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COMPLEXITY OF URBAN ECOSYSTEM SERVICES IN THE CONTEXT OF GLOBAL CHANGE

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Abstract

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Occurrence and quality of urban green space is important for the well-being of urban populations. Access to green spaces generally improves human well-being and well planned urban green areas can play an important role in economic development as well. Benefits of urban green spaces are well documented, although in many cases they are not acknowledged and taken fully into account by all key stakeholders, or incorporated to planning, construction and maintenance practices. Furthermore, conflicts persist regarding different types of land use and design of urban green areas. Therefore, careful planning will be necessary in order to support both protection and enhancement of biodiversity and the needs of urban dwellers. This will require an interdisciplinary approach integrating quantitative and qualitative information on ecological, social and economical factors. Even more importantly, a transdisciplinary approach integrating science with urban planning is needed in order to manage the complexity of urban ecosystem services in the context of global change.

Key words: ecosystem services, global change, urban biodiversity, urban green structure

Introduction

Urban areas are conjoint with ecosystems on several levels. The majority of the world's biodiversity is found outside urban areas, but cities, towns and transport infrastructure have massive direct and indirect impacts on biodiversity. Some cities have affirmed their commitment to engage in the fight to reverse the loss of biodiversity and international initiatives have been recently established, e.g. Local Action for Biodiversity (2006), Cities and Biodiversity (2007) (ICLEI, 2008), aiming to establish local action plans for preservation and enhancement of urban biodiversity.

Biodiversity is considered to be a fundamental basis of goods and services needed for human well-being (MEA, 2003). Well-being of people living in urban areas is fundamentally dependent on ecosystem functions in semi-urban, rural and natural ecosystems. Within ur-

ban areas, the primary issue from the perspective of human well-being is whether the urban settlements provide a healthy and satisfying living environment for residents. The question is not only about built and social environments; the well-being and quality of life of urban people is also directly and indirectly influenced by the services produced by ecosystems. Urban development can threaten air quality, the quality and availability of water, waste processing and recycling systems, and many other qualities of ecosystems that contribute to human well-being (MEA, 2003).

Improvement of human well-being resulting from urban green areas is nowadays considered to extend far beyond merely aesthetic appeal (Tzoulas et al., 2007). Even though the importance of urban green areas is increasingly acknowledged, the role of biological diversity in these areas has been largely neglected in urban planning (Petersen et al., 2007).

The focus of this paper is on the challenges created by the complexity of the relationships between global environmental, social and economic changes and ecosystem services in urban areas. We review different dimensions of this complexity in order to identify effective approaches for urban biodiversity enhancement contributing to human welfare. The importance of understanding the interactions between urban social and ecological systems has grown especially during recent decades, when global changes have significantly affected and been affected by urbanization. We concentrate our investigation on changes in Europe over the past 50 years, when urban sprawl has been intensified and urban development (e.g. housing and recreation patterns, expansion of transport) has been transformed (EEA, 2006).

Defining urban biodiversity

The UN Convention on Biological Diversity (CBD, 1992) defines biodiversity as the variability among living organisms from all sources, including diversity within species, between species and of ecosystems. In short, the notion "urban biodiversity" can be interpreted as the diversity of living things in an urban area, e.g. in a city. However, the term "urban" has various different meanings and definitions (McIntyre et al., 2000). It can be viewed from the perspective of identity or culture, economy or ecology, or from several other perspectives. Geographically it relates to cities or intensively developed built-up areas (e.g. EEA, 2006). Here we will not limit the technical definition of urban area to a certain population density but use a more practical definition. An urban area is viewed as an ecosystem that is largely paved but forms a joint habitat for humans, plants, animals and other organisms.

Biodiversity is a portmanteau term, formed by combining biology and diversity. The concept of biodiversity first appeared in the beginning of the 1980s and has been defined and interpreted in various ways (Wilson, Peter, 1988; Savard et al., 2000). The most widely accepted definition of biodiversity is probably that adopted by the UN Convention on Biological Diversity (CBD) in 1992. Accordingly and by adapting the definition of biodiversity by the CBD, we define urban biodiversity as "the variability among living organisms from all sources and ecosystems within an area with an increased density of human-created structures in comparison to the areas surrounding it."

