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# Classifying and valuing ecosystem services for urban planning

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ABSTRACT

While technological progress has fostered the conception of an urban society that is increasingly decoupled from ecosystems, demands on natural capital and ecosystem services keep increasing steadily in our urbanized planet. Decoupling of cities from ecological systems can only occur locally and partially, thanks to the appropriation of vast areas of ecosystem services provision beyond the city boundaries. Conserving and restoring ecosystem services in urban areas can reduce the ecological footprints and the ecological debts of cities while enhancing resilience, health, and quality of life for their inhabitants. In this paper we synthesize knowledge and methods to classify and value ecosystem services for urban planning. First, we categorize important ecosystem services and disservices in urban areas. Second, we describe valuation languages (economic costs, socio-cultural values, resilience) that capture distinct value dimensions of urban ecosystem services. Third, we identify analytical challenges for valuation to inform urban planning in the face of high heterogeneity and fragmentation characterizing urban ecosystems. The paper discusses various ways through which urban ecosystems services can enhance resilience and quality of life in cities and identifies a range of economic costs and socio-cultural impacts that can derive from their loss. We conclude by identifying knowledge gaps and challenges for the research agenda on ecosystem services provided in urban areas.


## 1. Introduction

More than half of the world's population lives in cities (Dye, 2008) and more than two thirds are expected to live in cities by 2050 (UN, United Nations, 2010). Concentration of population in cityscapes dominated by technology and built infrastructure has fostered the conception of an urban society that is increasingly decoupled and independent from ecosystems (Ausubel, 1996). However, demands on natural capital and ecosystems services keep increasing steadily in our urbanized planet (Ayres and van den Bergh, 2005; Guo et al., 2010; Krausmann et al., 2009). Furthermore, extensive research has shown that decoupling of cities from ecological systems can only occur locally and partially, thanks to the appropriation of vast areas of ecosystem services provision beyond the city boundaries (Folke et al., 1997; Rees, 1992; Rees and Wackernagel, 1996). Just as any other social–ecological system, cities depend on ecosystems and their components to sustain long-term conditions for life (Odum, 1989), health (Maas et al., 2006; Tzoulas et al., 2007), security (Costanza et al., 2006a; Dixon et al., 2006), good social relations (EEA, European Environmental Agency, 2011) and other important aspects of human well-being (TEEB, The Economics of Ecosystems and Biodiversity, 2011).

Urban ecosystems are still an open frontier in ecosystem service research. Since the seminal article by Bolund and Hunhammar (1999) was published in this journal, a mounting body of literature has strived to advance our understanding of urban ecosystem services in their biophysical (Escobedo et al., 2011; Pataki et al., 2011), economic (Jim et al., 2009; Sander et al., 2010), and socio-cultural dimensions (Chiesura, 2004; Andersson et al., 2007; Barthel et al., 2010). Ecosystem services provided in urban areas were addressed by major initiatives like the Millennium Ecosystem Assessment (McGranahan et al., 2005) and The Economics of Ecosystems and Biodiversity (TEEB, The Economics of Ecosystems and Biodiversity, 2011), and have received increasing attention as part of the policy debate on green infrastructure (DG Environment, 2012). Yet, as compared to other ecosystems like wetlands or forests, the attention given to urban ecosystems is relatively modest. Most studies on the topic have focused on single ecosystem services and/or value dimensions. For example, whereas monetary values have been broadly examined in the literature, description or measurement of symbolic, cultural, identity and other non-economic values remain largely unexplored (Chan et al., 2012). This is also the case for the 'insurance value' stemming from the contribution of urban ecosystems and green infrastructure to the resilience of cities. To our knowledge there is also little understanding of the additional challenges to

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the valuation in urban ecosystems, characterized by high complexity, heterogeneity, and fragmentation (Pickett et al., 2001.

In an attempt to address these knowledge gaps, this paper draws on recent developments in ecosystems service research to synthesize knowledge to classify and value ecosystem services for urban planning. Specifically, we i) categorize the most relevant ecosystem services and disservices provided in urban and peri-urban areas, ii) identify economic and non-economic values associated to urban ecosystem services, and iii) examine challenges in measuring and articulating ecosystem service values in urban planning.

Ecosystem services are defined as benefits that humans obtain from ecosystem functions (de Groot et al., 2002; MA, Millennium Ecosystem Assessment, 2003), or as direct and indirect contributions from ecosystems to human well-being (TEEB, The Economics of Ecosystems and Biodiversity, 2010). The range of our inquiry is restricted to 'urban ecosystem services', defined here as those provided by urban ecosystems and their components. Urban ecosystems are those where the built infrastructure covers a large proportion of the land surface, or those in which people live at high densities (Pickett et al., 2001). They include all 'green and blue spaces' in urban areas, including parks, cemeteries, yards and gardens, urban allotments, urban forests, wetlands, rivers, lakes, and ponds. Definitions of urban areas and their boundaries vary between countries and regions, depending on land use type, total population, population density, distance between dwellings, and percentage employment outside the primary sector. Given that many ecological fluxes and interactions extend well beyond the urban boundaries defined by political or biophysical reasons, urban ecosystems are defined here in the broader sense that comprises the hinterlands directly managed or affected by the energy and material flows from the urban core and suburban lands, including city catchments, and peri-urban forests and cultivated fields (see Pickett et al., 2001, p.129). Because in the urban context ecosystems are by definition highly modified and fragmented, our analysis is not restricted to ecosystems as such, but also includes specific ecosystem components involved in the delivery of services such as individual trees, water surfaces, and soil surfaces (Nowak and Crane, 2002).

