Urban disaster risk reduction and ecosystem services

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Abstract

Urban areas are continuously growing worldwide and for the first time in human history they host more than half of the total human population. They have always been the places where most human interactions take place and where cultural, economic and political activities are concentrated. On the one hand, urban areas have enabled human populations to be less reliant on local ecosystems, building a wider service network and relying on more distant areas for the supply of resources. On the other hand, urban areas are increasingly located in or expand into hazard-prone areas. Cities are also responsible for ecosystem degradation, diminishing their regulating functions and buffering capacity with respect to hazards, further increasing urban risk. Though "hard" engineered technologies have traditionally been adopted to reduce the vulnerability of urban areas to hazards, "soft" technologies, utilizing natural infrastructure to mitigate hazard impacts, often provide cost-effective strategies, while also guaranteeing access to different sources of livelihoods. This chapter aims to introduce the particular features of disaster risk in urban areas, while focusing on both "local" and "distant" ecosystems and their role in mitigating the impacts of hazards in cities. Case studies are included which illustrate good practices in the adoption of an ecosystem approach in urban areas for disaster risk reduction.

1. The process of urbanization

Cities have been defined as "humankind's most durable artifacts" (Vale and Campanella, 2005). For threatened, damaged or destroyed as they have been throughout history by wars, epidemics, economic and political crisis, and disasters, they have seldom been abandoned (notable exceptions include ancient cities such as Mohenjo-daro in Pakistan and Troy in Turkey, and, more recently, Prypiat in Ukraine). Cities such as Baghdad, Istanbul, Athens, and Rome still stand as enduring footprints of human history.

Despite the existence of urban settlements as early as 4 thousand years B.C., urban dwellers never represented more than 10% of the global population until the second half of the 19th century, when their numbers started growing rapidly (UN-HABITAT, 2003). Urban population reached 1 billion in the early 1960s, 2 billion in the late 1980s and is now estimated at around 3.5 billion, accounting for 50.1% of the total population and outnumbering, for the first time in human history, the total of rural settlers. According to projections, urban growth will continue during the next decades, accounting for at least 90% of the global demographic increase. Cities and towns will be home to 6 billion people by the first half of this century, about 68% of the total human population (UNDESA, 2010).

This unprecedented concentration of people has led 21 urban areas to grow to over 10 million inhabitants during the last six decades (UNESCAP, 2005) and is expected to translate into regional megalopolis of up to 50 million inhabitants, such as the Hong Kong-Guandong or the Rio de Janeiro-São Paulo areas (Borja and Castells, 1997; Davis, 2004). But expansion is mostly taking place in small and middle-size urban centers, while the largest seem to stagnate. In 2007, 62% of the world's urban population resided in cities with less than 1 million inhabitants, and just 15% in agglomerations of more than 5 million (UNDESA, 2007).

Small towns, cities, megacities, and complex metropolitan areas are different forms of urban areas. They are -and have been- the locus of innovation and modernization, where secondary and tertiary sectors dominate over the primary sector (Albala-Bertrand, 2003). While these characteristics are progressively extending to rural areas, in particular in developed countries, urbanization allows individuals and social groups to interact, as an organismic whole, in order to give spatial expression to the flow of time, defining symbols, culture and future of an increasingly cosmopolitan humanity (Mumford, 1938).

There is a close link between urbanization and economic performance of modern nations: the UNISDR Making Cities Resilient campaign has defined urban settlements as "the lifelines of today's society" (UNISDR, 2010). Services, urban activities by definition, generate 63.2% of the global GDP (CIA, 2010). The most urbanized countries tend to have higher per-capita income (UNISDR, 2009a), higher average life expectancy and literacy rate, and stronger cultural and democratic institutions (Johnson et al., 2010). For the city dweller and rural migrant, urban life represents the opportunity of better medical care and education, richer cultural life, higher income and economic stability.

2. The urbanization of disaster risk

Historically, cities have also offered an opportunity for human communities to reduce their livelihood dependency on local natural resources, which characterizes the rural way of life. They allow for the development of collective coping strategies, by providing centralized, more reliable services and diversification of productive activities, sources of income and markets that can continue to provide food and shelter in times of hardship. Nonetheless, urban societies do not necessarily manage to make their environment completely safe. In fact, urbanization processes redefine the interactions between humans and ecosystems, transforming physical landscapes as well as building new forms and structures of social aggregation. They reshape, but do not necessarily reduce, the environmental risks communities face, including those related to natural hazards (Mitchell, 1999).

Table 1 reports data on some notable urban disasters. It is interesting to note how hazards traditionally associated with rural contexts, such as floods and droughts, are increasingly affecting cities all over the world, becoming more prevalent in rapidly urbanizing and developing countries (Blaikie et al., 1994), but also in highly developed urban settings.

Table 1. Some notable disasters in cities and metropolitan areas.(Sources:[1]EM-DAT, [2]Daniell and Vervaeck (2012), [3]O Globo (2011), [4]Cavallo et al. (2010), [5]OCHA (2009), [6]Louisiana (2006), [7]Pielke et al. (2008), [8]Desinventar Indonesia, [9]Munich Re, (2004), [10]Bradford and Charmichael (2007), [11]Strzepek and Smith (1995), [12]Tilling (1985), [13]Weems (2012), [14]Pereira (2006), [15]Porter (1994).The table lists exclusively urban disasters as well as preponderantly urban events (as in the case with the aggregated data from EM-DAT).

