# Section 4
# Ecosystems, ecosystem services and social systems in urban landscapes

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# Chapter 4.0
# Introduction to the section

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Ecosystem services are the conditions and processes through which natural ecosystems, and the species that make them up, sustain and fulfill human life and are often defined "the benefits human populations derive, directly or indirectly, from ecosystems" (TEEB 2009). The concept of ecosystem services has proved to be useful in describing human benefits from ecosystems. The Millennium Ecosystem Assessment - MA (2005) prepared by a group of over 1300 international experts, found that 60 percent of ecosystem services assessed globally are either degraded or being used unsustainably. Seventy percent of the regulating and cultural services evaluated in the assessment are in decline. However, there are considerable knowledge gaps about urban ecosystem services. MA covered almost every ecosystem in the world but did barely mention urban systems. On the other hand, the World Development Report (World Bank 2009), the world's largest assessment of urbanization, left out ecosystems. The goal of this section is therefore to contribute to fill the knowledge gap and review and discuss the scientific literature focusing on understanding the complexity of urban social-ecological systems and the interplay between humans and ecosystems through the lens of ecosystem services generated both locally and on a regional scale.

In chapter 4.1 McDonald and Marcotullio starts with addressing ecosystem services from a global perspective and ask a question that at first look very simple but in fact is extremely complex: Is urbanization good or bad for the environment? The question is used as a starting point for a broad overview of how cities affect the environment and whether there is any alternative to global urbanization. The chapter discusses this based on analyses of supply and demand of some specific ecosystem services including freshwater and climate regulation. The authors conclude that one answer to the question is that at a local level, cities may negatively impact some services such as freshwater, but at a regional or national level, concentration of human population in dense settlements may often provide benefits.

Redman in chapter 4.2 asks the question to what extent it is relevant to analyze episodes from the past for dealing with problems of the present and future urbanization. While the past does not offer simple, detailed, directly applicable solutions to the challenges of the present, the past does offer essential insights into the nature of socio-ecological interactions under a huge number of diverse conditions and the implications of the decisions that were made. After an historical overview of the rise of urban complexity, including the diverse set of drivers of urbanization through time, Redman addresses resilience in the urban context. Enhancing resilience of a system often means encouraging flexibility and adaptive capacity in the forms of redundancy, inclusiveness, monitoring, and preparedness for multiple futures. All of these efforts have associated short-term costs in a world striving for efficiency and "lean" organizations and lessons from history tells us the desired outcome may not be very easily achieved.

In chapter 4.3 Alfsen et al points out that cities are connected social, cultural and ecological systems. The chapter gives an overview of ecosystem services in the urban landscape and emphasizes that there is a need for a holistic approach to governance and management. The Ecosystem approach is a strategy for the integrated management of land, water and living resources that promotes conservation and sustainable use in an equitable way but does, however, not make the link between ecosystem functions and human security explicit. Today, with increased incidence of natural disasters and the looming threats associated with climate change, there is a deeper understanding of immediate and inextricable connections between human security, well being and functioning ecosystems. Our current systems of governance and resources allocations and public information have not, however, adapted in response to these threats. Several global initiatives aimed at improving governance of urban ecosystems, such as ICLEI/LAB and URBIS are presented.

In chapter 4.4 Bridgewater points out that there is a close cultural connection between urban settlements and wetland systems since many urban areas have been founded along the banks of great rivers, areas of freshwater seepage, or where groundwater is (or increasingly was) close to the surface. Bridgewater argues that the Ecosystem Approach could be used as an organising frame for improved management and governance also of constructed wetlands. The role of these so-called artificial systems in ensuring continued functioning of ecological systems and maximising the expression of wetland biodiversity in urban and peri-urban systems is highlighted.

Finally in 4.5 Colding addresses ecosystem services in the context of urban spatial planning. Urban planning has traditionally meant planning “for development” and recently shifted more towards “sustainable development”. However even such planning often ignores ecosystems and the natural configuration of the land. As a consequence ecosystems are rapidly becoming fragmented, transformed, or entirely lost, causing loss of ecosystem services, such as impoverishing water and air quality. This may erode ecosystem resilience, or the capacity of natural systems to buffer and reduce disturbances like heat waves, flooding, pollution, and anthropocentrically induced management mistakes. Colding reviews current development of smart growth and green infrastructure planning strategies and concludes that there exists a whole arsenal of green designs that can be adopted in cities to provide a range of ecosystem services and promote sense of place, and revitalize degraded neighborhoods.

As evidenced from this section there is a rapidly growing literature and awareness of the values of urban ecosystem services and strategies for improving management and governance linking the local to the global. However, urban areas are in continuous and rapid change and are facing enormous challenges, e.g. climate change and transformation to a future beyond oil. Ecosystems may have a large role in facilitating this transformation. Ecosystems provide flexibility in urban landscapes and help build adaptive capacity to cope with e.g. increased temperature and changing precipitation and through ecosystem services generated promote human well-being. However, knowledge is lacking and there is a need for creating learning arenas. Everyone involved in urban development, policy makers, urban designers scientists and planners need to a larger extent facilitate for more experimental designs and learning about the interactions between humans and ecosystems. Such strategies may gain from insights on adaptive co-management of ecosystems and lessons provided from sustainable natural resource management to increase the potential for adaptive learning and avoiding vulnerability traps during the process of urban transformation.

# Chapter 4.1
# Global effects of urbanization on ecosystem services

Robert McDonald and Peter Marcotullio

## Introduction

Many chapters in this book mention the demographic fact that more than 50% of *Homo sapiens* live in urban areas (UNPD 2007). This statistic is perhaps a bit stale, but many scientists still rehash it (e.g., McDonald 2008) to emphasize how truly dramatic global urbanization is. In tens of thousands of cities around the globe (Figure 1), concrete is being poured, bricks are being laid, and the great cities of the 21st century are being built. Humanity, in a metaphorical and sometimes literal sense, is on the move. It seems appropriate, then, to step back and ask what urbanization might mean for the environment.

This chapter attempts to answer a simple question often posed to the authors: Is urbanization good or bad for the environment? This question is so simplistic, but concerns such a complex topic, that perhaps it is unanswerable. Here we use it as a starting point for a broad overview of how cities affect the environment. Our discussion is focused on past several decades and the predictions of what the next decades may bring, in contrast to the long-term historical perspective of the following chapter by Redman. We first examine whether there is any alternative to global urbanization, which is implicit in our overarching question. Next, we provide some background information on the urban environmental transition, a theory that takes a historical perspective on urban-environmental relations. Similarly, we describe the concept of ecosystem services, which play an important role in our analysis. The bulk of the chapter is taken up with specific examples of urbanization's effect on provisioning, regulatory, and supporting services. We end by returning to our big question to analyze how close we can get to answering it.

## What is the alternative to urbanization?

Ironically, in an age of advancing global urbanization, cities are taking a lashing from environmentalists. Lester Brown (2001, p. 188), for example, emphatically states that "Cities are unnatural" and costly too. He argues that "People living in cities impose a disproportionately heavy burden on the earth's ecosystems simply because so many resources must be concentrated in urban areas to satisfy residents, daily needs" (Brown, 2001, p. 190). This viewpoint has been supported by the notion of the vast ecological footprints of cities (Wackernagel and Rees 1996). The result, in the eyes of ecologist Eugene Odum (1991), is that a "realistic" portrayal of the cities-to-Earth relationship is of that of parasite-to-host.

We question these categorical conclusions, by attempting to separate urbanization from other processes. Moreover, we ask, is there a plausible alternative to urbanization? Are there societies that are wealthy and not urban? Are cities being fled from as outdated technologies and modes of organization? The answer to all these questions is categorically, no. We define urbanization as a spatial phenomenon: the concentration of population. Many other changes occur with concentrating population during the development process. Urbanization contributes to these changes as both an outcome and significant driving force. Given the powerful intertwining of forces that associate development with urbanization it is futile, if not dangerous, to promote dramatic alternatives.

Demographers, urban geographers, economists and planners point to a number of factors that promote urbanization (for a review see Montgomery et al, 2003). Urban economic growth is related to: communications and transport; economies of scale and agglomeration economies; personal contact among workers and entrepreneurs; and efficiency gains from the high population density in cities. Urbanization is also strongly correlated with changes in population structure and decreases in fertility. These dynamics bring substantial benefits for and changes to industries and society (Montgomery et al., 2003).

Economists have noted that firms often gain benefits from being clustered near other similar firms, such as lower costs of production and increased specialization of the workforce. These benefits are examples of economies of scale and they encourage firms to agglomerate together in cities. Agglomeration economies are an important contribution to urban economic growth and wealth creation.

If transportation and communication costs are high it becomes costly to move people, goods and ideas. High transport costs enhanced urban growth during the early industrial revolution and in many cases cities developed around transshipment points, where reduced transportation costs mixed with the economic benefits of goods handling (Anas, Arnott, and Small 1998). However, over the past few decades, transportation costs have been reduced and communication has become easier, faster and more convenient. Within urban regions, workers can commute long distances, leading to concern about urban sprawl and an expansion of urban area in many rich countries. Companies have dispersed across countries, regions and even the globe. Moreover, in the developed world, economic structures have shifted from largely manufacturing to services. This decentralization of industry has resulted in the re-constitution of urban employment around service production, not manufacturing.

While technologies have reduced and simplified long distance connections and production has decentralized, the dispersion of population out of urban areas predicted by many (Toffler 1980; Webber 1964) has not emerged. Cities continue to exist and thrive. It isn't just cheap transport and communication and the agglomeration of production that advances urbanization. Personal contact enhances levels of trust and ensures confidentiality, among other important business fundamentals. This appears especially important for the production of advanced business and producer services, which is now the source of agglomeration economies in particular cities (Sassen 2001). The importance of personal contact has not diminished with technological advances (Montgomery et al. 2003). Indeed, technology and personal exchanges may often be complementary, forcing activities to agglomerate rather than disperse (Glaeser 1998).

Other factor responsible for continued population concentration include the fact that cities lower the costs per household and per enterprise for the provision of infrastructure (roads, pedestrian paths, piped water, sewers, drains, electricity) and services (day care, all forms of schools, health care and emergency services), and make it easier to govern large populations (Satterthwaite 2007; Bairoch 1988). Rising incomes within cities also support the development of specialized private markets (Montgomery et al. 2003). Given these dynamics, the long suggested correlation between urbanization and income (Williamson 1965) remains important today (Satterthwaite, 2007).

Demographers also note that the changes in employment, population structure and household fertility accompany urbanization. As people move to cities they leave the agricultural sector for employment in industry and services. Fertility is typically lower in cities than in rural areas (UNFPA 2007), as children become financially more burdensome. Hence, part in parcel with the demographic transition, societies urbanize.

Because urbanization is tightly bound up with a combination of processes often called development, there is simply no counterfactual to the emergence and dominance of societies organized around dense settlements. All economies urbanize and there is not a country with high economic developed that has also not experienced urbanization. In some regions, such as Latin America, urbanization was experienced at low levels of income, but by a large, low-income societies are less urbanized and high-income societies are urban.

That is not to say that national governments have not tried to control urbanization. As pointed out by the UNFPA (2007), there are a growing number of economies that have implemented policies to lower migration to urban agglomerations; from 51 percent in 1996 to 73 percent in 2005. The UNFPA suggests this is a sign of growing "anti-urban" policy bias. More importantly, these policies have had little long-term effect on urbanization and an arguable negative impact on economic growth. Indeed, some have argued that to reduce poverty, societies should accelerate urbanization.

Given the imperative that societies continue to organize spatially around and through cities. Our task is to tease out the impacts of spatial concentration from other aspects of development and to uncover the complex ways in which activities in urban areas can be changed so as to promote sustainable development.

## The Urban-environmental transition

One powerful tool with which to explore the relationship between the environment and urbanization is urban environmental transition (UET) theory (Figure 2, adapted from McGranahan et al. 2001). This notion argues that dominant conditions in urban environments shift along three dimensions with increasing wealth. The UET argues that as poor cities grow in wealth and begin the rapid industrialization process, environmental priorities shift from the "brown" agenda, which prioritizes concerns such as inadequate water supply and sanitation, indoor air quality, drainage and solid waste disposal, to those at the metropolitan-regional scale. At the metropolitan scale the dominant issues include water and air pollution, sometimes called the "gray agenda" (Marcotullio and Lee 2003). As cities continue to grow in wealth, urban environmental burdens shift again from metropolitan scale challenges to those most easily observed at the regional and global scale. Global scale challenges are associated with high consumption and emissions levels and the "green" agenda includes such concerns as acid rain, water scarcity, greenhouse gas and ozone depleting substance emissions.

The UET is not only a powerful tool for understanding shifting environmental conditions within cities, it also complements theories of development. Historically, sometime during the development process of Northern economies, a series of transitions occurred making urban life more hospitable than rural life. Residents of cities began to live longer and healthier lives (due to better diets and health care) increase household income faster and enjoy generally enjoy a better quality of life than their rural counterparts (see of example Haines, 2001). With these shifts there was also a shift in the intensity of selected per- capita environmental impacts of rural versus urban residents, such that urbanites became more efficient and had lower impact than rural peoples. For example, urban residents now use less energy per capita and therefore have lower greenhouse gas emissions than their rural counterparts (Brown, et al 2008). This may not be true in early stages of development (IEA 2008). Hence, the UET complements descriptions of social, economic and environmental changes with development in the now developed world.

As with development, however, shifts in environmental burdens and agendas are not only due to increasing population concentration; increasing wealth, technology, political, social and environmental crises and institutions also play a role. Technological advances have been considered vital to understanding changes during development (Pacey 1991; Diamond 1999) and have facilitated environmental transitions. For example, motorization was a technological solution to the health crises in cities due to urban horse urine and feces (McShane, 1994). A number of studies have also emphasized the importance of crisis in promoting dramatic changes in social organization and environmental conditions (Holling 2001). Changes in institutional context are also vital in explaining the history of development (North 1990). In the United States, a series of institutional shifts at the local, state and federal level helped to facilitate the consolidation of large metropolitan areas at the turn-of-the-ninetieth-century, promoting development of large infrastructure projects during the middle of the twentieth century, generating environmental policies that attempted to reduce pollution during the 1970s and 1980s and providing the global context from which cities, nations and regions are attacking the greenhouse gas problem.

Moreover, as mentioned above, the drivers of urbanization have changed over the past decades, with globalization, advances in technologies, new crises (financial, social and environmental) and the emergence of new institutions at all levels of governance, and so has the shape of the urban environmental transition. The linear, staged sequential pathway of North American urban environmental transitions no longer exists for currently rapidly developing economies. Specifically, the transitions now occur faster, sooner, and more simultaneously (Marcotullio 2007). For example, consider a poor or lower income city in Southeast Asia. Rather than simply experiencing challenges at the local level, urban residents are also faced with motorization and industrialization related pollution, urban sprawl, rising consumption and even green agenda issues, such climate variability and threats of sea level rise.

As most of the urban population growth is now in the developing world, the majority of urban residents are experiencing a number of environmental and ecosystem burdens simultaneously. These burdens are increasing at unprecedented speed. While these changes are frightful, these dynamics also provide opportunities. Some urban centers have taken advantage of these opportunities and have implemented integrated policies. For example, Singapore was one of the first cities to implement congestion pricing and Curitiba, Brazil, was one of the first urban centers to implement integrated land use-transport planning and Bus Rapid Transit. While they exist, however, the number of cities that have benefited by integrated environmental planning remains low.

**Ecosystem services**

As emphasized in the introduction to this section, ecosystem services has emerged as one of the most popular concepts in ecology of the last decade, and one that has helped unify economics and conservation biology. In many cases, ecosystem services are the opposite of the environmental burdens often studied as part of the UET. For instance, water pollution (an environmental burden) becomes troublesome when clean drinking water (an ecosystem service) is no longer available because the filtering capacity of natural ecosystems is overwhelmed.

An ecosystem service only has value, in a utilitarian or economic sense, when there is sufficient natural provision of some quantity and there is someone who wants that quantity. Both the supply of the natural resource and the demand are equally important in determining the value of an ecosystem service. Within ecology, ecosystem service supply mapping has become fairly common (Chan et al. 2006), while techniques for understanding the spatial variability in demand for ecosystem services have been less explored, with the exception of the concept of area-dependent ecosystem services like pollination (Kremen et al. 2007). Cities, as the home of the majority of humanity, become centralized places of demand for and consumption of ecosystem services (McDonald 2009).

Ecosystem services vary in how close the place of generation must be to the place of demand. For instance, shade trees can significantly reducing air conditioning costs when within 10-20m of a house. For parks to be used frequently for day-to-day recreation, they must be within a few kilometers of people's homes. Clean water for drinking must generally be taken from the same regional area in which a city exists. Some ecosystem services are in effect global, such as the ability of ecosystems to sequester carbon dioxide and thus mitigate climate change. Thus, the spatial scale at which cities consume ecosystem services vary greatly among services.

**Clean water**

Perhaps the most direct connection between human well-being and ecosystem services are provisioning services, resources humanity obtains from the natural world which are essential to our livelihood. Food, from cropland or rangeland, is an obvious example, for although agricultural systems are simplified versions of natural ecosystems, they would not be possible without supporting natural processes like soil nutrient and water retention. All the uses we make of plant cellulose for paper, cotton, and saw timber are another example, sometimes collectively called fiber provision. Provisioning services extend beyond these two examples to include most of the subject matter of natural resource management, such as fisheries. Provisioning services are also relatively easy to value monetarily, because the commodities they generate are often already traded in markets.

Here we consider one crucial provisioning service, access to clean water for drinking and other personal use. Natural ecosystems help humans have access to sufficient clean water. Forests and wetlands, for example, help filter out pollutants and sediments before they reach reservoirs, safeguarding water quality (Dudgeon et al. 2006). Similarly, forests can help generate sufficient water quantity in some climates, through water condensation on tree foliage, and wetlands can mitigate floods, through reducing the height of peak flow and slowing the movement of water through the hydrologic system. Water for urban residents is generally drawn from the same regional watershed in which it lies, giving this particular ecosystem service a unique spatial scale and directionality (upstream/downstream). It is worth noting that over time, cities build aqueducts to increase the spatial scale from which they can draw water, often going far away to find an adequate supply (McDonald 2009).

