Urban Ecology: Patterns of Population Growth and Ecological Effects

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Introductory article

Article Contents

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Currently, over 50% of the world's population lives in urban areas. By 2050, this estimate is expected to be 70%. This urban growth, however, is not uniformly distributed around the world. The majority of it will occur in developing nations and create megacities whose populations exceed at least 10 million people. Not all urban areas, however, are growing. Some are actually losing populations because of changing economic conditions and population demographics. Whether a city is growing or losing population, governances face unique challenges with respect to infrastructural, water and transportation needs. To meet these challenges, agencies within city government are cooperating by pooling resources and removing conflicting policies, partnering with the private sector to offset costs of infrastructure, and taking new approaches to design infrastructure. By linking ecological theory with urban design, a more integrative approach to create liveable spaces, which are sustainable, can be achieved in rapidly expanding and shrinking urban areas.

Urban Population Growth

By 2050, the world's population is projected to reach 8–9 billion people with more than 70% of the total population living in urban areas (**Figure 1**). The majority of people in the world did not always live in urban areas. In 1900, only 13% of world's population lived in urban areas. By 1950, the percentage of urban dwellers had increased to 29%. Currently, 50% of the world's population lives in cities, approximately 3.5 billion people.

Presently, the per cent of urban dwellers varies by nations and regions (**Figure 2** and **Figure 3**). For North America, New Zealand and Europe, the percentage exceeds 70%. Similarly, both the Caribbean and Latin American regions have urban populations exceeding 75%. By comparison, both Asia and Africa have less than 40% of their populations living in cities. By 2050, however, both Africa and Asia urban populations are projected to exceed 70%, whereas Australia, New Zealand and North American urban populations will exceed 90% (United Nations, 2008; **Figure 3**).

In 2007 developed nations had an estimated urban population of 909 million and their urban populations were projected to increase to 1.07 billion by 2050. By comparison, developing nations had an estimated urban population of 2.38 billion in 2007, which is projected to increase to 5.33 billion by 2050. Significant increases are projected for Asia (1.84 billion) and Africa (861 million). The urban populations in India and China are projected to increase by 625 and 574 million individuals, respectively. The urban population in Latin America, which includes Central and South America, is projected to increase by 641 million, whereas North America's urban population is projected to increase by 126 million with the greatest increase in the United States (115 million) (United Nations, 2008).

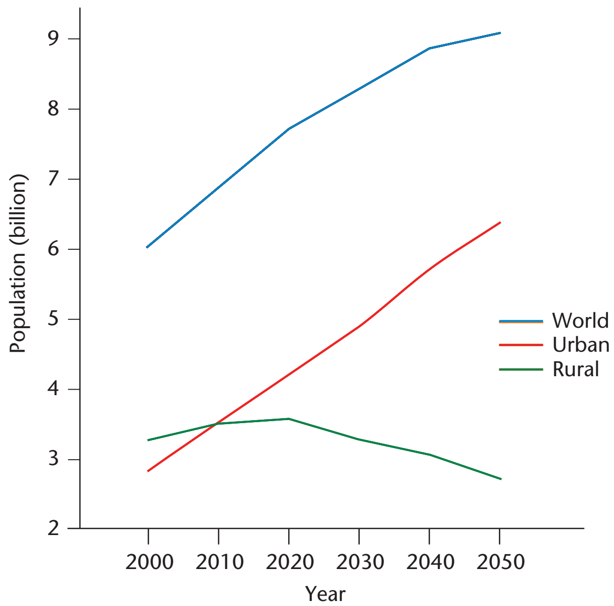

Figure 1 Estimated global population for the world, urban and rural areas from 2000 to 2050. Adapted from UN (2008).

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Not all regions, however, are projected to increase in urban population by 2050. For example, the Russian Federation and the Ukraine are projected to lose 19 and 8 million, respectively. Other Eastern European countries, such as Poland, Belarus, Estonia, Latvia, Lithuania, Hungary, Romania, Serbia, Croatia, Bosnia and Bulgaria are projected to decline by 30 million. By comparison, urban populations in Western Europe are projected to increase only by 44 million (United Nations, 2008).

