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Urban Watershed Services For Improved Ecosystem Management and Risk Reduction, Assessment Methods and Policy Instruments: State of the Art

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Summary

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Keywords: Urban Watersheds, Ecosystem Services, Water Supply And Sanitation, Disaster Risk Reduction, Valuation

JEL Classification: I14, Q01, Q25, Q54, Q57

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FEEM working paper

Urban watershed services for improved ecosystem management and risk reduction, assessment methods and policy instruments: state of the art

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Abstract

Under scenarios of increasing unplanned urban expansion, environmental degradation and hazard exposure, the vulnerability of urban populations, especially of their poorer segments, needs to be tackled through integrated economic, social and environmental solutions. Basing our analysis on the concept of ecosystem services, we suggest that urban areas would benefit from a shift in perspective towards a more regional approach, which recognizes them as one of many interconnected elements that interact at the watershed level. By integrating an ecosystem approach into the management of water-related services, urban management policies can take a first step towards fostering an improvement of the health of upstream and downstream areas of the watershed, activating environmentally sound practices which aim at guaranteeing the sustainable and cost effective supply of services. These strategies can for instance be supported by using payment schemes for ecosystem services or similar strategies, allowing for the redistribution of resources among communities in the watershed. From our analysis it results that, through the recognition of the primary role played by watershed ecosystems, cities can benefit from an enlarged set of policies,

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I14 - Health and Inequality, Q01 - Sustainable Development, Q25 – Water, Q54 - Climate; Natural Disasters; Global Warming, Q57 - Ecological Economics: Ecosystem Services; Biodiversity Conservation; Bioeconomics; Industrial Ecology

1 Introduction

Urban areas have established since ancient times strict connections with flowing water and water bodies. Old civilisations have settled along rivers to benefit from drinking water, sanitation and irrigation. Trading relied on waterways for the transportation and exchange of goods. This centrality was partly lost with the industrial revolution (Silva et al., 2006) and the advent of other means of transport. Moreover, as a consequence of industrialization, discharges and abstractions of water changed in quantity and in kind, and rivers have progressively been degraded and polluted. Since the beginning and middle of the 19th century, increasing quantities of nutrients and metals have been released in water bodies through point (industrial activities and urban sewages) and non-point sources (agriculture). Land cover changes in watersheds have occurred and intensified through the conversion of forest areas and wetlands, first into agricultural land and then into sealed surfaces (i.e. buildings and roads). Engineering works, such as the canalisation of river beds and the construction of dikes, have changed the shape and hydrology of rivers around the world.

Taking for granted the unlimited capacity of nature to provide these services, urban areas have been among the main drivers of environmental change in the past century. According to Srinivas (2013) there is currently no single environmental problem whose causes cannot be traced back to urban areas. As expanding cities rely on a wide range of ecosystem services for urbanisation and urban activities, the trend has been to seek for services from ever more distant areas or to substitute them with technological solutions. Both options imply increased costs for short-term measures and, often, additional environmental degradation. However, awareness is growing about the wide range of benefits urban areas actually obtain from surrounding ecosystems, for example from healthy watersheds, in terms of water purification, water regulation, timber, food products, and cultural services (e.g. recreation).

Ecosystems are defined as “a dynamic complex of plant, animal, and microorganism communities and the non-living environment interacting as a functional unit”, of which humans are an integral part (MA, 2005). Cities themselves can be considered as ecosystems (see Pickett et al., 2011 for a definition and description) however, their dependence on the wide range of environmental services that originate at the local as well as at the regional scale, makes them part of larger and more broadly defined ecosystems. There are numerous definitions of what ecosystem services are (see Braat and de Groot, 2012). We adopt the one provided by the MA (2005) which describes them as “the benefits people derive from ecosystems” and distinguishes among provisioning, regulating, supporting and cultural services. The worldwide loss of ecosystem services affects the wellbeing of human communities in a variety of ways, including by contributing to an increase of exposure and vulnerability to water scarcity and natural hazards, in particular for poor urban populations.

By bridging environmental and socio-economic perspectives and highlighting the dependence of human communities on well-functioning ecosystems, the ecosystem services concept and framework can promote the integration of environmental issues into policy agendas . This aspect can be of particular interest for urban areas although the approach has often been of conceptual rather than of direct operational value. As Norgaard (2010) highlights, three main limitations must be taken into consideration when making use of the term in environmental science and policy management, namely: 1) the possibility of providing quantitative information on the relation between the characteristics of ecosystems and the services provided is quite limited, as there is little ecological knowledge around the concept of ecosystem services (i.e. ecologists, generally focusing on single species, populations and communities, provide little quantitative insight into the capacities of ecosystems to function and to provide services); 2) existing knowledge on specific ecosystems is difficult to be transferred because of the complexity and the distinctive traits of every single ecosystem (and this seems to be also due to the local, different influences of human history and local distinctiveness of social systems); 3) very little is known about the trade-offs between the provision of different services and no agreement was found in ecological terms concerning particular threshold conditions of a specific ecosystem (Norgaard, 2010). Therefore, despite the numerous attempts to quantify ecosystem services, the author suggests that the concept should be used to inform environmental policies and decisions with caution and as part of a larger solution to fine-tune environmental policies. While significant efforts and resources need to be invested to perform intrinsically complex ecosystem assessments, their role is however essential in a context, as is the one of environmental decision making, in which system uncertainties and decision stakes are high (Funtowicz and Ravetz, 1993).

Among the range of ecosystem services urban areas benefit from, those related to freshwater are of particular importance. According to the MA "four out of every five people live downstream of, and are served by, renewable freshwater services, representing 75% of the total supply" (MA, 2005). On the other hand, "inland water habitats and species are in worse condition than those of forest, grassland, or coastal systems" (MA, 2005). Thus, to draw the tight link between urban areas and more regional ecosystems, we proceed focusing on freshwater services for urban needs, such as water supply (Section 2.1), wastewater treatment (Section 2.2) and hydro-meteorological hazard mitigation (see Section 2.3). These functions are fundamental for human wellbeing, and will need increased attention as human population continues to concentrate in urban areas. Cities are in fact already home to more than half of humankind, with their population expected to attain almost 4 billion in 2015[1] (about 55% of the world total population). In addition, environmental change, and in particular climate variability, are threatening the capacity of ecosystems to deliver these services, adding a further reason for urgency to reversing the trend towards their exploitation and degradation.

In the past century, the growth of cities has often been characterized by the partial substitution of ecosystem services with man-made alternatives, through transformation and replacement of the

[1] http://esa.un.org/unup/CD-ROM/Urban-Rural-Population.htm

natural infrastructure providing clean water, wastewater remediation or flood protection. This approach frequently implied short-term visions and a limited capacity of adaptation to future changes like those induced by changing climatic conditions. Resorting to hard infrastructures for the management of natural resources and the prevention and mitigation of hazards often results in the degradation of the environment, the loss of local sources of livelihoods and ultimately in a reduction in the resilience and long-term adaptive capacity of the urban social-ecological system (Smith and Barchiesi, s.d.). For instance, most flood protection systems are based on the magnitude of events with lower return periods than those actually occurring in the long run. These structures distort the population's risk perception and have encouraged significant encroachment of floodplains, further exacerbating long-term risk in urban areas. Water diversions from more distant watersheds through engineered solutions have allowed meeting the needs of continuously expanding urban communities, posing however additional ecological and environmental problems. Finally, huge investment in water technology enables rich nations to adapt and cope with water scarcity without however tackling its underlying causes, whereas poorer countries remain vulnerable (Vörösmarty et al., 2010).

The restoration and improved management of ecosystems at the watershed scale through the integration of the notion of ecosystem services in local policy and decision-making aims at reversing this trend and is here proposed as a sustainable, long-term and cost-effective option enabling to better satisfy the multiple needs of urban areas, including their security, while improving the environmental conditions of watersheds. The pressuring need to manage and allocate water resources in a sustainable manner in the face of increasing environmental degradation and social inequalities, can arguably be better satisfied through the adoption of an ecosystem approach rather than by turning to the construction of additional hard infrastructures. Engineering works have demonstrated to have little consideration of the complex socio-ecological and co-evolutionary processes taking place within ecosystems. They often lead to ecological fragmentation, which compromises the ability of ecosystems to support human wellbeing through a wide range of services. Evidence also suggests that multi-stakeholder, cross-scale, adaptive water management is better suited to the complex and dynamic nature of healthy ecosystems, but that this long term, flexible adaptation process hardly takes place when technological solution based on hard infrastructures are put in place (Smith and Barchiesi, s.d.). It should nevertheless be considered that the adoption of an ecosystem approach for the satisfaction of urban needs should proceed along a broader redefinition and reduction of the demand of services from urban populations and the implementation of more sustainable urban activities, both at the local as well as at the regional scale.