The amount of water available varies globally over several orders of magnitude (Figure 3, top). Desert and grasslands biomes generally have less available water than forests, so cities in these biomes must also generally deal with having a smaller water supply. However, there are many different ways cities can get water, which complicates this simple picture. Some cities draw their water from rivers, making them relatively dependent on natural flows of water, although dams can create reservoirs that moderate seasonal or annual fluctuations. Some cities draw from groundwater, reducing their dependence on annual rainfall inputs to their watershed. However, if groundwater withdrawals exceed aquifer recharge, as is the case in Mexico City (Birkle, Rodriguez, and Partida 1998), the practice is unsustainable over many decades, and the city is essentially "mining water." Many cities are also dependent on snow and ice melt from higher elevations far upstream. Famously, most of the water supply of Los Angeles is snow melt from mountains more than 300 km away.

The amount of water used per-capita varies among cities. One central challenge in analyzing such statistics is how to define the conceptual boundary of a city's water use. At a national level, agriculture is always the largest consumptive use of water, often followed closely by industry. However, much of the output of these two sectors goes to urban dwellers, so in some sense a portion of these sectors water use is also attributable to cities. Some insight into urban trends can be seen by looking at national level data on domestic withdrawal of water and dividing it by the total population in that country (Figure 3, bottom). This is not an ideal metric of water use by urban residents, for domestic withdrawals are measured for water districts, which include some industry, and conflicting definitions of urban population make it impossible to use urban population rather than total population in the denominator (FAO 2009). However, it suffices to show a general pattern: countries with greater water resources tend to use more water per capita for domestic use, although this correlation is not particularly strong (R=0.11). Within the United States, more detailed city-level data reveals significant variation among U.S. cities. For example, residents in San Diego use 700 liters/person/day, while residents in Reno, NV use 1166 liters/person/day.

Per-capita domestic water use tends to increase as the average income increases (FAO 2009). For example, the average resident of Indonesia ($3,900 GDP/capita, in purchasing power parity) uses 28.9 $m^3$/person/year, while the average resident of Canada ($40,200 GDP/capita) uses 276.0 $m^3$/person/year. The overall correlation between per-capita domestic water use and per-capita GDP is fairly high (R=0.59). There are at least two reasons for the increase in water consumption with income. First, richer cities have fewer (or no) citizens without access to clean drinking water, an enormous gain for human health but one that does increase aggregate demand for water. For instance, 27.6%

of Sub-Saharan urban residents lack access to clean drinking water, 12.3% of Latin American and Caribbean urban residents, and essentially 0% of urban residents in the United States (UN-HABITAT 2006). Second, richer urban residents have access to technology that requires significant water to run, such as dishwashers and washing machines. Moreover, there is little economic incentive for urban residents to conserve water, because water tends to be underpriced for social and political reasons (e.g., there are significant government subsidies to create most urban water districts). In addition, urban residents are often wealthy enough that if charged for their water, they can afford to pay more for water than the agricultural sector. For example, in California urban water districts often buy water rights from upstream farmers.

In theory, rural to urban migration might lessen the population pressure on the environment in rural areas. However, as mentioned above, the agriculture sector is usually the main consumer of water in a country, so the fate of agriculture during urbanization is key to the overall water use. Usually the agricultural sector remains on the same land area, after urbanization, albeit with fewer laborers per hectare of agricultural land. Moreover, migration to cities increases the purchasing power of newly urban residents, who in turn consume more calories and a different mix of food products. The net effect is generally more agricultural production, which takes more water.

On balance, then, urbanization in developing countries appears to increase water use. Urban resident use of water is a small part of the total water use. However, the rise in incomes associated with urbanization causes a rise in consumption, increasing the total water footprint of a city. There seems to be potential for most of all of this consumption-driven increase in water use efficiency in agricultural systems. For example, significant amounts of water used in irrigation is lost to evaporation, a quantity that could be significantly reduced through other methods like drip irrigation.

**Regulating services**

Regulating services include a wide variety of functions that benefit humans through the control and maintenance of ecosystem processes. Examples of regulating ecosystem services include air quality maintenance, climate regulation, water regulation, erosion control water purification and waste treatment, regulation of human diseases, biological control pollination and storm protection. Regulating services may not be as well recognized as provisioning services, but attempts to put monetary values on all services suggest that regulatory services are the most important of ecosystem services for humankind (Costanza et al. 1997).

One important regulatory service is the ability of natural ecosystems to regulate climate, particularly in regards to humanity's greenhouse gas emissions causing global warming. Ecosystems worldwide are currently net sinks for $CO_2$. That is, they are absorbing and sequestering more carbon than they are losing or giving up. This was not always true. Terrestrial ecosystems were on average a net source of $CO_2$ during the nineteenth and early twentieth centuries, but became net sinks around the middle of the last century due to afforestation, reforestation and forest management in North American, Europe, China, among other regions, as well as due to the fertilizing effect of nitrogen deposition and increasing atmospheric $CO_2$ (MEA 2005).

Global atmospheric $CO_2$ concentrations have been dramatically impacted by anthropogenic activities, largely from the burning of fossil fuels and land use change

(Alley et al. 2007). In both cases urbanization and cities are implicated in generating more $CO_2$ than Earth's ecosystems can absorb. Urbanization decreases natural vegetation cover, decreasing potential carbon sequestration locally, while cities house the majority of human activities that involve fossil fuel consumption (industrial and commercial activities, which are heavy uses of energy). Globally, while only 50% of the world's population resides in cities, urban activities contribute more than 70% of anthropogenic greenhouse gas emissions (IEA 2008).

Activities in all urban centers, however, are not contributing these emissions equally. Cities of the developed world are considered to be the largest generators of $CO_2$ emissions. Cities in the European Union tend to use less energy per capita than US and Australasian cities, and therefore have lower $CO_2$ emissions (IEA 2008) and developed economies tend to have higher emissions than developing economies (Figure 4). At the same time, some studies suggest rapidly industrializing cities are also high contributors. For example, Dhakal and Imura (2004) report that in 1998, while Tokyo's emission levels were 4.84 tonnes of $CO_2$ per capita, Beijing's emissions were 6.9 tonnes per capita Shanghai's reached 8.12 tonnes per capita.

While cities are typically larger total contributors of $CO_2$ emissions than rural areas, residents in cities are sometimes more efficient and have lower per capita emissions. This is particularly true in cities in the developed world, where higher population densities but similar per-capita income relative to rural areas allows for less use of automobiles, more extensive urban public transport systems and more district heating. A study of the largest 1000 metropolitan areas in the USA in 2005 estimates that despite housing 66% of the nation's population and 75% of its economic activity, these locations emitted only 56% of the national carbon emissions from highway transportation and residential buildings (Brown, Southworth, and Sarzynski 2008). The authors conclude that metropolitan carbon per capita footprints are lower than the national average.

This relationship, however, is reversed in developing countries, where residents in cities use significantly more energy as a result of higher incomes and better availability of energy services compared with rural areas. For example, average resident of cities in China demand over 80 percent more energy than the per capita national average (IEA 2008).

An important question is whether population concentration contributes more $CO_2$ emissions than the alternative. This will necessarily remain an open question, as we currently do not have an alternative with which to compare. At the same time, we can focus on what current trends portend. On the one hand, dense settlements provide many services that reduce the carbon footprint of citizens, but this can only be accomplished if the necessary infrastructure is in place. In North America, Europe and Japan, living in cities provides benefits to regulating services by reducing per capita carbon footprints. On the other hand, in the developing world where most of the world's urban population growth will occur, residents consume more energy than those in rural areas and dense urban settlement patterns are therefore associated with higher carbon emissions. As the world urbanizes, we can expect that energy consumption, and therefore $CO_2$ emissions will increase dramatically in developing regions. Creating low-emission, green cities on a budget that developing countries can afford will be a major design and engineering challenge in the future.

**Biodiversity**

Important but often overlooked are the ecosystem structures and processes that enable other services to exist but which are arguably not of use themselves. For instance, soil forms very slowly, from the breakdown of minerals by biotic and abiotic process, yet without soil most crops could not be grown. Similarly, over time soil profiles tend to become stabilized by roots and other organic matter, reducing the likelihood of mass erosion. Despite their importance, these processes are often ignored because they do not directly affect most people's well-being. Moreover, they are extremely difficult to value in economic terms because no viable markets for them exist, and because most people find it difficult to contingently value them.

Biodiversity is often an important component for ecosystem service provision. For example, nitrogen fixation is very important for biological productivity, and only a few plants such as legumes can perform this service. Often, scientists do not know which components of biodiversity are necessary for ecosystem service provision, but they are certain there is some link. Paul Ehrlich illustrated this with his rivet metaphor: if one were flying in a plane and looked out a window and saw rivets begin to fall one-by-one off the wing, one could be certain that at some point the wing would detach from the plane, although it would be difficult for an engineer to say which particular rivet would be crucial (Ehrlich and Walker 1998).

Here we focus on the species-level component of biodiversity, discussing species richness and endemism. Both quantities are very unevenly distributed over the Earth's surface (Figure 5), and a whole academic discipline, biogeography, is dedicated to mapping them. Species richness is generally higher in higher productivity sites like tropical rain forests and lower in lower productivity sites like arctic tundra. The causes of this trend have been much discussed and disputed (Willig, Kaufman, and Stevens 2003). The number of species unique to one location, its endemism, is of more conservation concern, and is distributed very differently. Islands tend to have an unusually high degree of endemism because the geographical isolation encourages speciation. For both terrestrial and marine organisms, coastal areas are also places with a high degree of endemism because of the high habitat diversity (Dirzo and Raven 2003).

Cities tend to be similarly concentrated along coastlines and some islands (Figure 1), as well as major river systems. The ecology literature has explained this pattern by examining the correlation between human population density and productivity (Luck 2007), while the urban planning literature has focused on the importance of freshwater and marine trade routes for city formation. Regardless of its cause, the spatial correlation between urban growth and endemism means urban growth poses challenges for biodiversity disproportionate to its area. Within land converted to urban land-uses, most endemic species and much overall biodiversity is lost. However, a few generalist species will remain, joined by a suite of invasive species that tend to follow human settlement (e.g., the Norway rat). The net result of the expansion of urban land-cover is a reduction in total, global biodiversity, with the depauperate flora and fauna of cities sharing a common, "cosmopolitan," set of species (McKinney 2006).

One useful measure of land-use is the built-up area created for each new inhabitant of a city. A large study by Angel et al. (2005) calculated this measure for a globally stratified sample of 90 cities. Per-capita land-use varies by income, with low income countries (< $3000 GDP Per Capita PPP) taking 85 $m^2$/person, moderate income countries ($3000-$5200 GDP Per Capita PPP) taking 115 $m^2$/person, high income countries ($5200-$17,000 GDP Per Capita PPP) taking 170 $m^2$/person, and very high income countries (> $17,000 GDP Per Capita PPP) taking 350 $m^2$/person. The number of automobiles per 1000 people is also strongly correlated with income, and the presence of automobiles presumably plays some role in encouraging more sprawly patterns of development in rich cities (Kenworthy and Laube 1999). Over time, as urban areas in the developing world grow richer and automobiles grow more common, new settlement density in the developing world will continue to fall. However, it is worth noting that the density of settlement in the developed world varies widely, from 185 $m^2$/person in London to 621 $m^2$/person in Minneapolis, and so it is not clear exactly how sprawly the new cities in developing countries will be.

Rural land-use is generally less intense than urban land-use, and a greater proportion of species remain after human alteration of the natural ecosystem. There is, of course, substantial variation in the biodiversity impacts of different types of rural land-use, with agricultural systems losing more of their native biodiversity than pastureland or timberland. It has been occasionally argued that global urbanization may decrease loss of habitat in rural areas (Wright and Muller-Landau 2006). However, two factors limit the spatial scope of this "depopulation." First, many countries with fast rates of urban population growth also will continue to have rural population growth for the foreseeable future, albeit less than might have happened if the urban migration was hypothetically not present. Presumably habitat loss will continue in rural areas under these conditions. Second, rural areas are still needed to feed everyone, even if a greater proportion of humanity is in cities, so agricultural expansion may continue even if rural populations decline. Nevertheless, it is possible that certain rural locations that are marginal for farming and have declining populations may return to a semi-natural land cover. In this case, some native biodiversity may return, although experience with ecological restoration suggests secondary natural habitat usually never regains a full complement of native biodiversity (Ehrenfeld 2000).

On balance, urbanization and the associated economic process of development appears to increase the rate of biodiversity loss. There is a relatively small impact on global biodiversity from urban land area expansion itself (McDonald, Kareiva, and Forman 2008). However, in developing countries migrants to urban centers typically increase their income and their consumption, increasing the ecological footprint of cities. Cities, directly or indirectly, control the land-use of most rural areas, so an expansion of cities' ecological footprint will potentially affect a much larger amount of biodiversity.

**Conclusions**

Do cities and the urbanization process provide benefits or costs to environmental quality? We have argued that it is difficult to provide a straight forward answer to this question because urbanization is so completely bound up with other development processes that it is difficult to separate out the impacts of this process from other trends such as increasing wealth and consumption. Often critiques point to activities in cities suggesting that they are disproportionately burdensome without comparing the impacts of the same type and level of activity in non-urban areas. We have yet to be able to calculate the impacts of this type of spatial organization, as there are no non-urban developed societies to which it can be compared.

So our answer to this question is far from clear. There is evidence, however, that the influence of dense settlement patterns depends upon the ecosystem service, scale of impact and the development level of a city. For example, urban settlement is typically associated with the degradation of local water resources and the simultaneous extraction of this provision service from larger regions or from underground sources. Moreover, as water is used for agriculture that increasingly feeds urban populations, there are both direct and indirect connections of urban demand and overuse. While there are opportunities for water conservation for cities (as compared to rural users), these advantages often go unclaimed. Yet if we consider an alternative provisioning and distribution system at the regional level, the benefits of urbanization for water service conservation become clearer. That is, if people were spread over the landscape there is potential impact on water quality as well as loss and inefficiencies through distribution systems to provide the service to those demanding it. Hence, we would suggest that at a local level, cities may negatively impact water services, but at a regional or national level, they may provide benefits.

The same pattern may be true for regulating services and biodiversity with caveats. Certainly, fossil fuel consumption in and around dense settlements exacerbates climate change. At the national and perhaps global level, however, organizing in cities versus sprawled settlements provides benefits through energy efficiency and also may facilities afforestation and reforestation. Together these processes can lower emissions levels and increase sequestration potential. On the other hand, however, these trends are complicated as the lower energy efficiency levels of rural areas compared to those of urban areas, only emerge with higher levels of development and advanced urbanization. Finally, it seems that the location of cities has negatively impacted biodiversity at both the local level (where urbanization accompanies homogenization and general loss of species richness) and the regional level. At the regional level, increasing consumption within cities also increases pressure on hinterland biodiversity. Yet at the global level there is relatively low impact of urban land use on biodiversity. There is also an argument that concentrating population in cities provides more ecological space and multiple use conservation/recreational opportunities for delicate ecosystems.

It would seem then that our task for the future is complex and multi-fold. We suggest that there needs to be a concerted effort to indentify and analyze the specific costs and benefits of dense settlement organization. The goals are to seek out opportunities for both ecological and social solutions. These solutions may emerge through design, such as providing for natural biodiversity habitats in cities, increasing the diversity of types of open spaces in and around cities, re-cycling water and further increasing energy efficiency of buildings, improving transit infrastructure and the like. There are examples where some of these programs are already in place (Malmo, Sweden; Curitiba, Brazil; Singapore, Freiberg, Germany). In pursuing these goals society must also reduce poverty and address unequal access to ecosystem services. We recognize that in the quest to create more benign urban centers, there will be trade- offs to make, but opportunities costs should not be at the expense of livability for all peoples.