An important element of projecting urban population growth is how does one characterise an urban area – city, metropolitan area and agglomeration. A city is often defined as a municipality or local jurisdiction such as the City of Paris, whereas a metropolitan area is often delimited economically as an entire labour market, the area where employees are drawn from. So, the metropolitan area of Paris extends far beyond the 'city' boundary and contains over 1000 cities (www.demographia.com/db-define.pdf). Moreover, a metropolitan area often contains both urban and rural lands.

By comparison, an agglomeration contains only urban lands that are connected by development. This definition for an urban area may seem appropriate because it contains only developed land. However, as urban areas grow together, their individual designation becomes increasingly harder to identify. For example, Washington DC and Baltimore, Maryland have grown together to form a single agglomeration. Likewise, Tokyo-Yokohama and Osaka-Kobe-Kyoto have grown into a single agglomeration. Should these areas be reported as a single agglomeration or should they be designated as different metropolitan areas that form a large urban extent? Drawing metropolitan boundaries can be subjective, but economic factors such as labour pools and commuting distance can help demarcate a metropolitan area (www.demographia.com/db-define.pdf). Consequently, lists of the largest cities in the world will vary depending on how urban areas are delineated and what is defined as urban. For this article we

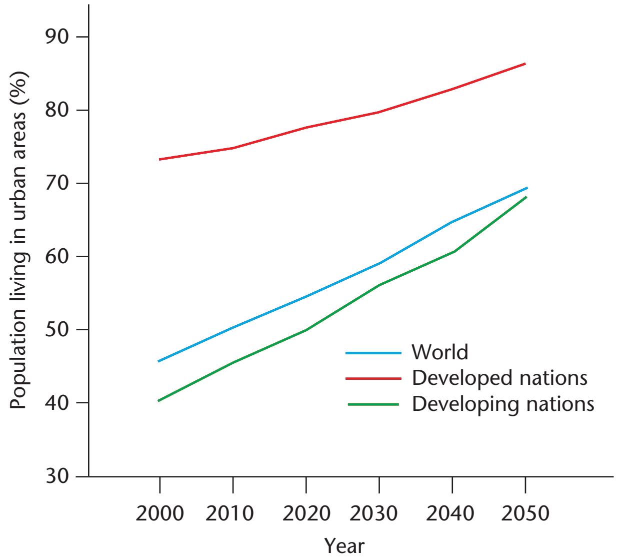

Figure 2 Estimated percentage of global population living in urban areas for the world, developed and developing nations from 2000 to 2050. Adapted from UN (2008).