Year	Event	City	Country	Fatalities	Economic losses (US$M, 2011 value)	Physical environment
2011	Tornado	Joplin, Missouri	USA	142[1]	7,000[1]	Great Plains
2011	Tohoku earthquake and tsunami	Sendai	Japan	20,319[1]	210,000[1]	Pacific coast
2011	Earthquake	Christchurch	New Zealand	181[1]	20,000[2]	Port Hills fault
2011	Landslides	5 cities in Rio de Janeiro state	Brazil	904[3]		Serra dos Órgãos reliefs
2010	Earthquake	Port-au-Prince	Haiti	222,570[1]	8,130[4]	Enriquillo-Plantain Garden fault system
2008	Cyclone Nargis	Labutta Township	Myanmar	84,454[5]		Irrawaddy delta
2008	Earthquake	Wenchuan	China	87,476[1]	88,681[1]	Longmen Shan fault system
2005	Hurricane Katrina	New Orleans	USA	1,464[6]	93,539[7]	River delta
2004	Tsunami	Urban areas in Aceh	Indonesia	165,357[8]	5081[8]	Malacca Straits coast
2003	Heat wave	Urban areas	France	> 14,800[9]	5,332[9]	Mid-latitude temperate
2000	Flood	Johannesburg	South Africa	80[9]	208[9]	Highveld plateau
1999	Earthquake	Istanbul, Izmit	Turkey	17,127[1]	26,807[1]	North Anatolian fault
1999	Tornado	Oklahoma City	USA	50[9]	2,680[9]	Oklahoma river basin
1998	Flood	Dhaka	Bangladesh	1,050[9]	5,859[9]	Ganges floodplain and delta
1995	Great Hanshin Earthquake	Kobe	Japan	5,297[1]	145,000[1]	Suma and Suwayama faults
1994	Earthquake	Northridge, California	USA	60[9]	45,189[9]	San Fernando Valley
1993	Flood	Cologne	Germany	5[9]	926[9]	Rhine river basin
1992	Hurricane Andrew	Greater Miami	USA	62[9]	42,258[9]	Wetlands, Biscayne bay
1992	Winter storm	New York	USA	20[9]	4,783[9]	Atlantic coast
1991	Wildfire	Oakland, California	USA	25[10]	3,276 buildings[10]	Pacific coast
1989	Loma Prieta Earthquake	San Francisco	USA	68[9]	18,185[9]	Pacific coast
1987	Heat wave	Athens	Greece	1,000[1]		Attica basin
1985	Earthquake	Mexico City	Mexico	9,500[1]	8,566[1]	Plateau, bed of the historic Lake Texcoco
1984	Hailstorm	Munich	Germany	0[9]	2,035[9]	Elevated plains of Upper Bavaria
1976	Earthquake	Tangshan	China	242,000[1]	22,180[1]	North China plain
1972	Earthquake	Managua	Nicaragua	10,000[1]	4,527[1]	Central American volcanic chain
1967	Flood	São Paulo, Rio de Janeiro	Brazil	> 600[9]	66[9]	Plateau, Atlantic coast
1962	Storm surge	Hamburg	Germany	347[9]	4,404[9]	River Elbe basin
1962	Flood	Barcelona	Spain	1,000[9]	734[9]	Mediterranean coast
1959	Typhoon Vera (Isewan)	Nagoya	Japan	5,089[1]		Low-level plateau, Kiso and Shōnai river basins
1954	Flood	Wuhan	China	30,000[1]		Yangze and Han river basins
1937	Typhoon	Hong Kong	China	11,000[11]		
1926	Miami Hurricane	Miami	USA	373[10]	161,100[7]	Wetlands, Biscayne bay
1923	Great Kantō earthquake	Tokyo	Japan	143,000[9]	36,703[9]	Tokyo bay

1908	Earthquake and tsunami	Messina	Italy	75,000[1]		Mediterranean coast
1906	Earthquake and fire	San Francisco	USA	3,000[9]	13,627[9]	San Andreas fault
1902	Volcanic eruption	St. Pierre	Martinique	> 30,000[12]	Entire city destroyed	Slopes of Pelée, Caribbean coast
1900	Galveston Hurricane	Galveston	USA	est 8,000[13]	105,780[7]	Galveston Island
1882	Tropical storm	Mumbai	India	100,000[9]		Konkan coast
1871	Fire	Chicago	USA	250[10]	17,420 buildings destroyed, 100,000 homeless[10]	Lake Michigan
1864	Tropical storm	Kolkata	India	50,000[9]		Ganges floodplain and delta
1755	Earthquake and tsunami	Lisbon	Portugal	>30,000[14]	85% of the buildings destroyed[14]	Tagus river estuary
1746	Lima-Callao Earthquake and tsunami	Lima	Peru	18,000[9]		Peruvian coastal plain, mountain slopes
1737	Tropical storm	Kolkata	India	300,000[9]		Ganges floodplain and delta
1731	Earthquake	Beijing	China	100,000[9]		Hai river system
1666	Fire	London	UK	8[15]	13,200 buildings destroyed, 100,000 homeless[15]	Thames river basin
1657	Meireki Fire	Edo (Tokyo)	Japan	100,000[10]		Tokyo bay
526	Earthquake	Antioch (Antakya)	Turkey	250,000[10]		Dead Sea rift
79	Volcanic eruption	4 cities on the gulf of Naples	Italy	18,000[9]	4 cities buried	Slopes of Vesuvius, Gulf of Naples
430 B.C.	Epidemic	Athens	Greece	30,000[10]		Attica basin

