# Chapter 11
# Urban Ecosystem Services

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**Abstract** We explore the potential of urban ecosystem services for improving resilience and quality of life in cities. First, we classify and categorize important ecosystem services and disservices in urban areas. Second, we describe a range of valuation approaches (cultural values, health benefits, economic costs, and resilience) for capturing the importance of urban ecosystem service multiple values. Finally, we analyze how ecosystem service assessment may inform urban planning and governance and provide practical examples from cities in Africa, Europe, and America. From our review, we find that many urban ecosystem services have already been

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T. Elmqvist et al. (eds.), *Urbanization, Biodiversity and Ecosystem Services: Challenges and Opportunities: A Global Assessment*, DOI 10.1007/978-94-007-7088-1_11,

identified, characterized and valued, and have been found to be of great value and importance for human well-being and urban resilience. We conclude that the use of the concept of urban ecosystem services can play a critical role in reconnecting cities to the biosphere, and reducing the ecological footprint and ecological debt of cities while enhancing resilience, health, and quality of life of their inhabitants.

## 11.1 Reconnecting Cities to the Biosphere

Cities are interconnected globally through political, economic, and technical systems, and also through the Earth's biophysical life-support systems (Jansson 2013). Cities also have disproportionate environmental impacts at the local, regional, and global scales well beyond their borders (Grimm et al. 2000, 2008; Seto et al. 2012), yet they provide critical leadership in the global sustainability agenda (Folke et al. 2011). Although urbanized areas cover only a small portion of the surface of the planet, they account for a vast share of anthropogenic impacts on the biosphere. Still, the impacts of urbanization on biodiversity and ecosystems as well as the potential benefits from ecosystem restoration in urban areas remain poorly understood (see e.g., McDonald and Marcotullio 2011). For further discussion on urban restoration ecology, also see Chap. 31.

### *11.1.1 Ecology of vs. Ecology in Cities*

Cities appropriate vast areas of functioning ecosystems for their consumption and waste assimilation (see Chaps. 2 and 26). Most of the ecosystem services consumed in cities are generated by ecosystems located outside of the cities themselves, often half a world away (Rees 1992; Folke et al. 1996; Rees and Wackernagel 1996;

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Deutsch and Folke 2005, see Chap. 2). Folke et al. (1997) estimated that the 29 largest cities in the Baltic Sea Drainage Basin, taking into account only the most basic ecosystem services such as food production and assimilation of nitrogen and carbon, appropriate ecosystem areas equivalent to the size of the entire drainage basin, several hundred times the area of the cities themselves (Chap. 26). Thus, our analysis needs to go beyond what is sometimes referred to as "the ecology *in* cities" (Niemelä et al. 2011), which often focuses on single scales and on designing energy-efficient buildings, sustainable logistics, and providing inhabitants with functioning green urban environments, to put more focus on "the ecology *of* cities" characterized by interdisciplinary and multiscale studies with a social-ecological systems approach (Grimm et al. 2000; Pickett et al. 2001, see also Chap. 3). This framework acknowledges the total dependence of cities on the surrounding landscape and the links between urban and rural, viewing the city as an ecosystem itself (Grimm et al. 2008). We need to be concerned with the generation potential, not only to uphold and safeguard the well-being of city inhabitants, but also to effectively manage the potential of cities as arenas for learning (this aspect is discussed in detail in Chap. 30), development, and transformation.

### *11.1.2 Urban Ecosystems and Ecological Infrastructure*

Definitions of urban areas and their boundaries vary between countries and regions (for a discussion on "What is urban?" see Chap. 1). The focus of this chapter is on the services and benefits provided by urban ecosystems, defined here as those areas where the built infrastructure covers a large proportion of the land surface, or as those in which people live at high densities (Pickett et al. 2001). In the context of urban planning, urban ecosystems are often portrayed as embedding both the built infrastructure and the ecological infrastructure. The concept of ecological infrastructure captures the role that water and vegetation in or near the built environment play in delivering ecosystem services at different spatial scales (building, street, neighborhood, and region). It includes all 'green and blue spaces' that may be found in urban and peri-urban areas, including parks, cemeteries, gardens and yards, urban allotments, urban forests, single trees, green roofs, wetlands, streams, rivers, lakes, and ponds (EEA 2011). Defining clear boundaries for urban ecosystems often proves difficult because many of the relevant fluxes and interactions necessary to understand the functioning of urban ecosystems extend far beyond the urban boundaries defined by political or biophysical reasons. Thus, the relevant scope of urban ecosystem analysis reaches beyond the city area itself; it comprises not only the ecological infrastructure within cities, but also the hinterlands that are directly affected by the energy and material flows from the urban core and suburban lands (Pickett et al. 2001, p. 129), including city catchments, and peri-urban forests and cultivated fields (La Rosa and Privitera 2013). Whilst virtually any ecosystem is relevant to meet urban ecosystem service demands, the focus here is on services provided within urban areas.

## 11.2 Classifying Urban Ecosystem Services

In recent years a mounting body of literature advanced our understanding of urban ecosystem services in their biophysical, economic, and socio-cultural dimensions. Furthermore, urban ecosystem services were addressed by major initiatives like the Millennium Ecosystem Assessment (Chapter 27 in MA 2005) and The Economics of Ecosystems and Biodiversity (TEEB 2011), and also have received increasing attention as part of the policy debate on ecological infrastructure. Yet, despite the fact that more than half of the world's population today lives in cities, the attention given to urban ecosystems in the ecosystem services literature has yet been relatively modest as compared to other ecosystems like wetlands or forests. This section aims at classifying and describing ecosystem services provided in urban areas and how these may contribute to increase quality of life in cities.

Building on previous categorizations of ecosystem services (Daily 1997; de Groot et al. 2002), the Millennium Ecosystem Assessment (MA 2005) and The Economics of Ecosystem Services and Biodiversity (TEEB 2010) grouped ecosystem services in four major categories: provisioning, regulating, habitat, and cultural and amenity services (TEEB 2010) (Fig. 11.1). Provisioning services include all the material products obtained from ecosystems, including genetic resources, food and fiber, and fresh water. Regulating services include all the benefits obtained from the regulation by ecosystem processes, including the regulation of climate, water, and some human diseases. Cultural services are the non-material benefits people obtain from ecosystems through spiritual enrichment, cognitive development, reflection, recreation, and aesthetic experience as well as their role in supporting knowledge systems, social relations, and aesthetic values. Finally, supporting or habitat services are those that are necessary for the production of all other ecosystem services. Examples include biomass production, nutrient cycling, water cycling, provisioning of habitat for species, and maintenance of genetic pools and evolutionary processes.

Because different habitats provide different types of ecosystem services, general classifications need to be adapted to specific types of ecosystems. Urban ecosystems are especially important in providing services with direct impact on human health and security such as air purification, noise reduction, urban cooling, and runoff mitigation. Yet, which ecosystem services in a given scale are most relevant varies greatly depending on the environmental and socio-economic characteristics of each geographic location. Below we provide a classification and description of important ecosystem services provided in urban areas using the Millennium Ecosystem Assessment and the TEEB initiative as major classification frameworks, and drawing on previous research on the topic (e.g., Bolund and Hunhammar 1999; Gómez-Baggethun and Barton 2013).

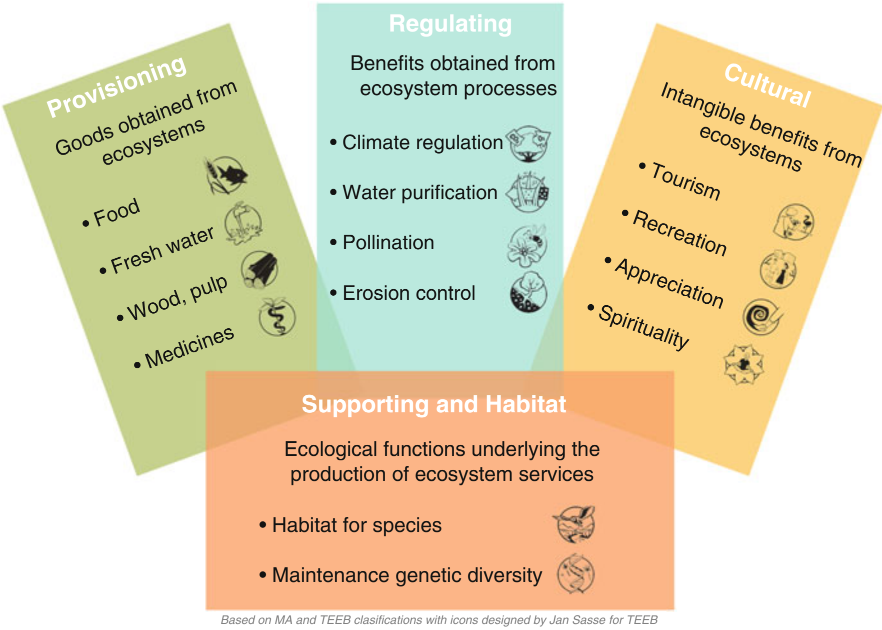


**Fig. 11.1** Classification of ecosystem services based on the Millennium Ecosystem Assessment (MA 2005) and the Economics of Ecosystems and Biodiversity initiative (TEEB 2012) (Produced by Gómez-Baggethun 2013 with icons designed by Jan Sasse for TEEB. Icons reproduced from Jan Sasse for TEEB. Published with kind permission of © Jan Sasse and TEEB 2013. All Rights Reserved)