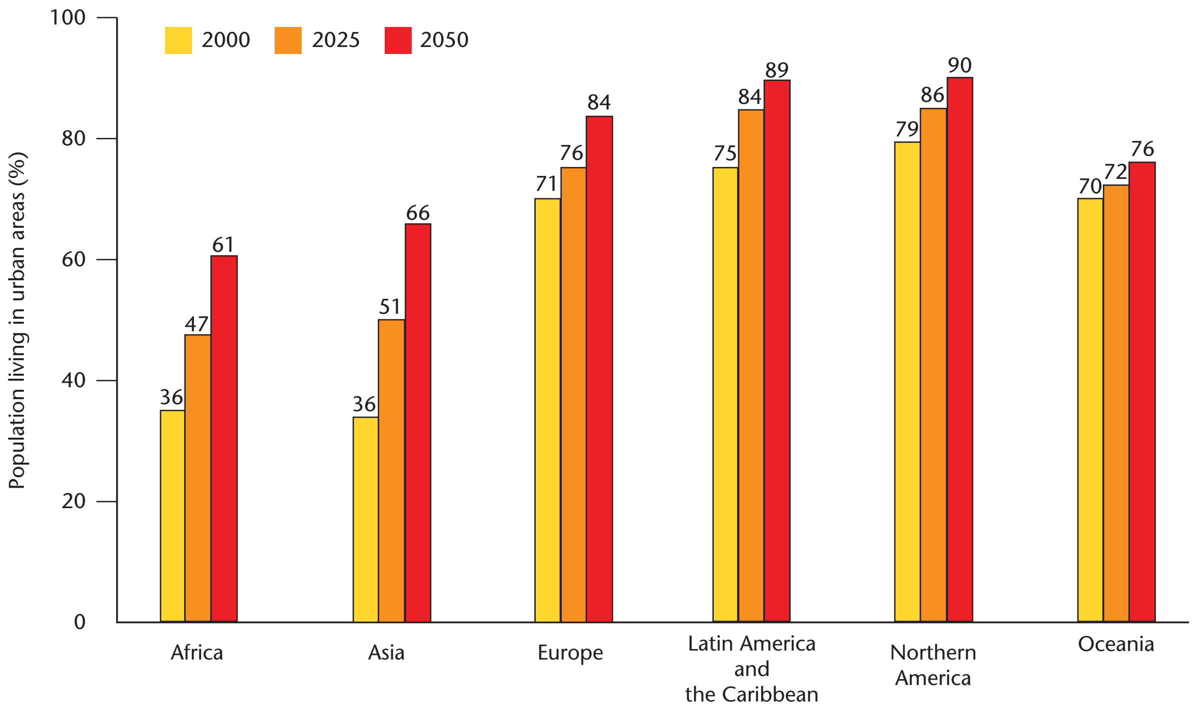

Figure 3 Estimated percentage of population in urban areas by geographical regions for 2010, 2025 and 2050. Modified from UN (2008).

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follow the definitions and designations used in Demographia World Urban Areas: Population and Projections (Demographia, 2010).

Based on Demographia (2010), the most populated city in the world is Tokyo-Yokohama, Japan with 35.2 million people. The second largest city is Jakarta, Indonesia with 22 million people. In fact, there are 7 cities whose population exceeds 20 million and 26 cities with populations greater than 10 million. Cities whose populations exceeds 10 million are often called megacities. Currently, the majority of these cities occur in developing nations. Further, there are 396 cities whose populations exceed 1 million and 736 cities with populations greater than 0.5 million.

The idea of megacities is not new. For instance, London, England was considered a megacity during the nineteenth century. There, however, are differences between industrialised megacities and developing megacities. First, the earlier, industrialised megacities grew slowly, thus enabling the urban area to 'absorb' the growth. Governments were able to plan and react accordingly. Today, megacities in developing countries are growing at phenomenal rates. Some cities are projected to increase by 50% over the next two decades (Morichi, 2005). Similarly, as industrial megacities grew, so did their economy, thus providing the financial foundation for investment, employment and growth. By comparison, megacities in developing countries often lack the investment capital needed to create the financial foundation for adequate infrastructure and expansion. Consequently urban poverty is increasing in many of the megacities in developing nations. This is not to say that urban poverty is absent in industrial megacities, but rather, urban poverty represents a greater proportion of the population in developing nations and the proportion continues to increase. Currently, over 37% of the world's poverty lives in urban areas (United Nations, 2008).

What is urban poverty? There is no consensus as to how to define urban poverty because it can vary from country to country. In general, from an economic perspective, urban poverty is defined as a population whose income, consumption or standard of living is below a median common index of material welfare (Masika *et al.*, 1997).

Another way to rank cities is by its urban foot print as defined by the size of the urban area. New York with a land base of 11 264 km^2 has the largest urban foot print. In fact, 7 of the top 10 largest urban foot prints occur in the United States (Demographia, 2010). These large foot prints indicate a sprawling pattern of low-density commercial and residential settlements. This outward growth has been characterised as suburbanisation. However, suburbanisation is not just confined to the United States. It is also being observed in other nations (e.g. Europe) as urban populations grow.

Urban density, which combines both population size and size of urban areas, gives still a different ranking. Like the other approaches, urban density is tenuous because of being based on a delineated urban area. Nonetheless, Demographia (2010) lists Dhaka, Bangladesh as the most densely populated urban area in the world with 40 100 individuals per km^2 or roughly 1 person per 25 m^2. Of the top 10 most densely populated urban areas, five occur in India and three occur in China. Currently, there are 218 urban areas with urban densities exceeding 10 000 individuals per km^2 and the majority of these areas are located in Asia. In Europe, Portsmouth, United Kingdom is the most densely populated city with 4700 individuals per km^2. For the United States, Los Angeles is the most densely populated urban area with a density of 2400 individuals per km^2or 1 person per 416 m^2 (Demographia, 2010).