As vulnerable populations and unprotected physical capital increasingly concentrate in cities, disaster risk patterns follow urban development (UNISDR, 2009a). For economic and military purposes, many urban centers have been founded in fertile floodplains, hilltops and volcanic slopes, river crossings and coastlines, and have grown significantly exposed to dangerous natural events (UN-HABITAT, 2010). Hazard events, even small ones, threaten large numbers of people, as urban areas are more or less densely populated. By 2050, 870 million people worldwide are expected to be living in cities in highly seismic areas and 680 million in areas affected by severe storms (Lall and Deichmann, 2009).

The rise in human exposure is accompanied by the concentration of economic activities, livelihoods and infrastructures. Urban habitats are hotspots of wealth prone to suffering huge economic losses when a hazardous event strikes (see Table 1, which includes all the costliest events ever recorded). In addition, the concentration and diversity of activities, buildings and land uses magnifies the risk of cascading effects, when an initial natural disturbance triggers another or multiple technological hazards (also known as *natech* events), which often have catastrophic, long-lasting effects in and around urban areas. Such was the case of the 1999 earthquake in Izmit, Turkey, which triggered a fire in an oil refinery, causing the release of toxic gases and widespread environmental damage (Vatsa, 2005), or the urban fire after the 1906 San Francisco earthquake, or the 2011 Tōhoku tsunami which caused the Fukushima nuclear disaster in Japan.

Cities have always relied on a peripheral hinterland for essential functions such as food, water and raw material production or waste disposal. Globalization has expanded the urban areas' influence to a global scale, to include any region, no matter how remote or disconnected, that participates in its production and consumption processes. Such interconnections mean that a city will both influence and be influenced by any hazard event hitting any area providing its inputs or absorbing its outputs (Showers, 2002). On the other hand, as cities are crucial joints in increasingly global, economic and political processes, the damages they suffer will easily affect activities well beyond their geographical limits (Surjan and Shaw, 2009; Munich Re, 2004).

Despite these factors, living in a city does not necessarily mean being at great risk. Urban dwellers might enjoy a safe living location, good-quality housing and widespread access to education, health care, employment and income opportunities. Nevertheless, in many cities and towns, urbanization translates into higher deaths and damages where the local institutions are not able to provide their citizens with access to resources that reduce their exposure and vulnerability:

sufficient and sustainable income and asset base, safe shelter, adequate access to essential services, safety nets, political and civil representation, appropriate disaster and emergency management systems (Satterthwaite, 2010). The urban poor, who are deprived of adequate access to these essential goods and services, and are induced to live in unsafe conditions –such as flood zones or degraded industrial areas– are more vulnerable, especially in developing countries (Global Forum on Local Development, 2010). Yet it is precisely in cities of developing countries, where demographic growth over the next decades is expected to take place (UNDESA, 2009) and where the bulk of future disaster risk is expected to accumulate.

3. Urban centers and ecosystem services

In this chapter, we argue that disaster risk is increasingly a manifestation of urban growth and its depleting effects on ecosystems' capacity to support life and biodiversity, purify air and water, and mitigate extreme natural events such as floods, landslides, coastal storms, and wildfires. As most of the production, consumption and distribution of wealth takes place in urban areas or depends on the lifestyle of their dwellers (GDRC, 2011), cities ultimately determine global-scale processes such as deforestation, modification of the composition of the atmosphere and oceans, and alteration of the world's biogeochemical cycles, that leave no ecosystem completely devoid of direct or indirect human influence (Vitousek et al., 1997).