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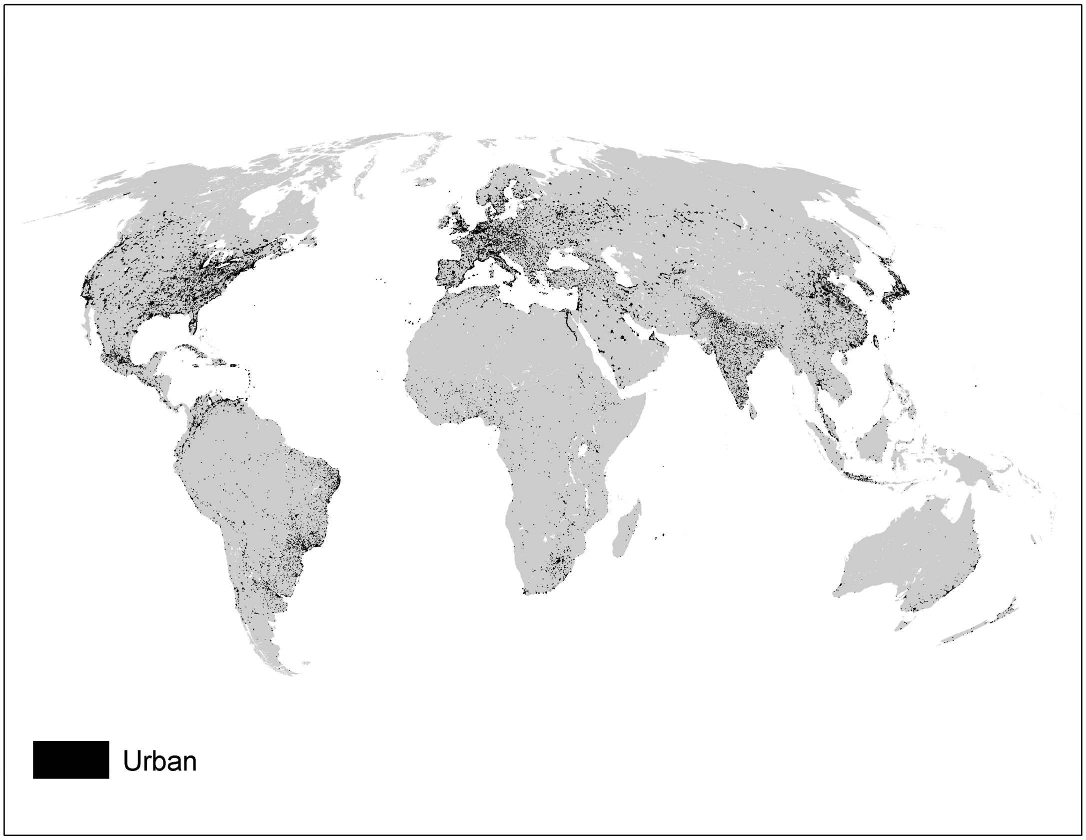
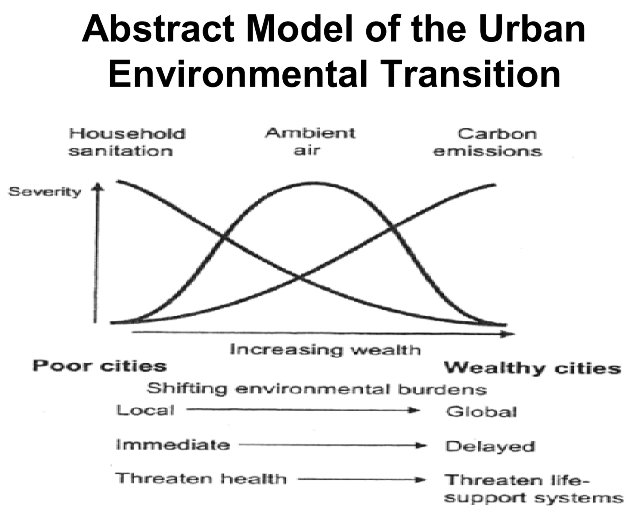
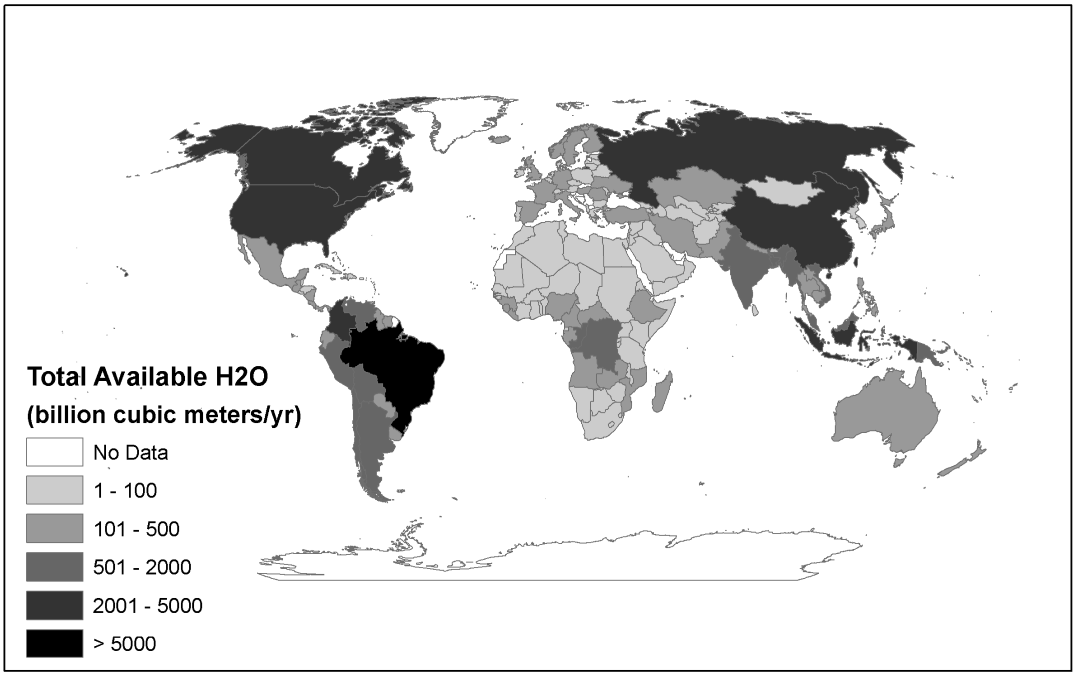



Figure 1. Urban land-cover, as defined by the Global Rural/Urban Mapping Program (GRUMP alpha 2004). To make urban area visible at this scale, the width of each urban area is expanded slightly.




Source: McGranahan, et al, 2001

Figure 2. The Urban-Environmental Transition. As cities get wealthier, the type of environmental burdens they face changes systematically.



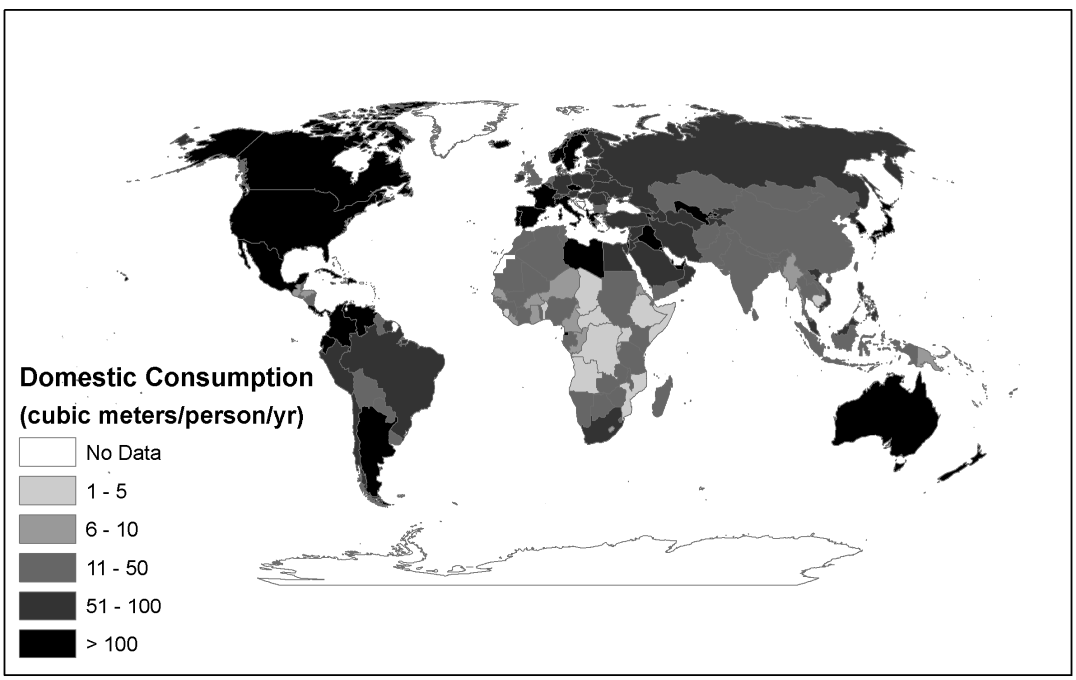




Figure 3. Global patterns of water availability (top) and domestic consumption per capita (bottom). Data from FAO AquaStat (2009).

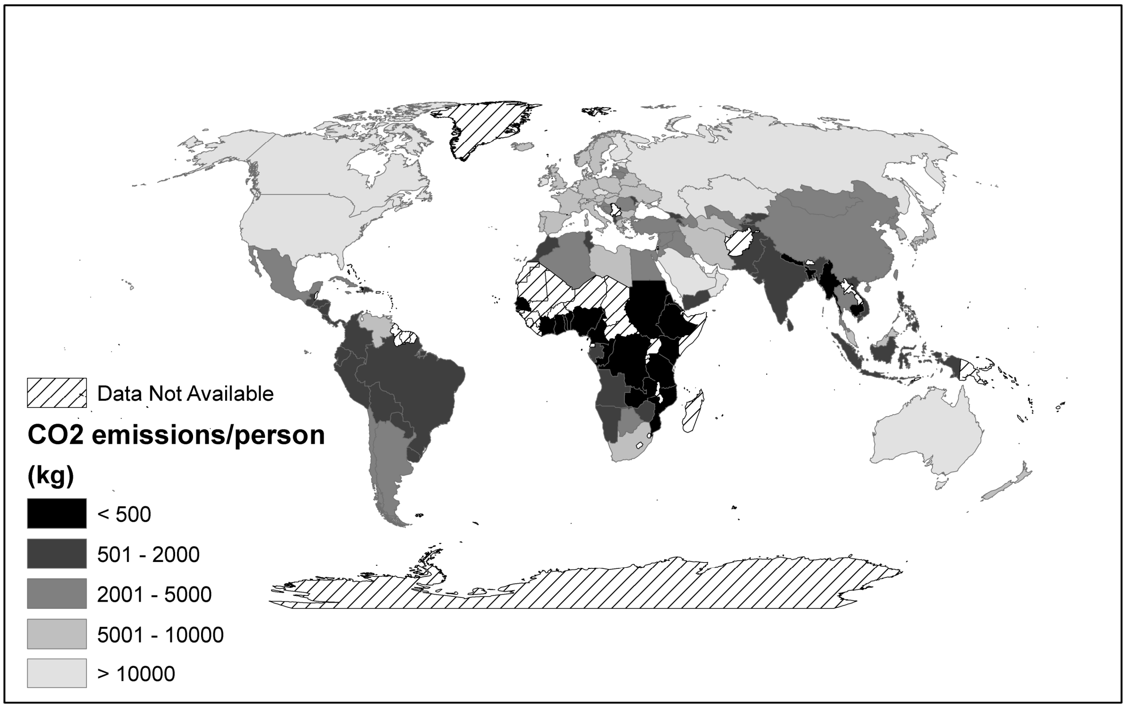



Figure 4. Global patterns of carbon emissions per-capita. Data from IEA, 2008.

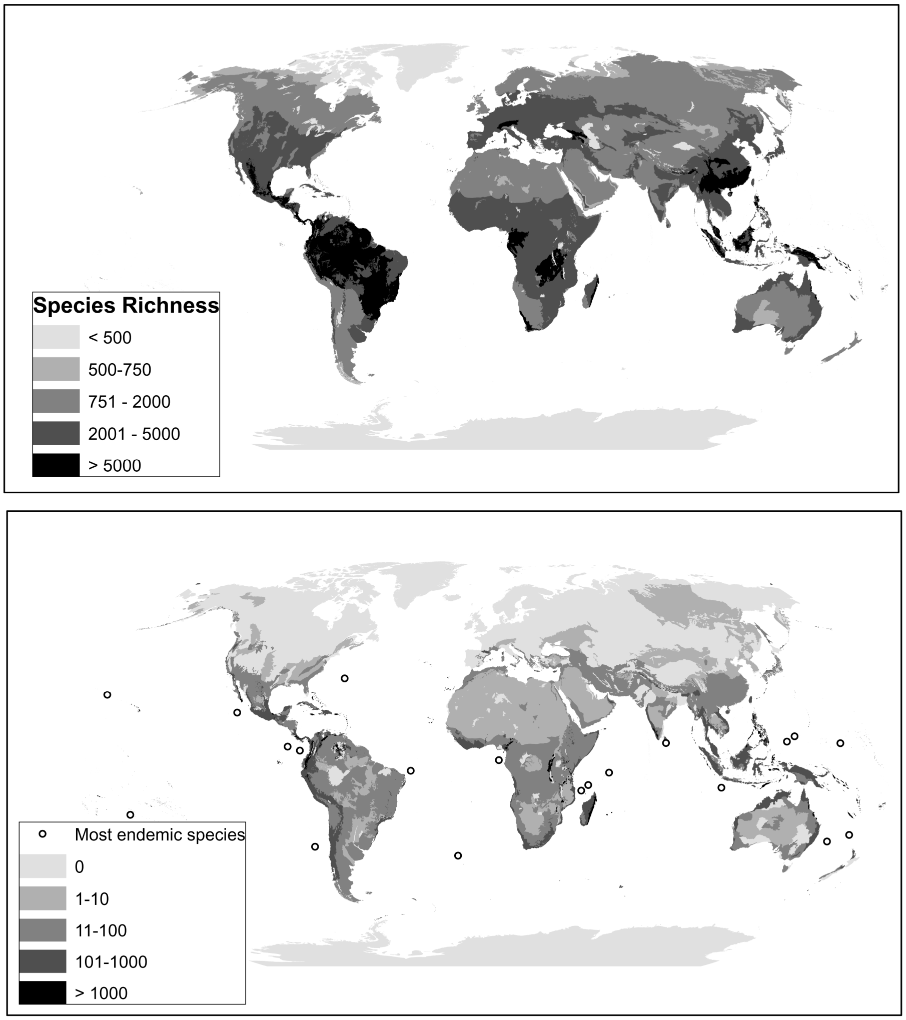



Figure 5. Global patterns of species richness (top) and endemism (bottom). Species richness is the total number of plant and vertebrate species in WWF ecoregions. Endemism is expressed as the number of endemic species per million $km^2$ of area in the ecoregion. For reference, the 20 ecoregions with the highest endemism are marked with circles. Data from WWF Wildfinder (2006).

## Chapter 4.2

# Social-ecological transformations in urban landscapes - a historical perspective

Charles L. Redman

### Introduction

The growth of urban centers in virtually every part of the globe has engendered a profound alteration in all forms of social-ecological relationships. Although the amount of land covered by cities remains small and the proportion of the global population living in cities historically has been low, the direct demands of urban dwellers and the reorganization of productive systems and impacts of urban decision-makers have transformed social-ecological systems throughout history (Boone and Modarres 2006). It is possible to trace the development of these patterns in historic cities in various parts of the world. Processes such as population growth, enhanced food production systems, and specialization of labor and trade underwrote the emergence of cities (Redman 1999). At the same time the increasing size and ubiquity of cities set in motion important feedback processes whereby social –ecological systems were transformed in ways to further support and facilitate the continued growth of urbanism and the associated social hierarchies. Along with this increasing complexity came a restructuring of social relationships and institutions related to governance. Hierarchical governance, economic interdependence, and class structured society became, and continue to be, hallmarks of urban society. These very processes and the feedbacks that promoted the growth of cities have at the same time introduced into these systems vulnerabilities that threaten their sustainability.

All of these processes emerged as a result of decisions made by individuals and groups of individuals organized into informal and formal institutions including governments at all scales from local to international and of various political persuasions. If all decisions could be characterized as a series of discrete trade-offs with predictable outcomes, then the historical trajectory and contemporary condition of social-ecological systems would be straightforward to explain. However, many if not most, of the important decisions that are made in society are made under conditions where the optimal trade-off is not readily identifiable due to differing valuations among potential participants, changing contexts in the future and an inherent uncertainty of outcomes even if conditions could be predicted. Hence, examining the origin and history of cities and networks of cities has the potential to reveal how decisions actually have been made in many varied contexts and the resulting short and long term implications of those decisions. The past can be a rich source of insight in evaluating the options we have for the future.

## Why Look to the Past?

Some question the relevance of episodes from the past for dealing with problems of the present and future. While it is not being claimed here that the past offers simple, detailed, directly applicable solutions to the challenges of the present, it is strongly argued that the past does offer essential insights into the nature of socio-ecological interactions under a huge number of diverse conditions and the implications of the decisions that were made (Costanza, et al. 2007). Two additional points strengthen this case. First, for at least the last 20,000 to 40,000 years, people have been biologically and mentally indistinguishable from those of us alive today; and second, people in the past faced real environmental crises. There is little question that during the past 10,000 years we have modified, with increasing speed, our cultural trappings and social organizations, creating in the ensuing years environmental problems of increasing severity that are more global now than they were in the past. We must not, however, underestimate the impact environmental crises had on people in antiquity (Butzer 1982; Crumley 1994; Deneven 1992; Redman 1999; Diamond 2005). Having environmental degradation force the abandonment of a homeland in which generations of one's ancestors lived and died is a disaster that few of us face today.

There are many scientists that argue that we have entered an era that is unique due to the unprecedented number of people on the Earth, the intensity and extent of human impacts on the Earth, and problems introduced by modern technologies (chapter 4.1). Pulitzer Prize winning ecologist and geographer, Jared Diamond, acknowledging this position has recently identified what he considers to be the twelve fundamental social-environmental threats facing the modern world (2005). Eight of those twelve he believes were fully in operation in the past and that historic and prehistoric case studies may reveal insights that would contribute to solutions for the present and future. In terms of human decision-making and the operation of socio-natural ecosystems, the past has a great deal to tell us about how people confront threats to the sustainability of relationships between and among social and ecological systems.

In addition to being a general source of insight, the past does offer some unique insights unavailable from contemporary studies. First, contemporary studies usually have to content themselves with investigating a truncated historical cycle, that is, not having completed one cycle, while archaeological and other historical case studies can provide not only completed cycles, but often multiple completed cycles. This allows greater understanding into the dynamics of phases of a single cycle, of linked cycles, and of how they might change as systems reorganize. It also permits more in-depth monitoring of the slow processes and low frequency events that appear to be the key to ultimate system resilience (Gunderson and Folke 2003; Scheffer et al. 2001). Although ecologists know that ecosystem structure and function may take decades or centuries to fully respond to disturbance, ecological studies almost exclusively examine ecosystem dynamics over intervals of a few days to a few years. Rare decades-to-century scale studies suggest that some human impacts are enduring, yet only a few integrative ecological studies of human land use cover time scales, even as long as a century (Foster 2000; Heckenberger et al. 2003; Mann 2002; Roberts 1998; Vitousek et al. 2004). Based on the growing availability of long term databases, an increasing number of ecologists strongly assert that the current condition of many landscapes and the dynamics that govern them could not be understood without close attention to the effects of historic land use (Foster et al. 2003; Redman and Foster 2008).

Second, the "deep time" perspective allows us to understand the ultimate, as well as the proximate, causes of the collapse of social and ecological systems. Ecologists have historically viewed land use as a key human impact without addressing the social dynamics that lead humans to alter the landscape in diverse ways. Collaborations with social scientists who seek to address these dynamics will allow ecologists to understand the ultimate in addition to the proximate drivers of human-environment interactions (McGlade 1999; Collins et al. 2000; Diamond 2005). In particular, the long-term history of human-environment interactions contained in the archaeological record reveals that many human responses and strategies, while apparently beneficial in increasing production in the short-term (even over a few generations), nonetheless led to a serious erosion of resilience in the long-term, resulting in the collapse of both environmental and social systems (McGovern et al. 1988; van Andel et al. 1990; Kirch et al. 1992; Redman 1999; Diamond 2005). It is only with the long-time perspective that we can identify which of many seemingly beneficial near-term actions truly contribute to long-term resilience, and identify the ways in which some seemingly rational choices lead, in the end, to undesirable outcomes. The converse of this is that some social adaptations or cultural traditions may appear inefficient or "illogical" when viewed in the short-term, end us reducing risk and increasing resilience in the long-term (Butzer 1996).