With the projected growth of the urban population, one might expect that most of that growth would occur in megacities. In fact, megacities will absorb less than 12% of the total projected growth. Actually, more than 50% of the projected urban population growth will occur in cities of a population of less than 0.5 million. Growth in these smaller cities will occur primarily because of the expected urban growth in Africa. Another 23% of expected population growth will occur in cities with populations between 0.5 and 1 million (United Nations, 2008).

Regardless of whether a city is a megacity or a small city, the projected urban population growth creates challenges and opportunities. For most cities, challenges include spatial management, infrastructure, social inequities and ecological degradation. Opportunities include economic concentration, new markets and cultural diversity. By comparison, a different set of challenges and opportunities are created for those urban areas whose populations are expected to decline. In the following section, we will provide a cursory overview of some of these challenges and opportunities for urban areas that are increasing and decreasing in population.

Megacities

On average, the world's total population is increasing by 280 thousand individuals daily (Kötter, 2004) and more than 70% of this growth will occurs on land without any formal planning (Doytsher *et al.*, 2010). This growth often causes the urban area to increase significantly. For instances, Bangkok, although not a megacity, increased from 67 km^2 in 1950 to over 1000 km^2 today. Consequently, these informal communities place severe constraits on planning for current and future infrastructural needs and significantly degrade the environment.

New infrastructure will be needed for waterworks, bridges, power grids, sewers, landfills and transportation systems including rail, roads and ports. In the United States, an additional 50% increase in residential infrastructure will be needed to meet expected population growth (Nelson, 2004). When one adds the repair of existing infrastructure to the projected need, the United States will have to spend approximately 6.5 trillion dollars by 2030. Recognising the importance of infrastructure, both China and India are currently spending approximately 8–9% of their gross national product annually on infrastructure. For many growing urban areas, however, it is unlikely that government will be able to fund all of the infrastructural needs of a city. A partnership between public and private sectors may be necessary to provide the essential resources to meet and complete infrastructural projects (Glaeser, 2011).

Another infrastructure barrier is compartmentalisation of policies. Often governmental agencies for housing, transportation and water are located in different ministries or departments and often act independent of each other. So, actions by one agency may be counterproductive with the goals of another agency. A synergistic or integrative management will be needed to meet future infrastructure goals if a desirable living condition is to be achieved. One solution is to consider infrastructure as part of the urban ecosystem and design and develop multipurpose structures that meet the needs of residents, serve multipurpose and reduce carbon emissions (see the section on Designing cities ecologically) (**Figure 4**).

Another fundamental concern for future cities is providing adequate water for drinking, sanitation needs and agricultural production. Of these three needs, agricultural production is the biggest consumer of water. The world's population uses approximately 4.4 km^3 of water per year, whereas food production for this population consumes 10 000 km^3 of water per year. With the world's urban population adding an estimated 70–100 million people per year, water needs, just for food production to feed this population increase, equal about twice the flow of the Nile River (Varis, 2006).

Because of the informal nature of areas rapidly developing, governments are hesitant to build the infrastructure needed to provide basic services. Subsequently, high income areas, which have infrastructure, often have official water supplies and pay a set rate for those services. Because of the lack of infrastructure in poor areas, water is often sold by vendors at 10–100 times official rates, causing further economic inequities (Varis *et al*., 2006).

Similarly, with the lack of infrastructure, sanitation and waste management are major health and environmental issues for the urban poor. For example, 41% of Jakarta's populations discharge their waste directly into surface waters which are used for drinking and washing. These conditions, however, do not reflect all megacities. Istanbul, for instance, with a population of over 11 million, treats

Figure 4 A designed rain garden to serve as a bioretention facility as part of a watershed restoration project in Baltimore, Maryland. Photos by Ken W. Belt.

over 95% of its waste water and serves as an example for other cities (Varis *et al*., 2006). Governance, location and geography, and economic viability all play important roles in providing water services in megacities (Mavropoulos, 2010).

