Ecological Economics 86 (2013) 285–291

Contents lists available at SciVerse ScienceDirect

Ecological Economics

journal homepage: www.elsevier.com/locate/ecolecon

Reaching for a sustainable, resilient urban future using the lens of ecosystem services

Åsa Jansson

The Beijer Institute of Ecological Economics, The Royal Swedish Academy of Sciences, Box 50005, 104 05 Stockholm, Sweden

A R T I C L E I N F O

Article history:
Received 28 November 2011
Received in revised form 7 February 2012
Accepted 6 June 2012
Available online 25 July 2012

Keywords:
Sustainable cities
Resilience
Ecosystem services
Ecology *of* cities
Ecology *in* cities
Biodiversity

A B S T R A C T

Based on recent research on erosion of ecosystem services, planetary boundaries and predicted pace of urbanization, it is now apparent that humans need to reconnect to the biosphere and that cities in this context, properly managed, could provide great opportunities and arenas for social ecological change and transformation towards sustainability To take advantage of these opportunities one needs to keep in mind that most of the ecosystem services consumed in cities are generated by ecosystems located outside of the cities themselves, not seldom half a world away. In order to operationalize our knowledge, hypothesis and theories on the connections between the work of nature and the welfare and survival of humans over time, we suggest the use of the ecosystem service framework in combination with the merging of the concept "ecology *in* cities", mainly focusing on designing energy efficient building, sustainable logistics and providing inhabitants with healthy and functioning green urban environments, and the "ecology *of* cities". The "ecology *of* cities" framework acknowledges the total dependence of cities on the surrounding landscape and the ever-ongoing dance between urban and rural, viewing the city as an ecosystem.

1. Introduction

The view of people and nature being interlinked and part of the same system, a social ecological system, is not new, but has been lost in the process of increasing our intra-disciplinary depth of knowledge, only to reappear as the absolutely essential framework within which the cure to our contemporary predicament can be found. In order to operationalize our knowledge, hypothesis and theories on the connections between the work of nature and the welfare and survival of humans, we need a concept that will help us clarify and quantify those links and their effects. It is in this framework that the ecosystem service concept becomes useful. The origin of modern concern for ecosystem services can be said to date back to 1864 with the publication of George P. Marsh's book "Man and Nature", in which several ecosystem services are recognized. Expanding on the list of services described in the Study of Critical Environmental Problem report (SCEP, 1970), Holdren and Ehrlich (1974) more or less completed the list of services normally cited and the terms "public services of the global ecosystem" (Ehrlich et al., 1977) and "nature's services" (Westman, 1977) paved the way for the introduction of the term "ecosystem services" (Ehrlich and Ehrlich, 1981). The realization had dawned that seemingly disparate events in the economic, environmental, and political spheres are interconnected.

The general definition of ecosystem services is: "Ecosystem services are the conditions and processes through which natural ecosystems, and the species that make them up, sustain and fulfill human life" (Daily, 1997).

1.1. Different Classifications of Ecosystem Services

After the establishment of ecosystem services as a recognizable field of study several classification and accounting schemes were generated. de Groot et al. (2002) e.g. observed the scattered state of the increasing amount of information on the ecological and socio-economic value of goods and services and the difficulties of comparative ecological economic analysis due to a lack of a standardized framework for the assessment of ecosystem functions, goods and services. To meet these difficulties a general classification was provided by grouping ecosystem services into four main categories:

(1) Regulation functions e.g. prevention of soil erosion, storage and recycling of nutrients, purification of air and water, generation of top soils, maintenance of biological diversity and regulation of the chemical composition of the atmosphere. These types of function help maintain the delicate balance of the earth's biosphere, our life support system.
(2) Habitat functions provide space and a substrate for e.g. cultivation, recreation and tourism.
(3) Production functions provide resources e.g. oxygen, water, food, medicines, fertilizers and energy.

E-mail address: asaj@beijer.kva.se.

0921-8009/$ – see front matter © 2012 Elsevier B.V. All rights reserved.
doi:10.1016/j.ecolecon.2012.06.013

(4) Information functions provide opportunities for e.g. esthetic and cultural enrichment, recreation, research and education.

This classification later partly provided the basis for the Millennium Ecosystem Assessment classification (Millennium Ecosystem Assessment, 2005). The MA distinguishes four different classes of ecosystem services:

1) Provisioning services, the products obtained from ecosystems, including, for example, genetic resources, food and fiber, and fresh water.
2) Regulating services, the benefits obtained from the regulation of ecosystem processes, including, for example, the regulation of climate, water, and some human diseases.
3) Supporting services, those are necessary for the production of all other ecosystem services. Some examples include biomass production, production of atmospheric oxygen, soil formation and retention, nutrient cycling, water cycling, and provisioning of habitat.
4) Cultural services, the non-material benefits people obtain from ecosystems through spiritual enrichment, cognitive development, reflection, recreation, and esthetic experience as well as knowledge systems, social relations, and esthetic values.

Still, as pointed out by Boyd and Banzhaf (2007) and Wallace (2007), the classification of ecosystem services presented by the Millennium Ecosystem Assessment does not work well for guiding practical accounting exercise or landscape management, respectively. Wallace (2007) suggests a framework utilizing the terms intermediate and final services and benefits, while Fisher and Turner (2008) drawing largely on Boyd and Banzhaf (2007), propose a slightly different definition.

For the purpose of this introduction however, which focuses on illuminating the connections between the work of nature and the underpinning of welfare and survival of humans in a sustainable urban context, the Millennium Ecosystem Assessment definition will suffice. The fact that there are different definitions of the ES concept needs not be worrisome in itself. In fact it could be seen as a health sign that the concept is very much alive and is being scrutinized and developed to better fit the wide range of complex and different situations where it can be useful (Costanza, 2008). It is however crucial to be clear about which definition is being used and the advantages and limitations of a particular definition.