Third, the fields of archaeology and history, when supplemented with anthropological and sociological perspectives, allow a rich understanding of the linked dynamics of human behavior, social dynamics, and ecological systems across broad scales of organization—from individual households to hamlets, villages, cities, and civilizations. Few other social sciences encompass such a broad organizational spectrum, preferring instead to concentrate more narrowly on "bottom up" (e.g., household, village) or "top down" (e.g., nation, state) levels of organization. If the operation of a system is predicated on linked dynamics across scales—particularly the interaction of "fast" and "slow" variables or the "mismatch" of scales at which social and ecological variables interact—then examination of these linkages from both social and ecological perspectives will be crucial (Folke et al. 2002). Archaeological perspectives can provide critical bridges to fill some of the gaps left by present-day or near-historic studies focused on a narrower spectrum of human organizational scales.

Finally, the archaeological record allows us to identify those emergent features that appear to be inevitable—or at least highly probable—in societies increasing in complexity, including social stratification, compartmentalization of information, and, at certain scales, ecological simplification. One of the first challenges of conceptualizing sustainable futures will be to distinguish those features of social systems, and human interactions with the environment, that can be altered to achieve more desirable social and ecological outcomes, and those that are so much a product of history, human development, and biological, social, and cultural evolution, that we must accept their undesirable constraints in fashioning our visions of the future (NRC 1999). An archaeological perspective can contribute to meeting this challenge by documenting the full arrange of interactions that have and have not existed at least up to this point in history.

## Drivers and consequences of urbanization through history

One of the most significant milestones in the development of human societies was the growth of the first cities of Sumer on the Mesopotamian plain of southern Iraq. This process involved much more than just an increase in the size of settlements; it included fundamental changes in the way people interacted, in their relationship to the environment and in the way they designed their communities and the world around them. Writing, legal codes, the wheel, the plow, metallurgy, mathematics, and many engineering principles—all commonplace in our modern world—were first developed in the cities of Sumer (the name they called themselves). Despite the vast scope of these technical developments, the most significant changes were those of social organizations. As some groups of people acquired access to resources that allowed increased production—for example, better farmland, more irrigation water, or rare goods traded from other regions—social class became one of the main principles structuring interactions within communities. These communities became organized according to the emerging hierarchical political and administrative systems, which often used written legal codes, centralized wealth and relied on coercive force. These processes occurred at different times in each part of the world, but there is good archaeological evidence for what we are willing to call cities in at least Mesopotamia by 3000 B.C., soon thereafter in many other parts of the Old World and by the early Christian era in specific regions of North and South America.

The emergence of urban society introduced a whole new set of socio-ecological interactions. One set of interactions derives from the fact that there were just more people in the world, requiring greater food production and extraction of more materials to build their cities, processes that in themselves allowed further growth of population. Advancing agrarian techniques and urban life allowed people to invest their labor in permanent facilities and to accumulate more goods. The creation and concentration of goods and the productive capacity to create more became the hallmark of urban society. The increased demands put on local environments by growing urban populations were partly mitigated by the greater labor invested to transform their landscapes to sustain a high level of production and extraction. Many efforts employed to increase productivity took the form of management and transformation of ecosystem through redirecting the hydraulic system through irrigation or modifying the landscape structure through terracing. Other efforts involved technological innovations such as breeding for crop/animal improvements, the plow and eventually tractor to expand the scale of positive soil manipulation, and increasing complex tools from sickles and silos eventually to combines and food processing facilities that improved the harvesting and storing of an ever increasing quantity of food and other produce.

At least at the outset, each of these basic strategies did act to increase the amount of food and other goods available to a society, facilitating the growth of its population and an expansion in the energy it could devote to civilizational institutions. However, these same strategies demanded increases in labor input and often an overutilization of the landscape, diminishing its long-term productivity and at the same time potentially stimulating social unrest. Around the world urban societies are based on food production system that rely on increasing labor input and potential overutilization of the landscape have developed institutions and supporting ideologies that act to keep the society integrated and operating in a reasonable manner. However, successful these strategies are at most time and in most places they do introduce several weaknesses into the system that make them more vulnerable to crises. Slowly diminishing soil fertility, lack of alternative food sources, decision-makers who are removed from the scene of production and reliance on outside groups for essential goods are all conditions that weaken the resilience of a society when it faces trouble and continues to threaten our contemporary world (Redman 1999; Diamond 2005; Fisher et al. 2009).

A second major transformation accompanying urbanization is the change in the mobility patterns of individuals and community groups. In pre-modern times individuals were very tightly tied to their social group and community, but many of these communities were not expected to remain in the same location over time and in fact many societies built in the expectation of movement whether it be generational or seasonal. These movements were responses to productive potential of the landscape and it was easily recognized that under many circumstances it would be easier to move the people to the resources than the resources to the people. Mobility could also be a response to group size getting too large or regional population too dense. This mobility characterized the early millennia of the human career. However, with the advent of agricultural village life substantial labor was invested in ecosystem management strategies in order to maintain and enhance the yield of a particular landscape providing a strong incentive not to abandon the location. The permanence of communities themselves was further encouraged by the investment in stationary facilities from housing to manufacturing and food storage facilities. As some villages grew into towns and some of those into cities they were characterized by increasing investment in immoveable facilities, ultimately city walls and public buildings that would further discourage mobility.

This transformation in the built environment was accompanied by social and political changes that also appeared to encourage sedentarization. With sedentarization, people have developed a strong psychological and cultural attachment to where they live—a sense of place. This attachment to a particular landscape often is reinforced by cultural traditions and myths of origins. However, it is likely that these ideologies of attachment to a territory grew in concert with changes in the broader political organization of society. Early in the development of urban society kinship, that had been the primary means of organizing human relationships, was superseded first by religiously defined authority and then by a secular, often territorially defined organizational structure, the state. Political authority quickly became paramount in defining the social order, the duties of individuals, and the economic system. Kinship has remained important to this day in many relationships and religious authority in some societies has retained, or is currently attempting to reassert its primacy, but in general, kin, religion and even ethnicity have become subdivisions within the more encompassing secular/territorial state and retain their hegemony over only restricted sets of activities. This has led political leaders, in an attempt to increase membership in their state (or city state), to enact measures to attract and retain a large population of potential labor (and possible military conscripts) within their territorial boundaries. Identity has become associated with the state as have rights, privileges, and obligations. At different points in history such as with the Assyrians, Romans, and ultimately European colonial expansion, the states themselves have moved major segments of their population around to ensure political control or enhance economic success. However, the more pervasive pattern has been to encourage and enforce stability of residence. The mobility of particular social groups between urban and rural areas and even among different cities is as old as urbanism and served a variety of purposes. However, with the increasing necessity of states identifying their territory with precision it was inconvenient to have ambiguous borders and large groups of people moving up and back between what the rulers considered different states. In medieval times, one was closely tied to the feudal lands associated with your city and ruler, while in China even today one belongs to a particular territory or city and loses significant rights by leaving that location. During the $19^{th}$ and 20th centuries in particular, many countries have tried to settle the still nomadic elements of their societies and to fix national borders.

Toward the end of the $20^{th}$ century a new process challenged the primacy of impermeable, fixed state borders—globalization. The movement of raw materials, manufactured goods, food and financial instruments has increased in scope to the point where many consider the world a single productive unit and market. Goods are being moved in unprecedented quantities from where they can be produced cheaply to where people have the financial resources to purchase them. At first glance this appears to contradict the initial observation cited above that it is easier to move people to resources than resources to people. Although this appears to be true at one level, a countervailing pattern of people moving to the productive resources is picking up momentum with Globalization and may reverse several centuries of sedentarization. In a totally globalized world the formerly industrialized world (North American and Western Europe) would produce few goods, purchasing them from countries with the least expensive labor, energy and raw materials. To a great extent this is true, but there are other forces at work. The industrialized nations of the world want to hold on to the benefits of being producers for both economic and political reasons and that means they need to add inexpensive labor to their countries. This has meant a great flow of labor, and often families as well, from Africa, Latin America, and parts of Asia to North America, Western Europe, and the Gulf States. This process may allow former industrialized countries to remain somewhat competitive in the global markets, but given the "territorial" basis of citizenship it creates a conundrum for how to treat the labor immigrants. We are in the middle of this complex process and it is difficult to predict its future trajectory, but whatever it is profoundly affecting the social-ecological interactions in both donor and recipient states and at a grander scale, the political-demographic configuration of the world.

The third major transformation that was accelerated by the growth of cities is for problem-solving to be achieved through the formation of institutions that often involved more complex forms of information flow and hierarchical ordering of human interactions. A key attribute of cities from the earliest times is that they emerged as foci of diverse activities. They allowed people to specialize in their productive activities and then to exchange goods and services as needed. As the numbers of people involved and the diversity of tasks increased it became obvious that production and exchange would be best handled by specialized institutions whether they relied on a formal administrative apparatus as characterized the Sumerian redistributive economy or a market exchange system that depended on an institutionalized order, but was more bottom-up as in late pre-Hispanic Mexico. With the emergence of these institutions there also arose an "elite" that benefitted disproportionately from the productivity of the more numerous "commoners". Other elements of the administrative hierarchy could be involved with maintaining order and ensuring security through a monopoly on the use of coercive force and the creation and promulgation of various ideologies that help explain the way people were to behave and the importance of the hierarchical order. Overall, there was a flow of goods and information from the numerous citizens through a series of administrative levels to the top administrators of the city or state. They in turn, made decisions, allocated resources and positions back down through the hierarchy. Although this has relatively effectively served the needs of large social groups around the world for millennia, it has also introduced potential vulnerabilities into the urban system that periodically bring the system down. The first is the very cost of the administrative hierarchy and particularly the elite at the top. Introducing complexity into a system may have some functional advantages, but it also must be recognized that there are serious costs as well. The second weakness is that as information and goods flow up and down the administrative hierarchy there is a "loss" in the precision of the information and a drain of the goods traversing the hierarchy. The third weakness that is introduced is that people at different positions in the hierarchy may in fact have different views on the world and its proper operation. This contextual aspect to decision-making is related to both perception and values and is the most insidious of the weaknesses of increasing social complexity. When societies solve problems confronting them or take advantage of opportunities afforded them, again and again there are winners and there are losers. Who is in each camp seems to be patterned by which party already holds the wealth, access to information, and power within the society.

**Towards an understanding of urban resilience**

The continued resilience of cities and the broader urban society relies on an improved understanding and favorable resolution of several important issues in socio-ecological relationships. By bringing together such a large number and diversity of people into cities it has become clear that most problems do not have simple solutions. Most solutions will involve trade -offs and ideally the concerned parties can agree on what an optimal set of trade-offs would be. Building a freeway reduces congestion for drivers who pass through a neighborhood, but how does one measure that against the cost to the people whose home must be destroyed to build the highway, let alone the more general shared impacts like increased air pollution or green house gases. Hence, the resolution of most sustainability challenges requires explicit attention to the normative values of the parties involved. For those with a natural or physical sciences background, problems are solved by "objectively" applying the scientific method to empirical evidence allowing one to reach the "correct" solution and hence, they are not accustomed to problems having multiple "correct" solutions depending on how one figures in context and competing value systems. Nevertheless, this is the reality of socio-ecological relationships and sustainability problems. The issue should not be whether to acknowledge the importance of incorporating normative values--they must be--but how to compare or "rank" alternate values. This is a fundamental problem of sustainability. It is possible to look at the past and evaluate which values were adhered to or abandoned by societies with long-term success versus decisions made by societies that collapsed (Diamond 2005). The difficulty comes when trying to apply this framework to the future where the context and the values to be held at a future time are not known with clarity.

If one acknowledges the necessity for taking account of the values of participants then it becomes extremely important to have a methodology for who is to be included in decision-making. In ideal situation it might be best to have "all" parties represented, but the definition of "all" and the power relationships among them would still mean that the ideal is not likely to be attained. The other problem with relying on a totally inclusive set of participants is that the group could become gridlocked by too many viewpoints and too many competing values to resolve. Hence, to move forward in an analysis to support a decision one must develop an explicit framework to evaluating the range and weighting of participants in the activity. This opens the possibility for biases being introduced by selection of participants, but this is virtually always the case, but done implicitly and hence without recognition of the bias.

A related issue in reaching decisions about managing socio-ecological interactions is once a trade off is agreed upon, is determining which individuals and groups are to bear the cost of the solution reached (i.e., the losers). This is often only dealt with in a superficial manner (e.g., the taxpayer) without in depth analysis of less obvious costs and cascading impacts of the proposed solution. In general it is the politically weak, the economical disadvantaged and future generations that appear to most often bear the cost of sustainability solutions. How to reverse this process does not so much require scientific insight as it requires political agility and willpower.

One further issue to be addressed at this point involves how one deals with the ubiquitous trade-off between having socio-ecological processes operate efficiently versus building resilience into those relationships. Enhancing resilience of a system often means encouraging flexibility and adaptive capacity in the forms of redundancy, inclusiveness, monitoring, and preparedness for multiple futures. All of these efforts have associated short-term costs, yet we live in a world that is striving for efficiency and "lean" organizations. Just-in-time production/distribution systems, small government, and even cost-effective non-profits are driving forces of our competitive, globalizing world. A strong argument for "investing" additional resources in building resilience is that in the "long-term" these costs are well justified. However, issue remains that to succeed one must get through the short-term before the long-term is relevant. We need to build approaches and systems that instill long-term logic and investment into short-term decisions.

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# Chapter 4.3
# The Urban Landscape as a linked social and ecological system and a platform for equity and governance of ecosystem services

Christine Alfsen, Ashley Duval and Thomas Elmqvist

## Introduction

The constantly evolving urban landscape is a complex mosaic of human modifications, metabolic flows, networks and built structures (e.g. Alberti et al. 2003). As stressed in chapter 4.1 and in many other chapters, urban areas represent novel combinations of stresses, disturbances, structures, and functions in ecological systems. Therefore, understanding how urban ecosystems work, how they change, and what limits their performance, can add to the understanding of ecosystem change in general in an ever more human-dominated world (Pickett et al. 1997, Elmqvist et al. 2008). Today, cities are facing enormous challenges, e.g. climate change and transformation to a future beyond oil. Ecosystems may have a large role in facilitating this transformation. Ecosystems provide flexibility in urban landscapes and help build adaptive capacity to cope with e.g. increased temperature and changing precipitation and through ecosystem services generated promote human well-being. Restoration of ecological functions in cities is a so far neglected but extremely important investment in urban adaptive capacity and resilience. It is therefore in the context of the dramatic changes occurring on the global urban landscape, that we argue for the necessity to recognize, map and sustain ecosystem functions and services within urban regions. By doing so, a novel look at the impact of urbanization in the environment may be derived which will bridge the divide between rural, natural and urban areas (see chapter 4.1). The consequences of such an approach for land use management and governance of access rights would be profound. In merging economic, social and ecological objectives on a unified landscape, mutual exclusion subsides and ecosystem functions are leveraged to secure human well being and security. This recognition may be best illustrated by viewing cities as connected social, cultural and ecological systems.

While the urban landscape gives us a highly visible snapshot on the way human compete over access to land and ecosystem, an approach to urban planning based on combining social, cultural and ecological perspectives provides us with some of the tools needed to manage complex and transforming urban systems. The Ecosystem approach (CBD 2000-2008) is a strategy for the integrated management of land, water and living resources that promotes conservation and sustainable use in an equitable way. Originally meant to enhance communities' ownership of conservation strategies in areas defined as "natural", it recognizes that the cultural diversity of humans comprises an integral component of many ecosystems, and that given the complex and dynamic nature of ecosystems and the absence of complete knowledge, adaptive management is required. However, the Ecosystem Approach, while integrating sectors/disciplines needed to manage the landscapes, was not intended to be applied to complex and fast transforming urban systems. Conceived as it was, before the threats associated with climate change had reached public consciousness; it did not make the link between ecosystem functions and human security explicit. Today, with increased incidence of natural disasters and the looming threats associated with climate change, we have a much keener sense of the immediate and inextricable connection between human security, well being and functioning ecosystems (MA 2005). Our current systems of governance and resources allocations and public information have not, however, adapted in response to these threats.

**Urban landscapes as innovative social-ecological arenas**

We argue that the urban landscape is the right place to begin crafting integrated and cross sectoral responses to global challenges. The magnitude of socio economic impacts resulting from ecosystem failures in urban environments make human-ecosystem interlinkages impossible to ignore. This in turn facilitates mobilization of resources and people and governments at all levels to build social-ecological resilience through adaptive and strategic planning. On a human dominated planet, environmental solutions rely on innovative applications of science and technology rather than on strict nature preservation methods. Urban regions have the added advantage of concentrated scientific, technological and financial resources that are needed to find solutions that work for people and the environment (Redman chapter 4.2).

*Urban ecosystems and ecosystem services*

A city is among other things, a physical and social mechanism for acquiring and delivering ecosystem services to a dense human population (Lee 2006). The Millennium Ecosystem Assessment (2005) found that 60 percent of ecosystem services assessed globally are either degraded or being used unsustainably. Seventy percent of the regulating and cultural services evaluated in the assessment are in decline. However, urban areas were largely left out even though urban ecosystems contribute to several environmental regulation services and cultural services of importance for human well-being (Bolund and Hunhammar 1999). Urban ecosystem services may be generated in a diverse set of habitats, including parks, cemeteries, vacant lots, streams, lakes, gardens and yards, campus areas, golf courses, bridges, air ports and landfills.

The urban landscapes present novel ecological conditions, such as rapid rate of change, chronic disturbances, and complex interactions between patterns and processes. Firstly, compared with ecosystems in rural areas, urban systems are highly patchy and the spatial patch structure is characterized by a high point to- point variation and degree of isolation between patches. Second, disturbances such as fire and flooding are suppressed in urban areas, and human-induced disturbances are more prevalent as well as intense human management of urban habitats. Third, because of the ‘heat-island’ effect, that is, higher mean temperatures in cities than in the surroundings, cities in temperate climates have significantly longer vegetation growth periods. Fourth, ecological successions are altered, suppressed, or truncated in urban green areas, and the diversity and structure of communities of plants and animals may show fundamental differences from those of nonurban areas. Furthermore, cities are the most important points of introduction of exotic species. Although cities sometimes may be species rich, having higher species diversity than surrounding natural habitats, this is often due to a high influx of non-native species and formation of new communities of plants and animals. To what extent exotic species contribute to reduced or enhanced flow of ecosystem services is virtually unknown for any urban area, but since introduced species make up a large proportion of the urban biota, it is important to know not only to what extent introduced species are detrimental, but also to what degree some of the introduced species may enhance local diversity and maintain important functional roles.