Stressing the interconnections between urban areas and their surrounding watersheds has the potential to lead to more informed urban management decisions, as trade-offs between urban activities and the provision of ecosystem services at local as well as at the regional level can be more comprehensively highlighted. Conceiving cities as being part of larger ecosystems opens the path to new policy strategies in the face of socio-economic pressures on elements of the watershed that provide services. In order to support this process, valuation techniques are needed to assess the benefits of ecosystems and inform policy and planning decisions at the watershed level.

While Bolund and Hunhammar (1999) and Gómez-Baggethun and Barton (2013) categorise and describe the range of ecosystem services and disservices that originate within the urban and peri-urban area as well as some appropriate valuation methods for this scale, and Brauman et al. (2007) review hydrologic services, we locate cities within the broader watershed unit, emphasizing their connections and dependences on ecosystems through the analysis of water-related services. We also further develop the perspective described in Bahri (2012) on Integrated Urban Water Management, centring our analysis on the ecosystem approach to the management of urban watersheds. The aim is to illustrate how urban social-ecological systems benefit from and can enhance the quality of ecosystems at this broader scale. We argue that boundaries of urban ecosystems are often strictly connected with the watershed level (e.g. through the hydrology of urban areas) and that urban areas as well as regional ecosystems can derive benefits from such a shift of perspective. Amongst the services provided by watersheds (as listed in Table 1), we concentrate our analysis on those aspects directly connected to water supply, wastewater treatment and hydro-meteorological hazard regulation (Section 2). We then review relevant valuation techniques (Section 3) and policy tools (Section 4), and provide some conclusions in Section 5. This analysis is mainly done on the basis of a literature review.

2 Urban watersheds and ecosystem services

Due to their small size, unbalanced composition and extreme fragmentation, natural components of urban ecosystems only play a relatively minor role in providing services and enhancing the resilience of city dwellers. For instance, urban systems, which cover approx. 1% of land area, receive only 0.2% of global precipitation (possibly due to their location mainly in floodplains where precipitations are fewer compared to mountainous areas) and contribute in this same minor proportion to the global runoff (MA, 2005). At the same time, urban water services account for much higher percentages of the total freshwater abstraction, which reach from 20 to 30% of overall abstractions in countries of the European Community (EEA, 2009). Surrounding and more remote ecosystems support the bulk of a city's functions, even though their connections to urban communities are only mediated and indirect. It is at the watershed scale that most of the ecosystem services urban populations rely on originate and it is at this level that the linkages between the natural environment and the wellbeing of urban communities are most perceptible.

The focus of our analysis at the watershed level is in order to depict the interconnections between urban life, urban management and healthy watershed ecosystems (as "healthiness" is considered as a prerogative for watersheds to be able to provide services). All cities are located in a watershed and derive services from ecosystems that are found within these units. Therefore, while acknowledging the presence of nested hierarchies of urban ecosystems from the local to the regional scale, we concentrate on a shift in the definition of urban ecosystems which goes beyond the local social-ecological system (i.e. defined by ecosystems with a high density of buildings) and treat urban ecosystem at the regional scale, as any other ecosystem (Pickett et al., 2001), and whose boundaries are set by watersheds.

Watersheds, also known as drainage areas, are the land base from which rain or melting snow converge into a single point and drains as surface and/or groundwater in a water body, such as a lake, a wetland, a sea or a groundwater reservoir. It should be noted that the boundaries of surface watersheds and groundwater watersheds do not necessarily coincide. While surface water is conditioned by topographical features, and thus easy to be delimited, the extension of groundwater watersheds is defined by the: "1) hydraulic properties of the aquifer, 2) input to (i.e. recharge) and outflow from (i.e. discharge) the aquifer system, and 3) geological factors such as formations that block the flow of water and tilted formations that create a flow gradient"[2]. For the analysis of ecosystem services and for the management of watersheds, this divergence can pose relevant obstacles. To overcome them, it should be considered that a watershed has two components: a surface and a groundwater drainage.

As the boundaries of surface watersheds are based on topographical and physical borders, their size can range from several thousand square kilometres to a few hectares, spanning across administrative and political borders. Watersheds are usually part of larger systems of tributaries and effluents (FAO, 2007) and can include a variety of ecosystems, such as forests, wetlands, grassland, savannas, alongside with urban systems. Within a watershed, all components of the ecosystem affect the delivery of hydrological services to downstream users. Quality and characteristics of soils determine water infiltration and surface runoff, thus defining the retention capacity and the rate at which precipitation waters cross the watershed and their potential for causing inundations. Vegetation increases the rate of evapotranspiration and storage capacity of soils, while improving the water quality by filtration and absorption of nutrients and contaminants. Wetland ecosystems ameliorate water quality through removal of nutrients, principally nitrogen (N) and phosphorous (P) (Fischer et al., 2007), and, in particular floodplains wetlands, increase the retention capacity within the watershed, reducing the risk of flood hazards and increasing dry season flows (Bullock and Acreman, 2003) (see Table 1 for a complete list of watershed services).

[2] http://www.dnr.state.mn.us/watersheds/surface_ground.html

Table 1. Ecosystem services provided by or derived from inland water systems (Source: MA, 2005)

Provisioning	
Food	Production of fish, wild game, fruits, grains, etc.
Freshwater	Storage and retention of water for domestic, industrial, and agricultural use
Fiber and fuel	Production of logs, fuelwood, peat, fodder
Biochemical	Extraction of materials from biota
Genetic materials	Medicine, genes for resistance to plant pathogens, ornamental species, etc.
Biodiversity	Species and gene pool
Regulating	
Climate regulation	Greenhouse gases, temperature, precipitation, and other climatic processes; chemical composition of the atmosphere
Hydrological flows	Groundwater recharge and discharge; storage of water for agriculture or industry
Pollution control and detoxification	Retention, recovery, and removal of excess nutrients and pollutants
Erosion	Retention of soils
Natural hazards	Flood control, storm protection
Cultural	
Spiritual and inspirational	Personal feelings and well-being
Recreational	Opportunities for recreational activities
Aesthetic	Appreciation of natural features
Educational	Opportunities for formal and informal education and training
Supporting	
Soil formation	Sediment retention and accumulation of organic matter
Nutrient cycling	Storage, recycling, processing, and acquisition of nutrients
Pollination	Support for pollinators

While urban areas depend on provisioning and regulating services supplied by surrounding ecosystems, their expansion and activities directly reduce the capacity of watersheds to provide them. At least ever since the industrialization period, urbanization has been one of the main drivers of the degradation of ecosystem features, causing deforestation and soil erosion. As a consequence, runoff and stream flow increase, groundwater table falls, the sedimentation of rivers and river banks increases and hydro-geological hazards become more frequent. Biodiversity, essential for the resilience of ecosystems and for their capacity of providing services, is mostly negatively affected, often severely enough to run the risk of crossing potentially irreversible thresholds (Thompson, 2011), which, in turn, would have extreme consequences on urban areas. A vision that locates urban areas into watershed systems would thus improve the outcome both of urban planning and of watershed management, not least because urban activities drive land use changes at the watershed scale.

2.1 Water supply

Cities are located within surface and below-ground watersheds, and it is at these levels that the hydro-geological processes, essential to the creation and regulation of water supply for urban use, take place. As mentioned, at this scale, waters flow and are enriched with salts and minerals essential for life, while vegetation growing on slopes ensures absorption, filtration and release of runoff (FAO, 2007). The state of the ecosystems located in a watershed therefore affects both the quantity and the quality of water that flows within it, and supports in-situ (e.g. hydropower generation, water recreation, transportation and freshwater fish production) as well as extractive (including domestic) use for the local human community (Brauman et al., 2007).

As urban water demand grows with the increase of urban population (Fitzhugh and Richter, 2004) the pressure on the water system also increases. Productive activities such as farming, grazing or industrial manufacture located upstream, while benefiting urban areas, affect water streams, both above and below the surface, often reducing the range and the quality of services provided downstream.

Local governments and policies can be the driver of upstream ecosystem restoration due to the need to guarantee the supply of water of good quality and at low costs to their citizens. For instance, the rapidly growing urban population and the consequent degradation of the broadleaf forest around the Miyun reservoir (China), the primary source of water for Beijing City, have translated over the last decades into increasing stress for the basin's water resources, provoking a long series of urban water crisis (IUCN, 2010). In these circumstances, the need for restoring or enhancing ecosystem functions for improved water supply was urgent and has been favored through the development of a series of initiatives and compensation schemes instituted by the municipality, as further described in Section 4, Box 8.

The cost-effectiveness of ecosystem-based solution for urban water supply in both the short and the long term has further been demonstrated by a number of cases. The city of New York (US), for instance, is now deriving most of its clean water supply from surrounding watersheds, with no need for technological solutions, thanks to the restoration and appropriate management strategies of upstream ecosystems (for a description of the management strategies see Section 4, Box 9). In Bogotà (Colombia) a high elevation wetland ecosystem (called pàramo) provides the city with clean water with little seasonal variation and minimal need for treatment (Postel and Thompson, 2005), diminishing significantly the costs that the city should otherwise bear for managing water supply. Other case studies of cities relying on healthy ecosystems, in particular on forests, for freshwater supply are Melbourne (Australia), Istanbul (Turkey) and Singapore, and are extensively described in Dudley et al. (2003).