Indicators are used to quantify and communicate complex phenomena in a simplified manner. For example, the abundance of certain bird species can reflect the state of biodiversity (Bibby, 1999). Because of the complexity of ecological systems there is no universal indicator that can accurately reflect changes in biodiversity. Therefore, subsets of indicators are needed to obtain qualified assessments of trends in biodiversity. Such work has been carried out by several initiatives, including the Streamlining European 2010 Biodiversity Indicators (SE, BI 2010, 2007). An overall picture highlighting relevant changes can be drawn with carefully selected indicators, but it must be noted that hitherto there is no general, standardised expert methodology that would be able to capture all detailed varieties of urban biodiversity at different temporal and spatial levels.

Attempts to conserve biodiversity in an urban area are usually made from an essentially different perspective than the conservation of "pristine" nature, even though in many cases it is not possible to draw a sharp line between urban, semi-urban, agricultural and natural areas. Although the main interest in biodiversity discourse has traditionally focused on natural habitats, urban and semi-urban areas are nowadays also reviewed in national assessments of the state of biodiversity and other studies (e.g. Hallanaro, Pylvänäinen, 2002; EEA, 2004; Normander et al., 2009). For example, there are several examples from the Nordic countries (Löfvenhaft et al., 2002; Petersen et al., 2005; Yli-Pelkonen, Niemelä, 2006; Auvinen et al., 2007), and a number of European or worldwide initiatives and programmes have recently been launched in order to document, assess and protect urban biodiversity (ICLEI, 2008; Countdown, 2010). Although these studies and assessments are generally based on different methods, preferences and activities, results from cities where the structure and development of urban biodiversity are thoroughly assessed can be used as a knowledge base and some experience can be extracted for the planning of practices in other urban areas. As we describe later in the paper, such information is urgently needed by urban planners and decision makers.

Multifaceted global changes and urban development

Global environmental change is reverberating through networks of relationships that are particularly intensive in urban areas. Cities can be understood as concentration centres of production, consumption, and waste disposal that generate land use changes and a host of global environmental problems. Tackling the issues of global environmental change in urban systems has been widely studied worldwide (e.g. Grimmond, 2007; Parnell et al., 2007; Simon, 2007; Grimm et al., 2008).

Today, more than two thirds of the European population lives in urban areas. The growth of urbanization between 1950 and 1990 has resulted in an overall increase of urban population. The land cover that was lost to urbanization in most of Europe between 1950 and 2000 was principally occupied earlier by agriculture, with significant areas of natural vegetation (Petit et al., 2001; Gerard et al., 2010). Historically, the growth of cities was fundamentally linked to increasing population. The growth rate of built-up areas in Europe reached its

peak in the 1950s and 1960s, when the average annual growth rate reached 3.3% (Lavalle et al., 2002).

In subsequent decades the main wave of urban growth has moved further away from the city centres, allowing urban sprawl to extend the urban influence into the adjacent countryside (Antrop, 2004; Richardson, Baie, 2004; Couch et al., 2005; Grimm et al., 2008). Hence, the pressure of extensive urban development (urban sprawl) is no longer tied to population growth. Rather a variety of other factors drive the development of the modern city, including individual housing preferences, increased mobility and consumption, commercial investment decisions, and the coherence and effectiveness of land use policies at all levels (EEA, 2006).

Increased material and energy demand of production, human consumption and urban waste discharge, as drivers of global environmental change (Grimm et al., 2008), are also reflected in changed everyday practices that constitute the lifestyles of urban populations. Factors influencing everyday practices include family structure, with more single parent families and single person households, as well as specific ideals for living conditions, in which individual gardens are seen as an important and valuable feature of the home (Bhatti, Church, 2004). Smaller households tend to be less efficient, requiring more resources per capita than larger households. For example, a 2-person household uses 300l of water per day, whereas 2 single households use 210l each. About 60% of large European cities are over-exploiting their groundwater resources and water availability, something that also puts pressure on natural habitats (EEA, 1998; CEC, 2006; EEA, 2006).