The potential of generation of ecosystem services is often substantial (e.g. Pickett *et al.* 2008), but not very often realized. For example, urban parks and vegetation reduce the urban heat island effect and there is an important potential for lowering urban temperatures when the building envelope is covered with vegetation such as green roofs and green walls, with the largest effect in a hot and dry climate (Alexandri and Jones 2007). In relation to overall climate change mitigation, urban ecosystems may assimilate large quantities of carbon, e.g. in Stockholm County, ecosystems assimilate about 41% of the $CO_2$ generated by traffic and about 17% of total anthropogenic $CO_2$ (Jansson and Nohrstedt 2001), and residential trees in the continental United States could sequester 20 to 40 teragrams C per year (Jenkins and Riemann 2003). Vegetation may reduce noise levels, and dense shrubs (at least 5 m) wide can reduce noise levels by 2 dB(A), while a 50-m wide plantation can lower noise levels by 3–6 dB(A) (Bolund and Hunhammar 1999). Evergreen trees are preferred because they contribute to noise reduction year round (Ozer *et al.* 2008).

There are also direct health benefits of green areas, vegetation and trees, e.g. in a study from New York, presence of street trees was associated with a significantly lower prevalence of early childhood asthma (Lovasi *et al.* 2008). Green area accessibility has also been strongly linked to reduced obesity (e.g. Ellaway *et al.* 2007). In a review by Bird (2007), links were noted between access to green spaces and a large number of health indicators, e.g. coping with anxiety and stress, treatment for children with poor self-discipline, hyperactivity and Attention Deficit Hyperactivity Disorder (ADHD), benefiting elderly care and treatment for dementia, concentration ability in children and office workers, healthy cognitive development of children, strategies to reduce crime and aggression, strengthened communities, and increased sense of wellbeing and mental health. The distribution and accessibility of green space to different socio-economic groups, however, often reveals large inequities in cities (e.g. Pickett *et al.* 2008), contributing to inequity in health among socio-economic groups, although confounding effects are not always possible to separate (Bird 2007).

To what extent biodiversity and variation in species composition plays a role in the generation of environmental quality services is still poorly investigated (Elmqvist *et al.* 2008). For air quality, filtering capacity increases with leaf area, and is thus higher for trees than for bushes or grassland (Givoni 1991). Coniferous trees have a larger filtering capacity than trees with deciduous leaves (Givoni 1991). In the urban core there are probably fewer species and often very different species involved in generation of ecosystem services than in more rural areas. Interestingly, the number of plant species in urban areas often correlates with human population size, and diversity may correlate with measures of economic wealth as shown for example, in Phoenix, USA (Kinzig *et al.* 2005).

Cultural ecosystem services refer to the aesthetic, spiritual, psychological, and other benefits that humans obtain from contact with ecosystems. Such contact need not be direct, as illustrated by the popularity of the virtual experience of distant ecosystems. Nor need such contact be with wild or exotic nature, as shown by the ubiquity of e.g. urban gardens (Butler and Oluoch-Kosura 2006). Many cultural services are associated with urban areas and there is good evidence that biodiversity in urban areas plays a positive role in enhancing human well-being. For example, Fuller *et al.* (2007) have shown that the psychological benefits of green space increase with biodiversity, whereas a green view from a window increases job satisfaction and reduces job stress (Lee *et al.* 2009). This may have a strongly positive effect on economic productivity and hence regional prosperity. Several studies have shown an increased value of properties (as measured by hedonic pricing) with proximity to green areas (Tyrväinen 1997, Cho *et al.* 2008)

*Governance of urban ecosystems*

In the urban landscape , we propose to translate the general principles of adaptive governance (Folke et al 2005) into a set of methodologies, discourses and planning tools recognizing that: (1) in an urban and urbanizing planet, cultural and biological diversity is key to resilience of social, economic and ecological systems, (2) knowledge either scientific or local is key to management, (3) education is the main conduit for mainstreaming an empowering communities and (4) adaptive management is not only matter of building flexible institutions and governance systems at the relevant scale, it is also dependent on equity and particularly equitable access to land and resources.

While different cities in different regions of the world face many of the same environmental challenges in light of growing populations (chapter 4.1), the capacity to govern, respond to and meet challenges attached to such fast transformations and the approaches they employ in response vary drastically. In trying to understand these differences, world cities must first be conceptualized as belonging to three different groups; ***least developed, rapidly developing and developed*** (UNU-IAS 2003).

***Least developed cities*** have been defined as those which have experienced few benefits from globalization flows, although they are rapidly urbanizing. The ability to expand and modernize their infrastructure is impaired by socio-economic inequalities, often accompanied by severe environmental degradation (UNU-IAS 2003). Rapid urbanization has proceeded in the absence of accompanying economic growth, resulting in widespread poverty. A vicious cycle is formed by which the impoverished are pushed into settling down in ecologically vulnerable areas thus aggravating unsustainable pressures on the environment and impairing ecosystem services. Few resources can be spared towards preventative or precautionary measures, and as a result these cities are the hardest hit by epidemics such as AIDS and malaria, as well as natural disasters such as droughts, flooding and hurricanes. Lagos, Nigeria is one of the emerging global MegaCities of the

South, with a population expecting to reach 17 million by the year 2015 (UN Department of Economic and Social Affairs, 2004). Least developed but substantial cities such as Lagos challenge many of our assumptions about economic prosperity and demographic change, as the vast urban expansion accompanied by dramatic economic decline has marked a form of urban 'involution' (Gandy, 2005). Urbanization has been marked by a stark decline in the quality living, including the loss of much street lighting, exponential increases in traffic congestion, the rise of violent crime, virtual absence of sewage networks, and insufficient safe drinking water (Gandy 2005). Set upon a series of islands connected by rivers and lagoons, a sprawling population that now includes up to 200 different slums must contend with annual flooding in nearly half the households, often reaching knee-deep levels (Gandy 2005).

***Rapidly developing cities*** have often had growth facilitated by investment from public and private sources as well as far sighted policies from their national government. Oftentimes, the successes these cities have had competing with the technology and industries of developed cities have come with heavy environmental repercussions. Technical and socio-economic changes occur so rapidly that these cities are ill-equipped to address the simultaneous issues of public health, equity and environmental burdens that arise. This can be illustrated with the example of the increasing health and environmental costs of transportation in Asia, where more new cars were sold in 1995 than in North America and Western Europe combined (UNU/IAS 2003). In Bangkok, transportation accounts for seventy per cent of urban energy consumption, and estimates indicate that exposure to outdoor airborne particulate matter may contribute to up to 5,500 premature deaths each year and the high levels lead detected in children’s blood tests (UNU/IAS 2003).

***Developed cities*** in rich countries deal with a specific set of environmental issues, often related to urban encroachment upon rural areas of agricultural and forest land. The sprawling growth at the margins of urban centers is a major contributor to green house gas emissions as house hold numbers increase despite decreasing household size, and automobiles are increasingly relied upon to connect people to the city centers where they often work. For example, development in the US metropolitan areas has consumed thousands of acres of woodlands, wetlands and farmland. Fifty three percent of the wetlands of the lower 48 states were lost by the mid 1980s, and California continues to loose wetlands at a rate of almost 5,000 acres per year (UNU/IAS 2003). Some cities or districts of cities in the developed world share a demographic profile comparable to cities of the developing world, with regards to percent of population living below the poverty line, education and literacy levels and public health scenarios. These cases illuminate the necessity of using case specific approaches in implementing an ecosystem approach within urban areas, as the basic needs of a population that can be potentially addressed through environmental services vary from services inherently difficult to quantify such as more creative play amongst children to employment through green jobs in a disadvantaged community.

If we are serious about operationalising an approach that combines urban planning with healthy ecosystems, it is necessary to start a conversation with all the diversity among cities in mind and with recipients and users of the knowledge so as to adapt place based research to objectives and constraints of regional and local authorities. From the point of view of environmental education a subject vastly neglected, we should use the impetus given by the Decade for Education for Sustainable Development (2005-2014) to focus on the urban environment, the one that will be most familiar to future generations.

*Global Initiatives for improving urban ecosystem governance*

After decades of mutual neglect and artificial divide between nature on the one hand, and cities with their respective urban processes on the other hand, a shift in perception has started that include cities as a component of natural landscapes (Turner et al. 2004). Urban planners increasingly acknowledge that nature exists in cities and that biodiversity conservation must be part of municipal programs and investment. The ICLEI LAB initiative, begun in 2006, gathers 21 cities that have at different scales and in different ways operationalised nature conservation into municipal programs. Some have taken steps to conserve biodiversity at the municipal level e.g. Curitiba and have in the process acquired the status of "model cities". Others have acknowledged that biological diversity conservation must take place at the regional level (e.g. Ile de France) and have strived to bring together the many jurisdictions and stakeholders concerned by regional development. In developing countries where the poor often live off the environment for land, water and food, some municipal governments have acknowledged that strict conservation implemented by excluding people from the land will not work and worse will create social unrest. They are therefore attempting to incorporate the more disadvantaged segments of society in the process of understanding valuing and conserving the environment.

Various tools and approaches have been attempted to reconcile and mediate interests in the landscape. Most of them however have been devised and utilized to try and mitigate conflicts in sensitive 'natural' landscapes (eg CBD ecosystem approach, the biosphere reserve concept, peace parks, etc). Urban nature, broadly defined to include all sustaining ecosystems in the adjacent hinterlands as well as green spaces, parks and urban forest, is quickly becoming the most familiar and accessible, and in many cases useful, form of nature for the majority of the world's inhabitants. Furthermore, many natural areas distant from cities depend increasingly on wealth and knowledge generated in urban areas for their sustained existence. In light of these realities, it is time to turn the tables around and recognize the usefulness of environmental governance tools for urban regions. Here it is proposed to adopt the concept of "urban biosphere" as a scientific, educational and governance platform for better governance of the urban landscape and a reconnection between urban , rural and natural areas as well as a tool to building public interest through informed discussion at a relevant scale. Drawing on the pioneering " Biosphere Reserve concept" defined in 1995 in the Seville Strategy, produced by the UNESCO International Conference on Biosphere Reserves, and the Ecosystem approach defined by the CBD to promote the interdependent goals of biodiversity conservation , sustainable use and equitable access, the Urban Biosphere approach promotes science and knowledge for sustainability and resilience, education for empowerment and change and land use planning for mediation and conflict resolution.

Based on this, the Urban Biosphere Initiative, or URBIS, has developed as a multi disciplinary and multi stakeholder initiative that reconnects urban citizens to their natural environments through the following actions:

• Promoting an understanding of the dependencies between cities, their inhabitants and their natural environment through site based, policy relevant research on complex urban social ecological systems;
• Fostering citizen's appreciation of urban ecosystems through innovative education, communication and awareness programs;
• Developing a tool box for land and resource use planning for equitable growth while securing ecosystem services and functions at the relevant scale.

URBIS seeks to contribute to an increased understanding, valuing and reconnection of people and ecosystems in the urban landscape to:

1) *Increase the resilience of urban social-ecological systems*. Ecosystems such as wetlands and coastal areas may provide buffer against natural disasters such as floods and hurricanes but for this to be effective, the population must be made aware of these natural functions and learn to accommodate and prioritize nature even in heavily urbanized areas. In New Orleans, it is now quite widely recognized that the human tragedies caused by Hurricane Katrina constituted a manmade rather than natural disaster. Social and economic fragmentation and inequity played a key role in the initial reaction of the population to warnings and the debacle that followed. To this day when less than half of the population has returned, the public services, public health and educational systems have barely been reestablished thus threatening the long-term viability of the city. Yet in this case, so much of the problems of governance and access are rooted in history of race relations and the way the army corps of engineers conceived and implemented the levee system, that it is impossible to deal with the consequences of Katrina without questioning and reinventing the social as well as hydrological and ecological systems that makes the existence of a city possible. Solutions thus lie not only in rebuilding the levees but more importantly rebuilding the social fabric and cultural heritage so badly battered by the storm. The approach selected by Tulane University in a project conceived and implemented in collaboration with UNESCO and the Stockholm Resilience Center aims at creating a democratic and informed public forum to foster the dialogue on recovery through research, public debate, grassroots exchange and policy formulation concerning social, urban and ecological resilience. The River Sphere, a riverside campus of Tulane University dedicated to researching and understanding the Mississippi and the other great rivers of the world provides such a platform. There it is proposed that teams of scientists, engineers, educators, industrialists and residents will convene and conduct research to increase understanding of coastal ecosystems and communities. River Sphere will also promote knowledge of clean, available water as a focal point for hydro-energy, water rights law, water purification and distribution, etc.

2) *Improve equitable terms of access to resources*, support livelihoods based on the sustainable utilization of natural resources and distribution of benefits. In Cape Town South Africa, the Cape Flats Nature project implemented by the South Africa National Botanical Institute builds good practice in sustainable management of nature sites in the City's Biodiversity Network in a people-centered way that develops local leadership for conservation action and benefits the surrounding communities, particularly townships where incomes are low and living conditions poor. In Durban, the municipality has made a determination that natural ecosystem provide a range of valuable goods and services to its citizens including climate regulation, water regulation, water supply, erosion control, soil formation nutrient cycling, waste treatment, biological control, food production and genetic resources as well as a range of social, recreational and aesthetic services (reference). As a result, the municipality conducted an estimation of the value of such ecosystem services and estimated them at 400m per year in 2003 without incorporating benefits from tourism. This was a powerful way to make the case for investing into protection and conservation at all levels and scales.

There is hope that these initiatives will help to bridge science, planning , policy and practice and reinvent  a more holistic and symbiotic mode of urbanization and resource use  that benefits both citizens and the environment. This will require not just integration of disciplines and sectors.  The emerging paradigm should be built on the principles that saliency, legitimacy and accountability are integral part of everything we do as public and private actors in the landscape.  That applies to science, education and the business of government but also to those in the corporate sector shape the infrastructure and networks that shape our cities today and tomorrow.

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# Chapter 4.4
# Water services in urban landscapes

Peter Bridgewater

## Introduction

Many urban areas have been founded along the banks of great rivers, or in an area of freshwater seepage, where groundwater is (or increasingly was) close to the surface. There is thus a close cultural connection between urban settlements and wetland systems. The following vignettes give 8 different flavours of urban wetland ecosystems in urban areas, yet all linked by common themes.

Landing at Rome's Fumicino Airport and taking the train, you pass through flat lands, with extensive stands of *Arundo donax*, and occasionally very low hills, with again dense stands of *A. donax* at the foot, or seepage line. In the distance scattered *Pinus pinaster* groves can be seen, and clumps of planted or escaped *Eucalyptus camaldulensis.* But the underlying ecological connection is clearly the wetland systems, including seepage lines. This ecological connection forms a visible map of the hydrological systems of the coastal plain.

Northeast from Rome is perhaps the world's ultimate wetland city – Venice. Built in a functioning lagoon, Venice expresses all the delights and frustrations of a living wetland city. Venice is inscribed on the world heritage List (UNESCO 2009b), but as a cultural site. Yet the major threats to this listing come not directly from human activities but from natural events causing changes to the wetland system of the lagoon.

In Dubai, city of blowing sands and ever-higher concrete and glass towers, there is a wildlife refuge, a wetland, lined by mangroves (*Avicennia marina*). The inland edge of this reserve has little dense stands of *Phragmites australis*, and, occasional *A. donax*. The wetland is the Ras Al Khor Wildlife Sanctuary, a Wetland of International importance listed under the Ramsar Convention on Wetlands. (Ramsar 2009a) In a few special places there are constructed wetlands, featuring primarily *P. australis*, sometimes supplemented by *A. donax*. These wetlands are supplied by wastewater from showers and kitchens, and primarily treated sewerage. And away from the development native halophytic shrubs that represent highly ephemeral wetlands dominate the "desert". While *A.donax* is an alien species and *P.australis* is rare in the sand plain they do form stable wetland systems, provided the supply of water is kept up. They provide also a very important ecosystem service of removing nutrients and other pollutants from the waste water.

In Perth, Western Australia, there are many kinds of wetlands, ephemeral, open water fringed by macrophytes. The Becher wetlands, a group of wetlands, interspersed with the sprawling development, is described in detail by Semeniuk (2007). These wetlands include lakes, ephemeral wetlands, to small wooded swamps. Included in the overall wetland landscape of the Perth region are the salty shores of the Swan River, and (too many) obliterated wetlands, now visible only through old aerial photographs. Again we find clumps of *A. donax*, *P. australis*, with *Eucalyptus rudis*, a western member of *E. camaldulensis* group, lining some swamps and riverbanks: compared with Rome, therefore, a sort of reverse exchange of invasive alien species.

And In Brisbane, on the other coast of Australia, as you land at the Airport you notice abundant mangrove forest – much of which was created during the building of the new airport in 1988, admittedly after extirpating some existing wetland habitat. Airport expansion here continues to be controversial, but government is demanding continued attention to conservation and management of biodiversity (The Australian, 2007).

Hangzhou, China, has a wonderful wetland park (Xixi) of over 3,000 fish ponds, each one small and self contained, with a fringing vegetation which includes *P. australis*, and on the drier ridges Mulberry (*Morus alba*) and Persimmon (*Diospyros kaki*) trees. In the centre of this area is a centuries old Buddhist temple, where the monks spent time in contemplation, writing evocative poems. The Park has an educational centre established, and has become a focus for enjoyment and education, as well as ecosystem productivity. The Xixi wetlands management programme included restoration and recreation of wetland ecological systems, rebuilding the wetland food chain, re-establishing wildlife ecosystem diversity and stability, restoring the water purification function of the wetlands, and the prevention (and decrease) of eutrophication (XiXi 2009).