In general, according to a study conducted by the Trust for Public Land and the American Water Works Association on 27 water suppliers, a 10% increase in the forest cover in the source area would reduce approximately the water treatment costs of 20% (Ernst, 2004). Highlighting the value of healthy watersheds for the satisfaction of urban water supply needs at reduced costs can help making the case for the restoration and sustainable management of ecosystems, avoiding the ecological impacts of expanding water supply systems (e.g. trans-basin water diversions and dams).

The importance of healthy watersheds for the supply of freshwater to cities is perhaps the most evident link existing between urban areas and their regional ecosystem. As summarised in the Table 4, Section 3, the valuation of the availability of clean water for urban consumption has been the subject of much of the research on the assessment of urban watershed services.

2.2 Wastewater treatment

Cities also produce significant amounts of outputs (i.e. pollution and wastewater). A further advantage of locating human settlements along water courses consists of the possibility to discharge these outputs into the water and have them carried away from the settlements and decomposed. Ecosystems have provided these services throughout human history, and ecosystem-based solutions, especially in association with technological solutions, still are a recurrent management option for the treatment of outputs. Natural and constructed wetlands are in fact capable of removing sediments, nutrients, and other contaminants from water, and have therefore a fundamental role in the treatment of wastewater, and in particular of urban drainage. The use of wetlands for wastewater treatment is also effective in economic terms as these present lower costs of construction, operation (e.g. reduced energy consumption) and maintenance if compared with conventional sewage treatment, while providing a wide range of other services (e.g. recreation). Ecosystem-based solutions for wastewater treatment might therefore be especially important in developing context, where the availability of financial and human resources for technology-intensive options is lower.

It should be emphasized that, when quantities of outputs are increasing, rivers and water bodies are no longer able to provide their ecosystem functions without compromising the health of downstream ecosystems, which, in turn, affects the health of downstream dwellers. Ecosystem-based approaches should be associated with policies aimed at the reduction of pollutant emissions at the source as well as with technological solutions for the depuration of effluents before immission in water courses, wetlands or lakes.

The trade-off of these solutions lays in the increasing request for space compared with technological solutions, which is relevant for urban areas, where the economic value of land is often high. However, there remain currently only few urban wetlands, which offer a high value in terms of recreational opportunities, local livelihoods and flood protection (Boyer and Polasky, 2004). Ecosystem valuation exercises show that the multiple benefits provided by urban wetlands often outweigh the gains linked with infrastructural development initiatives, which, in addition, can have severe impacts on local livelihoods (see cases in Box 1 and Box 2). Nonetheless, there are only few examples of research on the role and value of urban wetlands, and most of them are based on hedonic pricing (Boyer and Polasky, 2004) (see Section 3).

Box 1. The Nakivubo Swamp, Uganda

The Nakivubo Swamp in Uganda provides wastewater purification, especially through nutrient retention, to the country's capital Kampala's sewage. A Study of the International Union for the Conservation of Nature (IUCN) estimated the wastewater and nutrient retention functions of the wetland through two different methods: the avoided costs of replacing natural wetland functions with manmade alternatives and the foregone expenditures on mitigating or offsetting the effects of wetland loss. The results of the valuation showed an economic value ranging between US$ 1 million and US$ 1.75 million a year, depending on the analysis method used, but which results in both cases in a net benefit (IUCN, 2003). The Wetlands Inspectorate Division and IUCN showed that a sewage treatment plant that would substitute the Wetland's function would cost over US$ 2 million to maintain each year. In addition to requiring the local community to bear a cost for a service the wetland was already providing, the establishment of a treatment plant would also have caused significant loss of livelihoods for the local population (IUCN, 2003).

Box 2. The Sanyang wetland, China

For the Sanyang wetland, which is located in the East China coastal zone along the Oujiang river and close to the centre of Wenzhou city, ecosystem services have been indicatively estimated by Tong et al. (2007). The water purification service accounted for 43% of the value of the wetland, circa 3900 US$ ha-1 yr-1, followed by disturbance (hazard) regulation, circa as 1250 US$ ha-1 yr-1 as the Wenzhou city and the Sanyang wetland are occasionally impacted by typhoons, heavy rain, and floods. The wetland has a surface of 1141 hectares which means that the total value of water purification performed by the wetland is US $ 4.45 million a year.

The use of wetlands for urban wastewater treatment has a long history, and has been used extensively by some cities in the early stages of urbanization, for instance in Berlin (Hobrecht, 1884) one of major European cities at the end of the 19th century or in Australian cities (Brix, 1994). In many cases these systems have been abandoned completely nowadays, but a scientific review of technologies for the construction of wetlands and the choice of adequate plants has contributed to a revival of these ecosystem functions either as a last step of a biological and/or chemical form of sewerage treatment, or as extensive plants serving particular, for instance seasonal, needs (Brix, 1994).

2.3 Hydro-meteorological hazard prevention and mitigation

Over the last decades, disaster[3] occurrences have been steadily on the rise, affecting an increasing number of people and causing an increasing amount of losses (Guha-Sapir et al., 2011) (see Figure 1 and 2). While there is a certain degree of confidence that the intensity and frequency of hazards have increased since 1950 (IPCC, 2012), it is clear that the raise in natural disaster losses are primarily due to socio-economic drivers (i.e. heightened concentration of vulnerable communities in hazard-prone areas, displacement, discrimination and corruption) and to environmental degradation (Lewis and Kelman, 2012).

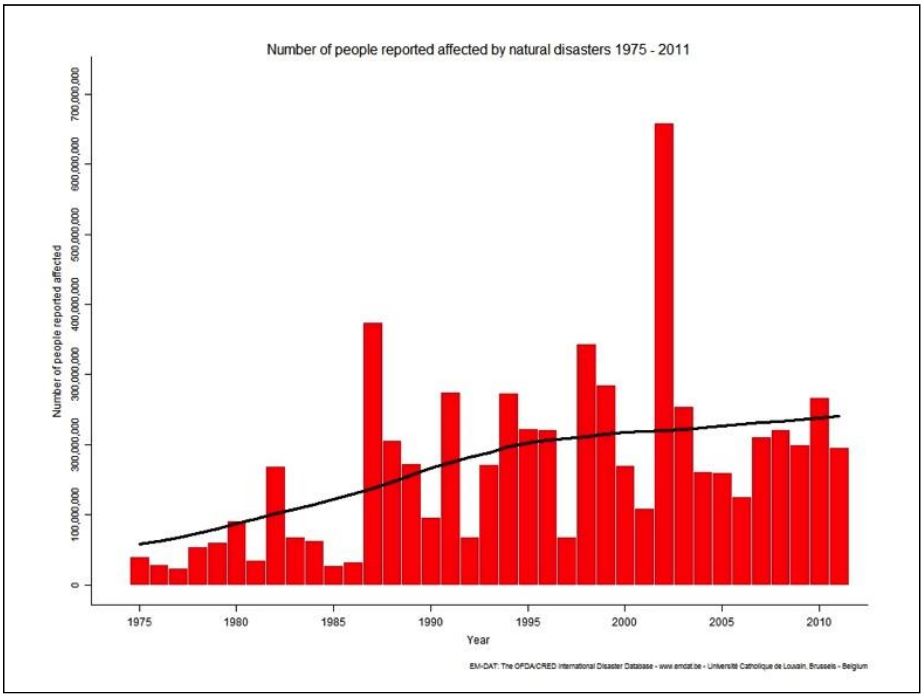

Figure 1. Number of people reported affected worldwide by natural disasters between 1975 and 2011 (Source: "EM-DAT: The OFDA/CRED International Disaster Database www.emdat.be – Université Catholique de Louvain – Brussels, Belgium")

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[3]According to CRED: a disaster occurs when at least one of the following four criteria is fulfilled: “10 or more people are reported killed; 100 people are reported affected; a call for international assistance; a declaration of a state of emergency” (http://www.emdat.be/criteria-and-definition)