Increasing house prices close to urban centres, greater mobility, expansion of transport infrastructure, and broadening of mental geographies – i.e. the mental comprehension of accessible space – contribute to and are aspects of a development where households settle further away from urban centres (Graham, Marvin, 2001). Economic development by consequent urban development generates the need for new transport infrastructures and therefore increases urban mobility and dependence on motorized transport. Improvements in urban transport are an important factor increasing labour market mobility.

Changes in lifestyles have also led to transport patterns dominated by growing use of private cars and decreasing occupancy rates of these cars (EEA, 2006). There has been a long-term growth in leisure time in industrialised countries since the 19th century, and increasing affluence has given people more money to spend on leisure activities (Roberts, 2006). How leisure time is spent – on indoor entertainment, family life, outdoor activities etc. – is a reflection of wider societal developments. For example, as fewer people are engaged in physical work, involvement in sports and exercise has gained a different role and status, and as stress becomes a more widespread condition in work life, more people seek stress relief, e.g. through the use of urban green areas. Although populations of industrialised countries tend to become less physically active (Livingstone et al., 2003), there is also a demand expressed by public authorities, sports organisations, citizen groups etc. for facilities for physical activity. An integral part of these societal developments are also changes in cultural ideals for what constitutes a good life and what constitutes healthy living.

Together these developments create a demand for urban planning capable of fulfilling a variety of purposes. Such a demand may imply support for the protection of biodiversity, which through the services provided (see next section) is considered an asset for an urban area, but it may also imply pressure on biodiversity due to wear and tear on the green areas and further demand for transport infrastructure or simply because non-diverse types of nature are preferred by the residents.

Urban green areas as a basis for urban ecosystem services

Green areas can serve as habitats for wildlife and enhance natural processes such as water and air filtration, flood water retention, climate regulation and noise reduction (Hough, 1995; Tjallingii, 1995; Bolund, Hunhammar, 1999; Pauleit, Kaliszuk, 2005). For example, urban trees can provide a variety of benefits, including improving air quality by filtering (Nowak, 1993), noise reduction (Anderson et al., 1984) and regulation of storm water runoff and improving water quality (Seitz, Escobedo, 2008). Trees contribute to microclimate regulation and absorption of excess water (Pauleit, Duhme, 2000) and they can provide much needed cooling during heat waves that are likely to become more common because of the global climate change (Oke, 1989; McPherson et al., 1995).

Exposure to and activities in nature have beneficial effects on humans (Swanwick et al., 2003), such as recovery from various stress factors emphasized by many eco-psychologists (e.g. Ulrich et al., 1991; Brown, Grant, 2005). For example, the Health Council of the Netherlands (2006) published a report which concluded that quiet green areas close to home compensate for noise and stress. Urban green areas can also serve educational purposes, especially because nature is not always seen as a vital element by the public and in particular by children (Borsus, 2008), and knowledge about biodiversity and its changes is relatively poor. Leisure activities play an important role in everyday life and in the formation of social and individual identities. To some extent leisure activities take place in and make use of green- and blue-space. Simply by being in a natural environment people improve their connection with nature and develop a sense of responsibility rather than alienation (Countdown, 2010). These effects and other lifestyle priorities are also expressed in housing patterns, with spread of suburbs, widespread wish for private gardens, various ways of using and cultivating those gardens, but also demands for green areas in densely built residential areas in the city cores.

Economic benefits of urban green space can be measured by proximity to recreational areas. Open green landscapes, coasts, and woodlands are considered to be desirable, because they can increase the economic value of urban housing and improve life quality. These benefits are in dwelling prices: increasing distance from urban green areas can lead to decrease in the market price of a dwelling (Anderson, Cordell, 1988; Tyrväinen, Miettinen, 2000). Family income also has significant correlation with urban patterns of biodiversity, in particular neighbourhood plant and avian diversity and park plant and avian diversity (Kinzig et al., 2005).

The presence of professionals with high education is one of the main factors in regional innovation and favourable economic development, as educated employees seek a high quality living environment and similarly large companies want to establish themselves in high quality surroundings (Hess et al., 2002). In order toattract these "key people" (Grossmann, 2000) development strategies of the regions, including urban areas, are shifted from obsolete locational factors towards soft factors of quality of life, such as desirable outdoor environment and ecologically healthy nature. The economic advantage of an urban area incorporating green space has already been demonstrated in many developed regions, e.g. in a study of the north and south side of the conurbation of West Holland (Manshanden et al., 2006). In other words, improvement of well-being and effectiveness of employees is also due to contact with nature at the workplace (Kaplan, 1993).