2. Reaching for Sustainability by Combining Ecology *of* and Ecology *in* Cities

Based on several recent reports (e.g. Folke et al., 2011; Millennium Ecosystem Assessment, 2005; Rockström et al., 2009) it is now apparent that humans need to reconnect to the biosphere and that cities in this context, properly managed, could provide great opportunities and arenas for social–ecological change and transformation towards sustainability (see e.g. UNESCO, 2011). To take advantage of these opportunities one needs to keep in mind that most of the ecosystem services consumed in cities are generated by ecosystems located outside of the cities themselves, not seldom half a world away (Deutsch and Folke, 2005). Folke et al. (1997) e.g. already estimated that the 29 largest cities in the Baltic Sea Drainage Basin, taking only the most basic ecosystem services like food production and assimilation of nitrogen and carbon into account, appropriate ecosystem areas equivalent to the size of the entire drainage basin. Thus, as urbanites, we need to concern ourselves not only with what is sometimes referred to as "the ecology *in* cities", mainly focusing on designing energy efficient building, sustainable logistics and providing inhabitants with healthy and functioning green urban environments, but also focus on "the ecology *of* cities". This framework acknowledges the total dependence of cities on the surrounding landscape, viewing the city as an ecosystem (Grimm et al., 2000, 2008). It is thus motivated to concern ourselves with both the generation potential of ecosystem services by ecosystem within as well as outside cities to most effectively manage the potential of cities as arenas for learning, development and transformation.

3. The Role of Biodiversity for Sustainable Ecosystem Service Generation

There is a growing concern about the consequences of biodiversity loss for the provisioning of ecosystem services and it has been clearly shown that biodiversity does indeed have positive effects on many ecosystem services (Balvanera et al., 2006; Díaz et al., 2005).

We are dependent on the interactions of this complex web for providing us with the essentials such as clean air, water, food, shelter, a sense of place, experiences of beauty, serenity and meaning (Millennium Ecosystem Assessment, 2005). There is also increasing scientific evidence on the essential role of biodiversity for building resilience in a changing world (see e.g. Jansson and Polasky, 2010; Elmqvist et al., 2003; Rockström et al., 2009).

Although mass extinctions, granted, have not wiped out all life, they do change the settings for who the "winners" will be in the next round. So the primary concern here is not whether this 6th extinction, referred to as the Holocene extinction (Chapin et al., 2000a, 2000b), which we find ourselves in, will deprive the Earth of all life, which is highly unlikely, but rather how well the planet will be able to provide for *our* species, *Homo sapiens*, in the future.

So, does this mean that we have no way of influencing our situation? Certainly not! But it will require cooperation and coordination of people and knowledge at a scale unprecedented in human history. A fundamental step in the right direction was taken on the 11th of June 2010 in the South Korean port city of Busan, when governments gave the green light to an Intergovernmental Science Policy Platform on Biodiversity and Ecosystem Services (IPBES). The independent platform will in many ways mirror the Intergovernmental Panel on Climate Change (IPCC), which has assisted in catalyzing world-wide understanding and governmental action on global warming. The new body will hopefully help bridge the gulf between the wealth of scientific knowledge, documenting accelerating declines and degradation of the natural world and the decisive government action required to reverse these damaging trends. The ecosystem service approach taken by the platform warrants an anthropocentric focus with the welfare and survival of humans at its core. Also, the 10th conference of the parties (COP) of the CBD (Convention of Biodiversity), held in Nagoya, Japan this year prompted the CBD to develop a new plan of action supported by 20 "SMART" targets for 2020 (Perrings et al., 2010). These targets will be evaluated on the basis of the ecosystem service framework developed by the Millennium Ecosystem Assessment (2005). The previous lack of such coordination and cooperation can at least partly explain why, despite its essential role, biodiversity only fairly recently became a growing part of ecological research and even later in economic research.

4. Scientific Basis for the Connection between Biodiversity and Ecosystem Services in an *Urban Context*

Through the presentation of the following list of ecosystem service I try to illustrate the dependence of city inhabitants on functioning ecosystems and the connections to biodiversity in an urban context, whether these systems are located within the boundaries of the city or not. The list is far from extensive, but will hopefully shed some light on the essential links between biodiversity, ecosystem service generation, human welfare and sustainable urban development in a resource appropriation context. To emphasize the importance of including ecosystem services generated both within and outside the urban area for building urban sustainability and resilience, an ecology *of*/ecology *in* cities distinction is also made.

4.1. Provisioning Services

4.1.1. Provision of Food

4.1.1.1. Ecology of Cities. The biodiversity of ecosystems (agro-ecosystems, marine-ecosystems, lakes, tropical forests, savannas etc.) directly provide the plants and animals for human consumption and today 35% of the planet's surface is used for growing crops or rearing livestock (Millennium Ecosystem Assessment, 2005). The implications of low genetic diversity for agriculture are massive. The historically selective breeding, which is the product of human genetic manipulation and not to be confused with "natural" biodiversity, has led to monocultures in the aspect of not only growing one crop but that the crop is comprised of nearly genetically identical plants. Nonexistent or low genetic diversity makes crops increasingly susceptible to disease. The plants are in a constant race with bacteria and without a healthy genetic diversity, entire crops could be wiped out. A horrific example was the Potato Famine in Ireland, where a vast majority of the entire potato crop was destroyed leaving one million people to starve to death.

Agro-ecosystems together with associated ecosystems supporting marine and freshwater fisheries, underpin global food security. The overfishing of the oceans (Jackson et al., 2001) and the trend of increasing dependence on fewer species in agriculture and aquaculture has led to the loss of genetic resources. Failure to maintain sufficient genetic diversity in crops and animal stocks, whether focusing on "natural" biodiversity, as is mostly the case in marine systems, or the diversity created through human genetic manipulation, as with crops and domestic animals but also to a great extent in aquaculture (see e.g. Rönnbäck, 2001), can incur high economic and social costs through a reduced ability to respond to diseases and future environmental changes. Maintaining high productivity over time in monocultures requires subsidies of chemicals, energy (Hooper et al., 2005), and financial capital (EASAC, 2009).