## *11.2.1 Provisioning Services*

### 11.2.1.1 Food Supply

Urban food production takes place in peri-urban farm fields, on rooftops, in backyards, and in community gardens (Andersson et al. 2007; Barthel et al. 2010). In most geographical contexts, cities only produce a small share of the food they consume, depending largely on other areas to meet their demands (Folke et al. 1997; Ernstson et al. 2010). In some geographical areas and in particular periods, however, food production from urban agriculture can play an important role for food security, especially during economic and political crises (Smit and Nasr 1992; Moskow 1999; Page 2002; Buchmann 2009; Barthel et al. 2011; Barthel and Isendahl 2013). Altieri et al. (1999) estimated that in 1996 food production in urban gardens of Havana included 8,500 t of agricultural products, 7.5 million eggs and

3,650 t of meat. Moustier (2007) provides an extensive summary of the importance of urban agriculture in 14 African and Asian cities. Among the results they found that 90 % of all vegetables consumed in Dar es Salaam (Jacobi et al. 2000) and 60 % of vegetables consumed in Dakar (Mbaye and Moustier 2000) originate from urban agriculture. With regards to staple foods such as rice, plantain banana, and maize, the situation is highly variable among cities. In Asia, the share of rice supplied by the city to urban residents ranges from 7 % (in Phnom Penh) to 100 % (in Vientiane, where pressure on land is low); Hanoi is an intermediary case with 58 % (Anh 2004; Ali et al. 2005). For a detailed examination of the connection between urbanization and food systems, see Chap. 26.

#### 11.2.1.2 Water Supply

The growth of cities throughout the world presents new challenges for securing water to meet societal needs (Fitzhugh and Richter 2004). Ecosystems provide cities with fresh water for drinking and other human uses and by securing storage and controlled release of water flows. Vegetation cover and forests in the city catchment influences the quantity of available water (for a global overview of cities' relationships with freshwater ecosystem services, see Chap. 3). One of the most widely cited examples of the importance of functioning ecosystems for city water supply is the New York City Watershed. This watershed is one of New York State's most important natural resources, providing approximately 1.3 billion gallons of clean drinking water to roughly nine million people every day. This is the largest unfiltered water supply in the United States (Chichilnisky and Heal 1998). Another example is the Omerli Watershed outside Istanbul, Turkey. The Omerli Watershed is the most important among the seven Mediterranean watersheds that provides drinking water to Istanbul, a megacity with over ten million people. The watershed, however, is threatened by urban development in and around its drinking water sources, and it faces acute, unplanned pressures of urbanization with potentially serious impacts on water quality and biodiversity (Wagner et al. 2007). For a detailed assessment on Istanbul, including further discussion on the Omerli Watershed, see Chap. 16.

### *11.2.2 Regulating Services*

#### 11.2.2.1 Urban Temperature Regulation

Ecological infrastructure in cities regulates local temperatures and buffers the effects of urban heat islands (Moreno-Garcia 1994). For example, water areas buffer temperature extremes by absorbing heat in summertime and by releasing it in wintertime (Chaparro and Terradas 2009). Likewise, vegetation reduces temperature in the hottest months through shading and through absorbing heat from the air by evapotranspiration, particularly when humidity is low (Bolund and Hunhammar 1999; Hardin and Jensen 2007). Water from the plants absorbs heat as it evaporates, thus cooling the air in the process (Nowak and Crane 2000). Trees can also regulate local surface and air temperatures by reflecting solar radiation and shading surfaces, such as streets and sidewalks that would otherwise absorb heat. Decreasing the heat loading of the city is among the most important regulating ecosystem services trees provide to cities (McPhearson 2011).

#### 11.2.2.2 Noise Reduction

Traffic, construction, and other human activities make noise a major pollution problem in cities, affecting health through stress. Urban soil and plants can attenuate noise pollution through absorption, deviation, reflection, and refraction of sound waves (Aylor 1972; Kragh 1981; Fang and Ling 2003). In row plantings of trees, sound waves are reflected and refracted, dispersing the sound energy through the branches and trees. It has also been shown that different plant species mitigate noise differently (see e.g., Ishii 1994; Pathak et al. 2007). Empirical research has found that vegetation factors important for noise reduction include density, width, height and length of the tree belts as well as leaf size and branching characteristics. For example, the wider the vegetation belt, the higher the density, and the more foliage and branches to reduce sound energy, the greater the noise reduction effect (Fang and Ling 2003). Noise reduction is also affected by factors beyond the characteristics of vegetation. For example, climate influences the velocity of sound propagation (Embleton 1963) and noise attenuation increases with distance between the source point and the receiver due to friction between atmospheric molecules when sound progresses (Herrington 1976).

#### 11.2.2.3 Air Purification

Air pollution from transportation, industry, domestic heating, and solid urban waste incineration is a major problem for environmental quality and human health in the urban environment; it leads to increases in respiratory and cardiovascular diseases. Vegetation in urban systems can improve air quality by removing pollutants from the atmosphere, including ozone ($O_3$), sulfur dioxide ($SO_2$), nitrogen dioxide ($NO_2$), carbon monoxide (CO) and particulate matter less than 10 μm (PM10) (Nowak 1994a; Escobedo et al. 2008). While significant differences in performance have been found between plant species (e.g., between deciduous and evergreen species), urban trees have been shown to be especially important in intercepting air pollutants (Aylor et al. 2003). The distribution of different particle size fractions can differ both between and within species and also between leaf surfaces and in waxes (Dzierzanowski et al. 2011). Removal of pollution takes place as trees and shrubs filter out airborne particulates through their leaves (Nowak 1996). Performance of pollution removal also follows daily variation because during the night the plant stomata are closed and do not absorb pollutants, and monthly variation because of the changes in light hours and because of the shedding of the leaves by deciduous forest during the winter.

#### 11.2.2.4 Moderation of Climate Extremes

Climate change is increasing the frequency and intensity of environmental extremes; this poses increasing adaptation challenges for cities, especially for those located in coastal areas (Meehl and Tebaldi 2004; Zahran et al. 2008). In Europe, heat waves have been the most prominent hazard with regards to human fatalities in the last decade. The European 2003 heat wave, for example, accounted for more than 70,000 excess deaths (EEA 2010). Ecological infrastructure formed by mangroves, deltas and coral reefs can act as natural barriers that buffer cities from extreme climate events and hazards, including storms, heat waves, floods, hurricanes, and tsunamis; this infrastructure can drastically reduce the damage caused to coastal cities (Farber 1987; Danielsen et al. 2005; Kerr and Baird 2007). Vegetation also stabilizes the ground and reduces the likelihood of landslides. Devastating effects caused by events like the Indian Ocean Tsunami in 2004 and Hurricane Katrina in 2005 have led a number of scientists to call for a new vision in risk management and vulnerability reduction in cities, based on wise combinations in the use of built infrastructure (e.g., levees) and ecological infrastructure (e.g., protective role of vegetation) (Danielsen et al. 2005; Depietri et al. 2012).

#### 11.2.2.5 Runoff Mitigation

Increasing the impermeable surface area in cities leads to increased volumes of surface water runoff, and thus increases the vulnerability to water flooding. Vegetation reduces surface runoff following precipitation events by intercepting water through the leaves and stems (Villarreal and Bengtsson 2005). The underlying soil also reduces infiltration rates by acting as a sponge by storing water in the pore spaces until it percolates as through-flow and base-flow. Urban landscapes with 50–90 % impervious cover can lose 40–83 % of rainfall to surface runoff compared to 13 % in forested landscapes (Bonan 2002). Interception of rainfall by tree canopies slows down flooding effects and green areas reduce the pressure on urban drainage systems by percolating water (Bolund and Hunhammar 1999; Pataki et al. 2011). Street trees in New York, for instance, intercept 890 million gallons of stormwater annually (Peper et al. 2007). Other means of reducing urban stormwater runoff include linear features (bioswales), green roofs, and rain gardens (Clausen 2007; Shuster et al. 2008). For example, green roofs can retain 25–100 % of rainfall, depending on rooting depth, roof slope, and the amount of rainfall (Oberndorfer et al. 2007). Also, green roofs may delay the timing of peak runoff, thus lessening the stress on storm-sewer systems. Rain gardens and bioretention filters can also reduce surface runoff (Clausen 2007; Villarreal and Bengtsson 2005; Shuster et al. 2008).