Kampala, Uganda, lies on the shores of lake Victoria, and largely covers the hills rising up to the east of the lakeshore. However, in low-lying parts of the city there are extensive papyrus swamps, some of which have been cleared, but the majority retained, as their function in moderating flooding is well recognised by the local community. They are also a source of water for some of the population. In addition, wetland edges are often used for food (especially Yam and banana) cultivation, although this cultivation rarely penetrates far into the wetland, and helps provide food for nearby residents. One particular site, Lutembe Bay Wetland System (listed as a Wetland of International Importance under the Ramsar Convention (Ramsar 2005)) is dominated by *Papyrus*, *Phragmites, Typha*. Threats come from the Water hyacinth, *Eichhornia crassipes*, an introduced submerged plant affecting open water in the area. The introduced species of fish Nile Tilapia, *Oreochromis niloticus*, *Oreochromis leucosticus*, & *Tilapia zillii*; and Nile perch, *Lates niloticus* in Lake Victoria has led to the extinction of several *Haplochromine* species in the vicinity of the Lutembe Bay Wetland System.

New York, with its complex of islands and fringing riverine edges is also a wetland city. The edges of the Hudson River, again with *P. australis* dominant, provide a range of ecosystem services for the metropolis, as well as habitat for a range of wildlife, including migratory species. In New York City environs tidal wetland losses result from both human caused and natural disturbances. These disturbances include:

- dredging
- watershed development
- filling

- eutrophication.

But wetlands are not just lost, they are also gained. For example, Shinnecock Bay showed a gain of 161 acres of tidal wetlands as a result of a landward movement of the tidal wetlands boundary from 1974 to 1995 (NYDEC 2009). Moriches Bay showed a gain of approximately 100 acres of tidal wetlands as a result of a landward movement of the tidal wetlands boundary from 1974 to 1998. Loss of wetlands because of permitted and unpermitted human activities was too small to be detected. The main cause of wetlands destruction has shifted from human caused factors such as filling to natural factors such as storms and flow restrictions.

At the delta of the vast Parana River, seaward of Buenos Aires are less densely populated municipalities, encompassed by the Delta del Paraná Biosphere reserve (UNESCO 2009). This coastal freshwater delta was declared as a biosphere reserve in 2000 and is located just north of Buenos Aires. Many species are at their southernmost limit of distribution. The flooded riverbeds are dominated by *Schoenoplectus californicus* and *Scirpus giganteus*. The Biosphere Reserve also contains low forests, forest ecosystems and secondary forests with Black Cottonwood (*Populu*s spp.) and several *Salix* spp. The latter are exploited for commercial purposes. The establishment of the Biosphere Reserve aims at revitalizing the economy of the region at the same time as conserving the natural and cultural values of the area. This biosphere reserve is dedicated to wetland protection, but also to its sustainable use, and education about its important function. While direct inhabitants are probably fewer than 3,000, it is increasingly popular destination for citizens of Buenos Aires.

Finally, 8 km from the centre of London, there is a recently developed wetland complex, again featuring *P. australis* and many other species, but developed from artificial reservoir basins. The site is also a Site of Special Scientific Interest under UK legislation supporting nationally important wintering populations of shoveler (*Anas clypeata)* and an assemblage of breeding birds associated with lowland waters and their margins (Natural England 2009). In addition to the nationally important numbers of shoveler, the site also supports significant numbers of wintering gadwall. Barn Elms Wetland Centre comprises a mosaic of different wetland habitats with the majority of the site comprising areas of standing open water, grazing marsh and *Phragmites* reed bed. Other significant habitats include *Salix* woodland and scrub. The Barn Elms reservoirs were constructed in 1886 but became redundant in 1989. Wetland habitat creation was initiated in 1995 and the site is now being managed as a nature reserve, as well as an educational and visitor facility.

These ten urban areas and their associated wetland ecosystems have many of the themes that characterise urban wetlands in the C21st., that is,

- an association with human activities, especially development and culture;
- invasive species,
- migratory species feeding and breeding ground;
- a focus for education;
- being recognised by international environmental agreements;

- an ability for the wetland to be restored or constructed; and
- a role in providing for a focus of sustainability in the urban system.

This chapter sets those themes in the context of the emerging paradigm of Ecohydrology and the application of the Ecosystem Approach of the Convention on biological Diversity.

**Wetlands and water in the urban environment**

The hydrological cycle (Fletcher and Ana Deletić 2008) supports and links all components of the environment, including the urban environment (see Illgen, chapter x.x. in this book). Water flows throughout the environment, from the atmosphere, on the surface and below the surface of the land. By environment, I mean the various biotic and abiotic elements that comprise marine, terrestrial (including aquatic) and subterranean (which includes aquifers, cave systems, and the saturated zone of the soil horizon) ecosystems as well as the atmosphere. The hydrological cycle links all these components of the broader environment, and this means that water resources are linked, *via* the water itself, to all the other components of the broader environment (such as soil, biodiversity, air).

Water itself appears as liquid, solid or gaseous (vapour) forms in the environment, depending on the particular situation. In the atmosphere water is usually as the vapour or liquid form, or occurs temporarily in the solid form as hail or snow in winter seasons. In terrestrial ecosystems, water is in the vegetation and the unsaturated zone of the soil horizon. Such water becomes part of the evapo-transpiration cycle - the term "green water" is used to describe this part of the water cycle. Marasalk *et al*. (2007) note that the direct and indirect impacts of different ecosystems or components of the water cycle need to be quantified with respect to local climate, urban development, cultural, environmental and religious practices, and other socio-economic factors.

Water in aquatic, marine and subterranean ecosystems appears in its liquid form, where it is usually termed "blue water" - this includes water held in aquifers, or in the saturated zone of the soil horizon. Aquatic ecosystems are those in which water is generally fresh or brackish (but in inland arid areas may include hypersaline systems). Coastal marine ecosystems include the estuarine and near-shore marine aspect of water, while the offshore marine ecosystem's primary influence on the hydrological cycle is through global, continental and regional weather patterns.

In urban systems, water can be both blue and green, but there are also substantial amounts of water which are grey (meaning pathogen free but not necessarily cleansed of all nutrients and chemical pollutants) and Black (meaning untreated water from human sewage systems, or untreated industrial waste water). These forms of water are human in origin and need various degrees of treatment, which has typically been mechanically or engineering based. However, new technologies allow a mix of hard and soft engineering approaches to deal with these types of water – where soft engineering refers to the construction or use of organic wetland systems as treatment sites for all grey and possibly some black waters.

Figure 1 shows the way these "coloured waters" move through the hydrological cycle. The Figure is simplified to make the main pathways clear, and the many indirect impacts are omitted.

There are biophysical, biochemical and ecological links within and between each of the coloured waters. Ecological processes play a critical role in regulating the hydrological cycle, and they are themselves affected by biophysical and biochemical processes occurring within the hydrological cycle. Here, the structural, functional and compositional aspects of biodiversity play a variety of roles, at several different scales, in governing linkages within and between the coloured water components of the hydrological cycle. Additionally, ecological functions and processes linked to the hydrological cycle both affect people as part of associated socio-cultural systems, and are, in turn, affected by human activities.

Water in the hydrological cycle is also affected by natural and human-induced processes of change to land, water and wetlands (see Illgen, chapter x.x. in this book). These can be due to changes in the topography and morphology of the landscape, which primarily affect the "blue water" component of the hydrological cycle, or due to changes in vegetation and land cover, which primarily impact on "green water" through affecting infiltration and evapo-transpiration rates and patterns.

Changes in land and water environments affect the rates and pathways by which water moves within the hydrological cycle, and also affect the quality of the water in its various forms and places. Connections between the hydrological cycle and the broader environment are bi-directional, in that direct impacts on the non-water aspect of the environment can affect water, while direct impacts on water (such as abstraction or waste discharge) can affect the broader environment as well. This is nowhere more evident than in the urban environment, where ecosystems suffer most from misuse of the water component.

In most countries, the conventional water sector, which is engineering in focus (and usually in management), deals with water primarily as a commodity. Water in Urban environments is delivered to people through some kind of infrastructure such as pumps and pipes, and is sourced from either or both groundwater or surface dams. This water is thus derived exterior to the component urban ecosystems.

In urban areas most residents see water as a service which is provided by the local authority, and for which they "pay". They do not see it as a resource that plays a key role in both their immediate, as well as the wider, environment, much less driving the functioning of key ecosystems, including ecosystem components of the urban landscape and its ecological infrastructure. The problem with the conventional approach to management of water as a commodity is that many of the values that people place on water, aside from just having an adequate supply when they turn on a tap, are dependent on water being a component of healthy, functional ecosystems.

In some urban areas, water is derived from ecosystems a distance away (e.g. New York) but in others (e.g. Perth, Western Australia) water is derived from ground water sources. In the case of distant supplies the immediate nexus between supply and need is not obvious, but where water is abstracted from groundwater at a rate greater than replenishment a range of issues can arise, including, inter alia, subsidence of the urban area (e.g. Bangkok, Mexico city). Other cities using a mix of ground and surface water resources can none-the-less be affected by pollution issues – e.g. in London and Paris water can have higher than desirable levels of nitrate pollution, as the run-off from farmlands around these urban areas recharges the ground water reserves that are drawn on for domestic water supply.

**Ecohydrology**

Ecosystems, particularly those in which water is a critical component or the main component, are typically resilient and can withstand a certain degree of impact, including abstraction of water, use of food and fibre resources, and transport of goods through the system. However, exceeding these limits changes the structure and function of an ecosystem irreversibly, leading to irreparable changes in the range, availability and quality of the ecosystem services formerly provided, including protection, production and purification of water supplies. Such changes in ecosystem services can be irreversible, or at the very least impose strong constraints on ecosystem management.

In many cases wetlands which act as provisioning of ecosystem services for urban environments are especially under pressure – whether inside the urban periphery or external to it. A case in point here includes the Wetland of International importance (Ramsar Site) known as the East Calcutta wetlands (Ramsar 2002). These wetlands are essentially resource recovery systems developed by the local people over times using wastewater from the city. In the recovery process it treats the wastewater and has saved the city of Calcutta from constructing and maintaining a wastewater treatment plant. It also is the only metropolitan city in the world where the Government has introduced development controls to conserve the water-bodies. These wetlands, however, are still under an intense encroachment stress of urban expansion. This task of conservation, therefore, needs further consolidation.

The quality of any living system cannot over time exceed the quality of the environment in which it is found. Of course, this is a process that is subject to many feedback processes: in today's terminology the drivers of ecosystem change. The Millennium Ecosystem Assessment (MA, 2005a) defined a new conceptual framework (MA, 2003), placing emphasis on the management of the environment to deliver ecosystem services, and through those services to enhance human well-being (McDonald & Marcotullio, chapter x.x. in this book). Well-being is more than simply human health, and reflects a more holistic approach. But to deliver better human health outcomes, we need to have healthy ecosystems – i.e. ecosystems that are able to continually deliver services to people and the biosphere.

One approach to solving these issues has become known as the ecohydrology approach. This approach links Ecology and Hydrology – sometimes combined (as in UNESCO 2009c) as ecohydrology (Bridgewater, 2002; Wagner, Marsalek and Breil, 2008). Ecohydrology has objectives that can be largely defined by the people and societies dependent on the ecosystem and associated water resources.
For wetlands there are four key points that underscore exactly what Ecohydrology is *viz*:

- Integrating water and biodiversity science at management relevant spatial and temporal scales;
- Understanding that ecological change is inevitable, and the role of people in managing change;
- Understanding the role of ecosystem services;
- Using ecosystem properties as indicators of change.

Linking these four points the natural and the social sciences must be brought together, preferably using the Ecosystem Approach developed by the Convention on biological diversity (CBD) (see Alfsen, chapter x.x. in this book). The Ecosystem Approach has, as its key feature, the relationship between people and the rest of the biosphere, and how that relationship is managed. The CBD website has full details of the evolution and current status of the Ecosystem approach (CBD 2009), but see also Sheppard (2004) for another perspective.
This organising framework deals with "natural" wetland systems attention and is also applicable to artificial wetlands constructed *inter alia* for sewage treatment, and for amelioration of flood plains. The role of such so-called artificial systems in ensuring continued functioning of linked ecological systems and maximising the expression of wetland biodiversity in urban and peri-urban systems is particularly important.

The need for maintaining and enhancing urban and suburban populations of wildlife has thus greatly increased in recent decades (Washington 1978). A key issue is that urban planners often have insufficient awareness and expertise in wildlife matters by (Davey 1967, Geis 1980). This lack of knowledge is often compounded by inadequate support from resource agencies for the development of appropriate strategies for wetland ecosystem conservation and management and their subsequent implementation. The solution to this dilemma is to encourage greater collaboration between agencies responsible for biodiversity and ecosystem management and municipal planners (Greer 1983) and to ensure planners are more alert to the link between wildlife (biodiversity) and the delivery of ecosystem services (MA 2005b).

Restoration of wetland features to encourage particular features is an essential part of urban wetland management. Eglington *et al*. (2008) show that shallow, small-scale flooded areas are of critical importance for breeding waders. Management tools such as foot drains, coupled with appropriate hydrological management, provide a means of retaining water throughout the breeding season. While their paper refers to a broader landscape approach, there is every reason to use these techniques in an appropriate urban environment. Installation of these features is relatively simple, but maintaining sufficient water levels within the system is critical, especially in the face of increasingly unpredictable water supplies associated with climate change – and that is exacerbated in urban environments.

Similarly, Smart et al. (2006) emphasise that "wet" features, of critical importance for breeding redshank which are common on coastal marshes, can be deliberately established on inland sites. Coastal marshes are less and less common and frequently threatened by dynamic coastal processes, whereas inland marshes are more abundant but largely unsuitable for breeding waders at present. They analyse the scope for improving the management of inland marshes for breeding redshank. As habitat suitable for breeding redshank frequently supports a range of other wader species, they propose this information can also direct management efforts to improve breeding wader populations in the wider countryside.

**Healthy wetlands, Healthy people.**

For urban areas, links between nature and health are often seen as important – and often in combative terms (see Tzoulas & Greening, chapter x.x. in this book). Concern about health and the environment is essentially concern about the relationships that exist between people and the rest of the biosphere and people frequently handle these relationships poorly. The need to integrate more fully the goals of conservation and ecosystem management and health ethics for a sustainable society is becoming ever clearer (Honari *et al*., 1999 other refs), and this is especially true for wetlands.

From the perspective of human health, wetlands (as defined by the Ramsar Convention, Ramsar, 2009b) have a real identity crisis. They are often seen simply as human health hazards, with malaria, bilharzias, and a whole host of other parasitic diseases typically associated with them. Two centuries ago, the dank surroundings of lakes and, worse, swamps were enough to provoke people into believing that to be simply close to such a landscape feature was to risk catching a fever. Urban wetlands suffered especially as people were uncomfortable at living next to what was seen as a source of disease

Recently, there has been an upturn in the rate of emergence or re-emergence of infectious diseases associated with wetlands, and those in urban fringes are especially concerned. Factors contributing substantially to this trend include intensified human encroachment on natural environments;

- reductions in biodiversity (including natural predators of vector organisms);
- habitat alterations that lead to changes in the number of vector breeding sites or in reservoir host distribution;
- niche invasions or interspecies host transfers;
- Human-induced genetic changes of disease vectors or pathogens (such as mosquito resistance to pesticides or emergence of antibiotic-resistant bacteria); and environmental contamination by infectious disease agents. WHO, 2007.

Water-related diseases affect over 2 billion people a year. Providing clean water and sanitation to poor communities would take pressure off their need to unwisely use wetland ecosystems, reduce waste flows and improve freshwater and coastal water quality.
Many of the people and sites affected adversely by ecosystem changes are highly vulnerable - and ill-equipped to cope with further loss of ecosystem services. Ecosystem changes, with an increasing risk of non-linear changes in ecosystems, including accelerating, abrupt irreversible changes potentially have a catastrophic effect on human health. The increased likelihood of these non-linear changes arises, in part, from the loss of biodiversity and growing pressures from multiple direct drivers of ecosystem change.

In May 2002, at a speech at the American Museum of Natural History, the UN Secretary-General outlined a so-called WEHAB initiative, by identifying five major areas for the World Summit on Sustainable Development, areas where concrete results are both essential and achievable. The WEHAB areas were: **W**ater, **E**nergy, **H**ealth, **A**griculture, and **B**iodiversity. The initiative recognised for the first time, the critical importance of biodiversity in delivering services in each of the other sectors. And by including water, biodiversity, health and agriculture it also brought together key concerns for the Multilateral Environmental Agreements.

Although a WEHAB Working Group was established, and published *A Framework for Action on Biodiversity and Ecosystem Management* in August 2002, this initiative has largely disappeared from view, and even the url no longer works! Crucially, the WEHAB working group paper highlighted the need to shift focus from the proximate causes of biodiversity loss to the underlying causes. It focuses on two key Action Areas: integration of biodiversity – and principles of sustainable development – in country development programmes and economic sectors; and halting the loss of biodiversity and restoring, if possible, biodiversity in degraded areas, as part of reversing loss of environmental resources. While these principles are applicable everywhere, they are especially important for wetland systems.

Importantly, reflecting the close linkage between the WEHAB framework and the Millennium Development Goals (MDGs) (UN, 2009), the two Action Areas in this WEHAB paper are built upon and consistent with targets of MDG 7 to 'ensure environmental sustainability.' The action frameworks provide indicative targets or milestones, with examples of activities – a 'menu' for further development of activities. While the linkages between biodiversity and the health aspects of development are still little understood, Harvard (2007) has an example of some key work in this regard.

Ideally, we should be building on biodiversity linkages evident between the five WEHAB areas. And yet, vital though it seemed at the time, WEHAB has not found much favour since the lead-up to the Johannesburg summit. With the theme of "Healthy wetlands, Healthy people", it represents a latent framework for the wetland biodiversity community to develop and use. However, we need to develop specific strategies, tools and ways of measuring success – such work is being undertaken through the Ramsar Convention

Science and Technical Review Panel (Ramsar 2009c). This will include monitoring ecosystem functions in all parts of the world and developing environmental assessment and indicators.