The value of species richness for enhanced biomass productivity has been shown for permanent grasslands and pasture ecosystems (Bullock et al., 2007; Tilman et al., 2001). Worm et al. (2006) investigated how biodiversity loss affects marine ecosystem services (food, water quality maintenance, and recovery from perturbation) across temporal and spatial scales and found that overall, rates of resource collapse increased and recovery potential, stability and water quality decreased exponentially with declining diversity.

4.1.1.2. Ecology in Cities. The occurrence of informal production of food in city areas is often referred to as urban agriculture and is a widespread strategy adopted by urban dwellers in many cities worldwide (see e.g. Pearson et al., 2010). As the urban population has grown, so too has the complexity of how to feed people who are so far removed from the actual production of foods and the use of urban agriculture for building food security is no longer only a third world issue. In 2002 e.g. the U.S. Census Bureau released a report stating that more than 1.3 million Americans are living below the official poverty line and thirty-three million people – including 13 million children – live in households that experience hunger or the risk of hunger. The potential for food production in American cities is great, and dozens of model projects are demonstrating successfully that urban agriculture is both necessary and viable (Carter et al., 2003).

Also, urban gardens, by providing habitats for e.g. pollinators, seed dispersers and pest regulators, not only contribute to the generation of ecosystem services today, but also through the maintenance of diversity within these groups (functional diversity), uphold the resilience of food production within urban areas during times of crisis and change (Barthel et al., 2010). The urban gardens, through the spillover of biodiversity, can also constitute a source of resilience to the surrounding urban landscape (Colding et al., 2006). Building on the notion of redundancy (Walker, 1992), sustaining diversity *within* functional groups is important. This aspect of biodiversity, referred to as response diversity, has been far less investigated (although see Nyström, 2006), and is a critical element in building resilience (Elmqvist et al., 2003). Jansson and Polasky (2010), by quantifying the difference in response (measured as decrease in numbers of pollinators per m^2) between members of a functional pollination group, under scenarios of urban development, show that the effect of response diversity within functional groups potentially matters and should be taken into account when making decisions on urban landscape management and the maintenance of resilience from a food security/pollination perspective. The increasing spatial contact between agricultural areas and the urban, i.e. that the agricultural and urban land use types are increasingly found next to each other, is a trend that can be seen all over Europe (EEA, 2006). This trend suggests that making sustainable trade-offs between alternative land uses and ecosystem services will become even more crucial in the future.

4.1.2. Provision of Water and Water Quality

4.1.2.1. Ecology of Cities. The global hydrological cycle, contributing to water provisioning, regulation and purification, is greatly influenced by ecosystems and vegetation, particularly forests have been shown to significantly influence the circulation of water e.g. through promoting higher rates of evapotranspiration ultimately leading to increased rainfall.

Although vegetation is undoubtedly a major determinant of water flows and quality the relationship between water regulation and purification and biodiversity is still poorly understood. Soil quality and soil biodiversity are intimately linked to water regulation and purification. The movement of water through soil changes water quality through e.g. the transformations of persistent organic pollutants (POPs), sequestration and conversion of inorganic ions (nitrate, phosphate, metals), and removal of disease-causing microbes (Lake et al., 2007) (see also "maintenance of soil quality" under the section Regulating Services).

4.1.2.2. Ecology in Cities. Change in precipitation is one of the expected impacts of climate change. Dore (2005) suggests that the changes are already observable — and are likely to intensify with additional warming. Further changes in precipitation patterns (both in intensity and variability) will increasingly require communities to control for drought and flooding. As more and more surfaces in the built up areas are made hard and impermeable, less water can percolate naturally into the soil leaving large amounts of water unprocessed with potentially high concentrations of pollutants. Thus, urban green areas in general are important for maintaining water quality and in the temperate climate region the effects of green roofs in particular has been shown to have a great potential for retaining and delaying rainwater during storms, thus also increasing the potential for purification of the water (Bengtsson et al., 2005; Emilsson, 2006; Villarreal et al., 2004). However, in arid and semi-arid climate regions, the usefulness of green roofs might not be an optimal approach for retaining and delaying rainwater, and more research is called for (see e.g. EPA, 2007). Although there are no obvious links between biodiversity on green roofs and increased retention of water, the connection is apparent for other types of ecosystem services (see Supporting Services).

4.2. Regulating Services

4.2.1. Climate Regulation

4.2.1.1. Ecology of Cities. Vegetation contributes to mitigation of surface and air temperatures by providing shade and evapotranspiration. The importance of biodiversity for climate regulation has been shown both for marine and terrestrial biodiversities (Díaz et al., 2005). Marine biodiversity e.g. influences the effectiveness of the biological pump that moves carbon from the surface ocean and sequesters it in deep waters and sediments and the efficiency of this trophic transfer and therefore the extent of carbon sequestration are sensitive to the species richness and composition of the plankton community. Also, biodiversity needs consideration in terrestrial mitigation strategies such as afforestation, reforestation slowed-down deforestation and biofuel plantations. The development of a heat island effect in cities has regional-scale impacts on energy demand, air quality and public health (Rosenzweigh et al., 2011).

Cities are extremely vulnerable to climate change impacts. The major hazards facing cities are heat waves, which will occur more frequently and be longer and hotter, and due to the location of many cities at the coast or next to major rivers, coastal storms and floods will also be among the major hazards (Rosenzweigh et al., 2011).