#### 11.2.2.6 Waste Treatment

Ecosystems filter out and decompose organic wastes from urban effluents by storing and recycling waste through dilution, assimilation and chemical re-composition (TEEB 2011). Wetlands and other aquatic systems, for example, filter wastes from human activities; this process reduces the level of nutrients and pollution in urban wastewater (Karathanasis et al. 2003). Likewise, plant communities in urban soils can play an important role in the decomposition of many labile and recalcitrant litter types (Vauramo and Setälä 2010). In urban streams, nutrient retention can be increased by adding coarse woody debris, constructing in-channel gravel beds, and increasing the width of vegetation buffer zones and tree cover (Booth 2005).

#### 11.2.2.7 Pollination, Pest Regulation and Seed Dispersal

Pollination, pest regulation and seed dispersal are important processes in the functional diversity of urban ecosystems and can play a critical role in their long term durability (Andersson et al. 2007). However, pollinators, pest regulators and seed dispersers are threatened by habitat loss and fragmentation due to urban development and expansion. In this context, allotment gardens (called community gardens in North America, i.e. a plot of land made available for individual, non-commercial gardening), private gardens and other urban green spaces have been shown to be important source areas (Ahrné et al. 2009). Also, research in urban ecosystem services shows that a number of formal and informal management practices in allotment gardens, cemeteries and city parks promote functional groups of insects that enhance pollination and bird communities, which in turn enhance seed dispersal (Andersson et al. 2007). To manage these services sustainably over time, a deeper understanding of how they operate and depend on biodiversity is crucial (Nelson et al. 2009). Jansson and Polasky (2010) have developed a method for quantifying the impact of change in pollination potential in the regional urban landscape. Their results indicate that while the impact of urban development on the pollination service can be modest, the erosion of the resilience of the service, measured through change in response diversity, could be potentially high. For discussion on response diversity see Elmqvist et al. (2003).

#### 11.2.2.8 Global Climate Regulation

Because urban areas exhibit multiple artificial surfaces and high levels of fossil fuel combustion, climate change impacts may be exacerbated in cities (Meehl and Tebaldi 2004). Emissions of greenhouse gases in cities include carbon dioxide ($CO_2$), methane ($CH_4$), nitrous oxide ($NO_2$), chlorofluorocarbons (CFCs), and tropospheric ozone ($O_3$). Urban trees act as a sinks of $CO_2$ by storing excess carbon as biomass during photosynthesis (Birdsey 1992; Jo and McPherson 1995; McPherson and Simpson 1999). Because the amount of $CO_2$ stored is proportional to the biomass of the trees, increasing the number of trees can potentially slow the accumulation of atmospheric carbon in urban areas. Thus an attractive option for climate change mitigation in cites is tree-planting programs. The amount of carbon stored and sequestered by urban vegetation has often been found to be quite substantial, for instance, 6,187 t/year in Barcelona (Chaparro and Terradass 2009) and 16,000 t/year in Philadelphia (Nowak et al. 2007b). Urban soils also act as carbon pools (Nowak and Crane 2000; Pouyat et al. 2006; Churkina et al. 2010). Yet, the amount of carbon a city can offset locally through ecological infrastructure is modest compared to overall city emissions (Pataki et al. 2011).

## *11.2.3 Cultural Services*

### 11.2.3.1 Recreation

Because city environments may be stressful for inhabitants, the recreational aspects of urban ecosystems are among the highest valued ecosystem service in cities (Kaplan and Kaplan 1989; Bolund and Hunhamar 1999; Chiesura 2004; Konijnendijk et al. 2013). Parks, forests, lakes and rivers provide manifold possibilities for recreation, thereby enhancing human health and well-being (Konijnendijk et al. 2013). For example, a park experience may reduce stress, enhance contemplativeness, rejuvenate the city dweller, and provide a sense of peacefulness and tranquility (Kaplan 1983). The recreational value of parks depends on ecological characteristics such as biological and structural diversity, but also on built infrastructure such as availability of benches and sport facilities. The recreational opportunities of urban ecosystems also vary with social criteria, including accessibility, penetrability, safety, privacy and comfort, as well as with factors that may cause sensory disturbance (i.e., recreational value decreases if green areas are perceived to be ugly, trashy or too loud) (Rall and Haase 2011). Urban ecosystems like community gardens also offer multiple opportunities for decommodified leisure and nowadays represent important remnants of the shrinking urban commons.

### 11.2.3.2 Aesthetic Benefits

Urban ecosystems play an important role as providers of aesthetic and psychological benefits that enrich human life with meanings and emotions (Kaplan 1983). Aesthetic benefits from urban green spaces have been associated with reduced stress (Ulrich 1981) and with increased physical and mental health (e.g., Maas 2006; van den Berg et al. 2010a). Ulrich (1984) found that a view through a window looking out at greenspaces could accelerate recovery from surgeries, and van den Berg et al. (2010b) found that proximity of an individual's home to green spaces was correlated with fewer stress-related health problems and a higher general health perception. People often choose where to live in cities based in part on the characteristics of the natural landscapes (Tyrväinen and Miettinen 2000). Several studies have shown an increased value of properties (as measured by hedonic pricing) with greater proximity to green areas (Tyrväinen 1997; Cho et al. 2008; Troy and Grove 2008; Tyrväinen and Miettinen 2000; Jim and Chen 2006).

#### 11.2.3.3 Cognitive Development

Exposure to nature and green space provide multiple opportunities for cognitive development which increases the potential for stewardship of the environment and for a stronger recognition of ecosystem services (Krasny and Tidball 2009; Tidball and Krasny 2010). As an example, urban forests and allotment gardens are often used for environmental education purposes (Groening 1995; Tyrväinen et al. 2005) and facilitate cognitive coupling to seasons and ecological dynamics in technological and urbanized landscapes. Likewise, urban allotments, community gardens, cemeteries and other green spaces have been found to retain important bodies of local ecological knowledge (Barthel et al. 2010), and embed the potential to compensate observed losses of ecological knowledge in wealthier communities (Pilgrim et al. 2008). The benefits of preserving local ecological knowledge have been highlighted in terms of increased resilience and adaptive capacities in urban systems (Buchmann 2009), and the potential to sustain and increase other ecosystem services (Colding et al. 2006; Barthel et al. 2010). For further discussion on how urban landscapes can serve as learning arenas for biodiversity and ecosystem services management, see Chap. 30.

#### 11.2.3.4 Place Values and Social Cohesion

Place values refer to the affectively charged attachments to places (Feldmann 1990; Altman and Low 1992). Research conducted in Stockholm, for example, found sense of place to be a major driver for environmental stewardship, with interviewees showing strong emotional bonds to their plots and the surrounding garden areas (Andersson et al. 2007). Attachment to green spaces in cities can also give rise to other important societal benefits, such as social cohesion, promotion of shared interests, and neighborhood participation (Gotham and Brumley 2002). Examples include studies conducted in Chicago, Illinois, United States, and Cheffield, United Kingdom (Bennett 1997). Environmental authorities in the European Union have emphasized the role of urban green space in providing opportunities for interaction between individuals and groups that promote social cohesion and reduce criminality (European Environmental Agency 2011; Kázmierczak 2013). Likewise, urban ecosystems have been found to play a role in defining identity and sense of community (Chavis and Pretty 1999; Gotham and Brumley 2002). Research on sense of community in the urban environment indicates that an understanding of how communities are formed enable us to design housing that will be better maintained and will provide for better use of surrounding green areas (Newman 1981).

## 11.2.4 Habitat Services

### 11.2.4.1 Habitat for Biodiversity

Urban systems can play a significant role as refuge for many species of birds, amphibians, bees, and butterflies (Melles et al. 2003; Müller et al. 2010). Well-designed green roofs can provide habitat for species affected by urban land-use changes (Oberndorfer et al. 2007; Brenneisen 2003). In cold and rainy areas, golf courses in urban setting can have the potential to contribute to wetland fauna support (Colding and Folke 2009; Colding et al. 2009). Old hardwood deciduous trees in the National City Park of Stockholm, Sweden are seen as an important resource for the whole region for species with high dispersal capacity (Zetterberg 2011). Diversity of species may peak at intermediate levels of urbanization, at which many native and non-native species thrive, but it typically declines as urbanization intensifies (Blair 1996).

