8 What is Urban Ecology and What Are Its Applications in Urban Development?

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Abstract

Urbanisation is one of the defining phenomena of the twenty-first century, which has affected all regions of the world. With a world population growing to more than nine billion people, there is also no serious alternative to the city as a human habitat. From an ecological perspective it is also the most effective and efficient form of organization of human life. However, cities, as we know them, generate major environmental burdens that not only affect the city dwellers themselves but are also associated with global impacts. Climate change, the exploitation of fossil fuels and non-renewable raw materials, the overexploitation of natural resources and, last but not least, the enormous problem of the release of substances as pollutants into the environment, which is only slowly being recognised to its full extent, must be mentioned at the forefront.

8.1 It is About the City of the Future!

Cities have never been ecologically sustainable in the narrower sense because as open systems they are dependent on imports of energy and materials from the surrounding environment (Elmqvist et al. 2013). Even the boldest visions of urban agriculture producing in skyscraper towers and a radical but very difficult to implement change in human consumer behaviour are unlikely to lead to cities becoming completely self-sufficient. This is contradicted by the high and ever-increasing concentration of human consumers in cities and the intensity of economic processes that consume energy and raw materials in a limited area. However, cities could be much better organized and thus become more efficient from an ecological point of view than they are today.

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So what should the city and urban region of the future look like? It would probably be impossible to give just one answer to this question. Cities of the future should have a high quality of environment and life, at the same time the ecological footprint should be as small as possible, and they should be resilient and adaptable, especially with regard to climate change. What these goals mean in concrete terms for cities and how they can be achieved must be answered individually for each city. Munich, Leipzig, Shanghai and Dar es Salaam each face their own unique challenges. If we assume that there will be no major destruction caused by wars or other disasters, then the European city will presumably, even at the end of the twenty-first century, resemble the city as we know it today in many areas of its appearance. However, its way of functioning will change radically as a result of social change and global environmental changes. European cities must drastically reduce their consumption of resources. Land growth must be curbed, but in compact cities, concepts such as "dual inner development" (DRL 2006) must simultaneously ensure and develop an appropriate and ecologically efficient provision of urban nature as "green infrastructure" (Pauleit et al. 2011). Only in this way can adaptation to climate change with the increasing overheating phenomena, heat waves and heavy rainfall events be managed. This is the only way to achieve appropriate access to urban nature for citizens.

Copenhagen has set itself the ambitious goal of becoming climate neutral by 2025 (City of Copenhagen 2012a). Bicycle traffic is also being promoted as an environmentally friendly means of transport (City of Copenhagen 2008). In order to reduce the future risk of flooding caused by heavy rainfall events, which the city had to painfully experience on 2 July 2011, the so-called "Cloudburst Management Plan" was adopted (City of Copenhagen 2012b). It provides for the large-scale redesign of street spaces, squares and green areas in order to increase the water retention capacity and thus relieve the sewerage system. However, it does not stop at the plan, as the first projects are already being implemented. Squares and entire urban quarters are being redesigned, which will then not only be better prepared for the demands of climate change but will also be more liveable because the quality of open space has improved through more and higher quality urban greenery. Biodiversity will also benefit from more trees and other vegetation elements.

Copenhagen can therefore serve as a model for ecologically oriented urban development. However, Copenhagen is an economically prosperous urban region, and solutions developed there cannot simply be transferred to other cities, for example in old industrialised regions that are struggling with structural economic problems. Here, in turn, special approaches must be developed for the ecological city of the future that specifically addresses the challenges there, such as the high proportion of derelict land. From 1989 to 1999, the Emscher-Park International Building Exhibition in the Ruhr area set a benchmark for the ecological reconstruction of this industrial region. The focus was on restoring and promoting the landscape and ecological quality, which was seen as the basis for a more comprehensive renewal of the Ruhr area (Minister für Stadtentwicklung, Wohnen und Verkehr des Landes NRW 1997; IBA 1997). Particularly well-known examples among many others are the renaturation of the Emscher river, the conversion of steelworks in the north of Duisburg into a large park and the securing of the Zollverein coal mine in Essen as a world cultural heritage site. Existing brownfield sites, on which species-rich communities had settled, could not only be secured but also formed the basis for the design of a new type of open space.