4.2.1.2. Ecology in Cities. Among suggested ecological temperature mitigation strategies in cities are the planting of trees and green roofs. For impact assessments of the different strategies see e.g. Rosenzweigh et al. (2011). Still, again the point of differences between climate regions must be made and although trees may also contribute to the mitigation of surface and air temperature in arid and semi arid climates, there might be a serious trade off with e.g. water appropriation to take into account. Thus, issues of maintenance and associated costs are relevant in this context (see discussion on economic valuation in Section 5). In addition to the connection between urban biodiversity and the climate regulating service provided by vegetation, other services, such as the provisioning of habitat for wildlife, also demonstrate connection to biodiversity (UFBP, 2010).

4.2.2. Air Quality (Ecology in Cities)

Urban vegetation and green areas influence air quality. Both urban forests (Jim et al., 2009) and green roofs (Clark et al., 2005) have documented effects on improving air quality in cities. Still, the air quality benefits of urban vegetation are generally very poorly documented and often exaggerated (see e.g. Pataki et al., 2011). As with the climate regulation service there are no clear links between biodiversity and the generation of the air quality improvement service provided by vegetation and soils.

4.2.3. Health (Ecology in Cities)

4.2.3.1. Green Spaces. The connection between green spaces, especially in an urban context, and human health and recovery rates is a rapidly expanding field of research (see e.g. Grahn and Stigsdotter, 2003; Mårtensson, 2004). Maas et al. (2006) e.g. show that the percentage of green space in people's living environment has a positive association with the perceived general health of residents. Furthermore, Fuller et al. (2007) show that urban public green spaces have measurable physical and psychological benefits and that these psychological benefits increase with the species richness of urban green spaces. These results indicate that emphasis on biological complexity in the context of urban green space management can enhance human well-being in addition to biodiversity conservation. Also, green space coverage increases more rapidly than city area, yet declines only weakly as human population density increases. Thus, compact cities (small size and high density) show very low per capita green space allocation (Fuller and Gaston, 2009), which might contribute to the debate on “smart growth” and “compact cities”.

4.2.3.2. Noise Reduction. The notion of soundscape is a new approach to assess the connections between green space, noise reduction and urban sustainability (see e.g. Irvine et al., 2009). A conservative estimate suggests that noise leads to an annual cost of approximately 10 billion euro per year in the EU and that e.g. the creation of green roofs may be an effective way to reduce the noise pollution of our cities while at the same time adding other services as well (Lagström, 2004).

4.2.4. Pollination Services

4.2.4.1. Ecology of Cities. The International Convention on Biological Diversity specifically cites pollination as a key ecosystem function that is threatened globally. Over 75% of the world's crop plants and many species that are the base for plant-derived pharmaceuticals, rely on pollination by animal vectors. In a recent review of the importance of pollinators in changing landscapes for world crops Klein et al. (2007) state that of 107 important crops pollination is essential for 13, highly dependent for 30 and moderately important for 27. There is clear evidence of recent declines in both wild and domesticated pollinators, primarily due to habitat loss and fragmentation, agrochemicals, pathogens, alien species, climate change and the interaction between these drivers (Potts et al., 2010). The ecosystem service of pollination is relevant from an urban perspective as urban land use likely will have a large effect on terrestrial ecosystems in this century (Sala et al., 2000), and the resulting habitat fragmentation is considered to be a major threat to wild pollinators (Allen-Wardell et al., 1998). The importance of biodiversity in this context is apparent e.g. in view of the consequences of relying on a single species for pollination, such as the honey bee *Apis mellifera*, (Kremen et al., 2002).

4.2.4.2. Ecology in Cities. In urban areas gardening forms part of the urban landscape mosaic potentially contributing to several ecosystem services e.g. pollination, seed dispersal and pest regulation, which also spill over to the surrounding landscape (Ahrné et al., 2009; Samnegård et al., 2011). Andersson et al. (2007) acknowledge that the generation of ecosystem services depends on both social and ecological features and their study thus focuses on management, its ecological consequences, and social drivers. In their approach they combined (1) quantitative surveys of local species diversity and abundance of three functional groups of ecosystem service providers (pollinators, seed dispersers, and insectivores) with (2) qualitative studies of local management practices connected to these services and their underlying social mechanisms, i.e., institutions, local ecological knowledge, and a sense of place. The study focused on the ecology of three types of green areas: allotment gardens, cemeteries, and city parks.

4.2.5. Biological Control

4.2.5.1. Ecology of Cities. Most farmers in industrialized nations are aware of the hazards connected with pesticide use, but information about the benefits of alternative pest control strategies is often lacking. Biological control of pests by natural enemies is thus an important ecosystem service. It has been shown that yield increases attributable to predators can be compared with yield increases from insecticide use for the evaluation of different management strategies (Östman et al., 2003) and that complex landscapes characterized by highly connected crop-non-crop mosaics may be the best for long term conservation, biological control and sustainable crop production (Tscharntkea et al., 2007). The importance of biodiversity in this context has been show e.g. in the reduced frequency with which biocides need to be applied (Palumbi, 2001).

4.2.5.2. Ecology in Cities. As with pollination, urban gardens can also promote biological control with potential spillover effects into the surrounding landscape (Andersson et al., 2007).

4.3. Supporting Services (Provision of Habitat in Urban Settings)

Green roofs with varying substrate thicknesses, which create different microhabitat conditions, harbor a greater potential for diverse suites of organisms to establish. Thus, well-designed green roofs can provide habitat compensation e.g. for species affected by urban land-use changes (Brenneisen, 2003).

Also, golf courses, appropriate climatic conditions provided, can have the potential to contribute to wetland fauna support, particularly in urban settings where they may significantly contribute to wetland creation (Colding and Folke, 2009; Colding et al., 2009).