A synthesis of the above classification of urban ecosystem services is provided in Table 11.1

## 11.2.5 Ecosystem Disservices

Urban ecosystems not only produce ecosystem services, but also ecosystem disservices, defined as "functions of ecosystems that are perceived as negative for human well-being" (Lyytimäki and Sipilä 2009, p. 311). For example, some common city tree and bush species emit volatile organic compounds (VOCs) such as isoprene, monoterpenes, ethane, propene, butane, acetaldehyde, formaldehyde, acetic acid and formic acid, all of which can indirectly contribute to urban smog and ozone problems through CO and $O_3$ emissions (Geron et al. 1994; Chaparro and Terradas 2009). Urban biodiversity can also cause damages to physical infrastructures; microbial activity can result in decomposition of wood structures and bird excrements can cause corrosion of stone buildings and statues. The root systems of vegetation often cause substantial damages by breaking up pavements and some animals are often perceived as a nuisance as they dig nesting holes (de Stefano and Deblinger 2005; Lyytimäki and Sipila 2009).

Green-roof runoff may contain higher concentrations of nutrient pollutants, such as nitrogen and phosphorus, than are present in precipitation inputs (Oberndorfer et al. 2007). Further disservices from urban ecosystems may include health problems from wind-pollinated plants causing allergic reactions (D'Amato 2000), fear from dark green areas that are perceived as unsafe, especially by women at night-time (Bixler and Floyd 1997; Koskela and Pain 2000; Jorgensen and Anthopoulou 2007), diseases transmitted by animals (e.g., migratory birds carrying avian influenza, dogs carrying rabies), and blockage of views by trees (Lyytimäki et al. 2008). Likewise, just as some plants and animals are perceived by people as services, as

**Table 11.1** Classification of important ecosystem services in urban areas and underlying ecosystem functions and components

| Ecosystem functions | Ecosystem service type | Examples | Key references |
|---|---|---|---|
| Energy conversion into edible plants through photosynthesis | Food supply | Vegetables produced by urban allotments and peri-urban areas | Altieri et al. (1999) |
| Percolation and regulation of runoff and river discharge | Runoff mitigation | Soil and vegetation percolate water during heavy and/or prolonged precipitation events | Villarreal and Bengtsson (2005) |
| Photosynthesis, shading, and evapotranspiration | Urban temperature regulation | Trees and other urban vegetation provide shade, create humidity and block wind | Bolund and Hunhammar (1999) |
| Absorption of sound waves by vegetation and water | Noise reduction | Absorption of sound waves by vegetation barriers, specially thick vegetation | Aylor (1972); Ishii (1994); Kragh (1981) |
| Dry deposition of gases and particulate matter | Air purification | Absorption of pollutants by urban vegetation in leaves, stems and roots | Escobedo and Nowak (2009); Jim and Chen (2009); Chaparro and Terradas (2009); Escobedo et al. (2011) |
| Physical barrier and absorption of kinetic energy | Moderation of environmental extremes | Storm, flood, and wave buffering by vegetation barriers; heat absorption during severe heat waves; intact wetland areas buffer river flooding | Danielsen et al. (2005); Costanza et al. (2006b) |
| Removal or breakdown of xenic nutrients | Waste treatment | Effluent filtering and nutrient fixation by urban wetlands | Vauramo and Setälä (2010) |
| Carbon sequestration and storage by fixation in photosynthesis | Global climate regulation | Carbon sequestration and storage by the biomass of urban shrubs and threes | Nowak (1994b); McPherson (1998) |
| Movement of floral gametes by biota | Pollination and seed dispersal | Urban ecosystem provides habitat for birds, insects, and pollinators | Hougner et al. (2006); Andersson et al. (2007) |

(continued)

**Table 11.1** (continued)

| Ecosystem functions | Ecosystem service type | Examples | Key references |
|---|---|---|---|
| Ecosystems with recreational values | Recreation | Urban green areas provide opportunities for recreation, meditation, and relaxation | Chiesura (2004); Maas et al. (2006) |
| Human experience of ecosystems | Cognitive development | Allotment gardening as preservation of socio-ecological knowledge | Barthel et al. (2010); Groening (1995); Tyrväinen et al. (2005) |
| Ecosystems with aesthetic values | Aesthetic benefits | Urban parks in sight from houses | Tyrväinen (1997); Cho et al. (2008); Troy and Grove (2008) |
| Habitat provision | Habitat for biodiversity | Urban green spaces provide habitat for birds and other animals that people like watching | Blair (1996); Blair and Launer (1997) |

Modified from Gómez-Baggethun and Barton (2013) based on a literature review
Note: The suitability of indicators for biophysical measurement is scale dependent. Most indicators and proxies provided here correspond to assessment at the plot level

**Table 11.2** Ecosystem disservices in cities (Modified from Gómez-Baggethun and Barton 2013)

| Ecosystem functions | Disservice | Examples | Key references |
|---|---|---|---|
| Photosynthesis | Air quality problems | City tree and bush species emit volatile organic compounds (VOCs) | Chaparro and Terradas (2009); Geron et al. (1994) |
| Tree growth through biomass fixation | View blockage | Blockage of views by trees standing close to buildings | Lyytimäki et al. (2008) |
| Movement of floral gametes | Allergies | wind-pollinated plants causing allergic reactions | D'Amato (2000) |
| Aging of vegetation | Accidents | Break up of branches falling in roads and trees | Lyytimäki et al. (2008) |
| Dense vegetation development | Fear and stress | Dark green areas perceived as unsafe in night-time | Bixler and Floyd (1997) |
| Biomass fixation in roots; decomposition | Damages to infrastructure | Breaking up of pavements by roots; microbial activity | Lyytimäki and Sipila (2009) |
| Habitat provision for animal species | Habitat competition with humans | Animals/insects perceived as scary, unpleasant, disgusting | Bixler and Floyd (1997) |

Modified from Gómez-Baggethun and Barton (2013)

discussed above, animals such as rats, wasps and mosquitoes, and plants such as stinging nettles, are perceived by many as disservices. A summary of disservices from urban ecosystems is provided in Table 11.2.

## 11.3 Valuing Urban Ecosystem Services

### *11.3.1 Ecosystem Services Values*

Valuation of ecosystem services involves dealing with multiple, and often conflicting value dimensions (Martinez Alier et al. 1998; Chan et al. 2012; Martín-López et al. 2013). In this section, we broaden the traditional focus of the ecosystem services literature on biophysical measurement and monetary values to explore a range of value domains, including biophysical, monetary, socio-cultural, health, and insurance values, and discuss concepts and methods through which they may be measured and captured.

#### 11.3.1.1 Biophysical Values

Quantifying ecosystem service performance involves the use of biophysical measures and indicators. The difficulty of measuring ecosystem services in biophysical terms increases as the focus shifts from provisioning, to regulating to habitat, to cultural services. Thus, while most provisioning and some regulating ecosystem services can be quantified through direct measures, such as tons of food per hectare per year, or tons of carbon sequestered per hectare per year, in most cases measurement in biophysical terms involves the use of proxies and indicators.

Biophysical measures of ecosystem services are often presented as a prerequisite for sound economic valuations. While this may hold true, biophysical measures themselves often provide powerful information to guide urban planning. Thus, various biophysical indexes of urban green areas have been used for guiding planning procedures in cities (revised in Farrugia et al. 2013). An early attempt was made in Berlin, Germany with the Biotope Area Factor (BAF), which scored land surface types in development sites according to their ecological potential and formulated target BAFs for specific urban functions which developers were obliged to meet in order to obtain approval for any development proposal. Malmö City Council in Sweden adopted a similar system to incorporate green and blue infrastructure in land use planning, while aiming to reduce the extent of impervious surfaces in any development plans (Kruuse 2011). Another attempt to quantify the value of green areas was made in Kent Thameside in the United Kingdom (Defra 2008), which scored ecosystem services such as biodiversity, recreation and flood regulation using surrogates. The Southampton City Council in the United Kingdom developed a version of the Green Space Factor (GSF) tool to evaluate the contribution of green areas to water regulation flood control (Finlay 2010).

A summary with examples of indicators and proxies to measure ecosystem services and disservices is provided in Table 11.3.