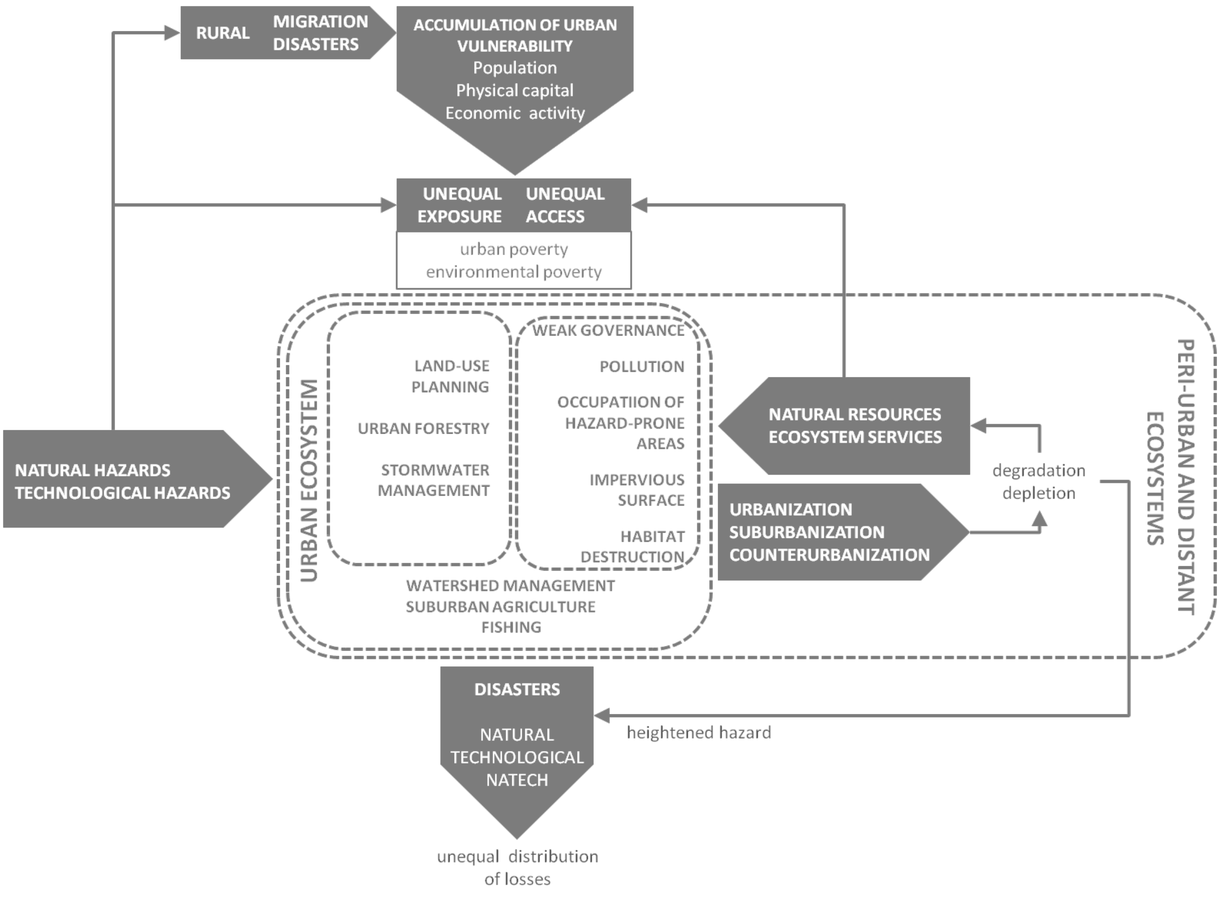

Figure 1. Interactions between the social and ecological systems in urban areas in the production of urban risk and disasters. Source: authors' own elaboration.

Nonetheless, much like any other ecosystem, cities are functional units in which dynamic complexes of micro-organism, plant, animal and human communities interact with a non-living environment (CBD, 1992). What differentiates urban landscapes is that they are predominantly characterized by elements that have been created or modified by human beings (Wilkie and Roach, 2004). They are socio-natural landscapes defined by the interplay of a community acting with its specific biophysical environment (Srinivas et al., 2009), and can be analyzed through ecological models in order to better understand them as a system of relations (Pickett et al., 1997) (see Figure 1).

Urban dwellers depend on both the built environment and the natural capital for their well-being. In particular, they rely on biologically productive ecosystems, located in both local and remote or peri-urban areas, for the whole array of fundamental services that ecosystems provide.

Local ecosystems

An urban landscape can encompass extremely diverse natural features, including coastal zones, forests and vegetated areas, reliefs, water bodies and streams. Such components, no matter how small in size, play a multifold role in supporting a safe and satisfying living environment for the urban dwellers (Bolund and Hunhammar, 1999). As cities are usually dominated by built infrastructure, the benefits provided by local ecosystems are easily overlooked in planning processes. Urban nature is often only regarded as an amenity, and therefore fragmented and depleted.

Box 1. *Urban flood reduction in New York, USA (UNISDR, 2011)*

In New York (USA) the capacity of the obsolete sewerage system is systematically exceeded during intense storm events, which has led to flooding in New York City streets. A significant amount of polluted water flows directly into local water streams without being processed in the water treatment plants. Instead of spending an expected US$6.8 billion to improve the system, the city has decided to finance green infrastructure for US$5.3 billion (New York City, 2010). Trees, lawns and gardens will be planted on roofs, streets and sidewalks. They will absorb and percolate more rainwater to the ground and reduce the burden on the city’s sewage system, while improving air and water quality and potentially reducing the need for water and energy.

An ecosystem-based strategy has also been envisaged to ensure clean water supply. In 1997, the city committed to invest around US$1.5 billion over 10 years to restore and protect the surrounding watersheds, as well as to promote measures that improve the local economies of watershed residents (Postel and Thomson, 2005). A comprehensive study by the National Research Council 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 agreements with landowners, and zoning ordinances (Pires, 2004). It noted how the establishment of protected natural reserves, national parks and wilderness areas allows for both the conservation of local biodiversity and the enhancement of water resources on which the city depends (Postel and Thomson 2005).

Box 2. *Chicago, USA: Green Permit Program (Kazmierczak, A. and J. Carter, 2010)*

Chicago's Department of Buildings (DoB) (USA) has developed an incentive program that encourages developers to incorporate green design elements, including green roofs on new buildings. The initiative is known as the Green Permit Program. It is part of a larger portfolio of initiatives aimed at making Chicago’s built environment more sustainable and better at managing storm water and mitigating urban floods. The incentive is an expedited permit process, through which developers can save both time and money. Additional benefits of the program include mitigation of greenhouse gas emissions through reduced need for heating and cooling in buildings with green roofs. The program is enhancing the city’s image and the emergence of businesses specializing in green roof installation.