While these and other projects are models of how the goals of ecologically oriented urban development can be implemented in concrete terms, this project-based strategy must also be embedded in a broader view of regional contexts. The image of the sharply delineated city here and the country there is no longer appropriate today, nor is it conducive to achieving the goals. Large contiguous open spaces in the urban environment can fulfill important ecological functions for supplying the city with drinking water and fresh air, they are important for recreation and the production of food. However, peri-urban and rural areas must also receive adequate compensation for the provision of these services in order to satisfy their specific needs. Urban development should not only be thought of from the city, but also the rural area (Piorr et al. 2011). The image of the Rural-Urban Region, which consists of interconnected urban core areas, peri-urban areas as well as rural areas, may offer a meaningful basis for this, as it is based on the realities of the spatial structures existing today. Urban ecology as an inter- and trans-disciplinary approach should explore the possibilities for more sustainable development of these rural-urban regions and support their implementation in action concepts. However, the latter will only be possible if politics is also enabled to make decisions on the level of rural-urban regions. But this is precisely what is lacking.

Shanghai, as an example of a megacity in an emerging economic country, faces its own challenges, not only because of its enormous size and population density. But here, too, ecological goals for urban development are recognised as important and major investments are being made in the development of an urban green space system (Chapter 4).

Cities such as Dar es-Salaam, whose population is growing at an almost explosive rate, and this without comparable economic growth, must find completely different answers than the cities of highly industrialised countries. Models for the city of the future must take particular account of the fact that 70 to 80% of the population live in unplanned slums (URT 2004) and that this is unlikely to change much in the coming decades, given annual urban population growth rates of up to 5% (Di Ruocco et al. 2015). The aim cannot, therefore, be to replace the African city, however dysfunctional it may be at present, with European urban models, but rather to help it gradually develop into a model of its own. Prof. J. Schellnhuber, Director of the Potsdam Institute for Climate Impact Research (Potsdam Institut für Klimaforschung), for example, writes about the need to develop functional slums in cities in developing countries (SZ 2015). This demand may sound sobering, but it takes note of reality. One particular concern must be to ensure that the population is fed and supplied with basic necessities. Urban and peri-urban agriculture should therefore play a key role in ecologically oriented urban development. It is equally important in these cities to keep river valleys and other risk zones free from the settlement to avert recurring risks and those aggravated by climate change from the growing population.

Looking at these challenges for ecologically oriented urban development, in a nutshell, this could be frustrating for the reader, as it does not give a clear, unambiguous picture of the city of the future from an ecological perspective. The challenges in detail and the prerequisites for the development of solutions are too diverse and different. However, the theoretical and methodological approaches to urban ecology presented in this book make it possible to approach the major challenges of urban development and thus gain insights that enable the development of respectively adapted problem-solving strategies.

8.2 It is All About Urban Structure!

What is the urban landscape? Results of the biotope and structural type mapping have shown that cities are a diverse mosaic of different building and green structures, each with its own ecological characteristics (Chapter 2). They differ in their flora and fauna, microclimate and soils. Land use and surface cover, that is, the proportion of sealed or vegetation-covered areas, are therefore also referred to as key ecological features (Pauleit and Breuste 2011).

Natural elements, such as rivers or mountains, are landmarks; they give cities a special character with their unique shapes and expressions of flora and fauna. However, urban development has usually strongly influenced the natural conditions and the proportion of remnants of the natural and historical-cultural landscape is small. Moreover, they are often fragmented into small areas. Nevertheless, they play an outstanding role in biodiversity, because it is precisely these near-natural habitats that contain a large proportion of regionally typical and rare species.

Public green spaces can also make up a significant proportion of the urban green structure. However, the largest share of urban green spaces is in private and institutional hands. This means that biodiversity in the city and ecosystem services such as temperature regulation can only be secured in the long term by planning that takes into account the entire urban landscape. For this reason alone, ecologically oriented urban development cannot dispense with investigative approaches that cover the urban landscape as a whole. Biotope and structure type mapping in combination with surface cover surveys from aerial or satellite imagery or gradient analyses are practicable approaches to capture and analyse the urban landscape and its ecological characteristics.

Since urban planning can influence land use and building structure through instruments such as land use plans, approaches such as structural type mapping also provide an interface for introducing ecologically relevant information into urban planning. They provide a basis for answering questions crucial to urban development, such as the required proportion, characteristics and distribution of green spaces in order to provide desired ecosystem services, for example, to regulate the urban climate.

In Germany, more than 200 cities have carried out biotope mapping (Werner 2008), but comprehensive flora and fauna surveys are already a rarity. While it is possible to compare the population numbers and densities of European cities, there are no comparative figures for ecologically as basic characteristics as the degree of land sealing or the total percentage of vegetation, or even more specifically, of their tree population. From a global perspective, the data is even more limited, with the exception of North America and Australia. South American, Asian and especially African cities have hardly been researched from an ecological point of view, and the above-mentioned data only exist for a few examples.

8.3 It is All About the Special Nature of Urban Ecosystems!

Cities are ecosystems that are strongly shaped and controlled by humans. Urban ecosystems are unique in their close interdependence and the interactions (*feedbacks*) between natural and man-made structures and are therefore extremely complex. Urban ecosystems are characterized by small-scale varying, often extreme biotic and abiotic factors compared to the surrounding area (Haase 2011).