"Ecosystem services" is the concept which has been developed to stress the importance for human welfare of biodiversity in ecosystems. Early versions of the concept originated in the late 1960s and early 1970s, but most classifications, assessments and wider discussions have emerged since the late 1990s (e.g. Constanza et al., 1997; Daily, 1999; Farber et al., 2002; de Groot et al., 2002; MEA, 2003). The concept also contributes significantly to understanding of relations between ecosystem functions and human welfare in urban areas.

Many typologies addressing these benefits have been employed by projects aimed to develop urban green planning (Boverket, 1992; Hess et al., 2002; URGE, 2004; Saarela, Söderman, 2008). Currently, probably the most widely used is the classification to regulating, provisioning, cultural and supporting services from the Millennium Ecosystem Assessment (MEA, 2003). Provisioning services are to a limited extent directly relevant in urban areas in Europe, for example when people grow vegetables, fruits and herbs in and obtain firewood from their allotments and gardens. Benefits from regulating and cultural services in urban surroundings are much more relevant for the majority of European urban dwellers, considering both the qualitative and quantitative aspects.

Whether green spaces can effectively produce ecosystem services depends on a variety of factors such as the overall provision of green spaces, the size, diversity and distribution of green spaces within the city, as well as the design and management of the individual green spaces and expectations directed towards them (e.g. Nowak et al., 1996; Jankauskaite, 2006; Zhu, Zhang, 2007).

Not all ecosystem functions are valued as important and beneficial. Many ecosystem services are not noticed at all, or their importance is noticed only after they have been degraded. Some ecosystem functions, such as unpleasant noises or behaviour of animals, transmission of diseases or economic losses caused by nuisance animals, can be seen as disservices to human welfare (Lyytimäki et al., 2008). Biodiversity is valued differently by different people and even by the same people in different situations and only certain kinds of biodiversity are perceived as enjoyable, beautiful or safe. In order to enable efficient biodiversity policies and urban planning it is important to know what kind of potential harm biodiversity can produce for people and what kind of biodiversity is regarded as unpleasant. These negative issues should be explicitly recognized and dealt with in planning processes together with ecosystem services (Lyytimäki, Sipilä, 2009).

The challenge of urban socio-ecological complexity

Integrated studies clustering both ecological and social systems in urban areas have been conducted mostly in connection with urban planning (Pickett et al., 1997; Grimm et al., 2000; Pickett et al., 2001; Yli-Pelkonen, Niemelä, 2005). As Pickett et al. (2001) concluded there is motivation of urban planning and architecture as professional practise to incorporate ecological principles, to make environmental amenities available to residents, and to decrease negative impacts on urban environments. In order to achieve these objectives complex data are required by planners, in the sense of ecological and ecosystem functions in urban areas rather than static biodiversity descriptions. Lack of relevant information and its interpretation for urban planners was also pointed out by Yli-Pelkonen and Niemelä (2006), in which study the interviewed planners and ecologists considered ecological information to be important for preserving valuable urban nature, diminishing negative environmental impacts of construction and for enabling nature-related experiences and services for urban residents.

However, the question remains whether the information about potential services coming from urban ecosystems is the most relevant and required for planners and decision makers. Bolund and Hunhammar (1999) chose six functions of ecosystem services important for urban systems and particularly for Stockholm city, stressing that ecosystems generate a number of different services simultaneously and that even if individual values are small the overall value of urban ecosystems might be significant. Another approach, which has the opposite procedure, starts with detailed mapping of urban green areas and subsequently their classification on the basis of assignment of function (or cluster of functions) for each type of urban green. This approach, based on biotope mapping methods first carried out in Germany (Sukopp, Weiler, 1988; Sukopp, Wittig, 1993; Sukopp, 2002), was performed in Bratislava city (Reháčková, Pauditšová, 2004), where the structure and distribution of green patches were evaluated together with their ability to provide biocentric (ecological) and anthropocentric functions, and in Nitra city concerning recreational function (Supuka et al., 2005). Specific locally managed green areas were analysed in the study of Colding et al. (2006), with listed potential ecosystem services and emphasis on their significant role in management of the urban biodiversity. Testing of the environmental performance of land use via clustering of the urban land cover types (Pauleit, Duhme, 2000) presents a more practical approach for the urban planning purposes.