#### 11.3.1.2 Economic Values

Conventional economic valuations are restricted to priced goods and services, which represent only a limited subset of ecosystem services (i.e., those which are exchanged in markets). As price formation is conditioned to the existence of supply and demand relations, every change in human well-being lacking a market is invisible to conventional economic accounts. The economic literature refers to these effects as environmental externalities, which can be either negative (e.g., pollution) or positive (e.g., ecosystem services). The public good nature of most ecosystem services implies that their economic value is often not adequately reflected in management decisions that are mainly based on economic information (e.g., cost–benefit analysis). Consequently, it is argued, ecosystem services with no explicit economic value tend to be depleted.

**Table 11.3** Examples of indicators and proxies for measuring urban ecosystem services and disservices in biophysical terms

| Ecosystem services | Examples of biophysical indicators and proxies |
|---|---|
| *Provisioning services* | |
| Food supply | Production of food (t/year) |
| Freshwater supply | Water flow ($m^3$/year) |
| *Regulating services* | |
| Water flow regulation and runoff mitigation | Soil infiltration capacity; % sealed relative to permeable surface (ha) |
| Urban temperature regulation | Leaf Area Index |
| Noise reduction | Leaf area ($m^2$) and distance to roads (m); noise reduction [dB(A)]/vegetation unit (m) |
| Air purification | $O_3$, $SO_2$, $NO_2$, CO, and $PM_{10}$ µm pollutant flux (g/$cm^2$/s) multiplied by tree cover ($m^2$) |
| Moderation of environmental extremes | Cover density of vegetation barriers separating built areas from the sea |
| Waste treatment | P, K, Mg and Ca in mg/kg compared to given soil and water quality standards |
| Climate regulation | $CO_2$ sequestration by trees (carbon multiplied by 3.67 to convert to $CO_2$) |
| Pollination and seed dispersal | Species diversity and abundance of birds and bumble bees |
| *Cultural services* | |
| Recreation and health | Area of green public spaces (ha)/inhabitant (or every 1,000 inhabitants); self-reported general health |
| Cognitive development and knowledge preservation | Participation, reification, and external sources of social-ecological memory |
| *Habitat for biodiversity* | |
| Habitat for biodiversity | Abundance of birds, butterflies and other animals valued for their aesthetic attributes |
| *Ecosystem disservices* | *Examples of indicators proxies* |
| Air quality problems | Emission of VOCs (t/year)/vegetation unit |
| View blockage | Tall trees close to buildings |
| Allergies | Allergenicity (e.g., OPALS ranking) |
| Accidents | Number of aged trees |
| Fear and stress | Area of non-illuminated parks |
| Damages on infrastructure | Affected pavement ($m^2$) wood ($m^3$) |
| Habitat competition with humans | Abundance of insects, rats, etc. |

Modified from Gómez-Baggethun and Barton (2013), based on various sources

Because biodiversity loss generally involves long-term economic costs that are not adequately reflected in conventional economic accounts (Boyer and Polasky 2004; Tyrväinen et al. 2005; TEEB 2010; EEA 2011; Escobedo et al. 2011; Elmqvist et al. forthcoming) economic valuation of ecosystem services attempts to make visible the 'hidden' economic costs from the conversion of ecological infrastructure to built infrastructure (or from natural capital to human-made capital). These may include sanitary costs related to health damages from air pollution (Escobedo et al. 2008, 2011; Escobedo and Nowak 2009) and costs from increased property damages with loss of natural barriers to climate extremes (Costanza et al. 2006a).

Over the last few decades, a range of methods have been developed to calculate economic costs resulting from loss of ecological infrastructure. Avoided cost methods, for example, show that loss of urban vegetation can lead to increased energy costs in cooling during the summer season (McPherson et al. 1997; Chaparro and Terradas 2009). Likewise, decline of water regulation services from land-use change and loss of vegetation in the city catchments increase the dependence on water purification technologies, which are generally very costly (Daily and Ellison 2003). Economic costs may also derive the loss of ecosystem services such as air purification (McPherson et al. 1997; Nowak and Crane 2002), noise reduction by vegetation walls (Bolund and Hunhammar 1999), carbon sequestration by urban vegetation (McPherson et al. 1999; Jim and Chen 2009), buffering of climate extremes by natural barriers (Costanza et al. 2006a), and regulation of water flows (Xiao et al. 1998). These costs are not merely hypothetical. In most cases they are real economic costs derived from the partial substitution of ecological infrastructure and ecosystem services by built infrastructure and different economic services. Table 11.4 shows examples of quantitative measures of economic values directly or indirectly attached to ecosystems services in the urban context.

When pollutants are not specified, calculations include $NO_2$, $SO_2$, $PM_{10}$, $O_3$ and CO). Results from Jim and Chen (2009) concerted from RMB to $US after Elmqvist et al. forthcoming. Not all figures were normalized to net present values and therefore they should be taken as illustration only.

Using combinations of valuation methods is often necessary to address multiple ecosystem services (Boyer and Polasky 2004; Costanza et al. 2006b; Escobedo et al. 2011). The choice of valuation methods is determined by factors including the scale and resolution of the policy to be evaluated, the constituencies that can be contacted to obtain data, and supporting data constraints, all subject to a study budget (Table 11.5).

Avoided expenditure or replacement cost methods are often used to address values of regulating services such as air pollution mitigation and climate regulation (Sander et al. 2010). Meta-analyses on economic valuations of ecosystem services show that hedonic pricing (HP) and stated preference (SP) methods (and contingent valuation in particular), have been the methods most frequently used in urban contexts (Boyer and Polasky 2004; Tyrväinen et al. 2005; Costanza et al. 2006b; Kroll and Cray 2010; Sander et al. 2010; Brander and Koetse 2011). Economic valuation using hedonic pricing has often been used to capture recreational and amenity benefits (Tyrväinen and Miettinen 2000), views and aesthetic benefits (Anderson and Cordell 1985; Sander et al. 2010), noise reduction (Kim et al. 2007), air quality (Smith and Huang 1995; Bible et al. 2002; Chattopadhyay 1999), and water quality (Leggett and Bockstael 2000). A review by Kroll and Cray (2010) shows that hedonic pricing methods have been used mainly to value property features at neighborhood scales, especially in relation to open space, vegetation, and wetlands (Table 11.6).

Table 11.7 suggests potential valuation methods that can inform urban planning issues at different scales.

**Table 11.4** Examples of economic valuations of five urban ecosystem services. Examples from empirical studies conducted in Europe, USA, and China

| Ecosystem service | City | Ecological infrastructure | Biophysical accounts | Economic valuation | Reference |
|---|---|---|---|---|---|
| Air purification | Barcelona, Spain | Urban forest | 305.6 t/y | €1,115,908 | Chaparro and Terradas (2009) |
| | Chicago, USA | Urban trees | 5,500 t/y | US$ 9 million | McPherson et al. (1997) |
| | Washington, USA | Urban trees | 540 t/y | – | Nowak and Crane (2000) |
| | | | 0.12 t/ha/y | | |
| | Modesto, USA | Urban forest | 154 t/y | US$ 1.48 million | McPherson et al. (1999) |
| | | | 3.7 lb/tree | US$ 16/tree | |
| | Sacramento, USA | Urban forest | 189 t/y | US$ 28.7 million | Scott et al. (1998) |
| | | | | US$ 1,500/ha | |
| | Lanzhou, China | Urban plants | 28,890 t pm/y | US$ 102 | Jim and Chen 2009 |
| | | | 0.17 t pm/ha/y | US$ 6.3/ha | |
| | | | 1.8 million t $SO_2$/y | – | |
| | | | 10.9 t $SO_2$/ha/y | | |
| | Beijing, China | Urban forest | 2,192 t $SO_2$/y | US$ 4.7 million | Jim and Chen (2009) |
| | | | 1,518 t pm/y | US$ 283/ha | Elmqvist et al. (Forthcoming) |
| | | | 2,192 t $SO_2$/y | | |
| | | | (132 t $SO_2$/ha/y) | | |
| Microclimate regulation | Chicago | City trees | Saved heating 2.1 GJ/tree | US$ 10/tree | McPherson et al. (1997) |
| | | | Saved cooling 0.48 GJ/tree | US$ 15/tree | McPherson (1992) |
| | Modesto, USA | Street and park trees | Saved 110,133 Mbtu/y | US$ 870,000 122kWh/tree | McPherson et al. (1999) |
| | | | | US$ 10/tree) | |
| | Sacramento, USA | Urban vegetation | Saved 9.8 MW/ha/y | US$ 1,774/ha/y | Simpson (1998) |
| | Beijing, China | Urban forest | 1.4kWH/ha/day | US$ 12.3 million | Jim and Chen (2009) |
| | | | | US$ 1,352/ha/y | |

(continued)