In reality, urban ecosystems also provide food, fuel and fiber, and even though most urban dwellers do not directly rely on local ecosystems for food and raw materials, urban and suburban agriculture practices have proved a valuable coping strategy in times of hardship (Altieri et al., 1999). Urban vegetation allows for improved water drainage, by providing permeable areas that absorb excess runoff in case of precipitation (see Box 1 and Box 2), and filter water-borne sediments and pollutants (Guglielmino, 1997). By providing shade, absorbing heat, improving air circulation, and consuming solar energy, green areas and water bodies also help to control temperatures and counters heat island effect (Pickett et al., 2001) (see Box 3), which will increasingly be relevant in future climate when heat waves are expected to be more frequent and longer lasting (Meehl and Tebaldi, 2004). An extensive review of the potential role of local ecosystems in mitigating the impacts of heat waves in urban areas is presented in Depietri et al. (2012). Vegetation can also act as a windbreak during winter storms (McPherson, 1994).

Box 3. *Stuttgart, Germany: Combating heat island and poor air quality with green aeration corridors (Kazmierczak, A. and J. Carter, 2010)*

Stuttgart (Germany), home to more than 2 million people, is a highly industrialized area located in a valley with mild climate and low-intensity winds. Since the 1970s, it has experienced a steady decline in air quality. The situation has worsened as the valley slopes underwent increasing urbanization, which increasingly prevented natural air circulation from taking place around and through the urban center. As a consequence, the urban heat island effect became more pronounced, and is expected to worsen as heat waves get more frequent and intense due to climate change.

In order to control overheating, Stuttgart city government planned a series of ecosystem-based measures that may contribute in reactivating air flow and restoring wind patterns. New land-use and zoning regulations were passed based on data and evidences collected in the Climate Atlas, which maps temperature patterns and air flows throughout the city. Urban plans have prioritized open green spaces and vegetation cover, especially in the more densely built-up areas.

Urban green spaces, in particular urban trees, also generate tangible benefits on the health conditions of urban dwellers. They help reduce noise, a major cause of stress, hypertension, hearing loss and sleep disturbances, and enhance air quality by removing air pollutants, which are positively related to respiratory and cardiovascular illnesses (Nowak, 1994; see also Hillsdon et al., 2009; Ulrish, 1984). Urban green areas also contribute to making cities diversified landscapes that can be favorable habitats for a varied flora and fauna (Kühn et al., 2004; Donnelly and Marzluff, 2006). Finally, they play an essential role in defining the cultural identity of a city, by characterizing its physical landscape and providing spaces where its cultural and social life can take place. Nature thus is "essential to achieving the quality of life that creates a great city and that makes it possible for people to live a reasonable life within an urban environment'' (Botkin and Beveridge, 1997, p.18).

Peri-urban and regional ecosystems

Despite their multiple functions, local ecosystems alone do not suffice in supporting the life of large, dense communities of urban dwellers. Cities have been defined as parasites to the biosphere (Odum, 1971), underscoring how the net flow of ecosystem services is invariably into urban centres rather than out of them (McGranahan et al., 2005). Their ecological footprint steadily grows well beyond their boundaries, as they rely on an increasingly global hinterland as a source of inputs and a sink of outputs (Tarr, 1997), but it is particularly at the peri-urban and regional scales that ecosystems play a direct role in reducing the levels of risk in urban communities. For instance, cities are part of a watershed[1], which usually includes a variety of different ecosystems, such as forests, savannas, grasslands, shrublands, or wetlands. At the watershed or river basin scale, the interplay among its natural components allows for the delivery of ecosystem services, such as the supply of freshwater, treatment of wastewater, and regulation of the hydrological cycle, that are essential to the life of urban communities.

[1] A watershed is defined as the topographical unit from which rain or melting snow drains into a given body of water.

Forests and vegetation cover around urban areas allow more water to percolate into the ground, reduce runoff, and ultimately mitigate the impact of stormwater. They account for improvements in the recharge of groundwater, guaranteeing better access to water resources during dry periods, while also enhancing their water quality, by filtrating and absorbing nutrients and contaminants (Pickett et al., 2001). Figuerola and Pasten (2008) estimated, basing their analysis on a previous study by Núñez et al. (2006), the economic value of temperate forests located in the Llancahue watershed (Chile) to be of US$937.9 per hectare for the summer period and US$355.3 per hectare for the rest of the year, with respect to their role in contributing to fresh water supplies in Southern Chilean cities. Peri-urban forests also provide wood and non-timber products that can play an important role in sustaining people's livelihoods, and guaranteeing open recreational spaces for the city's inhabitants.

Vegetation helps, to a certain extent, regulate the flow of rainwater into water streams, which is a crucial variable in the functioning of agricultural systems, industrial activities and energy production facilities. It also mitigates the action of wind and rain, especially on slopes and riverbanks, thereby protecting against soil erosion, conserving soil fertility and avoiding associated

Box 4. *Reforestation in the Rokko Mountain Range, Japan (Ministry of Environment, Government of Japan, 2011)*

The Rokko Mountain Range is a series of elevations surrounded by a population of 2.3 million, living in the cities of Kobe, Ashiya, Nishinomiya, and Takarazuka. Following urban growth and deforestation of the mountains´ vegetation cover, frequent floods and landslides affected human settlements in the area as early as the 17th century, and reached a catastrophic peak during the second half of the 19th century, when deforestation culminated. In the last decade of the 19th century, the government enacted the River Law, the Erosion Control Law and the Forest Law, in order to enforce some basic concepts of conservation and restoration of natural landscapes around the country. In 1895, the Hyogo Prefecture began planting trees in order to stabilize slopes and prevent soil erosion. Tree species with high fertilizing effects were introduced to achieve complete reforestation as quickly as possible on lands where parent rock had been exposed.