Human health is not just about being not sick, however. The Millennium Assessment uses rather the term “human well-being”. Solving issues of poverty and management of natural disasters are critical to achieving human well-being, as recognised by the last Ramsar Conference of the Parties. (Ramsar, 2009d). For the poor, food security depends to a large extent on biodiversity, through direct consumption of wild foods, wild plants for farm production, medicines, fuel, and the trading in species and products. Conversely, loss and change of biodiversity can increase hunger and food insecurity. Wetland ecosystem degradation means less water for people, crops and livestock, lower crop yields, and higher risks of natural disasters. Nevertheless, the relationship between biodiversity and poverty is complex and not linear. This is exemplified through human – wildlife conflicts, increased mobility of pests and diseases, and introduction of invasive species, innocently or deliberately. And nowhere more obviously than in urban wetlands.

**Future research directions**

Wetlands in an urban environment pose research and knowledge management challenges not just from the physical and biological environments, but also from the socio-economic and cultural environments. Elaborating research programmes that seek to integrate these worlds, as well as testing the resilience limits of each are essential to enhance our understanding of urban wetlands.

Additionally, understanding the physical and biological effects of above and ground water flows is another key element. This is of course, essential and special in urban areas that are close to or atop Karstic systems – but it applies more generally as well. Wetlands are often surface expressions of the groundwater components – and may even be indicators of the health of such ground water systems. (Semeniuk, 2007).

Accordingly, the list below is a sample of 10 key areas which need further study, or which are embryonic research areas deserving of future attention.

1. Understanding the range and distribution of urban wetland types, including lakes, rivers, swamps and groundwater aquifers.

2. Identifying how different urban wetland types are reacting to current and projected rates of ground water abstraction and how recharge from surface wetlands to groundwater can be improved.

3. Examining the consequences of global change (including climate change) on the loss and degradation of urban wetland biodiversity, including species that cannot relocate and migratory species that rely on a number of wetlands at different stages of their lifecycle.

4. Building an understanding of urban wetland ecosystem connectivity in space and time in the urban environment.

5. Testing how much continuing loss and degradation of urban wetlands is leading to reduction in the delivery of wetland ecosystem services, and examining the demand for these services, and the consequences of their reduction/loss on human health.
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6. Examining the science-policy interfaces necessary to ensure the cross-sectoral focus that operates on urban wetland ecosystems can be developed to allow policy makers and decision makers to conserve and manage wetland ecosystems and their services in the context of achieving sustainable development and improving human well-being.

7. Urban wetlands deliver a wide range of critical and important services (e.g. fish and fibre, water supply, water purification, coastal protection, recreational opportunities and increasingly, tourism) vital for human well-being. Understanding the economic valuation of these services is critical to engaging in the broad debate about management of ecosystems, the biodiversity that supports those ecosystems and how to maintain the natural functioning of wetlands.

8. Urban wetland loss and degradation has primarily been driven by land conversion and infrastructure development, water abstraction, eutrophication, pollution and over-exploitation. Research into the balance between these threats is needed to ensure long-term conservation and management of wetland ecosystems.

9. Since management of wetlands and water resources is most successfully addressed through integrated management at the river (or lake or aquifer) basin scale; understanding how wetlands in an fragmented urban environment can persist and successfully deliver ecosystem services.

10. Research into the application of the wise use principle and guidelines of the Ramsar Convention (Bridgewater, 2008), and its role in maintaining ecosystem services of the wetland in urban environments..

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# Chapter 4.5
# The role of ecosystem services in contemporary urban planning

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## Introduction

Urban spatial planning has traditionally meant planning “for development”. Due to later decades´ pressing challenges related to the global biodiversity crisis and climate change, the planning mode has shifted towards “sustainable development” of cities. Today urban planners interested in achieving sustainable development, or “sustainable cities”, adopt different approaches in plans and designs for cities. Despite that planning nowadays includes sustainability as a central criterion when laying out roads, streets, buildings and other components of the built environment, it is often argued that conventional planning practices ignore the natural configuration of the land during the planning stages (Benedict and McMahon 2002). As a consequence ecosystems are rapidly becoming fragmented, transformed, or entirely lost, causing loss of ecosystem services, such as impoverishing water and air quality. This eventually this erodes ecosystem resilience, or the capacity of natural systems to buffer and reduce disturbances like heat waves, flooding, pollution, and anthropocentrically induced management mistakes.

In many countries today, the pace of urban land development far exceeds the rate of population growth. For example, the amount of urbanized land in the United States increased by 47% between 1982 and 1997. During the same period, the population grew by only 17% (Fulton et al. 2001). Moreover, across the largest 100 metropolitan areas in the U.S., employment decentralization have become the norm, with only 22% of urban residents working within three miles of city centers and over 35% working more than ten miles from centers. As a consequence, air pollution from traffic emissions increases, adding to greenhouse gases and eventually to climate change. This has led many planners to realize that the problem is not growth itself, but the *pattern* of growth (Daniels and Lapping 2005).

Urban Sprawl has been identified as America’s leading land use problem (Freilich 1999). There are several definitions in the literature of what urban sprawl is, but it generally refers to the spread of urban congestion into adjoining suburbs and rural areas, leading to the loss of ecosystems, or as “low-density, dispersal automobile dependent land use patterns” (Litman 2009).

There exists a whole arsenal of strategies that modern-day policy makers and planners can adopt to steer away from unsustainable urban growth in and around cities (see i.e. Doremus 2003). Of key influence for integrating ecology in urban planning has been Ian McHarg’s work on comprehensive, ecologically based planning and design (McHarg 1969). The applicability of systematic land-use planning for determining areas for development, or for conservation involving the system of map overlays of different categories of natural features (e.g. hydrology, geology, soils, vegetation, and wildlife), represents a prominent feature of this approach. Similarly, systematic conservation planning (Margules and Pressey 2000) has more recently emerged as a range of methods to determine, implement and manage a set of areas containing desired conservation targets with the minimum expenditure of resources (Gordon et al. 2009).

In this chapter I review two of the most prevalent planning strategies proposed to combat urban sprawl, i.e. *smart growth theory* and *green infrastructure planning*. The former is predominantly derived from frustration over the failure of American planning projects, and is becoming increasingly adopted among planners in North-American and European metropolitan regions. The latter is predominantly proposed by ecologists and conservationists, and has been influential in conservation planning in many countries. By elucidating some of the characteristic features and propositions of these seemingly disparate approaches to combat urban sprawl, I set these in communication with insights pertaining to the generation and management of urban ecosystem services, as identified in recently emerged empirical studies. I thoroughly discuss the implications of the two approaches as well as shed light on urban designs that hold potential to be developed into more exhaustive frameworks for governance of urban ecosystem services. I conclude by summarizing the major insights of this chapter.

**Urban sprawl and ecosystem services**

Urban development is claimed to generate some of the greatest local extinction rates of species, and frequently eradicates a large proportion of native flora and fauna (McKinney 2002). Due to that land use in urban areas has a particularly strong influence on biodiversity, some scholars predict that it will likely have the largest effect on terrestrial ecosystems in the coming century (Sala et al., 2000). As recent studies of satellite data indicate (Hansen et al., 2004), land use continues to intensify in formerly occupied areas (e.g., urban areas) often with an overlap of location of areas rich of biodiversity (Ricketts and Imhoff, 2003). This is due to that humans tend to settle in areas with high ecosystem productivity with people most dense on lands suitable for agriculture or in low elevation and coastal areas with high levels of biodiversity (Colding 2007).

The uncontrolled spread of urban congestion into adjoining suburbs and rural areas often leads to a net loss of natural habitats and consequently to the erosion of many ecosystem services. On the other hand, urban biodiversity usually peaks at the suburban scale of cityscapes, where species tend to be ‘urban adapters’ (Blair 2001), confined to forest edges and adjacent open lands. Animals within this category often exploit many resources, including human-subsidized foods (McKinney 2002). Such species tend also be less sensitive to the presence of humans and pets. It is important to recognize that while biodiversity often peak at suburban levels, urban sprawl may lead to the loss of overall regional biodiversity in the urban landscape (Colding and Folke 2009).

There has so far been hardly any attempt to link urban planning for the sustainable governance of ecosystem services. It can be argued, though, that many ecosystem services provided by natural systems resemble those services that urban planning strive for, i.e. facilitating and distributing services for the general public, freely enjoyed on a day-to-day basis. Like public spaces, ecosystem services are *strategically critical* to the health and quality of life of a city environment. While *provisioning* services (products obtained from ecosystems like food and fiber), often are privately consumed they represent priced goods that may be enjoyed by a multitude of urban residents at markets. On the other hand, *regulating* services (benefits obtained from regulation of ecosystem processes like air- and water filtration), *cultural* services (nonmaterial benefits obtained from ecosystems, like spiritual enrichment, cognitive development, recreation, and aesthetic experiences), and *supporting* services (necessary for production of all other ecosystem services), are considerable more difficult to evaluate in economic terms. In and around cities, this group of services provides a range of "free" services enjoyed by a greater set of urban dwellers. Since they are not adequately priced (and valued), they run the risk of becoming mismanaged, adversely affecting most dwellers. It is therefore essential to develop institutions and designs systems for their sustainable management.

Given that urban sprawl represents one of the leading land use problems in many city regions (Freilich 1999), both "smart growth planning" and "green infrastructure planning" have become popular in many countries in coming to grip with this phenomenon. They are more closely described in the following.

**Green infrastructure planning**

Having its roots in planning and conservation efforts that started 150 years ago, "green infrastructure" is an approach for combating the adverse effects on biodiversity resulting from urban sprawl. Green infrastructure can be described as "an interconnected network of green space that conserves natural ecosystem values and functions and provides associated benefits to human populations" (Benedict and McMahon 2002: 12). Much of the foundation of green infrastructure planning draw on the principles of island biogeography theory (MacArthur and Wilson 1967), inspired by three patterns which had long been recognized as part of island ecology:

- that larger islands tend to support more species
- that remote islands tend to support fewer species
- that there is often a turnover of species on islands, with newcomers replacing other species that become extinct (Forbes et al. 1997).

The application of island biogeography principles to urban settings has been widely used in the planning and design of terrestrial nature reserve. When transferring these principles to terrestrial systems, the key assumption made is that 'habitats' or reserve sites themselves cannot function as isolated parts, or "islands", when surrounded by land of different types that is hostile to the species living within the reserves (Forbes et al. 1997). The surrounded land to a reserve, the "matrix", or the "background ecological system" has the highest degree of connectivity of a landscape, largely determines to what extent organisms may move or spread to other natural habitat patches. In the design of habitat networks, connectivity is the central objective to achieve in green infrastructure planning. Connectivity is a measure of how connected or spatially continuous a network is (Forman 1995). In green infrastructure planning, this can be achieved by way of habitat corridors, i.e. areas of land that facilitates species movement between larger habitats (Forbes et al. 1997). This involves protecting, creating, and restoring connections between parks, reserves, and other important ecological areas. Such habitat corridors may include hedge rows, road and railway verges, strings of open space sites, parkways, and riparian trails that function as a route for species movement. In order to avoid potential negative effects of habitat connections (see Dawson 1994, Scmid 1995), wildlife biologists usually recommend it is better to protect existing connections between habitats than to create new ones (Forbes et al. 1997). Green infrastructure planning therefore is said to work best when the framework pre-identifies both ecologically significant lands and suitable development areas (Benedict and McMahon 2002).

One prominent example of habitat networks that have long played a significant role in the development of urban, sub-urban, and even rural areas is greenways, defined as a "network of land containing linear elements that are planned, designed and managed for multiple purposes including ecological, recreational, cultural, aesthetic, or other purposes compatible with the concept of sustainable land-use" (Ahern 1995: 134). Urban greenway systems date back to the 19th century, as part of an evolving landscape form that had its roots in the planning concept of medieval towns (Searns 1995). Besides ecological, recreational, and heritage motives, urban greenways need to comply with a core set of human dimensions to improve their success in a community, including cleanliness, naturalness, aesthetics, safety, access, and appropriateness of development (Gobster and Westphal 2004). Greenways are therefore mainly designed and managed to provide recreation and amenity rather than for the protection of biodiversity (Benedict and McMahon 2002).

The principles for green infrastructure are also used by planners in management of greenbelts and green wedges, i.e. belts of predominantly undeveloped land to limit urban sprawl and to connect rural areas with suburbs and urban areas. While the greenbelt idea originated from Ebenezer Howard's notion of a model "Garden City" in England in the late 19th century, contemporary planners often apply the ideas of biological core areas, corridors, and buffer zones on greenbelts in master plans for cities (RUFS 2001). To what degree proponents of green infrastructure planning is in favor of compact urban development to combat urban sprawl is hard to determine. However, the view is sometimes explicitly voiced among scholars and practitioners (see e.g. Benedict and McMahon 2002; Daniels and Lapping 2009). The two approaches are however largely compatible with both advocating the preservation of natural habitats in urban fringe and rural areas.

**Smart growth planning**

Due to the explosive sprawl witnessed in many peri-urban areas, matched by a decline or slower growth in the central cities and older suburbs, Katz (2002) describes how a new planning approach arose over a decade ago in the United States as a reaction to the widespread frustration with sprawling development patterns. This new thinking – commonly referred to as *smart growth* or *New Urbanism* - argues that metropolitan settings can grow in radically different directions if only major and deliberate government policies on land use, infrastructure, and taxation are adopted.

The term smart growth (abbreviated as SG in the following) became more widely popular when Maryland's 1997 legislation provided planning initiatives to promote compact development to combat sprawl (Daniels and Lapping 2009). In parallel with "compact urban development" that concentrates growth in the center of a city to avoid urban sprawl, SG advocates compact, transit-oriented, walkable, bicycle-friendly land use, including mixed-use development with a range of housing choices. A dominant feature of urban designs involving SG is *accessibility*, e.g. the ability for urban residents to reach desired goods, services and activities within close ("walkable") distance (**Figure 1**). Planners adopting SG strive therefore to locate new development within already developed areas, encouraging infill development and redevelopment of older facilities and brownfields.

Proponents of SG planning argue that current planning strategies of land use and transport patterns often reflect distorted market-oriented policies rather than reflecting true consumer preferences. Therefore, SG strategies are said to represent market reforms to “correct” these distortions with the goal to increase efficiency and equity, and making consumers and the economy better off overall” (Katz 2002; Litman 2009). Strategies adopted to change current consumption behavior may range from adopting various pricing mechanisms such as additional cost fees for housing that require more dispersed infrastructure and for parking in sprawling areas, to strict regulations and favorable tax policies, to investments in public transit (for more, see Litman (2009)).

While the SG framework predominantly emphasizes social benefits, policy makers often point to environmental benefits to justify city compactions. Localization of new development within already developed areas, infill development and redevelopment of brownfields are often claimed as efficient ways for land use consumption. Such land-use developments are said to spare more remotely located ecosystems from being transformed into urban fringe development that threatens prime farmlands, wetlands, and unique wildlife habitat (Litman 2009).

The SG framework is also often labeled as a land-use policy for combating climate change (Chatterjee 2009). While compact growth has been shown to improve long-term air quality at a geographic scale compatible with secondary pollution formation and transport due to reduced vehicle travel (Stone et al. 2007), very few studies have looked into this relationship at more depth. Even though smart growth may reduce green house gas emissions in metropolitan areas, this proposition needs to be further determined. In a rigorous overview study by Susan Handy (2005), exploring how well the available evidence supports SG planning propositions about the relationships between transportation and land use, she concludes that these questions have not yet been fully resolved and that the ability to predict the impacts of smart growth policies still remains limited.

SG land-use development as a planning policy has also been questioned in terms of its feasibility and acceptability to the communities affected. Breheny (1997) asks whether compaction can be acceptable to the communities affected by it and questions to what degree high levels of urban compaction can be achieved in practice. For one thing there are limits of brownfield and infill sites for housing development and these are also associated with high construction costs. Moreover, Breheny also doubts whether it is feasible to assume that companies will be persuaded to return to city core areas they once have abandoned. A recent study by Filion (2009) shows that high-density multifunctional development nodes in the Toronto metropolitan region have had limited capacity over recent years to attract new office and retail development, as well as meeting walking and public transit patronage objectives. Filion asserts that high-density suburban node developments are vulnerable to economic recessions.

**Generation of urban ecosystem services**

Recent urban ecological research reveal that the generation of many types of ecosystem services depend on locally managed green areas and the willingness of their stewards to manage and sustain these habitats (Colding et al. 2006). Such habitats predominantly represent semi-natural ecosystems, i.e. ecosystems with a high degree of human impact that are managed by so called “green-area user groups” by way of informal institutions (Colding et al. 2006). Green-area user groups involve groups and landholders that manage land individually or in cooperative form, such as in associations, clubs, or similar organizational units (Barthel et al. 2005; Elmqvist et al. 2004; Elmqvist et al. 2008), and where management is based on leisure and recreational activities or conducted through civil interaction, rather than based upon profession (Ernstsson et al. 2009).

Semi-natural ecosystems have until recently been regarded as having little ecological value by ecologists, and have therefore been largely ignored in ecological inventories. They have therefore seldom been integrated in conservation planning frameworks. A good example of semi-natural ecosystems constitute private domestic gardens that often cover extensive parts of the landscape in urban settings and often form quite coherent greenbelts in cities suitable for migration and species movement (see e.g. Jeffcote 1993; Gaston et al. 2005; Colding et al. 2006). In a study of greater Stockholm, Sweden, Colding et al. (2006) showed that over 80% of the green cover of suburban real estates (i.e. ‘‘low-building’’ and ‘‘part-time’’ summer houses) consist of garden cover when all buildings and impermeable surfaces were deduced. Furthermore, allotment areas, domestic gardens, and golf courses provided numerous ecosystem services (**Table 1**) and covered nearly 18% of the surveyed land area, representing well over twice the area covered by protected areas and over half of the land demarcated as green wedges. Studies of other cities reveal a similar pattern, with domestic gardens covering as much as 23% of the land area in Sheffield (Gaston et al. 2005) and as much as 27% in Leicester, England (Jeffcote 1993). These semi-natural urban landforms also house a considerable rich number of flora and fauna, including rare and threatened ones (see e.g., Blair 1996; Maurer et al. 2000; Thompson et al. 2003).