Like water, transportation infrastructure is directly linked to public health and economic well-being. Government tries to plan transportation infrastructure to reduce such congestion, improve safety and accessibility. Unfortunately, because of fragmentation of authority and responsibilities of agency, transportation planning and implementation is often piecemeal that can contribute to congestion, the very issue that planners are trying to relieve. Nonetheless, improved transportation infrastructure can reduce traffic congestion and improve air quality. Transportation contributes to approximately 7–10% of the total emissions in a megacity. Other contributing factors include households (15–20%) and industry (60–70%). The effect of transportation, however, is expected to grow as more private cars are being purchased for personnel use. For instance, in Beijing, China, a 4–5 fold increase in the number of cars and trucks is expected to occur by 2020 (Dhakal *et al*., 2002). The switch to alternative fuels such as propane/natural gas and electric would alleviate expected increase of emissions from the transportation sector either in developing or developed countries.

Megacities are the economic hubs of a country; however, the economy is a double-edge sword. Many individuals migrate to urban areas because of economic opportunity, medical benefits and improved living conditions. At the same time, governance often lack funding to build and support infrastructure for basic necessities such as clean water and routinely spend available funds on attracting investments and stimulating economic growth which reinforces additional migration into the city. This positive feedback loop is negated to some extent as government needs to build infrastructure to attract commerce. Subsequently new roads, water supplies and sanitation facilities provide a service for the city's population and improve living conditions while at the same time demonstrate long-term commitment to creating economic conditions for growth.

Shrinking Cities

Shrinking cities are the antithesis of megacities. Where megacities are growing and adding population, these cities have lost human population over several decades which, subsequently, have lead to excess of infrastructure especially housing and commercial buildings. It should be noted that a megacity could become a shrinking city if it experiences a declining population because of changing economic, social or ecological conditions. For instances, in the United States Baltimore, Maryland grew rapidly, but economic and social changes during the 1970s resulted in a drastic decline in population from 2.7 million in the 1970s to less than 650 thousand in 2011.

Shrinking cities occur principally in the United States, Eastern Europe and the Russia Federation and result primarily from economic changes, but population demographics also play important roles. Economic factors include industries leaving the area such as the case with Detroit in the United States and northern England, and the collapse of a region's economic base as observed in Eastern Germany with the unification of Germany (Mulder, 2006). Because of economic instability, people, especially the young, move out of the area in search for employment and immigrants do not move in because of the lack of employment. In addition, with fewer young individuals, there are fewer births resulting in a further decrease in the population.

The loss of population has economic, social and ecological ramifications. Economically, with industries leaving, there is a loss of tax revenue. With the remaining population becoming older, there is increased economic demand to provide social services and retirement benefits. Likewise, there are utility costs to maintain existing infrastructure but the service base has declined resulting in higher costs per customer. These economic changes create a vicious cycle in the system. With diminishing revenues, more people may move out further decreasing the population. With fewer people, there may be an insufficient workforce to attract new industries and businesses to build a viable tax base.

Although it may seem intuitive for city government to consolidate the existing population and remove unused infrastructure, in reality these issues are more complex. In fact, this type of top-down approach can actually destroy the very social fabric of a neighbourhood. Often within neighbourhoods of abandoned homes or blocks of row houses live individuals and families. Consolidation would require for them to leave their homes, homes that may have been in the family for several generations. It would also mean that the destruction of historical buildings and sites, a loss of a sense of place. Consequently, social injustice issues abound. These social ramifications can be far reaching and create long-term social unrest especially if economic conditions do not improve. Inevitably, residents, business owners and workers need to work together to create plans for the revitalisation of their neighbourhoods and work with urban planners to create those neighbourhood.

Ecologically, shrinking cities provide a unique opportunity to actually improving the natural systems in an urban area. The demolishing of vacant building and the clearing of abandoned lots create opportunities for urban gardens and agriculture, opening streams and creating wooded habitat. In fact, the amount of green space can actually increase. The creation of more natural environments within a shrinking city can improve the liveability of area by increasing biodiversity, providing food for local residents and improving the overall health of residents thus enhancing its attractiveness to people and business (see Franzke, 2007, e.g. http://www.bauhaus-dessau.de/index.php?umbaustadt-dessau-urban-redevelopment-planning-workshop-1). This type of revitalisation can lessen the effect of the loss but it will not return the city to its former glory. Nonetheless, with rising oil prices and the cost of gas, a net migration inward rather than outward into suburbs may actually serve as a catalysis for renewal.