In recent years, in response to the public demand for landslide protection generated by the 1995 Kobe earthquake and the increasing value of Mount Rokko as a recreational area and as a source of potable water for the city, the Prefecture developed the Rokko Mountain Range Green Belt Development Project, aimed at improved forest quality, soil stability, water run-off and water availability, through planting deep-root trees and developing undergrowth vegetation. Between 1996 and 2005, by allocating approximately 1,300 ha for public land and forest reserve, the project has resulted in preventing damages due to hydro-geological hazards with a total cost estimate of 4,598.4 billion yen, at a total cost of 690.5 billion yen, whilst providing additional cultural and recreational benefits to the urban population.

downstream costs (Morrow et al., 1995). It contributes to stabilizing soil, by creating a root system that helps reduce the frequency and magnitude of mass movements such as landslides, avalanches and mudflows (Stolten et al., 2008; Teich and Bebi, 2009) (see Box 4). (cross reference with landslide chapters Papathoma and Glade)

Wetlands in the urban periphery improve water quality through removal of nitrogen and phosphorous. Wetlands and peatlands also provide storage space for flood waters (see Box 5), groundwater recharge and maintenance of dry season flows (cross reference with wetlands chapter).

Coastal forests and mangroves, seagrass and coral reefs, dunes and saltmarshes effectively mitigate small and medium scale coastal hazards such as wind waves and coastal floods caused by storm surges, and have proved effective to some extent in protecting people from sea-level rise (UNEP-

Box 5. *Flood reduction in the Boston's Charles River Basin, USA (Platt, 2006)*

Boston's history has always been closely connected to the Charles River which has allowed the city to serve as port and marketplace for the entire inland region. More than 10% of the river's watershed area (about 8,000 hectares) consists of freshwater wetlands (Platt, 2006).

In the 1950s and 1960s, as urban and industrial development reclaimed large parts of the floodplain, disastrous flood events became a major threat to the low-lying settlements. In the 1970s, a flood management project was designed jointly by the Charles River Watershed Association (CRWA) and the Army Corps of Engineers based on a set of hard engineering and ecosystem conservation solutions, including: "acquisition and protection of several thousand acres of wetlands for water storage; promotion of floodplain and wetland regulation by local administrative authorities; construction of a new dam at the river's mouth to alleviate overflow of the basin in Boston and Cambridge" (PEDRR, 2011, p.8).

By 1983, about 8,100 natural wetlands were acquired from private owners by the Corps and transferred to administrative authorities for management as natural flood storage and ecological restoration sites. The economic value of wetlands in the Charles River Basin has been estimated at $153,535 to $190,009 per acre (Thibodeau, 1981). Concurrently, several municipalities in the watershed began to regulate wetland use, which have helped to preserve natural water storage, reduce development in the floodplains, and reduce pollution of wetlands and streams. Efforts towards rehabilitation, especially with respect to monitoring and improving the status of river water quality have continued throughout the 1990s and 2000s, with endorsement from the United States Federal Government (PEDRR, 2011 p.8). After four decades, the CRWA has achieved measurable improvement in flood mitigation, water quality and public recreation.

WCMC, 2006; (cross reference to TNC and rivamp chapters).

4. Urbanization, environmental degradation and disaster risk

Evidence from the UNISDR's Global Assessment Reports 2009 and 2011 point to ecosystem degradation, induced by poorly managed urbanization processes, as a main driver of disaster risk at the global scale. As deforestation, wetland reclamation, land development and alterations of water flows degrade ecosystems within and around urban centres, their capacity to deliver services, including those that reduce people's exposure and vulnerability to natural hazards, is compromised (Abramovitz, 2001).

The scarcity of permeable surfaces, such as soft soils and green areas, in and around cities, can multiply, by up to a factor of 10, the amount of water that runs off the ground, increasing peak discharge in a watershed (Gholami et al., 2010), lag time (Espey et al. 1965) and flooding (Nirupama and Simonovic, 2006).The amount of water and the debris transported during heavy rainfalls easily exceeds the city's sewage system capacity, particularly in absence of drains or without a separate storm sewer system, typically leading to urban floods. These are a recurrent feature in cities as diverse as Mumbai (Gandy, 2008) and New York (New York City, 2010), that can reach a staggering proportion as in the recent case in Bangkok in 2011 (The Guardian, 2011/11/03). Increases in flood risk due to heavy urbanization have been measured in the watershed of the Upper Thames River, around the City of London, Canada (Nirupama and Simonovic, 2006) and in coastal areas of Galicia, northwestern Spain, after forest fires burned land cover in watersheds and heavy rains upstream (Fra.Paleo, 2010). In Taiwan, the clearing of forests to increase land availability for productive activities has led to reduced slope stability, increased sediment and pollutant delivery downstream, and increased peak flows in a region that is highly exposed to typhoons and other meteorological hazards (Lu et al., 2001).