**Table 11.4** (continued)

| Ecosystem service | City | Ecological infrastructure | Biophysical accounts | Economic valuation | Reference |
|---|---|---|---|---|---|
| Carbon sequestration | Barcelona, Spain | Urban forest | 113,437 t (gross)<br>5,422 t (net) | | Chaparro and Terradas (2009) |
| | Modesto, USA | Urban forest | 13,900 t or 336 lb/tree | US$ 460,000 or US$ 5/tree | McPherson et al. (1999) |
| | Washington DC, USA | Urban forest | 16,200 t<br>3,500 t/h/y | US$ 299,000/y<br>US$ 653/ha/y | Elmqvist et al. (Forthcoming) |
| | Philadelphia, USA | Urban forest | 530,000 t (gross)<br>96 t/ha<br>16,100 t (net)<br>2.9 t/ha/y | US$ 9.8 million (gross)<br>US$ 297,000 (net) | Nowak et al. (2007b) |
| | Beijing, China | Urban forest | 4, 200,000 t<br>256 t/ha/y | US$ 20,827/ha/y | Jim and Chen (2009) |
| Regulation of water flows | Modesto, USA | Urban forest | Reduced runoff 292,000 $m^3$ or 845 gal/tree | US$ 616,000 or US$ 7/tree | McPherson et al. (1999) |
| | Sacramento | Urban trees | Annual rainfall reduced by 10 % | US$ 572/ha | Xiao et al. (1998) |
| Aesthetic information | Modesto, USA | Urban forest | 88,235 trees | US$ 1.5 million<br>US$ 17/tree) | McPherson et al. (1999) |
| | Guangzou, China | Urban green space | 7,360 ha | US$ 17,822/ha/y | Jim and Chen (2009) |

Modified from Gómez-Baggethun and Barton (2013)

Legend: *PM* particulate matter, *t* ton, *y* year, *lb* pound, *ha* hectare, *GJ* gigajoule, *Mbtu* million British Thermal Units, *MW* megawatt, $m^3$ meters cubed, *gal* gallon, *kWh* kilowatt hours

**Table 11.5** Economic valuation of ecosystem services in urban planning

| Scale | Urban planning issue | Role of economic valuation | Methodological challenges |
|---|---|---|---|
| Region | Prioritizing urban growth alternatives between different areas | Valuing benefits and costs of (i) urban revitalization (ii) urban infill (iii) urban extension (iv) suburban retrofit (v) suburban extension (vi) new neighbor-hoods with (vii) existing infrastructure (ix) new infrastructure (x) in environmentally sensitive areas | Comprehensive benefit-cost analysis at multiple scales and resolutions at multiple locations is expensive |
| | Fair and rational location of undesirable land uses (LULUs) | Value of the impacts and disservices of e.g., power plants and landfills and foregone ecosystem service values of ecological infrastructure | Using benefit-cost analysis to allocate infrastructure with local costs versus regional benefits may not achieve fair outcomes |
| | Preservation of productive peri-urban farm belt | Willingness to pay for preservation of open space and 'short distance' food | Large import substitution possibilities for locally produced food |
| | Water availability to support urban growth | Valuation to support full cost pricing of water supply. Incentive effects of removing water subsidies | Can require inter-regional geographical scope of valuation |
| | Using transferable development rights (TDR) to concentrate growth and achieve zoning | Determine farmer opportunity costs and benefits of foregoing urban development as a basis for predicting the size of a TDR market | |
| Neigh-borhood | Preserving views, open spaces, and parks in neighborhoods | Willingness to pay of households for quality and proximity of recreational spaces | Accounting for substitute sites and recreational activities |
| | Conserving soil drainage conditions and wetlands | Valuation of replacement costs of man-made drainage and storage infrastructure | Hydrological and hydraulic modeling required |
| | Conserving water | Costs of household water harvesting, recycling and xeriscapes | Cost-benefit evaluation requires comparison with full costs of water supply |
| | Natural corridors | Quantify opportunity costs of preserving corridors | Difficulty in specifying habitat connectivity requirements of corridors |
| | Local farm produce | Willingness to pay for local, fresh produce | Large import substitution possibilities for locally produced food |
| | Edible gardens | Recreational value of home gardens | |

(continued)

**Table 11.5** (continued)

| Scale | Urban planning issue | Role of economic valuation | Methodological challenges |
|---|---|---|---|
| Street-scape | Street trees | Value pedestrian safety through slowing traffic; disamenities of heat islands; absorption of stormwater, and airborne pollutants | Associating ecosystem service values at neighborhood and street level to individual trees |
| | Green pavements for stormwater management | Willingness to pay of households for green streetscape; additional costs of larger dimension storm-water | |
| Building | Green rooftops<br>Yard trees<br>Lawns vs. xeriscapes | Additional costs of traditional stormwater management; mitigation of heat island | Associating ecosystem service values at neighborhood and street level to individual roofs, trees and lawns |

Produced by Barton et al. (2012), based on a listing by Duany et al. (2010)

**Table 11.6** Overview of hedonic pricing studies in cities

| Scale | Property feature | # of studies |
|---|---|---|
| National/regional | Policies affecting property rights | 5 |
| Regional/neighborhood | Open space | 28 |
| | Water & wetlands | 24 |
| Neighborhood/streetscape | Open space vegetation & trees | 20 |
| Streetscape | Pavement type | 7 |
| Streetscape/property | Climate & temperature | 5 |
| Building | Energy efficiency | 7 |

Produced by Barton et al. (2012), adapted from Kroll and Cray (2010)

#### 11.3.1.3 Social and Cultural Values

People bring various material, moral, spiritual, aesthetic, and other values to bear on the urban environment; their values can affect their attitudes and actions toward ecosystems and the services they provide. These include emotional, affective and symbolic views attached to urban nature that in most cases cannot be adequately captured by commodity metaphors and monetary metrics (Norton and Hannon 1997; Martinez Alier et al. 1998; Gómez-Baggethun and Ruiz-Pérez 2011; Daniel et al. 2012). Here, we refer to these values broadly as social and cultural values. The ecosystem services literature has defined cultural values as "aesthetic, artistic, educational, spiritual and/or scientific values of ecosystems" (Costanza et al. 1997, p. 254) or as "non-material benefits people obtain from ecosystems through spiritual enrichment, cognitive development, reflection, recreation, and aesthetic experience" (Millennium Ecosystem Assessment 2005, p. 894).

Social and cultural values are included in all prominent ecosystem service typologies (Daily et al. 1997; de Groot et al. 2002; Millennium Ecosystem Assessment 2005). Yet, compared with economic and biophysical values, social, cultural, and other non-material values of ecosystems and biodiversity have generally been neglected in much of the ecosystem services literature. Moreover, social and cultural values may be difficult to measure, often necessitating the use of more holistic approaches and methods that may include qualitative measures, constructed scales, and narration (Patton 2001; Chan et al. 2012). In some cases, tools have been developed to measure these values using constructed scales, as in the case of sense of place (Williams and Roggenbuck 1989; Shamai 1991) and local ecological knowledge (Gómez-Baggethun et al. 2010a). In other cases translating cultural values into quantitative metrics may be too difficult or produce results that are nonsensical or meaningless.

Recent research has made substantial progress in the quest to better integrate social perspectives and valuation techniques into the ecosystem services framework, and to enable a fuller representation of socio-cultural values in research and practice (e.g., Chan et al. 2012). Articulation of social and cultural values in decision-making processes may require, in most cases, some sort of deliberative

**Table 11.7** Potential valuation methods for urban ecosystem service valuation

| Valuation method | Types of value, ecosystem services | Scale | Constituencies | Constraints |
|---|---|---|---|---|
| Hedonic pricing (Revealed Preferences) | Use values (option value) | Building, streetscape and neighborhood characteristics | Home and property owners | Observable quality variables. Spatially explicit |
| | Cultural services (amenities) | | | Autocorrelation and latent variables |
| Travel cost (Revealed Preferences) | Use values | Regional park/recreational destinations | Recreational visitors | No/low travel costs to neighborhood open spaces. Spatially explicit. |
| | Cultural services (amenities) | | | Locational self-selection. |
| Contingent valuation (Stated Preferences) | Use and non-use values | All infrastructure scales, easier for location specific policy scenario | Households or individuals, often as voters | Hypothetical, question framing issues, information burden |
| | All ecosystem services, but often amenities | | | Usually not spatially explicit |
| | Service bundles | | | |
| Choice experiments (Stated Preferences) | Use and non-use values | All infrastructure scales, but easier for location specific policy choice alternatives | Households or individuals, often as consumers | Hypothetical, question framing issues, |
| | All ecosystem services, but often amenities. Incremental service levels, controlling for bundles | | | Information burden |
| | | | | Usually not spatially explicit |
| Production | Use values | Neighborhood and regional scale | Natural scientists, experts | Requires spatially explicit biophysical modeling. |
| Function/Damage cost Replacement cost | Regulating services Use values | Building, streetscape, neighborhood level municipal infrastructure | Engineers, experts | Determining service equivalence for man-made replacement; depends on health and safety standards |
| | All services, but often regulating services | | | |