5. How to Reach for a Sustainable and Resilient Urbanization and Start Reconnecting to the Biosphere

A future sustainable urbanization requires a reconnection of human development and progress to the capacity of the biosphere and essential ecosystem services (Folke et al., 2011). Since the majority of the world's population lives in urban areas, one way of facilitating this reconnection is to, through the lens of ecosystem services, combine the concepts of ecology *of* and ecology *in* cities. Furthermore, we also need to recognize that today's world is a highly interconnected one, characterized by cascading social–ecological interactions and planetary boundaries that create vulnerabilities, but also opportunities for social–ecological change and transformation. Tipping points and thresholds highlight the importance of understanding and managing resilience. In this context we need to recognize the fundamental role that biodiversity plays in building resilience in a reality of complex and dynamic social ecological systems (see e.g. Elmqvist et al., 2003; Folke et al., 2004; Rockström et al., 2009; Walker and Meyers, 2004). However, recognizing that biodiversity is a prerequisite for human well-being as well as for building resilience is one thing; operationalizing that knowledge is another. The functional aspect of biodiversity, that is, the identity, abundance, and range of species traits, appears to be considerably more important than species number in determining the effects of biodiversity on many ecosystem services (Díaz et al., 2007; Hooper et al., 2005). Biodiversity supplies the species and the variety of traits needed for maintaining functions for ecosystem service generation. Thus, translating the work of biodiversity into ecosystem service generation and the quantification of resilience e.g. through the mapping of functional and response diversity, is one step of operationalizing this knowledge (Jansson and Polasky, 2010).

The up to date shortcomings of the scientific community to clarify the role of biodiversity as an essential component for building resilience might partially explain the fact that despite encouraging efforts, such as the TEEB initiative and the launching of the IPBES, the 10th conference of the parties of the CBD concluded that the majority of nations have fallen far short of the 2010 target to reduce the rate of loss of biodiversity (Butchard et al., 2010). Although one might argue that this loss has not substantially contributed to a decrease in human welfare, recent research shows that a significant number of countries judged to be gaining wealth according to conventional indicators, are actually moving in the opposite direction or showing a mitigated increase in wealth, when loss of natural capital is included (Arrow et al., 2004; Millennium Ecosystem Assessment, 2005).

Also, the results from the MA are clear, 60% of the ecosystem services are being eroded or used unsustainably and we are thus living off the capital and not the interest. This is not a sustainable strategy over time. Based on this reality it is crucial to increase our efforts to illuminate the connections between biodiversity, ecosystem services and human well being in a changing world. We need to acknowledge not only the role that urbanization plays in the erosion of biodiversity and ecosystem service generation through e.g. land use change and fragmentation at the local scale (Allen-Wardell et al., 1998), but also the fact that urban areas are hot spots that drive environmental change at multiple scales. Material demands of production and human consumption alter land use and cover, biodiversity, and hydrosystems locally to regionally, and urban waste discharge affects local to global biogeochemical cycles and climate (Grimm et al., 2008).

In this context it is also important to keep in mind that urbanization, if properly managed, potentially can aid in strengthening biodiversity and ecosystem service generation in the social-ecological landscape, thus providing arenas for social–ecological change and transformation (see e.g. Barthel et al., 2010; Colding and Folke, 2009; Ernstson et al., 2010). An additionally productive way of examining the ecology of cities is provided by Moffatta and Kohlerb (2008), suggesting that the built environment be understood as a complex social–ecological system, where multiple-related metabolisms interact at different scales. Another fruitful path of reconnecting to the biosphere is by demonstration of economic value (see TEEB, 2010). A major conclusion of the MA was that future policies must aim at fulfilling human needs but at a smaller cost on natural systems. An important part must be to correct the historical bias against natural services in the context of weighing the costs and benefits of particular economic choices. It is also concluded that the distortion is compounded by measures of wealth that fail to take natural capital into account (Millennium Ecosystem Assessment, 2005). Due to the fundamental role that ecosystem services play in underpinning human welfare (Millennium Ecosystem Assessment, 2005), the valuation of ecosystem services has become one of the most significant and fastest growing fields of research in environmental and ecological economics, during the past 30 years. Despite this impressive development, the valuation of ecosystem services in an *urban context* is still modest (although see TEEB, 2011). Furthermore, the connection between biodiversity, ecosystem functioning and the economics of ecosystem services is a field that has also experienced a profound transformation during the last decade not least by the work provided within the TEEB framework, with the purpose of providing the analysis and tools required to do economic analysis of ecosystem services and biodiversity (TEEB, 2010) (see also Loreau et al., 2002; Naeem et al., 2009).

Acknowledgments

I would like to thank the Beijer Institute of Ecological Economics, The Royal Swedish Academy of Sciences, Stockholm, Sweden, for funding this research. I also want to thank three anonymous reviewers for insightful comments and Dr Leonie Pearson for inviting me to be a part of this special issue.