Ecological Degradation

In the previous sections, we addressed the issues of rapid urban growth and shrinking populations in urban areas. We also discussed some of the ecological ramifications associated with the rapid addition or loss of population and presented some design recommendations that may enhance resilience and adaptability in urban areas. In this section we will look at the effect of this projected growth on biodiversity, particularly in the tropics because of the project human growth in that region. Although biodiversity can have multiple definitions, we define biodiversity in this article, as species-level patterns of distribution (Dirzo and Raven, 2003).

The demand for agricultural and urban land to support the projected population growth will increase the demands for food, energy and shelter. Conversions to agricultural and urban land-use will degrade, fragment or destroy existing natural systems. The effect of this land-use change on biodiversity will be especially significant in the tropics where more than 60% of all known species occur (Dirzo and Raven, 2003). The loss of tropical lands will occur not only from the accretion of urban areas but also from global industrialisation and commercial agriculture. **See also**: Ecological Consequences of Habitat Fragmentation

Biodiversity may not seem important to humans in their everyday lives, but it plays a critical role in providing ecosystem benefits on which humans must have to survive. For example, bees are critical for pollination of crops and fruits, and many plants are used for pharmaceutical purposes. The loss of biodiversity will affect the quality of human life. **See also**: Ecosystem Services

The extinction of species because of humans is not a recent event. For instance, over the past 1000 years, over a 1000 species of birds on central Pacific islands have gone extinct because of human colonisation (Pimm *et al*., 1994). Nonetheless, during the past 500 years the rate of extinction has accelerated several hundred times over historical rates (Pimm and Brooks, 2000). Currently, there are over 11 000 threatened species facing extinction because of habitat degradation and destruction resulting primarily from infrastructure (e.g. human settlements, transportation and utilities and dams), agriculture, extraction activities (e.g. mining, fishing and hunting and logging) and the introduction of invasive species (Dirzo and Raven, 2003). Present rate of tropical forest deforestation is between 8 and 15 million ha/year (Grainger, 2008). If this rate continues, Dirzo and Raven (2003) projected that 50–75% of all tropical species may become extinct in the next 50 years. These possible losses do not capture the potential effects of climate change on species and on the tropics. **See also**: Biodiversity – Threats; Biotic Homogenization

The future availability of ecosystem services and benefit derived by humans in both urban and rural areas might be seriously compromised with the loss of biodiversity and habitats. For instance, the loss of forest cover can result in increased flooding and the subsequent loss of human life and infrastructure. The loss of pollinators and frugviores may cause a decline in reproduction and regeneration of tropical plants used by humans. Further, there is the likelihood of loss of pharmaceutical products since at least 25% of these products are derived from tropical plants (Sohdi *et al*., 2007).

Overall, the potential losses in biodiversity and the projected growth of the human population establish the need for conservation and effective land use planning. Conservation of habitats, alone, will not save natural areas. Creative urban design and land use planning that maintains landscape connectivity, concentrates human activities and conserve ecological important habitat formulates the foundation for long-term sustainability in urban and urbanising landscapes. **See also**: Conservation Biology and Biodiversity; Landscape Ecology

Designing Cities Ecologically

Improving human well-being and the quality of the environment within, downstream and downwind of cities presents an important challenge for the twenty-first century. This opportunity can be met by linking the science of ecology with the profession of urban design (Johnson and Hill, 2001). Urban design is an inclusive term that includes architecture, landscape architecture and planning of cities and regions. The term further acknowledges that many important changes in urban systems emerge from attention to individual projects, and involve a democratic, civic process.

One approach of urban design to the changing nature of cities is to make individual buildings and projects more efficient. Often referred to as green building, this approach exploits solar exposure and sheltering from cold winds, building insulation and use of high-efficiency materials. The goal is to reduce the energy, water and material resource demands of individual buildings (Beatley, 2000). Green building can be considered a strategy to improve the efficiency of projects that are a part of traditional architecture. However, there are additional ways for urban design to exploit ecological knowledge.

