings from 53nd IFLA Worldwide Congress, 20–22 April 2016, Turin (I)

Institute of Global Education (2004) http://www.ecopsych.com/2004ecoheal.html. Accessed 21 June 2016

ISTAT (2014) Rapporto annuale 2014. La situazione del Paese. http://www.istat.it/it/archivio/120991. Accessed 4 June 2016

Jones O, Cloke P (2002) Tree cultures: the place of trees, and trees in their place. Berg, Oxford

Jones O, Cloke P (2008) Non-human agencies: trees in place and time. In: Knappett C, Malafouris L (eds) Material agency: towards a non-anthropocentric approach. Springer, New York, pp 79–96

Kaplan R (1993) The role of nature in the context of the workplace. Landsc Urban Plan 26:193–201

Konijnendijk CC (2008) The forest and the city: the cultural landscape of urban woodland. Springer, Berlin

Latour B (2005) Reassembling the social: an introduction to actor-network-theory. Oxford University Press, Oxford

Martin KS, Wing J (2007) The discourse and discipline of GIS. Cartographica 42(3):235–248

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Ministero dell'Ambiente (2013) Norme per lo sviluppo degli spazi verdi urbani. http://www.minambiente.it/sites/default/files/archivio/normativa/legge_14_01_2013_10.pdf. Accessed 3 May 2016

Schumacher F (1973) Small is beautiful. Blond and Briggs, London

Taylor AF, Kuo FE, Sullivan WC (2001) Coping with ADD: the surprising connection to green play settings. Environ Behav 33:54–77

Tyrväinen L, Pauleit S, Seeland K, de Vries S (2005) Benefits and uses of urban forests and trees. In: Konijnendijk CC, Nilsson K, Randrup TB, Schipperijn J (eds) Urban forests and trees – a reference book. Springer, Berlin, pp 81–114

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