References

Ahrné, K., Bengtsson, J., Elmqvist, T., 2009. Bumble bee (*Bombus* spp.) along a gradient of increasing urbanization. PLoS Biology 4 (5), e5574.
Allen-Wardell, G., Bernhardt, P., Bitner, R., Burquez, A., Buchmann, S., Cane, J., Cox, P.A., Dalton, V., Feinsinger, P., Ingram, M., Inouye, D., Jones, C.E., Kennedy, K., Kevan, P., Koopowitz, H., Medellin, R., Medellin-Morales, S., Nabhan, G.P., Pavlik, B., Tepedino, V., Torchio, P., Walker, S., 1998. The potential consequences of pollinator declines in the conservation of biodiversity and stability of food crop fields. Conservation Biology 12, 1–11.
Andersson, E., Barthel, S., Ahrné, K., 2007. Measuring social–ecological dynamics behind the generation of ecosystem services. Ecological Applications 17 (5), 1267–1278.
Arrow, K., Dasgupta, P., Goulder, L., Daily, G., Ehrlich, P., Heal, G., Levin, S., Maler, K.-G., Schneider, S., Starrett, D., Walker, B., 2004. Are we consuming too much? The Journal of Economic Perspectives 18 (3), 147–172.
Balvanera, P., Pfisterer, A.B., Buchmann, N., He, J.-S., Nakashizuka, T., Raffaelli, D., Schmid, B., 2006. Quantifying the evidence for biodiversity effects on ecosystem functioning and services. Ecology Letters 9, 1146–1156.
Barthel, S., Folke, C., Colding, J., 2010. Social–ecological memory in urban gardens: retaining management of ecosystem services. Global Environmental Change 20, 255–265.
Bengtsson, L., Grahn, L., Olsson, J., 2005. Hydrological function of a thin extensive green roof in southern Sweden. Nordic Hydrology 36 (3), 259–268.
Boyd, J., Banzhaf, S., 2007. What are ecosystem services? The need for standardized environmental accounting units. Ecological Economics 63, 616–626.
Brenneisen, S., 2003. Ökologisches Ausgleichspotenzial von extensiven Dachbegrünungen—Bedeutung für den Arten- und Naturschutz und die Stadtentwicklungsplanung. Doctoral dissertation, Institute of Geography, University of Basel, Switzerland.
Bullock, J.M., Pywell, R.F., Walker, K.J., 2007. Long-term enhancement of agricultural production by restoration of biodiversity. Journal of Applied Ecology 44 (1), 6–12. http://dx.doi.org/10.1111/j.1365-2664.2006.01252.x.
Butchard, et al., 2010. Global biodiversity: indicators of recent declines. Science 328, 1164.
Carter, A., Mann, P., Smit, J. (Eds.), 2003. Community Food Security in the United States: Farming from the City Center to the Urban Fringe. A Primer Prepared by the Community Food Security Coalition's North American Urban Agriculture Committee. Published by the Community Food Security Coalition, Venice California.
Chapin III, F.S., Zavaleta, E.S., Eviner, V.T., Naylor, R.L., Vitousek, P.M., Reynolds, H.L., Hooper, D.U., Lavorel, S., Sala, O.E., Hobbie, S.E., Mack, M.C., Díaz, S., 2000a. Consequences of changing biodiversity. Nature 405, 234–242.

Chapin III, F.S., Zaveleta, E.S., Eviner, V.T., Naylor, R.L., Vitousek, P.M., Lavorel, S., Reynolds, H.L., Hooper, D.U., Sala, O.E., Hobbie, S.E., Mack, M.C., Diaz, S., 2000b. Consequences of changing biotic diversity. Nature 405, 234–242.

Clark, C., Talbot, B., Bulkley, J., Adriaens, P., 2005. Optimization of green roofs for air pollution mitigation. Proceedings of the Third North American Green Roof Conference: Greening Rooftops for Sustainable Communities. The Cardinal Group, Washington, DC, pp. 482–497. Toronto.

Colding, J., Folke, C., 2009. The role of golf courses in biodiversity conservation and ecosystem management. Ecosystems 12 (2), 191–206.

Costanza, R., 2008. Ecosystem services: multiple classification systems are needed. Biological Conservation 141, 350–352.

Daily, G. (Ed.), 1997. Nature's Services. Societal Dependence on Natural Ecosystems. Island Press.

de Groot, R.S., Wilson, M.A., Boumans, R.M.J., 2002. A typology for the classification, description and valuation of ecosystem functions, goods and services. Ecological Economics 41 (3), 393–408.

Deutsch, L., Folke, C., 2005. Ecosystem subsidies to Swedish food consumption from 1962 to 1994. Ecosystems 8 (5), 512–528.

Díaz, S., Tilman, David, Fargione, Joseph, 2005. Millennium ecosystem assessment, ecosystems and human well being: current state and trends. Chapter 11, Biodiversity Regulation of Ecosystem Services. http://www.maweb.org/en/Condition.aspx.

Díaz, S., Lavorel, S., de Bello, F., Quétier, F., Grigulis, K., Robson, T.M., 2007. Incorporating plant functional diversity effects in ecosystem. Ecology and Society 15 (3), 20 http://www.ecologyandsociety.org/vol15/iss3/art20/ service assessments. Proceedings of the National Academy of Sciences, December 26, 104 (52):20684–20689.

Dore, M.H.I., 2005. Climate change and changes in global precipitation patterns: what do we know? Environment International 31 (8), 1167–1181.

EASAC, 2009. Ecosystem services and biodiversity in Europe. Policy Report 09. 978-0-85403-738-4. www.easac.eu.

EEA. European Environment Agency, 2006. Urban sprawl in Europe. EEA Report 10/2006. EEA, Copenhagen. ISBN 92-9167-887-22.

Ehrlich, P.R., Ehrlich, A., 1981. Extinction: The Causes and Consequences of the Disappearance of Species. Random House, New York. 305 pp.

Ehrlich, P.R., Ehrlich, A., Holden, J., 1977. Ecoscience: Population, Resources, Environment. W.H. Freeman, San Francisco.

Elmqvist, T., Folke, C., Nyström, M., Peterson, G., Bengtsson, J., Walker, B., Norberg, J., 2003. Response diversity, ecosystem change and resilience. Frontiers in Ecology and the Environment 1, 488–494.

Emilsson, T., 2006. Extensive Vegetated Roofs in Sweden: Establishment, Development and Environmental Quality. http://diss-epsilon.slu.se/archive/00001088/.

EPA, 2007. Characterization of Green Roof Performance Parameters in the High Elevation, Semi-Arid, Temperate Colorado Front Range Region. http://www.epa.gov/region8/greenroof/pdf/Final%20RARE%20Greenroof%20Proposal%20Feb07.pdf.

Ernstson, H., van der Leeuw, S., Redman, C.L., Meffert, D.J., Davis, G., Alfsen, C., Elmqvist, T., 2010. Urban transitions: on urban resilience and human-dominated ecosystems. Ambio. http://dx.doi.org/10.1007/s13280-010-0081-9.