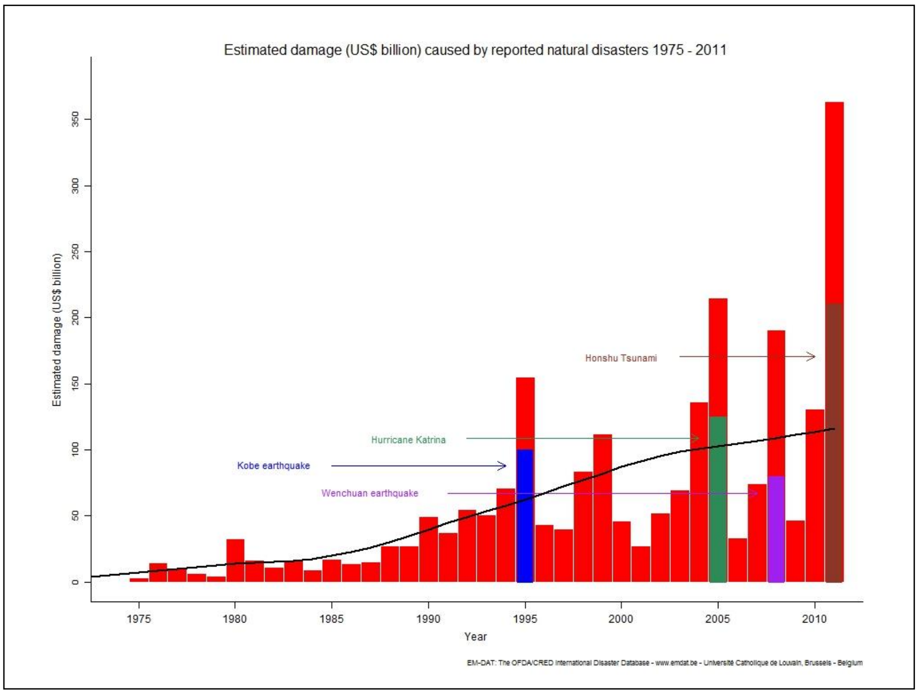

Figure 2. Estimated damages in US$ caused by reported natural hazards worldwide between 1975 and 2010 (Source: "EM-DAT: The OFDA/CRED International Disaster Database www.emdat.be – Université Catholique de Louvain – Brussels, Belgium")

Weather-, climate- or water-related hazards (such as droughts, floods, windstorms, tropical cyclones, storm surges, heat and dry spells, droughts, landslides and wild fires) cause the highest share of damages worldwide. As is shown in Figure 3, floods and storms are at the origin of the majority of disasters that occurred between 1980 and 2011 (see Figure 3). In 2011 only, hydrological[4] disasters were by far the most frequent (52.1%), followed by meteorological[5] ones (25.3%) (Guha-Sapir et al., 2011). This highlights centrality of the processes that take place in watersheds with respect to disaster risk reduction.

[4] "Events caused by deviations in the normal water cycle and/or overflow of bodies of water caused by wind set-up" (e.g. floods, mass movements – wet) (source: http://www.emdat.be/classification)

[5] "Events caused by short-lived/small to meso scale atmospheric processes (in the spectrum from minutes to days)" (e.g. storm) (source: http://www.emdat.be/classification)

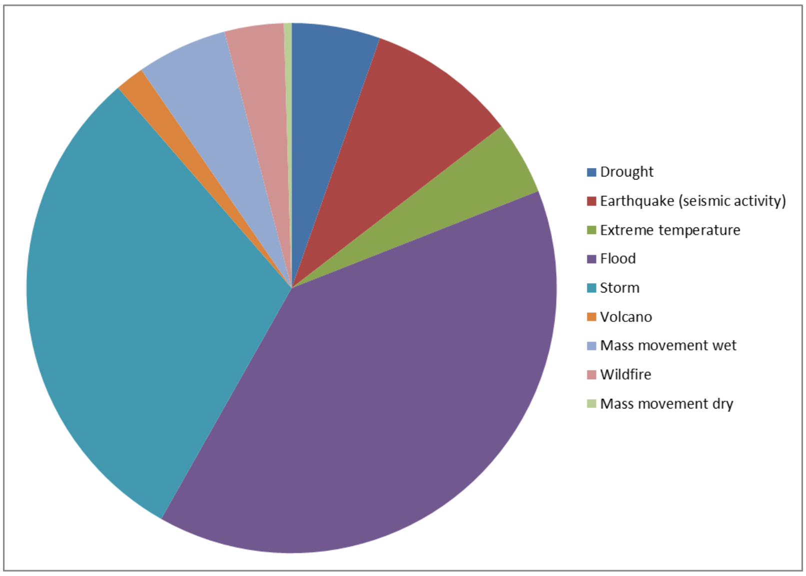

Figure 3. Number of disasters per hazard type during the period 1980-2011. (Source: "EM-DAT: The OFDA/CRED International Disaster Database www.emdat.be – Université Catholique de Louvain – Brussels, Belgium").

Urban areas are no exception to these trends, with a reported growth in the number of disasters and in particular those associated with weather events (such as heavy winds and rains, floods, landslides and fires) (Dodman et al., 2013). The total increases in economic and human damages are in fact mainly associated with growing exposure of vulnerable populations in cities (Lall and Deichmann, 2009). In Colombia and Peru, the urbanization rate of municipalities showed positive correlation to both hazard exposure and vulnerability (Serje, 2010). According to Hupper and Sparks (2006), urbanisation of hazard-prone areas, alongside with environmental degradation are the prominent causes of the higher impacts of hazards (See also Barredo, 2009). These observations are consistent with the interpretation of risk as the product of social processes, which has become prevalent over the past decades. Disasters are the result of the interaction between natural and economic, social and political processes (Cannon, 2008). Urban expansion and development are thus generating new patterns of hazard, exposure and vulnerability (see Box 3). In these conditions, the adoption of an ecosystem approach that recognises the functions of in-situ and surrounding ecosystems would significantly reduce exposure and vulnerability of urban populations. It should additionally be noted that, while major hazardous events have the potential of causing widespread destruction in urban areas (e.g. Hurricane Katrina in New Orleans or the Tohoku Earthquake in Sendai), cities are also the scene for many smaller events, mostly concentrated in informal settings were the urban poor reside, which often go completely unrecorded (Dodman et al., 2013).

The regulation of the hydrological cycle at the watershed scale is of fundamental importance for cities. Healthy or well-managed forests and soils can significantly contribute to the regulation of water flows, storing and slowly releasing waters, thus buffering the impacts of extreme events, including in downstream urban areas (see Depietri et al., 2011 for a review of the flood regulating functions of urban watershed ecosystems). In Pakistan, illegal logging and deforestation largely contributed to the devastating effects of the 2010 flood that affected about 20 million people[6] swiped away entire villages[7] and made homeless several million people (Lewis and Kelman, 2012). In Taiwan, the clearing of forests to make space for productive activities and infrastructures has led to reduced slope stability, increased sediment and pollutant delivery downstream, and increased peak flows, a fact that is particularly problematic in a region highly exposed to typhoons and other meteorological hazards (Lu et al., 2001). Though water regulation is a poorly investigated and valued service, there are a number of examples in the literature that demonstrate how watershed restoration can significantly reduce the intensity of weather related events while improving environmental awareness and the reducing long term risk. One example is the Watershed Management Program of Portland (USA), which had the main function to preserve and restore the floodplain to allow flood waters from Johnson Creek to flow freely, while maintaining and restoring biodiversity, improving air and water quality, and providing cultural services. Further examples are presented in Box 4 and 5, in PEDRR (2011), and in Section 3, Table 4.

Box 3. The Marikina River, Philippines

As a result of uncontrolled encroachment and unregulated disposal of waste, the Marikina River, which flows through Marikina City (the Philippines), had become a highly polluted urban waterway, likely to trigger frequent, potentially destructing floods (Yu and Sayor, 2008). Starting in 1993, the "Save the Marikina River" program operated over more than a decade to relocate the population of informal settlements, reduce dumping and establish a recreational park around the river for flood control. Despite being a complex process, the relocation of informal settlements was a success, and 10 years later, the affected communities were satisfied with their safer houses and improved service provision.

[6] http://www.emdat.be/search-details-disaster-list

[7] 85 villages of Punjab 21 of Baluchistan and 7 villages of Azad Jammu and Kashmir have been affected by the floods (http://www.who.int/hac/crises/pak/sitreps/floods_swat_28july2010.pdf)

Box 4. Parque La Agua, Santiago (Chile)

Another case is the Parque La Aguada in Santiago, Chile, currently under construction. It aims at restoring the city's main ecological corridor to revitalize an abandoned industrial area (World Bank, 2012). Concentrated around Zanjón de la Aguada, a temporary stream, the flood park will cover 60 hectares of river bank, which will provide recreational services during the dry season. The Aguada Flood Park is part of the Santiago Inner Ring Initiative and will cover a 4-kilometer section of the stream, which can no longer accommodate the high-intensity flows of the rainy season. The park also aims to provide economic and social benefits for the adjacent communities (World Bank, 2012)..

Box 5. Cheonggyecheon Restoration Project (South Corea)

The 2005 Cheonggyecheon Restoration Project created a 6 kilometres public recreation space centred on a seasonal stream in the central business district of Seoul, South Korea. During a period of rapid economic growth, the stream had been transformed into a culvert to make space for transportation infrastructure. In a US$ 900 million effort to improve the environmental quality of Seoul, the metropolitan government removed concrete surfaces and elevated highways to release the historic stream and create a park and floodway, thereby revitalizing the adjacent neighbourhoods (World Bank, 2012).

Droughts and water scarcity also affect urban watersheds. It is in fact estimated that 41% of the world's population lives in river basins where the per capita water supply is so low that disruptive shortages could occur frequently (Fitzhugh and Richter, 2004). Ecosystem-based measures to protect and restore upstream watersheds areas can be implemented to reduce the risk of droughts in cities (see Box 6 for an example).

