Chapter 1
Green and Blue Infrastructure in Cities

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1.1 Definitions

Over 50% of the global population currently lives in urban areas. Cities are particularly exposed to climate change and environmental problems due to the impact of anthropic activities. In urban environments, additionally, the negative effects of climate change are amplified by settlement features (impervious surface, buildings, transport infrastructure, socio-economic activities). Flooding, heat and drought, in particular, are hazards which are increasingly characterising the urban areas (see Chapters 2 and 3). More than 40% of urban land is currently covered by impervious surfaces as roads, buildings and parking lots (Benedict and McMahon, 2012). Climate change and anthropogenic pressures, such as land-use conversion, have altered the functions of ecological systems and have consequently modified the flow of ecosystem services in terms of their scale, timing and location (Nelson *et al.*, 2013; see Chapter 5). This trend is going to increase as the urban world population is expected to rise to over 67% by 2050 (UN DESA, 2012).

Urban resilience can be defined as the ability of an urban system to adapt (maintain or rapidly return to previous functions) when facing a disturbance (Pickett *et al.* (eds.), 2013; Lhomme *et al.*, 2013; Meerow *et al.*, 2016). According to academic and policy interests, it is crucial to improve urban resilience to cope especially with climate imbalances and related issues. Implementing a traditional grey approach, alongside green and blue design strategies, can enhance urban resilience, especially in a long-term time frame. Traditional grey infrastructure, as concrete buildings, underground drainpipes, and pumping stations, can be effective but mono-functional and non-adaptive tools. On the contrary, green infrastructure (GI) integrates natural processes and is more flexible and adaptive (Voskamp and

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Van de Ven, 2015). GI can, thus, have a crucial role to cope with climate change in cities (Elmqvist *et al*., 2015).

The term *green infrastructure* (GI) was coined in Florida, in 1994, and appears for the first time in a report to the governor on land conservation strategies, which stresses that natural systems are important infrastructure components (Firehock, 2010). Infrastructure is commonly defined as facilities and services necessary for a society, community, and/or economy to function. These facilities and services can be *hard* (e.g., transportation and utilities) or *soft* (e.g., institutional systems such as education, health care and governance). GI is considered *soft* and is important for building capacity, improved health, job opportunities, and community cohesion (Rouse, 2013). It includes natural, semi-natural, and artificial networks of multifunctional ecological systems related to urban areas (Sandstrom, 2002; Tzoulas *et al*., 2007). It features waterways, wetlands, woodlands, wildlife habitats, greenways, parks, and other natural areas, which contribute to the health and quality of life for communities and people (Benedict & McMahon, 2001; Benedict *et al*., 2006; European Commission, 2010).

GI, in fact, can be defined as an "interconnected network of green space that conserves natural ecosystem values and functions and provides associated benefits to human populations" (Benedict & McMahon, 2001) or as "a strategically planned and managed network of wilderness, parks, greenways, conservation easements, and working lands with conservation value that supports native species, [and] maintains natural ecological processes". Furthermore, GI is designated as "a successfully tested tool for providing ecological, economic and social benefits through natural solutions" (Benedict & McMahon, 2012).

The 2013 European Commission Communication, *Green Infrastructure (GI) – Enhancing Europe's Natural Capital*, states that GI is strategically designed and managed to provide ecosystem services on a wide scale. It comprises green spaces (or blue spaces in the case of aquatic ecosystems) and other physical terrestrial elements such as coastal and marine features. GI can also be found both in rural and urban settings (European Commission, 2013). In addition, GI is "an effective response to a variety of environmental challenges that is cost-effective, sustainable, and provides multiple desirable environmental outcomes" (EPA Administrator Lisa Jackson, Testimony before the U.S. House of Representatives, Committee on Transportation and Infrastructure, Subcommittee on Water Resources and Environment, March 19, 2009, in New York City Department of Environmental Protection (2010).

Rouse notes that different definitions are related to the scale under observation. At the city and regional scale, GI can be outlined as a multifunctional open space network. At the local and site scale, it can be described as a stormwater management approach that mimics natural hydrologic processes (Rouse, 2013). Benedict and McMahon's investigations specify that it is possible to devise GI at all scales: "the individual parcel, the local community, the state or even the multi-state region" (Benedict and McMahon, 2012). At the parcel scale, green infrastructure can be outlined when home and business design revolves around green space. At the community level, green infrastructure can be planned as a system of greenways connecting public parks. At the state or regional level, green infrastructure can be enacted protecting the linkages already existing between natural resources, as forests and prairies, which are the natural habitat of specific animal species.

The multiscalarity of GI has a great strategic importance. At the landscape scale, as stated by Rouse, GI is most effective in providing services and benefits when it is part of a physically connected system (Rouse, 2013). Planners and designers should, hence, establish physical and functional connections across scales to link sites and neighbourhoods to cities and regions (e.g., connections among natural reserves or regional parks). The growth of ecological engineering acknowledges the importance of merging ecology and design with green infrastructure, replacing conventional engineering structures with green features that can perform ecosystem service functions, such as waste management or energy efficiency retention (Mitsch and Jørgensen, 2003; Margolis and Robinson, 2007).