Smaller habitat parcels like allotment areas, community gardens, and cemeteries have also been found to sustain considerable pollinator and invertebrate diversity in cities and contribute to the maintenance of ecosystem services like pollination, seed dispersal, and insect-pest regulation (Cane 2001; Colding et al. 2006; Colding in press; Anderson et al. 2007; Hougner et al. 2006). Urban golf courses contribute to provide important habitats for species in urban settings. In greater Stockholm over a quarter of all available permanent, freshwater ponds is located on golf course that contribute in sustaining metapopulations of both threatened amphibians and macroinvertebrates (Colding et al. 2009). More broadly, urban golf courses have been shown to positively contribute to biodiversity, and if managed appropriately provide a measure for restoring and enhancing biodiversity in urban settings and to promote critical ecosystem services, like species migration, pollination, natural pest control, and even water purification (Colding and Folke 2009). Educational institutions may sometimes harbor the largest and last remaining green areas in highly urban developed settings and can be extremely significant in terms of biodiversity (e.g. Patwardhan et al. 2001; Kulkarni et al. 2001).

**The simplification of the urban landscape**

Land-cover maps often classify biological patches in built-up areas as physical ones, thereby simplifying the fine-grained texture of the urban landscape and the small-scale pattern of juxtaposed semi-natural land uses. For example, much semi-natural land, including all domestic gardens are classified as ‘‘built-up’’ lands in official land-classification statistics of Sweden (Colding et al. 2006) - a situation mirrored in most city-regions of the world (Foresman et al. 1997). Such oversimplified land classification result in cities assumed to have less green cover than actually is the case. Furthermore, it discounts the essential landscape processes that are linked to semi-natural land uses in suburban areas and which contribute to the support of organism groups and populations in larger natural habitats like nature reserves due "ecological land-use complementation" (**Figure 2**). Such oversimplification also shapes peoples' attitudes toward urban lands that creates an unfortunate divide between urban areas for biodiversity conservation and areas used for other purposes, when, in reality, species utilize a number of different habitats in the urban landscape (Melles et al. 2003). This largely creates impressions of the urban landscape being "binary", consisting merely of developed and undeveloped natural lands.

Recent studies show opportunity to improve intensively managed landscapes, e.g., urban and agricultural areas dominated by human activities, through greater engagement of ecologists and other urban practitioners in the process of ecological landscape design (Lovell and Johnston 2008). Such an approach encourages the exploration of multifunctional solutions to meet demands of growing populations, while minimizing the negative impacts of human activities on the environment (Lovell and Johnston 2008). One critical objective in the creation of such multifunctional landscapes is to increase heterogeneity in the spatial pattern of the landscape itself (ibid) such as through ecological land-use complementation (Colding 2007). By this token the developed matrix in the urban landscape holds considerable potential to be designed and configured in ways that improve conditions for both humans and other biological organism groups. This, however, requires that semi-natural green spaces in a multitude of forms be preserved and nurtured in developed areas.

There exists a multitude of ways for how both existing and new green sites can be designed in compact cities to provide a range of ecosystem services (see e.g. Jim 2004). For example, ecological engineering, which operates at the interface between technology and environment, can be explored to design and restore ecosystems. Mitsch and Jorgensen (1989) emphasize that ecological engineering is about designing societal services such that they benefit society and nature, and that such designs be system-based and integrate society with its natural environment (Mitsch 1993; 1996). Ecological engineering play a critical role in the restoration of ecosystems that have been substantially disturbed by human activities such as environmental pollution or land disturbance.

**Implications of smart growth and green infrastructure planning**

Both the green infrastructure and smart growth planning paradigms can be argued to reinforce the stereotypic view that developed urban landscapes consists of lands of low ecological value, i.e. the "built" environment, and that nature best is preserved near and beyond the urban fringe. The smart growth planning paradigm does this on grounds that compaction reduces per capita land consumption. I have here, however, highlighted that much urban and suburban land use positively contribute to the generation of ecosystem services and that opportunity exists to improve intensively managed landscapes to bolster this potential further. However, compaction severely reduces opportunity for people to directly engage with nature. In the SG planning paradigm, a greater fraction of the urban populace will inevitable become “landless” due to that residents increasingly will come to live in multi-family dwellings without associated gardens. Hence, much of the urban population is removed from the opportunity to own land, to have an input into the use of urban land, and arguably, the ability to understand or have concern for land conservation outside and inside cities (Kendle and Forbes 1997). It will also be extremely hard to motivate the existence of smaller parcels of semi-natural land such as allotment areas, community gardens, or other forms of urban agriculture in a compact development scenario. Sharing the concerns of Breheny (1997) regarding feasibility and acceptability, it will be ethically difficult to exclude non-gardeners in such property rights arrangements. It would also be impossible for governments to subsidize such land uses through public means as presently done in some countries.

While public green spaces may exist in densely populated areas, certain dimensions to public domains are particularly important for understanding the enclosure behind public lands in cities (Lee and Webster 2006; Colding in press). One is ‘congestion’, referring to the degree of competition within a public domain, or the numbers of individuals who jointly consume it, and the range of tastes amongst those individuals (or groups) (Lee and Webster 2006). When public domains become congested, they need governing in such a way that use rights become clear and enforceable; however, to design, create and administer such a system of rights is a costly business in terms of transaction costs (Colding in press). When congestion generates excessive costs then there is likely to be pressure to reform property rights and subdivide the public domain either into private domains or smaller public domains (e.g. club goods).

Another dimension of public domains is ‘separation of attributes’ which is likely to be established if it is cost effective and a sufficient demand exists for this. For example, the rights regarding the different attributes of a park can be separated and allocated to various groups of consumers such as recreational space for sports, habitats for wildlife, restaurants etc. In a congested public domain, markets and governments will strive towards a separation of these rights according to different attributes (Lee and Webster 2006). A telling example of the separation of attributes is public parks that have degraded due to underfunding in Stockholm city during economic recessions. In conjunction to restoration of these parks, local government agencies open up for several types of private establishments, such as cafés, amusement areas, etc to finance costs of restoration. This inevitable results in the successive loss of green space.

The green infrastructure planning paradigm arguably also discounts the role that semi-natural land use may play in cities. It typically focuses on preserving larger tracts of land beyond the urban fringe, and the designation of land for nature preserves or greenbelts. The emphasis on linear corridors as links in such habitat networks hardly ever consider cohesive domestic garden belts, nor golf courses despite that they often represent biological assets in urban settings (Colding and Folke 2009). Suffice to say, this planning paradigm has been shaped by insights derived from ecological studies of more pristine ecosystems and the island biography theory.

The designation of protected areas, green belts, and green wedges has so far been the central tenet in green infrastructure planning. Protected area management is, however, costly for most governments both in terms of land acquisition and management (Colding et al. 2006). Many parts of London’s protected green belt have been severely degraded due to lack of money partitioned for management, and as a result have been largely avoided by local inhabitants for recreation (Greater London Authority 2001). In response to this, local boroughs initiated the creation of community forests that encompass several hundred hectares of green belt land for residents living nearby to manage and maintain.

It is important to note that informal management of urban green areas for the most part bear their own cost in terms of management expenditure and transaction costs. Such management is mainly voluntarily based. In contrast, most parks and protected areas are managed through public means, with government expenditures, making such management more vulnerable to economic recession and political power shifts (Colding et al. 2006).

### The pedagogic role of nature in cities

Insights developed in environmental psychology shows that ecologically impoverished metropolitan areas contribute to increased 'environmental generational amnesia' among city dwellers (Miller 2005). People that are not interacting with ecosystems early and regularly are less likely to support necessary environmental efforts in society (Kaplan et al. 1998), such as economic measures to combat climate change. Hence, from a planning perspective, it is important to consider the *pedagogic responsibility* that cities hold for mitigating further ecological illiteracy among urban populations. In this context many locally managed, semi-natural ecosystems represent important 'learning arenas' for ecosystem services, as they provide visible and measurable examples of human interaction with dynamic ecosystems (cf. Grimm et al 2008). To gain the much needed, broad-based public support for a sustainable use of ecosystems, inside and outside cities, the places where people live and work need also to offer opportunities for meaningful interactions with functioning ecosystems ( Rosenzweig 2003; Miller 2005). In this respect and in order to help mitigate the growing disconnection of urban residents from nature (Pyle 1978, 1993), novel property right designs and land-management approaches, of which some have been dealt with here, need to be developed that may foster the pedagogic role that engagements with nature can foster.

To date, a number of environmental organizations and neighborhood associations are demanding a voice in zoning and planning decisions that affect their communities (McDaniel and Alley, 2005); however, few approaches exist for their inclusion in biodiversity management activities. Research show that active land management can contribute to promote understanding about the feedback links between ecosystems and people by increasing environmental knowledge among urban populations where such knowledge tends to be low (Theodori et al. 1998; McDaniel and Alley 2005; McKinney, 2002). Kaplan and Kaplan (1989) even argue that people who do not experience nature early and regularly are less likely to develop strong emotional ties that motivate costly conservation efforts in society. Against this background it is relevant to ask whether urban compaction, as advocated by proponents of smart growth planning and many green infrastructure planners is socially feasible. In relation to this, Fyson (1996) showed that public preference for house types and their locations is very much opposite of that advocated by proponents of smart growth planning. Also, marketing surveys carried out by housebuilders in the UK reveal a strong preference for houses with gardens, with people being twice as satisfied with their location in rural areas than those in urban/city areas (Breheny 1997). Likewise, overall satisfaction with housing was lowest in urban centers and highest in the most rural areas. While the compaction logic suggests a need to switch from low-density to higher-density houses and flats, attitude surveys suggest that people overwhelmingly prefer houses, particularly those with gardens (Breheny 1997). Even though preferences may be subject to change given new governmental policies and incentives, compact development advocators have a real dilemma to redirect such preferences. To some people it would be the same as violating strong norms and community sense.

**Concluding remarks**

Twenty eight years have passed since Ehrlich and Ehrlich (1981) first coined the term "ecosystem services". While the concept nowadays frequently is used in ecology and increasingly so in economic assessments, it is hardly find in the urban planning-oriented literature to date. This is likely due to that only a fraction of ecological studies have been devoted urban systems (Collins et al. 2000) and that there exists a time-lag before new premises are 'filtering' into planning processes. However, and as suggested in this chapter, there exist strong motives for integrating a wider set of urban residents in management of ecosystem services. Against this background, it may be unwise for planners to rely too strongly on one, single planning strategy for improving urban sustainability. Both the two major planning strategies reviewed in this chapter propose compact development growth to combat the adverse effects of urban sprawl. However, and as shown here, many types of ecosystem services are generated in the developed landscape, also in sprawling, suburban settings. Moreover, the significance of creating meaningful opportunity for a greater populace of urban residents is important to combat ecological illiteracy among burgeoning urban populations. Not least to build incentives for measures that involve potentially high costs for avoiding biodiversity loss and unwanted effects due to climate change. Such meaningful opportunity should also be provided for in land uses of the urban, developed matrix. As discussed here, the urban matrix is often more heterogeneous than often recognized, contributing to habitat diversity and thereby increasing landscape diversity.

A great deal of people in city-regions also prefers to live in locations and houses with access to gardens. Hence, it is hard to justify the compact growth scenario in the smart growth and green infrastructure planning paradigms. While much human activity destroys ecosystems at an alarming rate on earth presently, people are also important for generating and sustaining a great deal of ecosystem services. More studies need to be conducted to assess whether the environmental benefits of making compact cities overweigh those of dispersed settlement growth. Until we gain more knowledge, a durable planning strategy would be to foster approaches and urban designs that qualitatively improve the urban landscape. *How* such a landscape ideally should be designed to more efficiently preserve the urban landscape and its associated services is a pressing issue. I agree with proponents of compact growth that the *pattern* of urban growth needs to be redirected. However, instead of displacing community residents and steer population growth into the labyrinths of dense city cores with little access to natural habitats and by way of top-down planning initiatives seems utterly old-fashioned. A more viable strategy would instead be to nurture and support the civic initiatives to self-organize around various urban activities such as around urban agriculture, community gardening, and partaking in the design and management of urban parklands. Planners should also facilitate for integrating "urban commons" into comprehensive planning (Colding in press). Such common property systems are extremely rare in cities presently, but hold potential to contribute sustaining and greening the world's cities.

As comprehensively described by Jim (2004), there exist a whole aresenal of green designs that can be adopted in compact cities to provide a range of ecosystem services. Such activities will likely boost social capital, promote sense of place, and revitalize degraded neighborhoods. This will likely also create more attractive cities that foster environmental stewardship, provide new job opportunities and contribute to overall economic development of cities that is more in tune with the life-supporting processes that sustain life itself. We are only in the beginning of developing strategies and tools to more sustainably govern ecosystem services in cities, of which there exist a gap of knowledge more generally (MA 2005). Policy makers, urban designers and planners need therefore to a larger extent facilitate for more experimental designs in cities. Such strategies may gain from insights on adaptive co-management of ecosystems and lessons provided from sustainable natural resource management (Folke et al., 2003) to increase the potential for adaptive learning and avoiding vulnerability traps during the process of urban redevelopments.

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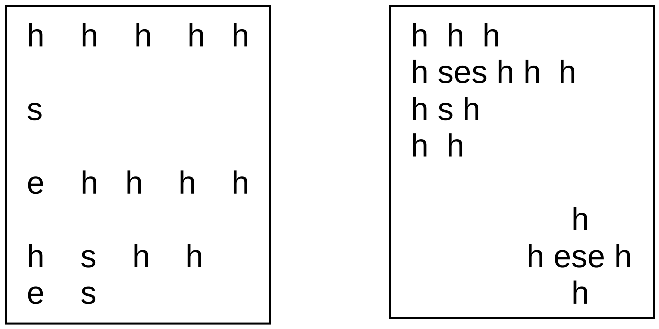
Table 1. Potential ecosystem services provided by three semi-natural green areas in Stockholm, Sweden. SOURCE: Colding et al. 2006.

| | **Allotment areas** | **Domestic gardens** | ***Golf courses*** |
|---|---|---|---|
| **Provisioning services** | | | |
| Fire wood | | X* | |
| Food (fruits & vegetables) | X* | X* | |
| Ornamental resources (flowers) | X* | X* | |
| **Cultural services** | | | |
| Aesthetic values | X | X | X |
| Inspiration | X* | X* | X* |
| Nature education | X* | X* | X |
| Recreation | X* | X* | X* |
| Social relations | X* | X | X* |
| **Regulating services** | | | |
| Air filtration | X | X | X |
| Erosion regulation | X | X | X |
| Noise reduction | X | X | X |
| Nutrient retention (in ponds) | | | X |
| Pest regulation | X | X | X |
| Regulation of microclimate | X | X | X |
| Surface water drainage | X* | X* | X* |
| **Supporting services** | | | |
| Habitat for flora & fauna | X* | X* | X* |
| Soil formation | X | X | X |
| Seed dispersal | X | X | X |
| Pollination | X* | X* | X |
| Water cycling | X | X | X |

*Indicates accentuated service in respective land use.

**Figure 1. Sprawl versus Smart Growth Land Use Patterns**
Both boxes contain the same overall density of housing (h), employment (e) and services (s), but on the left they are more dispersed and on the right they are more clustered, creating “villages”. Modified and adopted from Litman (2009).



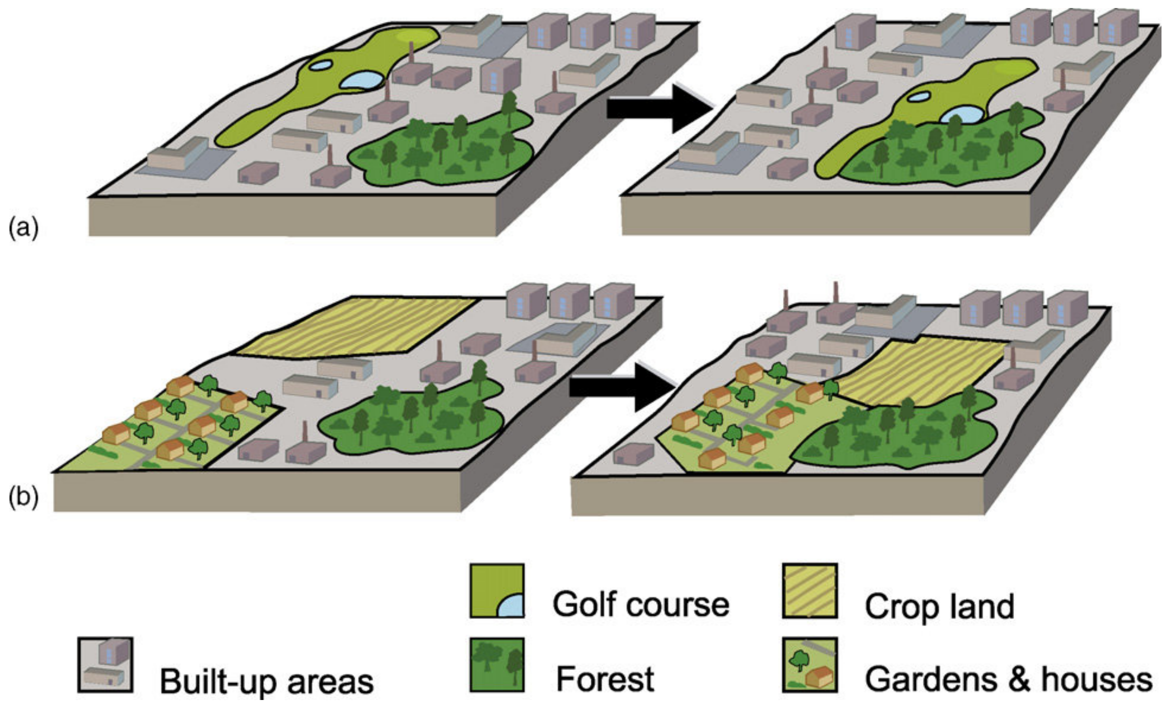



Figure 2. By adopting 'ecological land-use complementation' in urban spatial design, planners could promote ecosystem services. In situation (A) a golf course with freshwater ponds that is located adjacent to a forested area has greater potential to promote amphibians, relative to if it is located in isolation surrounded by urban built-up land. In this sense, the golf course and forested area complement each other, providing necessary habitats for amphibians to breed, forage and over-winter. Similarly, in (b) when urban gardens are clustered adjacent to forest patches and crop fields, pollinators may be promoted. Different pollinators may use gardens for collecting pollen and nectar resources, use adjacent forest habitats as nesting sites, and perform important pollination of food cultivars on adjacent crop fields. In this case, such a configuration could promote 'response diversity' to environmental stresses among pollinators. Source: Colding (2007).