Fisher, B., Turner, R.K., 2008. Ecosystem services: classification for valuation. Biological Conservation 141, 1167–1169.

Folke, C., Jansson, Å., Larsson, J., Costanza, R., 1997. Ecosystem appropriation by cities. Ambio 26, 167–172.

Folke, C., Carpenter, S., Walker, B., Scheffer, M., Elmqvist, T., Gunderson, L., Holling, C.S., 2004. Regime shifts, resilience, and biodiversity in ecosystem management. Annual Review of Ecology, Evolution and Systematic 35, 557–581.

Folke, C., Jansson, Å., Johan Rockström, J., Olsson, P., Carpenter, S.R., Stuart Chapin III, F., Crépin, S.C., Daily, A.-S., Danell, G., Ebbesson, K., Elmqvist, J., Galaz, T., Moberg, V., Nilsson, F., Österblom, M., Ostrom, H., Persson, E., Peterson, Å., Polasky, G., Steffen, S., Walker, W., Westley, B., Chapin, F., III, S.F., 2011. Reconnecting to the biosphere. Ambio Invited paper. Published on the 6th October 2011.

Fuller, R.A., Gaston, K.J., 2009. The scaling of green space coverage in European cities. Biology Letters 5, 352–355.

Fuller, R., Irvine, K.N., Devine-Wright, P., Warren, P.H., Gaston, K.J., 2007. Psychological benefits of green space increase with biodiversity. Biology Letters 3 (4), 390–394.

Grahn, P., Stigsdotter, U., 2003. Landscape planning and stress. Urban Forestry and Urban Greening 2, 1–18.

Grimm, N.B., Grove, J.M., Pickett, S.T.A., Redman, C.L., 2000. Integrated approaches to long-term studies of urban ecological systems. Bioscience 50, 571–584.

Grimm, N.B., Faeth, S.H., Golubiewski, N.E., Redman, C.L., Wu, J., Bai, X., Briggs, J.M., 2008. Global change and the ecology of cities. Science 756–760.

Holdren, J., Ehrlich, P., 1974. Human population and the global environment. American Scientist 62, 282–292.

Hooper, D.U., Chapin, F.S., Ewel, J.J., Hector, A., Inchausti, P., Laovorel, S., Lawton, J.H., Lodge, D.M., Loreau, M., Naeem, S., Schmid, B., Setala, H., Symstad, A.J., Vandermeer, J., Wardle, D.A., 2005. Effects of biodiversity on ecosystem functioning: a consensus of current knowledge. Ecological Monographs 75, 3–35.

Irvine, K.N., Devine-Wright, P., Payne, S.R., Fuller, R.A., Krausse, B., Gaston, K.J., 2009. Green space, soundscape and urban sustainability: an interdisciplinary, empirical study. Local Environment 14, 155–172.

Jackson, J.B.C., Kirby, M.X., Berger, W.H., Bjorndal, K.A., Botsford, L.W., Bourque, B.J., Roger, H., Bradbury, R.H., Cooke, R., Erlandson, J., Estes, J.A., Hughes, T.P., Kidwell, S., Lange, C.B., Lenihan, H.S., Pandol, J.M., Peterson, C.H., 2001. Historical overfishing and the recent collapse of coastal ecosystems. Science 293 (5530), 629–637.

Jansson, Å., Polasky, S., 2010. Quantifying biodiversity for building resilience for food security in urban areas: getting down to business. Ecology and Society 15 (3), 20.

Jim, C.Y., Chena, Wendy Y., Y., W., 2009. Ecosystem services and valuation of urban forests in China. Cities 26 (4) 187–19.

Klein, A.M., Vaissiére, B.E., Cane, J.H., Steffan-Dewenter, I., Cunningham, S.A., Kremen, C., Tscharntke, T., 2007. Importance of pollinators in changing landscapes for world crops. Proceedings of the Royal Society B – Biological Sciences 274, 303–313.

Kremen, C., Williams, N.M., Thorp, R.W., 2002. Crop pollination from native bees at risk from agricultural intensification. Proceedings of the National Academy of Sciences of the United States of America 99 (26), 16812–16816 24.

Lagström, J., 2004. Do extensive green roofs reduce noise? Publ no 010. University of Malmö Eco-Cycle Programme. http://www.greenroof.se/data/archive/media/Forskarrapporter/010–Reduce-Noice.pdf.

Lake, I.R., Harrison, F.C.D., Chalmers, R.M., Benthan, G., Nichols, G., Hunter, P.R., Kovats, R.S., Grundy, C., 2007. Case–control study of environmental and social factor in influencing cryptosporidiosis. European Journal of Epidemiology 22, 805–811.

Loreau, M., Naeem, S., Inchausti, P. (Eds.), 2002. Biodiversity and Ecosystem Functioning: Synthesis and Perspectives. Oxford University Press, Oxford, UK.

Maas, J., Verheij, R.A., Groenewegen, P.P., de Vries, S., Spreeuwenberg, P., 2006. Green space, urbanity, and health: how strong is the relation? Journal of Epidemiology and Community Health 60 (7), 587–592 2006 July.

Mårtensson, F., 2004. Landskapet i leken. En studie av Utomhuslek på Förskolegården. Acta Universitatis Agriculturae Sueciae, Doctoral thesis. Landskapsarkitektur. SLU, Alnarp.

Millennium Ecosystem Assessment, 2005. Ecosystems and Human Well-Being: Synthesis. Island Press, Washington DC.

Moffatta, S., Kohlerb, N., 2008. Conceptualizing the built environment as a social–ecological system, special issue: developing theories of the built environment. Building Research & Information 36 (3), 248–268.