Box 6. The Ciudades Y Cuencas Programme (Zampalinamé, Mexico)

In Mexico, the Ciudades Y Cuencas (Cities and Watersheds) Programme promotes the intensification of the relationships between urban citizens and the watershed providing them with freshwater, aiming at raise awareness on the role of watershed ecosystems and to collect resources to contribute to their enhancement. Since 2002, citizens of Zapalinamé (Mexico) pay a voluntary contribution to sustain conservation efforts for the watershed which is providing the city with freshwater. Funding raised by citizens (and integrated by foundations) is employed for environmental management of the natural reserve in the watershed (soil conservation and forest fire control), the constitution of a Water Fund, environmental education and to a small extent for social development projects addressing needs of landowners and communities in the watershed. These interventions are improving water quantity and quality and increasing the city's resilience to droughts. With 15% of the citizens currently paying the voluntary contribution, the initiative is expected to increase awareness about the importance of the natural reserve for the long term protection of the urban water supply (Lechuga Perezanta, 2009).

As mentioned, it is now widely accepted that the impacts of a hazard are the result of the interaction of the hazard itself and of the social and environmental properties of the affected system. Urbanization and urban activities can interact with natural processes in magnifying the impacts of natural hazards, as it has been the case for the cloudburst that killed thousands in Kedarnath and Rambada region of Uttarakhand State (India) on the 15th of June 2013. The disaster was partially attributed to the man-made reduction of the ecosystems' capacity to regulate hydrological extremes, mainly driven by the demand of urban dwellers for hydroelectric power and better infrastructure with little awareness of the potential impacts on upstream ecosystems (Gundimeda, 2013). In addition, when infrastructures are put in place to mitigate the impacts of hazards these often take into account short-term goals and tend to push the most vulnerable fringes of the population to the less desirable, often highly hazard-prone, land, further exacerbating their vulnerability (e.g. the construction of flood levees in New Orleans) (Cutter, 2006). These infrastructures are again often expensive to manage and can further exacerbate environmental degradation. Overall, urban poverty, environmental degradation and disaster risk are closely entangled (Deely et al., 2010).

Highlighting and assessing the interconnections between urban areas and watersheds is essential in designing interventions that preserve or increase the status of ecosystems to reduce the exposure and enhance the resilience of local human communities.

3 Valuation methods

Recognition of the value of ecosystems as described in the MA (2005) and in The Economics of Ecosystems and Biodiversity (TEEB) (2012) is growing and attempts for its quantification are increasingly practiced. In this section, we provide an overview on the main valuation techniques in use with some examples of applications to urban watersheds.

In general, ecosystem valuation techniques allow for the quantification and integration of the role ecosystems play in supporting human wellbeing in a particular location. They offer a series of tools for estimating the amount and distribution of flows of goods and services supplied by the environment and for comparing their evolution under different scenarios. At the watershed scale, valuation techniques need to inform river basin management about which parts of the ecosystem should be prioritized for restoration, improved or protected to guarantee the maintenance of ecosystem functions while supporting agriculture, industry and domestic services (Bergkamp et al., 2000). This is therefore an important step in making the nexus between cities and watershed ecosystems.

Valuation methods for ecosystem services can contribute to slowing down or possibly halting the exploitation and degradation of natural resources and allowing for their better allocation through more informed decisions, at both the individual and the societal level (TEEB, 2012). Though the ecosystem services concept was introduced as an informative notion to raise public interest for biodiversity and ecosystem conservation and restoration, in about three decades ecosystem services have increasingly being valued in monetary terms and, even if to a minor extent, incorporated into markets and payment mechanisms (Gómez-Baggethun et al., 2010). When proceeding to assessments, it needs to be recognised that not all ecosystem values can be expressed in monetary terms, as ethical and societal considerations, albeit of great interest, generally slip out of quantitative approaches. The consideration of non-monetary values alongside with cost-benefit analysis can be achieved recurring, for instance, to multi-criteria, participatory decision-making processes (Bergkamp et al., 2000). Kallis et al. (2013) suggest a framework for ecosystem services valuation which goes beyond the question of the appropriateness of monetary valuation and where environmental improvement and distributive justice are amongst the central criteria considered. As different societies attribute different values to natural goods and services, and as their socio-ecological conditions are in constant evolution, the valuations of ecosystem services are also strongly context-specific exercises (TEEB, 2012).

The value of ecosystems with respect to their services can refer to their biophysical properties or be based on human preferences. With reference to the valuation of services provided by watersheds, a list of the main indicators used for valuation in biophysical terms is reported in IUCN (2006, p. 25) (see Figure 4), while economic valuation methods of water infrastructures are extensively described in Emerton and Bos (2004). In the next sections we summarise the main valuation methods and link them with some examples and applications to urban watershed services.

Watershed services	Service attributes	State indicator	Sustainable use indicator
Provisioning services			
Water supply	• Precipitation, infiltration, soil water retention, percolation, streamflow, groundwater flow • Biotic and abiotic effects on water quality	• Water storage capacity (m^3/m^3) • Pollutant concentrations	• Discharge (m^3/year)
Food provision	• Crop, fruit and livestock production • Edible plants and animals (e.g. fish, algae, invertebrates)	• Agricultural water use (m^3/ha) • Fish stock (kg/m^3)	• Maximum sustainable water use for irrigation (m^3/year) • Net Productivity (kg/ha/year)
Non–Food goods	• Production of raw materials (e.g. timber, reeds) • Production of medicines	• Amounts available (kg/ha/year)	• Maximum sustainable harvest (kg/ha/year)
Hydro-electric power	• Flow for energy generation	• Storage capacity of riverbeds and lakes (m^3/km^2) • Slope (deg), elevation (m)	• Maximum sustainable energy production (kWh/year)
Regulating services			
Regulation of water flows	• Retention of rainfall and release (especially by forests and wet-lands) • Water storage by rivers, lakes and wetlands • Groundwater recharge and discharge	• Infiltration capacity (mm/h) • Water storage capacity of soils (m^3/m^3)	• Baseflow volume (m^3/year);
Hazard mitigation	• Reduced flood peaks and storm damage • Coastal protection • Slope stability	• Maximum natural water storage capacity (m^3/m^2)	• Size (km^2) and economic value (US$/$km^2$/year) are protected from flooding
Control of soil erosion and sedimentation	• Protection of soil by vegetation and soil biota	• Infiltration capacity (mm/h) • Slope length (m) • Barren land (%)	• Soil loss (kg/ha/year) • Sediment storage (kg/ha/year)
Water purification	• Reduced siltation of streams and lakes • Nutrient uptake and release by ecosystems • Removal or breakdown of organic matter, salts and pollutants.	• Nitrogen amount (kg/ha) • Total dissolved solids (kg/m^3) • Electric conductivity (µS/cm)	• Denitrification (kg/ha/year)
Supporting services			
Wildlife habitat	• Wildlife and nursery habitats	• Resident and endemic species (number) • Surface area per ecosystem type (ha)	• Increase or decline in species population size (number)
Environmental Flows	• Maintenance of river flow regime	• Area of critical habitats (ha) • Discharge for each season (m^3/day)	• Fish species and population • Total fish catch (t/year)
Cultural & amenity services			
Aesthetic and recreational services	• Landscape quality and features	• Stated appreciation • Recreational value (e.g. entrance fees (US$/visit)	• Houses on lakeshore (number/km) • Visitors (number/year)
Heritage and identity	• Landscape features or species	• Cultural significance and sense of belonging	• Visitors (number/year)
Spiritual and artistic inspiration	• Inspirational value of landscape features and species	• Books and paintings using water-shed as inspiration	• Pilgrims (number/year)

Figure 4. List of main watershed services and related biophysical indicators (Source: IUCN, 2006)

3.1 Monetary valuation methods

For what concerns strictly human preferences, despite a growing interest in non-monetary valuation methods, monetary valuation of ecosystem services remains prevalent in the ecosystem services literature (Haines-Young and Potschin, 2009). This is due to the fact that monetary valuation uses a measure more familiar to people and authorities/policy-makers, and, at present, more directly incorporable in private and public decision-making processes. Especially in urban areas, water is treated as a commodity, and, due to growing population and increased demand, the economic value of ecosystems providing water is substantial (see Box 7).

Box 7. The Llabcahue watershed, Chile

Núñez et al. (2006) estimated the annual economic value per hectare of native forest in Llancahue watershed (Chile) to be of US$ 162.4 for the summer period and US$ 61.2 for the rest of the year, with respect to their role in contributing to fresh water supplies in Chilean cities. This and other cases indicatively show that the economic value of ecosystems as water infrastructures is relatively high if compared with substitute, engineering solution (Emerton and Bos, 2004)

The Total Economic Value (TEV) is the framework that has been more widely used to estimate ecosystem services in monetary terms. It considers the aggregate amount of use, non-use and option values of the environment, and allows for measuring what individuals and societies gain or lose as ecosystems change. Use values relate to benefits obtained through direct (e.g. production of foods or raw materials) or indirect (e.g. benefits to productive activities through pest control and pollination) interactions with the natural ecosystem (EFTEC, 2005). Use of ecosystems can in turn be consumptive (e.g. use of timber or fuel wood) or non-consumptive (e.g. recreation and education). Non-use values are derived from the simple knowledge of the existence of the ecosystem, or that other people and future generations are or will be able to access the benefits it provides. The TEV framework can also include the ecosystem's option value (i.e. derived by the possibility of it providing known and unknown benefits in the future) but the opportunity of their inclusion in the TEV measurements is debated (TEEB, 2012).