In official documents (i.e., European directives) GI is a recurrent term, but the definition *green and blue infrastructure* (GBI) is increasingly used to designate all strategies targeted to increase urban resilience to climate change, improving the coping, adaptive and mitigation capacities within cities. Urban settlements, according to this definition, should be able to face weather extremes through water function management and the negative effects of anthropic activities (see Chapters 3 and 4). GBI uses ecosystem functions to deliver multiple benefits. It can enhance the water balance regime, decreasing stormwater runoff peak discharge. It can also reduce soil erosion, providing stormwater runoff cleansing to raise water quality, guaranteeing seasonal water storage and recharging the urban groundwater aquifer (Voskamp and Van de Ven, 2015).

1.2 Economic and environmental benefits

GBI can contribute to curb the negative effects of climate-related hazards, including storm surges, extreme precipitation, and floods (EEA, 2012; UNISDR, 2015). At the city scale, therefore, GBI is important to improve environmental conditions. Planning, developing, and maintaining GBI can integrate urban development, nature conservation, and public health promotion (Schrijnen, 2000; Tzoulas *et al.*, 2007; Van der Ryn, 1996; Walmsley, 2006). GBI plays an important role against intense storms as it enhances the resilience of communities to coastal flood and river flood risks (EEA, 2015). The U.S. Environmental Protection Agency emphasises the role of green and blue infrastructure in stormwater management: “Green infrastructure involves the use of landscape features to store, infiltrate, and evaporate stormwater. This reduces the amount of water draining into sewers and helps to lower the discharge of pollutants into water bodies in that area. Examples of green infrastructure include rain gardens, swales, constructed wetlands, and permeable pavements” (EPA, 2011). Current studies indicate the great contribution provided by GBI in terms of urban ecosystem services (European Commission, 2013).

Several techniques are included in the GBI approach. It is useful to group GBI in vegetated and non-vegetated systems to provide an overview (see Chapters 6 and 7). Combining green and blue measures with the use of vegetation can enhance urban resilience, supporting synergistic interactions at different spatial scales and establishing hydrologic connectivity in the catchment to control water resources and flood risk (Voskamp and Van de Ven, 2015). Moreover, GBI should be integrated in river restoration (see Chapter 8), especially in urbanised areas to maximise the efficiency of ecological and hydrologic connectivity, as demonstrated by the case studies presented in this investigation (see Chapters 9–13). In fact, the analysis of case studies allows describing how river restoration projects reduce ecological and environmental issues and the related social, economic and environmental effects.

Multifunctionality is among the most interesting outcomes of GBI. Environmental co-benefits comprise biodiversity conservation and climate change adaptation; social benefits include water drainage and creation of green spaces (EEA, 2015). Nature-based solutions can provide greater sustainable, cost-effective, multi-purpose and flexible alternatives than traditional grey infrastructure (European Commission, 2015). GBI also provides economic benefits creating job and business opportunities in fields such as landscape management, recreational activities, and tourism. It can stimulate retail sales and commercial vitality as well as other economic activities in local business districts due to the value of ecosystem services (Wolf, 1998; Rouse, 2013). GBI can help to preserve or increase property values (Economy League of Greater Philadelphia, in Southeastern Pennsylvania, 2010; Neelay, 1998); attract visitors, residents, and business to a community (Campos, 2009); and reduce energy, healthcare, and costs (Economy League of Greater Philadelphia, in Southeastern Pennsylvania, 2010; Heisler, 1986; Simpson and McPhearson, 1996).

The benefits of GBI are not easy to quantify due to its multifunctional nature, as different functions may require a range of different forms of measurement (European Commission, 2012). GBI monetary values can be communicated to stakeholders and communities, and can be easily incorporated into the policy decision-making process, although its benefits may be more variable than costs (Vandermeulen *et al.*, 2011; Naumann *et al.*, 2011). Among the most recognised economic benefits can also be mentioned stormwater reduction in the sewer system (Crauderueff *et al.*, 2012). According to Artie Rollins (Assistant Commissioner for Citywide Services, NYC), NYC Departments invest on GI as a cost-effective measure to reduce stormwater runoff, as the building costs of a sewage treatment plant to process water are significantly higher (Rollins, 2013). Benefits of GBI, moreover, are important at the community level. Public bodies play a crucial role to promote this type of urban design features. They actively support the integration of GBI as a sustainable strategy to meet water quality standards, but the involvement of communities can also make a remarkable difference (Angotti, 2008). Urban planning participative processes, above all, could ensure the support of local communities. GBI integration requires "a process of vertical and horizontal reciprocity between scales/agencies […] to provide the political platform for stakeholder interactivity, leading in the long-term to a consensus on the structure of policy making and GI delivery" (Mell, 2014). A lack of communication can delay the development of consensus (Mell, 2014). An in-depth analysis of top-down (Chapter 10) and bottom-up policies (Chapter 11) provides an explanation of these processes and relative case studies.

The evaluation of different contexts – political, geographical, sociological, environmental – strategies, and actors involved depicts a framework of projects and initiatives targeting the reduction of ecological and environmental issues in urban areas. The analysis of the case studies described is based on several approaches with regard to local/national policies, local community involvement, and private partnership, and includes interviews, on-site surveys, scientific literature reviews, newspaper research. This allows assessing outcomes, positive aspects, and future challenges.

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