The substitution of original land cover with highly impervious surfaces (asphalt, concrete), and the high level of thermal emissions related to concentrated, high-intensity energy and fossil fuel consumption are directly responsible for the heat-island effect, described as the difference between urban and rural temperatures in the same region, that can reach maxima of +10°C (Pickett et al., 2001). These conditions drastically amplify the incidence of heat waves and, together with higher concentrations of air pollutants, pose a serious threat to the life of urban dwellers, as demonstrated by the 70,000 deaths caused by the 2003 summer in Europe (EM-DAT, 2012). Hence, human-driven land-use changes in urbanized environments serve as triggers of potentially dangerous events, increasingly regarded as “socio-natural hazards” (Garatwa and Bollin, 2001).

5. Urban poverty and disaster risk

The incidence of environmental problems in urban areas and urban risk are closely associated with poverty (McGranahan et al., 2001). In cities all around the world, the poor tend to live in less safe locations and conditions, and have limited coping mechanisms that enable them to recover from shocks. This is particularly true for individuals who belong to vulnerable groups due to age, gender, ethnicity or income (Anderson, 2003). (see Box 6).

The mismatch between the demand for essential services, such as safe shelter, health care, and employment, and the limited capacities of national and local administrations to actually provide them pushes poor people to adopt “future eroding” strategies to cope with their daily needs, and translates spatially in the development of slums that characterize cities in many parts of the world. These settlements are usually located in marginal, unsafe land, prone to hydro-geological hazards, and are rarely served by networks of communication, transportation, water and energy, or healthcare services. In slums, constructions are often sub-standard, highly vulnerable to floods, earthquakes, fires, diseases and inhabited by people with very limited resources and capacity to recover from disasters (UNISDR, 2009a). Lack of access to the formal housing market pushes slum dwellers to environmentally unsafe locations, on land where it is either not desirable nor permissible to legally build – a phenomena especially demonstrated in developing areas such as the Payatas landfill in Manila, or in the riverine settlements in Santo Domingo (Pelling, 2003), but also in developed urban settings, such as Los Angeles, where Latinos tend to live in housing built before the introduction of anti-seismic building codes (Wisner, 1999).

Box 6. *Urban flood risk in Mozambique (Chege et al, 2007)*

It has been estimated that about 70% of the victims of the February 2000 floods in Mozambique were urban residents, a death toll largely caused by extensive urbanization and deforestation processes and lack of enforcement of land-use plans. In particular, it was the urban poor who suffered the most, especially those recently arrived in the country's cities following the civil war and the debt crisis and were forced to occupy buildings made of locally-retrievable materials and were in undesirable locations such as hillslopes and ravines.

Moreover, the urban poor continue to rely on local natural resources to secure access to food, fuelwood and building materials, and therefore can create additional risk through destructive livelihood practices. For instance, in the Rocinha favela in Rio de Janeiro, a steady urbanization process has taken place over the last decades, progressively improving the living conditions of the favelados, in particular on its bottom fringe that is closest to the formal city. Its upper fringe, however, still hosts communities of newcomers and poorer inhabitants who increasingly put pressure on the surrounding vegetation cover for their daily fuelwood and for further land reclamation. This results in frequent mudslides and rockfalls that seriously threaten the lives of the most vulnerable favelados (WWI 2004).

6. Ecosystem management for urban risk reduction

Urban governments are increasingly considering conservation and enhancement of natural infrastructure as key measures to protect people and investments in the face of natural hazards (see Box 7). The UNISDR global campaign for Making Cities Resilient regards the protection of ecosystems and natural buffers to mitigate floods, storm surges and other hazards as well as adapt to climate change as one of its 10 priorities (UNISDR 2010).

Cities can be in a favorable position to achieve risk reduction through sustainable environmental management, as local governments are increasingly responsible for land use and development planning, infrastructure development and maintenance, zoning and building codes, and social services provision. Unlike national governments that operate along clear sectoral lines, city governments often are better placed to work in a cross-sectoral manner, making it easier to adopt an integrated approach in tackling local issues. The proximity and density of urban population, businesses, structures and infrastructures allows for economies of scale when taking measures that mitigate natural hazards and reduce the community's vulnerability. By influencing a city's resource consumption pattern, urban governments also play a key role in determining the levels of pressure on local and global ecosystems, one of the main drivers of disaster risk both at the local and at the global scale (UNISDR 2011).

Box 7. *The Netherlands: Room for the River (Corvers, 2009)*

In the Netherlands a complex solution for flood mitigation, based on a network of canals, dykes and pumping systems, has traditionally, and until recently been regarded as a model of technological innovation. The Dutch model is now raising concerns of its environmental and economic unsustainability, and hard infrastructure is being replaced by ecosystem-based measures which take into account natural processes of periodic flooding. This new approach has now been formalized through the Room for the River Project. (cross reference to wetlands chapter).

At the local level, effective action can range from small-scale measures, such as green roofing or green windbreaks, to city-wide initiatives that preserve or restore green areas and water bodies to improve air quality, retain soil or stormwater, to integrated watershed management plans that require coordination between upstream and downstream communities and across administrative units. However, a strong integration with regional and national government agencies, as well as international institutions, is fundamental in risk governance; it is only at a wider scale that many drivers of risk can be tackled (e.g. at the watershed scale in the case of floods and droughts).