Treatment of rainwater and storm runoff is another aspect of ecological processes that can be better accommodated in urban systems. The predominant approach to management of rainwater in cities and suburbs it to remove it as quickly as possible. Common design strategies include straightening and armoring stream banks, and delivering water from impervious surfaces via pipes to receiving drainages. Consequently, the vast majority of headwater and even many larger streams have been filled, diverted, piped or replaced by gutters (Elmore and Kaushal, 2008).

Ecological research has documented that these stormwater management approaches forego most ecological benefits that stream ecosystems can provide to urban areas (Walsh *et al.*, 2005). The missing or impaired functions are many. For example, moving water quickly through channels prevents it from interacting with sediments, streambanks and moist floodplains – sites where much ecological work is done that reduces sediment load, converts soluble nitrates to forms that do not pollute streams and stores organic matter that fuels beneficial microbial metabolism in streams (Groffman *et al.*, 2004). Furthermore, classical urban design reduces infiltration into ground water, minimising the water-cleansing filtration process in soil while contributing to the volume of water that must be removed from streets and other impervious surfaces.

Urban designers are beginning to creatively compensate for the water management and cleansing shortcomings of the traditional city and suburb (Spirn, 1984). Including green spaces, both designed and remnant, in new developments and restoring such places in existing settlements are two key approaches. Expanding and restoring tree canopy in urban areas also contributes to favourable water balance, while also moderating microclimate and providing a variety of psychological and social benefits (Nowak *et al.*, 2007). Stormwater detention basins are principally aimed at reducing downstream flooding, but if they contain wettable substrates and fringing vegetation, they can also contribute to reduced nitrate and phosphate pollution, as well as supporting aquatic biodiversity. Rain gardens, green roofs, curb cuts and simple replacement of unnecessary impervious surfaces are design options that can improve the ecological management of water in city-suburban-exurban ecosystems. Such 'low-impact development' has been documented to greatly improve the amount and quality of stormwater runoff from suburban areas (Dietz and Clausen, 2008).

Another active area for enhancing the ecological functioning in cities and suburbs is urban agriculture. There is a long tradition of converting vacant lots to community gardens, where food can be produced, and native meadow plants and pollinators can be enhanced. Urban agriculture can ameliorate the lack of access to freshly produce that is so common in older cities and suburbs. Such 'food deserts' are compounded by the lack of access to private automobiles or adequate public transportation connecting such neighbourhoods to full-service grocery stores or farmers markets. The corner convenience stores and fast food outlets that dominate the neighbourhood food ecology and economy in many cities and older suburbs is inadequate to providing balanced, affordable nutrition.

Urban agriculture provides social benefits as well. Neighbourhood cohesion, community revitalisation, intergenerational transfer of knowledge and small-scale financial incentives are among the benefits that have been found in various urban places. Urban agriculture and gardening exploit ecological principles by making more space – both literal and cultural – available for processes of photosynthesis, consumption and decomposition within the city and suburb. By bringing these features of nutrient and energy cycling back to greater prominence and utility in urban areas, such design strategies can facilitate sustainability.

Principles from landscape ecology are filtering into urban design through concern with connectivity of green spaces. Urban designers and landscape architects have long recognised the benefits of green spaces in cities. This tradition has been stronger in Europe than elsewhere, but its significance is spreading globally. Benefits include exposure of urban dwellers to places and processes that are more clearly natural than those available in the built urban fabric from which wild or even feral elements are displaced and natural processes, such as those outlined in the previous paragraphs, are hidden from view or greatly compromised. Green networks, for example, support enhanced biodiversity and provide the opportunity for citizens to observe wildlife. Perhaps more immediate are the benefits of passive and active recreation, and the mitigation of mesoclimate near green nodes and connecting corridors. Both of these features can improve people's physical and mental health. Well-managed green spaces can be a boon to property values and an incentive to neighbourhood revitalisation. Finally, connected green spaces can act as a substrate and opportunity for student and public education.

These are just some instances of the role of greater sensitivity to ecological principles and processes, and hence to ecological outcomes, that are being exercised by contemporary urban design. Although there is no space to explore further examples here, they might include, waste water treatment, enhancement of public and nonmotorised transport and the reduction and improved management of solid waste. These and the examples explored above are important in moving urban areas towards greater sustainability, regardless of their starting point as industrial cities, shantytowns or new settlements.

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