Produced by Barton et al. (2012)

**Table 11.8** Socio-cultural values of ecosystems and biodiversity

| Socio-cultural values | Explanation | References |
|---|---|---|
| Spiritual values | In many places, especially among peoples with animistic religions, ecosystems and biodiversity are deeply intertwined with spiritual values | Stokols (1990) |
| Sense of place | Emotional and affective bonds between people and ecological sites | Altman and Low (1992), Feldman (1990), Williams et al. (1992), Norton and Hannon (1997) |
| Sense of community | Feelings towards a group and strength of attachment to communities | Doolittle and McDonald (1978), Chavis and Pretty (1999) |
| Social cohesion | Attachment as source of social cohesion, shared interests, and neighborhood participation | Bennett (1997), Gotham and Brumley (2002), Kázmierczak (2013) |

Produced by Gómez-Baggethun (2013)

process, use of locally defined metrics, and valuation methods based on qualitative description and narration. A set of values that may be labeled as socio-cultural and associated descriptions is provided in Table 11.8.

#### 11.3.1.4 Health Values

Multiple connections between urban vegetation and human health have been identified (Tzoulas et al. 2007; Bowler et al. 2010a), and the study of the links between green areas, human health and recovery rates is a rapidly expanding field of research (Grahn and Stigsdotter 2003). For example, access to green space in cities was shown to correlate with longevity (Takano et al. 2002), with recovery from surgeries (Ulrich 1984) as well as with self-reported perception of health (Maas 2006; van den Berg et al. 2010a). Proximity to green space reduced stress in individuals (Korpela and Ylén 2007), and children with attention deficit disorder have showed improved alertness (Taylor and Kuo 2009). Evidence also exists of other health benefits that correspond to green space availability (Hu et al. 2008; Bedimo-Rung et al. 2005; Ohta et al. 2007). Kaczynski and Henderson (2007) reviewed 50 quantitative studies that looked at the relationship between parks and physical activity and found that proximity to parks was associated with increased physical activity.

Green spaces have also been shown to influence social cohesion by providing a meeting place for users to develop and maintain neighborhood ties (Maas et al. 2009; Kázmierczak 2013). Other studies suggest that urban ecosystem services like air pollution reduction (Lovasi et al. 2008; Pérez et al. 2009) and urban cooling (Bowler et al. 2010b) have multiple long term health benefits. However, although the evidence of most studies suggests that green spaces have beneficial health effects, it should be noted that establishing a causal relationship has proven very difficult (Lee and Maheswaran 2010).

#### 11.3.1.5 Environmental Justice Values

Social practices not only affect which ecosystem services are produced through the management of urban ecosystems (Andersson et al. 2007), but also who in society benefits from them (Ernstson 2012). Urban political ecology is the study of ecological distribution conflicts (i.e., conflicts on the access to ecosystem services and on the burdens of pollution). Environmental justice (Hofrichter 1993) represents the perspective within political ecology that conceives of balanced access to ecosystem services and balanced exposure to pollution across groups as a fundamental right. The notion was first used in relation to environmental conflicts in cities of the United States, where minority groups including African Americans, Latinos, and Native Americans bore disproportionate burdens of urban pollution and exposure to toxic waste (Martínez Alier 2005). While the bulk of the literature has focused on unequal exposure to pollution, the study of environmental conflicts related to unequal access to the benefits of ecosystem services are likely to become an important field of research for political ecology in the coming years. A recent study by Ernstson (2012) draws on empirical studies from Stockholm, Cape Town, and other cities to inform a framework to relate ecosystem services to environmental justice in urban areas.

Ecological distribution conflicts not only emerge from unequal access to ecosystem services within cities but also from asymmetries in the appropriation of ecosystem services by cities vis-à-vis their surrounding environment and more distant regions (Hornborg 1998). Extensive research has shown that urban growth depends on the appropriation of vast areas of ecosystem services provision beyond the city boundaries (Folke et al. 1997; Rees 1992; Rees and Wackernagel 1996). Thus, an important associated value of urban ecosystem services resides in their potential to reduce the ecological footprint of cities, and thus, cities' ecological debt to the non-urban environment. Building on the ecosystem services concept, Gutman (2007) calls for a new rural–urban compact, where cities channel more employment opportunities and more income to the rural areas in exchange for a sustainable supply of products and ecosystem services provided by restored rural environments.

#### 11.3.1.6 Insurance Values

Urban ecological infrastructure and ecosystem services can play a major role in increasing the resilience of cities through enhancing their ability to cope with disturbance and adapt to climate and other global change. The contribution of ecological infrastructure and ecosystem services to increased resilience and reduced vulnerability of cities to shocks has been referred to as a form of insurance value (Gómez-Baggethun and de Groot 2010). Ecosystem services that are critical to the resilience of cities in response to specific disturbances include urban temperature regulation, water supply, runoff mitigation, and food production. For example, urban temperature regulation can be critical to buffer the effects of heat waves

**Table 11.9** Sources of resilience and carriers of social-ecological memory to deal with disturbance and change in urban allotments

| Category | Examples found in allotment gardens |
|---|---|
| Habits/rituals (*participation*) | Imitation of practices, exchange of seeds, embodied habits |
| Oral tradition (*participation*) | Ongoing negotiations, mentor programs, daily small talk |
| Rules-in-use (*reification*) | Norms of social conduct, norms towards the environment, property rights |
| Physical forms/artifacts (*reification*) | Written material, pictures, the gardens, tools, stories |
| External memory sources | Media and organizations external to individual allotment gardens |

Produced by Jansson (2012), modified from Barthel et al. (2010)

(Lafortezza et al. 2009; EEA 2010; Depietri et al. 2012), ecological infrastructure that enhances water supply can increase resilience to drought, and runoff mitigation provided by urban vegetation can reduce the likelihood of damages by flooding and storms (Villarreal and Bengtsson 2005).

Special attention has been given to the role that food production in urban allotments can play in increasing food security and building resilience to shocks, especially in times of economic and political crisis (Smit and Nasr 1992; Moskow 1999; Page 2002; MA 2005; UNEP 1996). The Millennium Ecosystem Assessment notes that "for many of today's urban dwellers, urban agriculture provides an important source of food and supplementary income" (MA 2005, p. 810). In Cuba, urban agriculture that emerged in response to the decline of Soviet aid and trade and the persistence of the trade embargo came to play a major role in food security (Altieri et al. 1999; Moskow 1999). Likewise, urban agriculture has provided an important safety net for landless peoples in sub-Saharan Africa (Maxwell 1999). At present, urban social movements associated with allotments gardens are emerging all around Europe (Barthel et al. 2010). Table 11.9 provides examples of how urban allotments can contribute to increasing resilience and storing social-ecological memory to deal with shocks.

Recent contributions have also noted the role of urban ecosystems in maintaining living bodies of local ecological knowledge (Andersson et al. 2007). Because local and traditional knowledge systems embed accumulated knowledge and practices to cope with environmental change, maintaining these bodies of knowledge can be essential for resilience to shocks (Barthel et al. 2010; Gómez-Baggethun et al. 2012).

Measuring the insurance value of resilience remains a challenging task. For example, there is growing evidence that increased resilience can bring multiple indirect economic benefits (Walker et al. 2010). Yet, translating the value of resilience into monetary metrics can be complicated and in some cases also useless. Because the economic value of ecosystem services is affected by the distance to ecological thresholds, trying to capture the value of resilience with economic valuation at the margin can be risky and even misleading (Limburg et al. 2002);

when thresholds are close, small changes can trigger abrupt shifts in ecosystem services and related values (Scheffer et al. 2001; Walker and Meyers 2004; Pascual et al. 2010).

## 11.4 Ecosystem Services and Urban Governance

### *11.4.1 Connecting Ecosystem Service Values to Urban Policy and Governance*

Local authorities in many cities throughout the world are looking for innovative ways to maintain and increase ecological infrastructure as a part of urban planning and design (Rosenzweig et al. 2009; see also Chap. 27). Yet, many studies have suggested that the ability of local authorities to implement ecological infrastructure is not sufficiently recognized and hence lacks further integration into spatial planning systems (Kruuse 2011). Economic and non-economic valuation of ecosystem services is often demanded by policy makers and practitioners as supporting information to guide decisions in urban planning and governance. Ways in which valuation can inform urban planning include awareness raising, economic accounting, priority-setting, incentive design, and litigation, thus broadly reflecting the objectives of "recognizing, demonstrating, and capturing value" as suggested in the TEEB report (TEEB 2010) (Fig. 11.2).