In public policy discourse, urban ecosystems are often portrayed as 'green infrastructure' (EEA, European Environmental Agency, 2011; DG Environment, 2012). This metaphor 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, region). Urban ecosystems may be seen as a broader concept in the sense that they can also include community-driven forest or river/lake areas close or within the city boundaries as well as private gardens not directly subjected to public urban planning.

The paper is structured in four main sections. Section 2 classifies and describes ecosystem services and disservices provided in urban areas. Section 3 discusses the range of economic and non-economic values associated to urban ecosystem services provided and identifies methods and tools by which such values may be elicited and quantified. Section 4 discusses the scope and limits of valuation methods in urban planning and identifies additional challenges for valuation in urban ecosystems. Section 5 synthesizes our main findings and points out priorities for the research agenda in urban ecosystem assessments.

## 2. Classifying Ecosystem Services Provided in Urban Areas

Building on previous categorizations of ecosystem services (Daily, 1997; de Groot et al., 2002; MA, Millennium Ecosystem Assessment, 2003) the TEEB report identifies 22 types of ecosystem services grouped in four categories: provisioning, regulating, habitat, and cultural and amenity services (TEEB, The Economics of Ecosystems and Biodiversity, 2010). Because different habitats provide different types of ecosystem services, general classifications need to be adapted to specific types of ecosystems (MA, Millennium Ecosystem Assessment, 2003). For example, if agroecosystems are critical for food production, wetlands for nutrient cycling, and forests for carbon sequestration, urban ecosystems are especially important in providing services with direct impact on health and security such as air purification, noise reduction, urban cooling, and runoff mitigation (Bolund and Hunhammar, 1999). Which ecosystem services in a given city are most relevant varies greatly depending on the environmental and socio-economic characteristics of each site. For example, natural barriers to buffer environmental extremes are critical for cities located in or close to coastal areas (e.g. New Orleans); air quality regulation can be of significance in cities severely polluted due for instance to topography of heat inversions (e.g. Santiago de Chile), but may be of secondary importance in cities where atmospheric pollution is favored by topography, as well as policy (e.g. Helsinki). Similarly, while urban green areas will generally play a secondary role in tourism, emblematic city parks can be an important part of the portfolio of attractions valued by city tourists (e.g. the Central Park in New York). A classification of ecosystem functions and services in urban areas with examples of proxies and indicators for biophysical measurement is provided in Table 1. For a comprehensive framework for urban ecosystem services indicators see Dobbs and Escobedo (2011).

### *2.1. Food Supply*

Urban farming takes place in peri-urban fields, rooftops, backyards, and in community vegetable and fruit gardens (Andersson et al., 2007). In general, cities only produce a small share of the total amount of food they consume. However 'for many of today's urban dwellers, urban agriculture provides an important source of food and supplementary income' (McGranahan et al., 2005: 810). Urban allotments also play a role in food security and resilience, especially in periods of crises (Barthel et al., 2010; Barthel and Isendahl, 2013). For example, Altieri et al. (1999) estimated that, in 1996, food production in urban gardens of Havana included 8500 tons of agricultural products, 7.5 million eggs and 3650 tons of meat.

### *2.2. Water Flow Regulation and Runoff Mitigation*

Ecosystems play a fundamental role in providing 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 (Higgens et al., 1997). Increasing the impermeable surface area in cities reduces the capacity of water to percolate in soils, increasing the volume of surface water runoff and thus increasing the vulnerability to water flooding (Villarreal and Bengtsson, 2005). Interception of rainfall by tree canopies slows down flooding effects and green pavements/soft lanes reduce the pressure on urban drainage systems by percolating water (Bolund and Hunhammar, 1999; Pataki et al., 2011).

### *2.3. Urban Temperature Regulation*

The so-called 'urban heat island effect' consists of local rises in the temperature of city areas caused by greenhouse gas emission from heating and traffic in combination with heat absorption by built surfaces (Moreno García, 1994). Urban blue and green space regulates local temperatures (Hardin and Jensen, 2007). Water areas absorb heat in summer time and release it in winter (Chaparro and Terradas, 2009) and vegetation absorbs heat from the air through evapotranspiration, particularly when humidity is low (Hardin and Jensen, 2007). Urban trees moderate local temperatures by providing humidity and shade (Bolund and Hunhammar, 1999).

### *2.4. Noise Reduction*

Traffic, construction and other human activities make noise a major pollution problem in cities, affecting health through physiological and