The valuation methodologies more commonly used are based on estimating the value of an ecosystem service by observing one of the following measures: a) its market value; b) how it influences the economic choices of people; and c) the people's reactions to simulated changes in its availability. Table 2 lists a series of valuation methods, articulated in the mentioned three main categories according to what they aim at observing, what watershed services they can be applied to, and what are their main advantages and limitations. As some valuation approaches are better suited to capture the value of specific ecosystem services, Table 3 lists the main water-related services analyzed in the previous chapters with the indication and their most appropriate valuation methods. For instance, for urban wetlands valuation, exercises have been carried out almost exclusively through hedonic pricing.

Monetary valuation methods are then incorporated in policy and decision instruments, as markets or the Payments for Ecosystem Services (PES), described in Section 4.

Table 2. Overview of monetary valuation methods (based on Pagiola et al., 2004)

Approach	Method	Acronym	Methodology	Application	Example	Advantages and limitations
Direct market valuation - observation of prices, quantity and costs of goods and service on a market	Market price	M	Observe prices of ecosystem good or service in markets	Environmental goods and services traded in markets	Timber and fuelwood production by forests	Data easy to obtain. Inapplicable to non-marketed services and to distorted markets
	Avoided cost	AC	Estimate losses avoided by ecosystem service	Ecosystem services that protect assets and capital	Erosion control by forests	Difficult to capture total damage and to relate it to ecosystem status
	Replacement cost	RpC	Quantify cost of man-made solution to provide the same benefit	Ecosystem services that have a manufactured alternative	Flood control by wetlands (as opposed to engineered structures)	Simple estimation, but depends on human and technological capital of a society, manufactured solution never provides all the benefits of an ecosystem
	Restoration cost	RsC	Quantify cost of restoring lost ecosystem services	Ecosystem services whose loss can be offset or restored	Restoring deforested area	Simple estimation, but full restoration of complex ecosystems is practically unattainable
	Production function	P	Estimate value of a service as an input for the delivery of a service or commodity in a market	Ecosystem services that provide a production input to marketed goods and services	Water purification by wetlands	Implications of ecosystems (and their change) in production are insufficiently understood
Revealed preference - observation of the economic actors' choices associated to a service	Travel cost	TC	Quantify direct and indirect costs to access the ecosystem's site	Areas and sites that provide recreational value	Protected area for recreational or educational purposes	Rely on actual behaviors, but technically difficult, high data requirements and possibly influenced by market failures
	Hedonic pricing	HP	Estimate influence of the ecosystem and of its change on the price of marketed goods and services	Ecosystems that modify the value of marketed good and services	Environmental amenities of buildings and sites for housing purposes	Rely on actual behaviors, but technically difficult, high data requirements and possibly influenced by market failures
Stated preference - observation of the economic actors' choices in a simulated market	Contingent valuation	CV	Estimate directly the people's willingness to pay for a service	Any ecosystem service	Loss of biodiversity	Allow to estimate non-use values, the actors' preferences are hypotetical and non verifiable

	Choice modelling	CM	Estimate the people's willingness to pay by ranking different investment options	Any ecosystem service	Loss of biodiversity	Allow to estimate non-use values, the actors' preferences are hypothetical and non verifiable
Others	Benefit Transfer	BT	Use results obtained in one context in a different context (e.g,)	Any service for which suitable comparison studies are available	Estimating the value of one forest using the calculated economic value of a different forest of a similar size and type	Allows estimate the value of ES when access to primary data are non-accessible

Table 3. Overview of valuation methods for watershed services (elaboration based on (Farber et al., 2006; TEEB, 2012))

Type	**Service**	**Valuation methods**
Provisioning	Water supply	M, P, RpC, RsC, CV
Regulating	Hazard protection	AC, RpC, CV
	Water regulation	M, P, AC, RpC, CV, HP
	Water purification	P, RsC

Table 4. Case study example of application of ES valuation methods in urban watersheds

Watershed and urban area	City/Urban area (inhab.)	Ecosystem to be recovered or protected	Service	Valuation methods	Value	Reference
Peñablanca Protected Landscape and Seascape	Tuguegarao City, Philippines (136,000 inhab.)	Watershed	Water supply	Contingent valuation	Most of the respondents were willing to pay between UD$ 1 and 1,7 per month	(Amponin et al., 2007)
Layawan Watershed	Oroquieta City, Philippines (68,945 inhab,)	Watershed	Domestic water supply and hazard mitigation	Contingent valuation	More than half of the respondents were willing to pay approx US$ 1,3 per month per household	(Calderon et al., 2012)
McKenzie Watershed	Eugen-Springfiel Metropolitan area, Oregon USA (200.00 inhab.)	Watershed forest	Water supply	Spatial analysis with Benefit transfer	Between US$ 10 and 48/acre/year	(Schmidt and Batker, 2012)
McKenzie Watershed	Eugen-Springfiel Metropolitan area, Oregon USA (200.00 inhab.)	Watershed forest	Hazard mitigation (flooding and landslides)	Spatial analysis with Benefit transfer	Between US$ 1.40 and 4/acre/year	(Schmidt and Batker, 2012)
McKenzie Watershed	Eugen-Springfiel Metropolitan area, Oregon USA (200.00 inhab.)	Watershed forest	Waste treatment	Spatial analysis with benefit transfer	Between US$ 52 and 182/acre/year	(Schmidt and Batker, 2012)
Chehalis watershed	Hoquiam, Aberdeen, Centralia, and Chehalis (141.00 inhab.)	Wetland	Flood protection	Spatial analysis with benefit transfer	US$ 6,357.71/acre	(Batker et al., 2010)
Sardu Watershed	Dharan, Nepal (118.000 inhab.)	Watershed	Drinking water	Market price	Circa US$ 273.000	(Paudel, 2010)
Johnson Creek, Lents area	Portland, Oregon, USA (576.000 inhab.)	Watershed Wetlands	Water quality services	Contingent valuation and avoided cost	US$ 549 per year per acre of wetland Total: US$ 2,388,982	(Evans, 2004)

Watershed and urban area	City/Urban area (inhab.)	Ecosystem to be recovered or protected	Service	Valuation methods	Value	Reference
Johnson Creek, Lents area	Portland, Oregon, USA (576.000 inhab.)	Watershed Wetlands	Flood protection	Avoided cost or replacement value	US$ 66,700 per 10-yr flood event for all residences Total: $5,437,451 over 100 years	(Evans, 2004)
Cusiles River basin	Matiguás, Nicaragua (9000 inhab.)	Watershed	Water supply	Contingent valuation	Higher willingness to pay under an infrastructure improvement scenario than under a PES approach	(Van Hecken et al., 2012)
Chaina micro-watershed	Villa de Leyva and Chiquiza (Boyacá Department), Colombia (4300 inhab.)	Watershed	Water supply	Contingent valuation	US$1.39/month (with large difference according to the type of users: farmers or recreational house owners)	(Moreno-Sanchez et al., 2012)

Estimation of the value of watershed services to urban areas allow to make explicit the links between the local and regional scales. In-situ contingent valuation seems to be the preferred method to value urban water-related services (see Table 4). Benefit transfer is also a valuation technique frequently recurring in the literature but seems to be less explored, possibly for the mentioned context-specificity of ecosystem services valuation.

Due to the context-specific nature of the valuation exercises, their results are extremely difficult to compare and scale up (Farber et al., 2006). In fact, even in the case of direct market observations for goods and services that are traded on global markets, their value will depend on local levels of demand and supply and access to economic assets and natural resources. The supply of one service is often strictly entangled with other ecosystem functions, which increases the overall value of the ecosystem. As an example, the value of a wetland can depend on the fact that it provides some or all of these services: flood control for downstream urban areas, water filtration for near sources of urban drinking water, opportunities for bird and wildlife watching and fishing (Boyer and Polasky, 2004). The value of each will be greatly influenced by the socio-economic context (e.g. distance from one or more cities, their size, their position up/downstream, their economic specificities). Context-specific valuation methods can, on the other hand, inform local policies on micro-level elements such as the amount of money downstream watershed users might be willing to pay to upstream users to maintain healthy ecosystems. The wide variety of estimates listed in Table 3 confirms the necessity to carry ad hoc, in-situ studies due to the high variability of the results obtained. With respect to the type of service assessed, water supply is highly considered in urban watershed studies, while there are fewer studies that focus on the hazard regulation and wastewater purification functions of watershed ecosystems for urban areas.