The above-mentioned studies, among others, demonstrate the significance of urban green areas, but the connection to the social factor is inadequately covered. According to Grimm et al. (2000), both ecological and social systems must be considered for a full understanding of human dominated ecosystems and the authors identified the drivers and the patterns of human activities. Similarly Pickett et al. (1997) incorporated social system components into human-ecological models and recognised spatial heterogeneity in both the natural and social components of urban ecosystems. In addition to structure and interactions of the social pattern, a historic trajectory is a key factor in the analysis. Social components are very dynamic, especially in the era of global environmental changes, when spatial forms of urban sprawl are rapidly changing and human activities are influenced by a variety of global

driving forces. By harmonising the social and ecological data across temporal and spatial scales, a comprehensive view of the urban ecosystem can be delivered to the planners.

Urban green structure as a key concept for integrative planning

Although the idea of a green city with rich biodiversity is warmly welcomed by many urban residents and policy-makers, policies and planning measures to preserve biodiversity in urban areas are heavily contested. Space is a scarce resource in urban areas, where conflicting demands for land use often occur. For example, demands from private households for more living space including private gardens can be in conflict with the need for species-rich natural and semi-natural areas and the demand for free access to public green spaces. Ironically, a higher priority given to experience of the outdoors and of nature may also lead to renewed pressure on biodiversity due to increased and intensified land use. It may be possible to resolve differences between conflicting demands, but such win-win solutions require integrated planning and a thorough understanding not only of the ecological facts but also concerning the demands and interests that are at stake.

Ecological approaches at different landscape levels have been used in land use planning. Here we focus on the concept of green infrastructure or urban green structure. This concept refers to all terrestrial, limnic and marine habitats within the urban landscape, i.e. areas neither covered nor sealed. It includes green spaces such as like parks, play grounds, sport fields, allotments, private gardens, industrial properties as well as roadsides and rail yards (e.g. Tjallingii, 2005; Supuka, 2008). Green infrastructure can further be defined as the subregional network of protected sites, nature reserves, green spaces and ecological corridors that serve as linkages. These linkages include river corridors and flood plains, migratory routes and features of the landscape which are important as wildlife corridors. Particularly the connectivity of these sites and functions is a crucial element for creating opportunities for multiple uses of green areas (Barker, 1997).

The concept of green structure can capture in a planning-oriented way many of the aspects of urban development and urban biodiversity. Its aim is the elaboration of planning and management tools for improvement of the structural role of green areas in the urban fabric (Tjallingii, 2005). In order to make the concept capable of addressing the multiple challenges brought up by global environmental changes, several dimensions must be considered, rather than biodiversity at the species level as the only dimension (Gyllin, 2004). Results of single discipline analyses standing alone may be beneficial, but they are unable to provide the comprehensive assessment needed by planning practice. We propose the following dimensions to integrate ecological and social systems sufficiently, including historical trajectories and driving forces as mentioned in the previous section:

- The psychological dimension: Different ways of perceiving the benefits and nuisances of green structure and the reasons behind them (past and recent).
- The health dimension: Beneficial and harmful effects of green structure on human health.

- The ecological dimension: Biodiversity and its development.
- The cultural dimension: Green structure as a part of urban history and identity; green areas as design elements.
- The social dimension: Relationships between green structure and changes in social behaviour, e.g. recreation, health, leisure and pedagogical meaning.
- The economic dimension: Direct and indirect benefits and costs of urban green structure.
- The legal and administrative dimension: Status of green structure in management practices.

Ecological conditions and the political and societal background for planning and development activities differ considerably throughout Europe, and tools suitable for one country or city are not necessarily suitable for other places or times. Therefore, the inclusion of elements of situational learning becomes crucial. Planning is very dependent on local contexts and the results can be spread rather by inspiration and examples of best practice than by a set of rigid tools to be used in uniform way (Aalbers, 2003).