The demand for accuracy and reliability of valuation methods increase successively when moving from a policy setting, requiring simply awareness raising (e.g. regarding costs of ecosystem service loss); to including ecological infrastructure in accounting of municipal assets; to priority-setting (e.g. for location of new neighborhoods); to instrument design (e.g. user fees to finance public utilities); or finally to calculation of claims for damage compensation in a litigation (e.g. siting of locally undesirable land-uses (LULUs)). While several monetary valuation methods are potentially applicable at different spatial scales, valuation studies in urban areas for support in any given decision-making context are more demanding because of requirements for higher spatial resolution and multiple scales of analysis. Using valuation of urban ecosystem services for decisions about ecological infrastructure requires attributing service values to the particular assets at specific locations. For regulating services this requires some form of spatially explicit biophysical modeling which increases valuation costs with increasing geographical scale and resolution (Fig. 11.2).

### *11.4.2 Ecosystem Services in Urban Planning and Design*

A better understanding of ecosystem services, their spatial characteristics and interrelations is very much needed in order to move ecosystem services from an

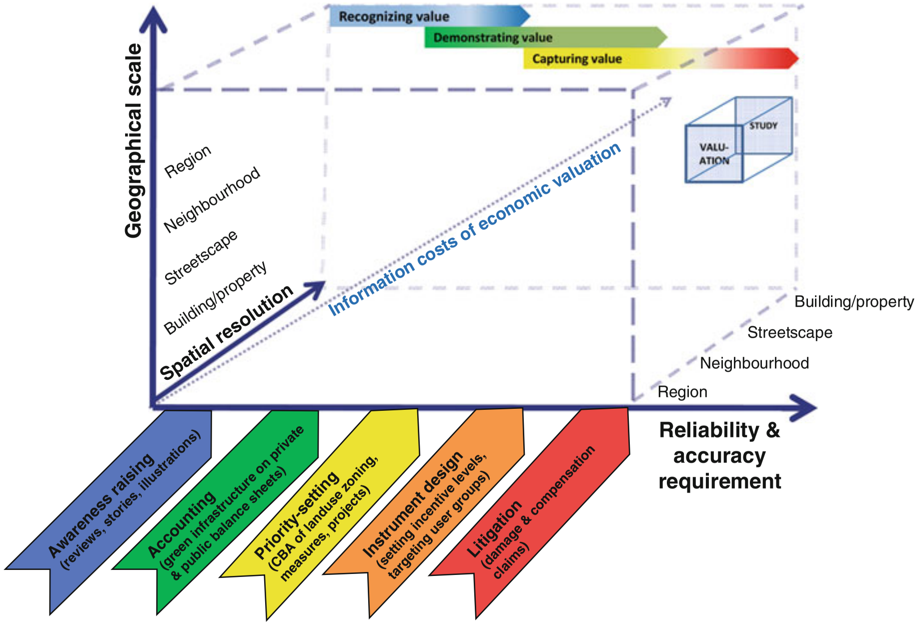


**Fig. 11.2** Trade-offs between scale, resolution, and accuracy in recognizing, demonstrating and capturing values in different decision-support contexts of valuation (Source: Adapted from Gómez and Baggethun 2012; Modified from Gómez-Baggethun and Barton 2013, p. 241. Published with kind permission of © Elsevier 2012. All Rights Reserved)

assessment tool to a practical instrument for planning and design (Troy and Wilson 2006). For a discussion of patterns and trends in urban biodiversity and design, with applications to ecosystem services, see Chap. 10. Ecosystem service research is slowly merging with landscape ecology and spatial planning to address the issue of the scales and structures related to the generation and utilization of ecosystem services (see e.g., Fisher et al. 2009). There are several possible spatial relationships between the scale at which one ecosystem service is generated and the scale at which people may benefit from it. Some services can only be enjoyed at the source (e.g., shading from vegetation or many recreational uses of green areas), whereas others spill over into adjacent areas (e.g., noise reduction, wind breaks and pollination). Such spill-over may be unidirectional or directional, the latter partly due to physical geography (e.g., of waterways, topography, and location of roads) and the location of the beneficiaries. The connection between ecosystem service source areas and end-users is mediated by social structures such as built infrastructure and institutions defining access to land. There are a wide range of solutions for providing the people in different cities with similar ecosystem services and city-specific scales of relevance for addressing each ecosystem service.

Spatial scales and landscape structure affect the possibilities and constraints for ecosystem service planning. Efforts to address bundles of services to create or maintain multifunctional landscapes have seen considerable progress in the last decade. On larger scales, access to multiple ecosystem services can be achieved by ensuring generation of different ecosystem services in different parts of the landscape—as long as they are accessible to the users (see Brandt and Vejre 2003). However, the scale in these studies is often coarse and is not well suited to pick up the small-scale heterogeneity of the urban landscape. When the potential service-providing areas are few and situated in a matrix of many and diverse users, the number of services expected from each of these areas is likely to increase. Multiple interests coupled with limited size will highlight trade-offs between services and potentially lead to conflicts.

The urban mosaic is often complex and characterized by multiple spatial boundaries between different land-uses. With such heterogeneity, relative location and context can be expected to be especially important. Some ecosystem services will rely on species that require easy access to two or more habitat types (Andersson et al. 2007). For example, Lundberg et al. (2008) described how long-term maintenance of an oak dominated landscape with highly valued cultural and aesthetical qualities in Sweden depends also on patches of coniferous forest, the latter providing the main seed disperser, Eurasian Jay (*Garrulus glandarius*), with breeding habitat. Other ecosystem services such as pest control or pollination rely on close proximity to a source area (e.g. Blitzer et al. 2012).

Many ecosystem services are directly mediated or provided by different organisms (Kremen 2005) and can thus be addressed through a focus on these organisms. From a temporal perspective, long-term provisioning of ecosystem services within cities raises concerns about population dynamics, including the risks of extinction (at least on the local scale) and potential for re-colonization. For many species, habitat within cities may be perceived as quite fragmented, suggesting not only that future urban development should try to avoid further fragmentation but also that increased connectivity should be one of the prime objectives for restoration efforts (Hanski and Mononen 2011). It seems reasonable that the general character of urban green structures should be as similar as possible to that of the hinterlands in order to benefit the most from potential near-city source areas of ecosystem-service-providing organisms. To draw on these source areas, cities need a connected green structure that reaches all the way through urban and peri-urban areas into the rural.

From a spatial perspective, at least two distinct strategies for ensuring ecosystem service generation can be identified (see Forman 1995). The first draws on traditional conservation planning and is foremost concerned with enhancing and securing internal values within a bounded area, for example biodiversity or recreational opportunities within a protected area. This approach advocates large areas, and if spatial issues are considered at all it is usually in terms of green area networks where "green areas" are not necessarily the same as ecosystem service generating areas. The second strategy adopts more of a landscape management perspective in which the focus is on enhancing the performance of all parts of the landscape (see Fahrig et al. 2011), not just the few large areas suggested in the first approach. Instead, this perspective highlights the potential of smaller units interspersed throughout an area (for example, small clumps of trees mixed with residential development may enhance overall biodiversity or aesthetic values). The two approaches are by no means incompatible or always opposing, but their focus, prioritizations, and trade-offs differ. Both are needed and address different aspects of ecosystem services.

## 11.5 Ecosystem Services in Three Cities

Since appropriate management strategies for ecosystems outside and within cities may differ due to, for example, the difference in social, ecological and economic pressures, it is essential to acquire a fairly detailed outline of a city's ecosystem service needs, both within and outside the city boundaries. The information on where different ecosystem services are being produced (i.e., the location of the production unit), whether inside the city itself or elsewhere, is also significant in determining how vulnerable or resilient a city and its inhabitants are to potential disruptions in the generation of ecosystem services when exposed to change. Assessing restoration/transformation potential in the urban landscape is important for mitigating disruptions in service generation and can be a powerful tool for urban planning. Furthermore, since the generation of ecosystem services in a specific ecosystem often affects the generation potential in other ecosystems, it is also crucial to identify spill-over effects. In the following tables a review of ecosystem services for three different cities are presented: Cape Town, New York, and Barcelona (in-depth assessments on Cape Town and New York are presented in Chaps. 24 and 19, respectively).