A series of case studies that address disaster risk reduction through ecosystem restoration and enhancement have been presented in the previous sections. The key features of these cases are summarized in Table 2. They all demonstrate how ecosystem conservation and enhancement can be long term cost-effective measures to reduce disaster risk in urban areas. Ideally, ecosystem-based urban risk reduction should be integrated into a broader framework of sustainable urban development.

Experience has shown that the reduction of disaster risk through ecosystem management is most effective when policy and legal frameworks are in place to support the action of urban governments. The participation and involvement of community stakeholders should be promoted to better evaluate existing ecosystem services as well as ensure effective communication and ownership of planned interventions. Environmental department staff are usually most directly responsible for ecosystems management, but mainstreaming such approaches into urban planning is essential (PEDRR, 2011).

Budgeting processes can be extremely relevant entry points for the integration of ecosystems in public management processes. Budgeting decisions express a system's political priorities between conflicting interests over limited resources. An ecosystem approach can expose the full value of services that urban and peri-urban ecosystems provide. They can allow public authorities and private investors to anticipate social and economic costs and benefits of their future actions for present and future generations, which are easily neglected in urban management. By considering the value of natural capital alongside economic and human resources, local authorities can better compare and identify different management options, taking more informed decisions and communicating these more clearly to the public (TEEB, 2011).

Urban and regional planning is another critical instrument for promoting proactive strategies to prevent hazard exposure and reduction of disaster risk, through the avoidance of conflicting land uses and the integration of multiple stakeholder interests (Fra.Paleo, 2009). Identifying the areas that contribute most to the personal and material security of urban dwellers and those that are most threatened by urbanization is a fundamental step to establishing spatial development policies that control and reduce the levels of risk (TEEB, 2011). The integration of an ecosystem management-based approach into urban planning can help reconcile environmental and developmental priorities of local authorities, and can contribute to creating safer, more sustainable cities.

Table 2. Policy measures dealing with various natural hazards and their relationship with the local ecosystem in various geographical areas.

Region/Country	City/Urban area	Ecosystem	Hazard	Anthropogenic impact	Policy issues

Rokko Mountain Range, Japan	Kobe, Ashiya, Nishinomiya and Takarazuka	Mountain region	Floods and landslides	Urban expansion and deforestation	Measure: • Rokko Mountain Green Belt Development Project (1995): Restoration of circa 1,300 ha to public land and conserving it as healthy forest Aims: • cost-effective solution for hydrogeological hazard mitigation • provision of additional cultural and recreational benefits to the urban population
Germany	Stuttgart	Valley	Heat waves	Highly industrialised region with increasing urbanisation	Measure: • new land use and zoning regulations based on data and evidence collected by the Climate Atlas Aims: • prioritise green spaces and vegetation cover, especially in more densely urbanised areas
Boston Charles River, USA	Boston	River basin, freshwater wetlands	Floods	Industrial development (1950's-60's)	Measure: • in the 1970s, a flood management project based on a set of hard engineering and ecosystem conservation solutions Aims: • measurable improvement in flood mitigation, water quality and public recreation
New York, USA	New York	Urban green areas	Local intense storm events	Obsolete sewerage system	Measure: • trees, lawns and gardens will be planted on roofs, streets and sidewalks Aims: • absorb and percolate more rainwater to the ground • reduce the burden on the city's sewage system, • improve air and water quality • potentially reduce the need for water and energy

Chicago, USA	Chicago	Urban green area	Storms and floods	Measure: • Green Permit Program: encourages developers to incorporate green design elements, including green roofs on new buildings Aims: • better manage storm water and mitigating urban floods

7. Conclusions

Despite evidence of their multiple benefits, including their cost-effectiveness, ecosystem-based risk reduction measures have not been widely implemented in urban areas. Historically, cities have been situated in strategic locations, such as floodplains, coastal flats, deltas, or hill slopes, which allowed for easy trade access, defensibility in case of war, availability of natural resources, but have generally been exposed to natural hazards. Therefore, urbanization frequently results in increasing exposure of unprotected populations and assets to hazardous events, and is currently a significant factor shaping risk at the global level. Disasters have thus increasingly gained an urban dimension.

Urban areas in developed countries have pursued safety through structural measures and "hard" engineering solutions. A few alternative examples of city administrations promoting improved ecosystems management in and around urban areas have been featured in this chapter. Many initiatives respond foremost to the need of reducing costs, while recognizing their added social and environmental benefits. For instance, the adoption of green building construction, particularly with respect to green roofing, like in New York and Chicago in the United States, illustrates how the high financial costs of complying with the Federal Clean Water Act and building separate storm sewer systems, have driven the transition towards a more cost-efficient, environmental-friendly, stormwater management system in these cities (Tian, 2011). Given that financial issues are even more of a priority for developing countries and cities, and given the high costs often associated with engineered measures, ecosystem-based solutions for risk reduction might provide more cost-effective options.

Successful implementation of sustainable ecosystem management for urban disaster reduction can only be achieved through changes in the urban governance and decision-making processes, by adopting more integrated approaches through cross-sectoral and multi-stakeholder dialogue. This further requires taking into account ecosystems in peri-urban and regional areas and the essential services they provide to urban centres.

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