Naeem, S., Bunker, D.E., Hector, A., Loreau, M., Perrings, C. (Eds.), 2009. Biodiversity, Ecosystem Functioning and Human Well Being: An Ecological and Economic Perspective. Oxford University Press, Oxford, UK.

Nyström, M., 2006. Redundancy and response diversity of functional groups: implications for the resilience of coral reefs. Ambio 35 (1), 30–35.

Östman, Ö., Ekbomb, B., Bengtsson, J., 2003. Yield increase attributable to aphid predation by ground-living polyphagous natural enemies in spring barley in Sweden. Ecological Economics 45 (1), 149–158.

Palumbi, S.R., 2001. Evolution — humans as the world's greatest evolutionary force. Science 293, 1786–1790.

Pataki, D., Carriero, M., Cherrier, J., et al., 2011. Coupling biogeochemical cycles in urban environments: ecosystem services, green solutions, and misconceptions. Frontiers in Ecology and the Environment 9, 27–36.

Urban agriculture, diverse activities and benefits for city society. In: Pearson, C., Pilgrim, S., Pretty, J. (Eds.), International Journal for Agricultural Sustainability, Special issue 8 (1, 2).

Perrings, C., Naeem, S., Ahrestani, F., Bunker, D.E., Burkill, P., Canziani, G., Elmqvist, T., Ferrati, R., Ruhrman, J., Jaksic, F., Kawabata, Z., Kinzig, A., Mace, G.M., Milano, F., Mooney, H., Prieur-Richard, A.-H., Tschirhart, J., Weisser, W., 2010. Ecosystem services for 2020. Science 330, 323–324.

Potts, S.G., Biesmeijer, J.C., Kremen, C., Neumann, P., Schweiger, O., Kunin, W.E., 2010. Global pollinator declines: trends, impacts and drivers. Trends in Ecology & Evolution 25 (6), 345–353.

Rockström, J., Steffen, W., Noone, K., Persson, Å., Chapin III, S.F., Rosenzweig, E.F., Solecki, C.W.D., Parshall, L., Lynn, B., Cox, J., Goldberg, R., Hodges, S., Gaffin, S., Slosberg, R.B., Savio, P., Dunstan, F., Watson, M., 2009. Mitigating New York city's heat island: integrating stakeholder perspectives and scientific evaluation. Bulletin of the American Meteorological Society 90, 1297–1312.

Rönnbäck, Patrik, 2001. Shrimp Aquaculture — State of the Art. Swedish EIA Centre Report, 1. Swedish University of Agricultural Sciences, Uppsala91-576-6113-8.

Rosenzweigh, C., Solecki, W., Hammer, S., 2011. Climate Change and Cities: First Assessment Report of the Urban Climate Change Research Network (ARC3). Cambridge University Press.

Sala, O.E., Chapin, S.F.I.I.I., Armesto, J.J., Berlow, E., Bloomfield, J., Dirzo, R., Huber-Sanwald, E., Huenneke, L.F., Jackson, R., Kinzig, A., Leemans, R., Lodge, D.M., Mooney, M.A., Oesterheld, M., Poff, N.L., Sykes, M.T., Walker, B.H., Walker, M., Wall, D.H., 2000. Global biodiversity scenarios for the year 2100. Science 287, 1770–1774.

Samnegård, U., Persson, A., Smith, H., 2011. Gardens benefit bees and enhance pollination in intensively managed farmland. Biological Conservation 144 (11), 2602–2606.

SCEP. Study of Critical Environmental Problems, 1970. Man's Impact on the Global Environment. MIT Press, Cambridge. 319 pp.

TEEB, 2010. The Economics of Ecosystems and Biodiversity: Mainstreaming the Economics of Nature: A Synthesis of the Approach, Conclusions and Recommendations of TEEB.

TEEB, 2011. TEEB Manual for Cities: Ecosystem Services in Urban Management. www.teebweb.org.

Tilman, D., Reich, P.B., Knops, J., Wedin, D., Mielke, T., Lehman, C., 2001. Diversity and productivity in a long-term grassland experiment. Science 294 (5543), 843–845.

Tscharntkea, T., Bommarco, R., Clougha, Y., Cristc, T.O., Kleijnd, D., Rande, T.A., Tylianakisf, J.M., Nouhuysg, S., Vidali, S., 2007. Conservation biological control and enemy diversity on a landscape scale. Biological Control 43 (3) 294–30.

UFBP, 2010. The urban forest biodiversity program. The SA Urban Forests — Million Trees Program. Over Six Years of Achievements 2003–2009. http://www.milliontrees.com.au/uploads/milliontrees/MT_Progress_Report.pdf.

UNESCO, 2011. Management of Social Transformations Programme (MOST). http://www.unesco.org/new/en/social-and-human-sciences/themes/social-transformations/most-programme/.

Villarreal, E.L., Semadeni-Davies, A., Bengtsson, L., 2004. Inner city stormwater control using a combination of best management practices. Ecological Engineering 22 (4–5), 279–298.

Walker, B., 1992. Biodiversity and ecological redundancy. Conservation Biology 6, 18–23.
Walker, B., Meyers, J., 2004. Thresholds in ecological and social–ecological systems: a developing database[online] URL:http://www.ecologyandsociety.org/vol9/iss2/art3.
Wallace, K.J., 2007. Classification of ecosystem services: problems and solutions. Biological Conservation 139 (3–4), 235–246.
Westman, W.E., 1977. How much are nature's services worth? Measuring the social benefits of ecosystem functioning is both controversial and illuminating. Science 197, 960–964.
Worm, B., Barbier, E.B., Beaumont, N., Duffy, J.E., Folke, C., Halpern, B.S., Jackson, J.B.C., Lotze, H.K., Micheli, F., Palumbi, S.R., Sala, E., Selkoe, K.A., Stachowicz, J.J., Watson, R., 2006. Impacts of biodiversity loss on ocean ecosystem services. Science 314 (5800), 787–790.