As most methods focus on valuing one or some of the whole range of services provided by an ecosystem, thereby neglecting the environment's diverse and complex values and benefits to the well-being of human communities, integration of different methodologies and participatory approaches to consider multiple services is often necessary. It should be made clear that monetary valuation need to be accompanied by a broader set of considerations. There is a wide range of situations in which the cost-benefit valuation of ecosystem services is not considered as feasible or an appropriate option (Kallis et al., 2013; TEEB, 2010). It has also been demonstrated that pricing can be counterproductive in terms of biodiversity conservation and equity in the access to resources (Gomez-Baggethun and Ruiz-Perez, 2011). Alternative assessment strategies, based on non-monetary values, are presented in the next section.

3.2 Non-monetary valuation methods

Estimating the value of environmental processes for human communities is grounded on biophysical assessments as well as on social and economic analyses. It is therefore inherently multidisciplinary in nature and often best pursued through participatory processes that actively involve stakeholders (Haines-Young and Potschin, 2009). For instance, the social value of a watershed is typically greater than the development value which would benefit a private owner (Boyer and Polasky, 2004). To express these values, participatory valuation exercise can lead to a simple ranking of different benefits provided by a watershed ecosystem to an urban area. As mentioned in Wilson and Howarth (2002), group valuation can be appropriate for ecosystem services that are generally public in nature, for which methods based on the elicitation of individual preferences, such as contingent valuation, might not be adequate. Table 5 lists and describes the main participatory valuation methods in use to assess ecosystem services. Few applications of participatory methods to the valuation of urban watershed services are available. Some of them are listed in Table 6.

Table 5.Participatory and non-monetary valuation methods

Approach	Method	Acronym	Methodology	Advantages and limitations
Non-monetary valuation methods/participatory appraisal	Individual index based method	IS	Rating and ranking choice models, expert opinion. Or questionnaires to individual stakeholders for semi-structured, narrative or in-depth interviews	Flexible and useful in contexts where there are conflicts between different views and it is necessary to establish the source of the disagreement.
	Individual experts views	IE	Delphi surveys (iterative process including a series of deliberations)	Particularly useful when existing knowledge is limited
	Group-based (e.g. focus groups)	GB	Including voting mechanisms, focus groups, citizens juries, stakeholders analysis	This approach is based on principles of deliberative democracy and the assumption that public decision making should result from open public debate. It is useful to gain insights about institutional linkages and relationships.
	Group stakeholders viewpoints requiring in-depth statistical analysis	Q	Q-methodology (helps determine the nature of individual relationships and perceptions of environmental problems and solutions)	MC assessment is particularly useful when stakeholders identify non-negotiable outcome
	Multi-criteria analysis	MCA	Multi-criteria analysis (helps structure decisions characterized by trade-offs between conflicting objectives, interests, and values; it can be complementary to CBA).	While CBA aims at economic efficiency, MCA includes value expressed in different terms. MC determines how one services is important with respect to other services (trade-offs)

Table 6. Example of non-monetary and participative valuation studies or urban watersheds

Watershed and urban area	City/Urban area (inhab.)	Ecosystem to be recovered or protected	Service(s)	Valuation methods	Value/results	Reference
Lobau floodplain, upper Danube river	Vienna City, Austria	Watershed wetlands	Recreation; groundwater abstraction for drinking water production	Multicriteria decision analysis (MCDA)	The majority of the involved management sectors preferred the higher connectivity options as compared to the Current Status option. Potential conflict between the ecological development and the drinking water production..	(Sanon et al., 2012)
Chicopee Watershed	Boston area, Western Massachusetts, USA (190,600 inhab. in the watershed)	Watershed	Water supply	Non-monetary deliberative method (Deliberative Attribute Prioritization Procedure DAPP: combines a multi-criteria analysis using pair wise comparisons with a process to reach group consensus)	Density of toxic waste sites has the highest priority weight with a value of 0.19. Runoff has then the next highest ranking with a priority weight of 0.15.	(Randhir and Shriver, 2009)

4 Policy and economic instruments

Urban water policies based on the results of valuation studies, derived from the application of the methodologies described in the previous sections, are essential to the management of a number of services provided by watersheds: provisioning of clean water in sufficient quantities, release of clean used water to the environment downstream or to the groundwater and protection from droughts and flooding. These services can be provided, and are provided (in particular in most urban areas of the richer countries) through centralised, technology-oriented measures, such as large-scale water retention systems, dams and long-distance pipelines ensuring freshwater provisioning, dikes and drainage systems as flood protection measures, sewerage systems and plants for wastewater reclamation and the reduction of pollution. However, these solutions have often demonstrated to lead to additional environmental degradation and to require continuous and expensive maintenance interventions. As described in the previous sections through numerous case studies, ecosystems provide alternatives or integrations to these technology-based systems. Ecosystems management approaches for resilience in urban areas make use of the existing natural landscape and can significantly decrease the cost and impacts of urban infrastructure projects (Boyer and Polasky, 2004). Even when they are adopted to replace or improve ecosystem services, technological solutions ultimately rely on functioning ecosystems (Brauman et al., 2007).

The separation between the human and ecological dimension that predominated in the past and still exists in development and hazard theories (Khan and Crozier, 2009; Khan, 2012), led scientists to find solutions to environmental problems, including natural hazards, through the modification, substitution and suppression of environmental processes. The application of an ecosystem approach stresses the connection between urban areas and local as well as more distant ecosystems, as are the watersheds in which cities are located and from which they derive important benefits. A better recognition of watershed services, their value and connections to the local urban environment would thus benefit urban areas in terms of social, economic and environmental efficiency, as described in the previous sections.

Ecosystem management strategies can help maximise the resilience-enhancement potential of natural systems for urban dwellers, by making full use of the capacities of wetlands and natural vegetation in water bodies for water reclamation and of green areas as buffer and regulating element against floods, for water retention and for groundwater recharge. The value of urban water-related ecosystems as alternative or complement to technical solutions has been recognized in many cases (see above). Ecosystem-based options may thus represent doubly effective solutions as urban areas not only benefit from watershed services but are also the drivers of ecosystem use, change and management at this scale.

A particular strategy that found multiple applications at the watershed scale are PES (Dillaha et al., n.d.; Smith et al., 2008). PES are defined as "(a) a voluntary transaction where (b) a well-defined environmental service or a land use likely to secure that service (c) is being 'bought' by a (minimum one) service buyer (d) from a (minimum one) service provider (e) if and only if the service provider secures service provision (conditionality)" (Wunder et al., 2008, p. 835). The literature on this arrangement is vast. Cases of payments for water provisioning services for cities are extensively reviewed in Buric et al. (2011). Most schemes reviewed by these authors were located in South America, in particular in Brazil, and, in the majority of the projects, forestation or reforestation were the main land-use changes implemented. The payments schemes were mainly realised in not extremely degraded watersheds and were driven by some of these aspects:

- avoiding expensive technological solutions for the improvement or conservation of quality of drinking water;
- acting early to protect critical watershed land, i.e. avoid imminent water pollution induced by the change of land-use practice;
- managing the risk of potential water degradation by making a preventive investment into conservation of the current water supply/quality;
- mitigating the effects of watershed degradation in order to improve the quality of water (Buric et al., 2011),

There seem to exist a series of preconditions that facilitate the decision and implementation of payments schemes, in particular the need for a community to prevent or halt initial condition of degradation. However, PES can ultimately facilitate the transfer of resources from urban areas to upstream social-ecological systems, which in turn has the potential to significantly improve the well-being of the downstream urban populations. PES programs have also demonstrated to contribute to curbing urban growth in rapidly urbanizing megacities such as Mexico City (DuBroff, 2009).

As described in Wunder et al. (2008), user-financed PES are generally better targeted and tailored to local conditions if compared to programs initiated by governments (or another third party). Not unlikely the ecosystem valuation exercises and their results, the PES programs demonstrated to be highly context-specific (Wunder and Albán, 2008). Especially in the global South, while economic valuation can be informative on the value attributed to up/downstream services, the actual structure of payments schemes can often be the result of complex social processes involving multiple stakeholders rather than of a merely technical assessment (Kosoy et al., 2007). For some examples of application of PES schemes see Box 8 and Box 9.

Box 8. The Miyun watershed in China

In response to the watershed degradation, from the mid-1980s the Government instituted strict controls on land and forest use, including a total ban on logging, and invested substantially in a reforestation program. The logging ban caused the forests to be neglected, rather than sustainably managed, with the consequence that they weren't contributing much to soil, water and biodiversity conservation. Also, local communities outside of Beijing were suffering increasing economic hardship, due to the lack of income alternatives to the exploitation of forest products.