Both interdisciplinary approach and participatory planning methods are needed in order to incorporate the varying values and perceptions of citizens, politicians, planners and other officials. Participatory methods can allow for the sharing of knowledge, sense of ownership of decisions (with direct benefits for delivery) and a level of flexibility in policy implementation because of the consensus that should have been achieved between the stakeholders (ECNC, 2007). The information obtained with participatory methods represents the so-called local ecological knowledge (LEK) and the social values of urban dwellers. In order to develop methods to meet the challenges regarding the use of LEK and to control both the ecological and social impacts of land use change, both ecological and social scientists should be integrated into the planning process (Yli-Pelkonen, Kohl, 2005). Integrating proper social impact assessments in the environmental impact assessment could also be a useful improvement of urban land use planning (Yli-Pelkonen, Niemelä, 2005).

Several examples of local participatory methods in urban planning can be found e.g. in Nordic cities, where perceptions and values of urban residents are incorporated with knowledge on the ecology of urban green structure. As the biotopes represent the ecological values of the area, "sociotopes" reflect the social and cultural values of citizens (Ståhle, 2004), and such assessments analysed by advanced geographical information systems (Rantanen, Kahila, 2009) can be used to inform experts, decision makers and the public and to support integrative urban planning.

Discussion and conclusion

Changes in land use and land cover are one of the major types of global changes affecting urban systems. Urbanisation, together with urban lifestyles of the population, puts a significant pressure on urban biodiversity even extending beyond city boundaries. Impacts of this pressure can be seen in the conversion of natural ecosystems, loss of productive agricultural land, fragmentation of natural habitats, pollution of air, soil and water, changes in the water cycle, and reduced biodi-

versity (Alberti et al., 2006; Schneider, 2006). Changes of biodiversity affect ecosystem functions and services and consequently human well-being in urban areas. This is an example of a cycle of socio-ecological interactions within global environmental change, significantly intensified over the last few decades. If we have knowledge of the driving forces of such changes, concrete pressures on ecosystems and biodiversity, their state and subsequent impacts on humans, we should be able to propose planning responses to reduce such processes.

This paper evaluated issues in a European context in order to provide an overview to investigate ecosystems services in complex and changing urban conditions. To conclude, as compared with the relatively well developed research agenda on urban biodiversity and its benefits, the integrated investigation of complexity of social, economical and ecological elements of urban biodiversity benefits is still rather rudimentary. Although single-discipline approaches have been developed (e.g. biodiversity indicators, monetary assessments of biodiversity), a lack of comparable urban data and a shortage of appropriate methods for obtaining and analysing different kinds of data across different dimensions of urban green structure impede investigation. As an example we can mention biotope mapping methodology, which despite providing very detailed ecological datasets (e.g. species, ecological conditions and processes) must be adjusted to integrate socio-economical demands. In particular, higher species diversity might not be compatible with the idea of more developed regulating ecosystem services, which could be prioritised by urban dwellers.

Furthermore, economic and management preferences for certain land use categories, regardless of possible benefits of ecosystem services, play important role in decision making and thus should be incorporated. As the results from cases presented above show, the social pattern has often been investigated and integrated to ecological knowledge rather superficially. The research approaches in the cited cases (e.g. built on potential profits of ecosystem services, characterising of green areas or land use as the main emphasis) provided information mostly on a limited single-scale level considered for urban planning rather than implementation of scale-explicit interdisciplinary research (Dirnböck et al., 2008).

Integrative concepts are very recent and their implementation is associated mainly with local biodiversity programmes. As a response to fill the gap in urban biodiversity research within global environmental change, a number of recent reports and initiatives (UN-HABITAT, 2001; IHDP, 2005; UNEP, 2007) have highlighted the need for multi-scale research into the drivers and consequences of dynamic urban processes.

The question is not only about the interdisciplinary approach integrating different kinds of data, but also about the transdisciplinary approach bridging scientific knowledge with planning practices and local knowledge. Urban lifestyle preferences and biodiversity preservation may be modified to support each other, but there is a need to involve stakeholders through effective negotiation and consensus building. Integrative development and planning to enhance the biodiversity of a city and to secure sustainable development at the same time should be supported by scale-explicit socio-ecological approaches.

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