However, since 1995, the Beijing Municipality has compensated upstream settlements with the annual payment of US$ 2.5 million for the adoption of soil and water conservation measures and subsidies to farmers who converted paddy fields to dry farmland, forest or grassland. Recognizing the multiple needs and functions associated with a watershed, in 2007 IUCN identified and then introduced through participatory processes a new set of forest management tools that allowed for a shift from a strict protection-oriented approach towards more sustainable resource use by forest-based communities. Local communities are responsible for applying silvicultural treatments that improve forest structure, quality and function. For instance, support has been provided to establish community-based cooperatives for marketing forest goods and services, with the aim of increasing and diversifying local income (IUCN, 2010).

Box 9. The New York PES Scheme, USA

Until the XIX century, New York's water supplies depended almost exclusively on a single, inner-city Collect Pond and the city wells were constantly contaminated by the wastewater produced by upstream settlements on the Erie Canal, which resulted in the cholera and yellow fever outbreaks of 1832. In 1842 a first aqueduct was finished, connecting the city to the nearby Croton watershed, which still supplies 10% of the city's freshwater and then to the Catskill-Delaware watershed, which supplies the 90% (Appleton, 2002). By involving the upstream stakeholders into the management of its water resources, the municipality has been able to establish land-use practices and policies that protect the services provided by the watershed ecosystems. In 1997 the city signed a Memorandum of Agreement, committing to invest around US$ 1.5 billion over 10 years to restore and protect the surrounding watersheds, as well as to promote measures to improve the local economies of watershed residents (Postel and Thompson, 2005). A comprehensive study of the National Research Council committee has highlighted a whole range of non-structural measures that have been established for water quality protection, such as land acquisition, buffer zone designations, conservation easements, and zoning ordinances (Pires, 2004). The process has allowed for changes that eliminated the need for industrial water filtration for the downstream megalopolis. It has been noted how the protection of these natural areas through the institution of nature reserves, national parks and wilderness areas allows both for the conservation of local biodiversity and for the enhancement of water resources the city depends on (Postel and Thompson, 2005).

The transfer of resources for environmental management and restoration of upstream areas also prevents land abandonment, which has negative environmental consequences. For instance, in the Miyun Case (see Box 8), as in other cases (Harden, 1996; Raj Khanal and Watanabe, 2006), land abandonment and spontaneous forestation as a consequence of restrictive land-use policies in response to overexploitation and degradation of watershed ecosystems has not had positive environmental impacts. Similarly, evidence suggests that cultivation and extensive maintenance of mountain slopes in the Middle Mountains of Nepal guarantees high degrees of stability while rapid de-intensification leads to slope instability (Smadja, 1992). Local food and livelihood security also tend to diminish when agricultural land is abandoned while the occurrence of mountain hazards, such as floods and landslides, increases (Raj Khanal and Watanabe, 2006). Other frequent consequences of land abandonment are "biodiversity loss, increase of fire frequency and intensity, soil erosion and desertification, loss of cultural and/or aesthetic values, reduction of landscape diversity and reduction of water provision" (Rey Benayas, 2007). The abandonment of agricultural land and subsequent unmanaged reforestation processes have often resulted in the loss of endemic species and the proliferation of invasive, often exotic, ones, causing additional environmental problems. The spread of non-native invasive tree species with high evapotranspiration requirements in the Western Cape watershed (South Africa) has negatively impacted water supply (Postel and Thompson, 2005). Local livelihoods therefore play a major role in healthy watershed management. The abandonment of slopes for floodplains has often “worsened people’s livelihoods, enhanced social conflict and taken critical environments out of community control” (FAO, 2007).

The creation of public parks and the restoration of rivers have been practiced in various urban contexts in which urban planners and water managers needed to prevent and mitigate hydro-meteorological hazards. While one of the earliest recognized successes may be Curitiba (Brazil), there are a handful of cases in Spain (see Box 10), Australia (see Box 11), the Philippines, Chile, and Korea. Areas dedicated to conservation and watershed services benefiting urban areas have shown to significantly overlap in the 105 cases analysed in a study by Dudley et al., (2003) where concerns for the integrity of water supply were the main reason for the instauration of protected areas.

Box 10. Flash floods in Barcelona, Spain

In Barcelona, the flash-flood-prone Besos River was restored to a meandering low-flow channel within a wider floodway of constructed wetlands (Martín-Vide, 2001). Intense urbanization in the 1960s had led to the encroachment of 300,000 poor residents into the original Besos floodplain. Planning for river restoration began in the mid-1990s in an effort to improve the environmental quality of the city, control floods, and provide a green recreation space for the target municipalities.

Box 11. Droughts and flash floods in Melbourne, Australia

In Australia, where frequent droughts and occasional extreme precipitation events have accelerated recognition of the particular importance of water as a natural resource in urban areas, the "Water Sensitive Urban Design principles" (WSUD) are gradually evolving from an experimental stage, where single measures are tested in small parts of the urban areas, into institutionalized practices. The State of Victoria has, for instance, mandated WSUD principles in its State planning provisions (Rijke et al., 2013). Facing recurring water scarcity and threatened by decreasing water availability due to climate change, all major Australian cities have to some extent modified their patterns of water management. Among them, Melbourne with its program "Total Watermark - City as a catchment" (City of Melbourne, 2009) has a forefront role in the implementation of watershed management principles into the urban context. The measures implemented cover both aspects of water quantities and quality, focusing mainly on rain- and stormwater harvesting and increasing water efficiency (considering both households and productive activities). The program is based on targets for the quantitative water balance and for the discharge of pollutants, related to stormwater runoff, aiming at the development of a "water sensitive city" conceived as "a catchment where stormwater and treated wastewater are important water sources" (City of Melbourne, 2009, p. 51). To this aim, a series of measures have been adopted, including non-structural techniques for water efficiency and prevention of stormwater pollution at the source, demand-management strategies, regulation, planning controls and financial incentives (City of Melbourne, 2009).

Evidence thus suggests that, when implementation policies are able to buffer the socio-economic disadvantage generally affecting marginal, upland and lowland communities and when ecosystem service users are willing to pay for improved environmental quality and service delivery, good watershed management and upstream/downstream balance can be achieved. Cities need therefore to be better connected to environmental management strategies and socio-economic practices of upstream and downstream communities.

5 Concluding remarks

In this working paper we presented urban areas as parts and defining units of catchments, with their own environmental and water balance, yet inextricably connected to the catchment basin in which they are located. The nexus between the urban system and its surrounding ecosystems are analyzed in two directions: water quality (nutrients regulation and pollutants removal) and quantity (water supply, drought and flood resilience). This approach aimed at highlighting, through the description of water-related services benefiting urban populations and of numerous related case studies, that urban management has the potential to be the driver of watershed conservation and restoration. Cities and urban areas should be incorporated as central administrative units within the management of watersheds as these derive important services and are most of the time the direct or indirect drivers of environmental degradation upstream and downstream. As suggested in Grimm et al. (2000), the ecology of cities should therefore better include this regional perspective. An important first step is to acknowledge the importance of local as well as of remote ecosystems in decision-making for urban management. This means that, when designing and implementing policies and planning, urban authorities might need to adopt a wider geographical perspective, which we suggest to be the watershed level. With an ever increasingly amount of people settling in urban areas, cities need to become the drivers of this regional ecosystem approach to improve the conditions of local and more distant ecosystems, not least through the transfer of resources. At this regard some summarizing remarks are:

- sustainable watershed management demands the inclusion of different sectors and stakeholders, promoting participative methods and solutions, as it stated in the principles of Integrated Urban Water Management (IUWM) (Bahri, 2012);
- ecosystem-based solutions should be particularly valued by local authorities, as many of the services ecosystems provide are included in their basic mandate. The nature of the competence of local authorities (linked to a territory, rather than to a specific matter), makes the use of integrated solutions generally easier and more effective;
- ecosystem-based solutions provide co-benefits that go well beyond their direct utility here analyzed. Benefits such as recreational, esthetical and spiritual opportunities, incrementing the economic value of properties, fostering the cultural life of urban dwellers and supporting biodiversity and life are some of the desirable side-effects of these interventions;
- integrating ecosystem management and restoration within urban planning and disaster risk reduction measures at the watershed level is a long term, (cost-)effective approach to increasing the resilience of human communities and urban centers, in particular in the face of natural hazards, while enhancing the quality of watersheds ecosystems, as demonstrated by the numerous case studies reported in this paper;
- though cities have been driving environmental degradation in the past century, it is increasingly at the urban level that social, economic and cultural change happens. Even in the lack of overarching national and international agreements, cities can then play a central role in improving regional ecosystem health through the transfer of resources while diminishing their own expenditures and risk;
- despite the limitations highlighted above, most of the studies available in the literature that attempt to assess urban watershed services rely on pricing. It is recommended that alternative valuation methods be applied to take into consideration a broader range of values and to examine the potential outcomes of different urban management options also according to the expected environmental improvement and consideration of social equity;

- water supply seems to be the most investigated service originating at the watershed level and benefiting urban areas. This can be the driving sector for this regional ecosystem approach. More research with concrete examples needs however to be carried out with respect to the capacity of urban watershed to perform hazard mitigation and wastewater treatment functions.

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