Urban ecosystems have their own typical urban climate due to dense building and sealing, as well as emissions from industry and traffic. In terms of land cover, tree and green space, many cities show a clear urban-rural gradient. Frequently used criteria for defining cities or “the urban” are, on the one hand, the high proportion of built-up or sealed areas and, on the other, high population density as two essential characteristics of urban systems compared to rural systems (Haase 2012, 2014).

With regard to their land use, cities and urban areas are used very intensively, a multifunctional use of most urban areas dominates, that is, the combined occurrence of the residential function but also of the work, traffic and recreation function. The urban land cover matrix is correspondingly complex (Larondelle et al. 2014; Chapter 2). Indicators for mapping urban land cover or land use are European-wide data sets such as Corine Land Cover and Urban Atlas, both provided by the EEA (Larondelle et al. 2014).

8.4 It is All About Urban Nature!

The diversity of urban nature is surprising at first sight. In the city you will find natural elements that are rarely or not at all found outside the cities. This is due to the special urban habitat conditions (temperature, humidity and water balance, light, air chemistry, soil condition). Man intervenes in the inter-species competition by using, caring for and planting them and causes constant disturbances. Neophytes, which are able to survive well under these conditions in competition with native species, enrich the flora additionally and make cities local “hot spots” of biodiversity with regard to species diversity.

Cities are also attractive habitats for animals. Their number of species in the city is even considerably higher than that of plants (approx. ten times higher, Klausnitzer 1993; Tobias 2011). Due to the loss of habitats outside the cities and the attractiveness of cities as habitats (e.g. food, lack of competition), wild animals colonize cities permanently. Cities are thus also substitute habitats for species that often have few habitats left in the intensively used agricultural landscape of the urban hinterland. However, there is still insufficient knowledge about populations, adaptation to habitat, dispersal and endangerment of wild animals in the city. Specialists as well as generalists and adaptable people find new habitats in the city.

Small-scale fragmentation, warmer and drier habitats and changing intensities of use are characteristics of urban nature, whose properties are thus diverse and essentially determined by man. Urban habitats are in a state of constant change due to changes in use and urban development. Stability is not so much a characteristic of urban nature. This is also not to be expected in view of the already noticeable climate change. Cities are even “pioneers” of climate change. Here, extreme climate conditions (compared to the urban environment) are already noticeable. Climate change will bring new, additional challenges for flora and fauna. Cities are the first “experimental fields” to show how flora and fauna will react to these changes.

People live consciously or unconsciously in urban nature and together with it. The diversity of urban habitats can be divided into four easy-to-describe nature categories (“nature types”—Kowarik 1993). These range from still existing non-urban “nature relics” to spontaneous vegetation on abandoned farmland. They all have their justification in the natural spectrum of the cities. Their perception, acceptance and use by urban dwellers, however, are quite different.

City trees along streets, in squares and city forests are appreciated by most city dwellers. For example, they enable a diverse range of ecosystem services and require little space. A city without trees is difficult to imagine and certainly not desirable. Derelict land presents us in succession with new, often still unknown urban nature, to which people at first still turn timidly, as they do not know, overestimate the risks of use and are culturally influenced, rather rejecting “unkempt” things.

Urban nature is neither primarily fragile nor is it first and foremost a risk area for humans. City dwellers must learn to understand urban nature better, to use this knowledge to shape it more consciously and to appreciate its diversity as a valuable and indispensable part of our city living space. Urban nature is not only a place for recreation and a contrast to the built environment but also a space for nature experiences that all city dwellers need and especially children demand and require.

The task of bringing nature in the city closer to the people in the city and turning urban nature into places of learning and experiencing nature alongside recreation is of particular importance. It is a space for recreation, inspiration, relaxation and learning. This requires a green infrastructure that is accessible to everyone.

8.5 It is About Ecosystem Services for People in the City!

"Urban ecosystem services" is a relatively new concept for assessing urban nature and urban ecosystems (Haase et al. 2014). Ecosystem services are those services of ecosystem structures and processes that contribute to human well-being.

Ecosystem services in cities can be divided into four types: producing, regulating, recreational and support services and assessed on a rural to urban gradient (Larondelle and Haase 2013). In the city, regulatory and recreational functions are more important than production services (Larondelle et al. 2014). Important in all cases are the so-called basic or supporting services, to which the habitat and biodiversity function but also soil formations are added.

A particularly important urban ecosystem service is the recreational function—it can be influenced by the number, size and above all the accessibility of urban green spaces by the city's inhabitants (Kabisch and Haase 2014). Furthermore, analyses of the perception of urban green and water infrastructure and their consideration in planning processes play an increasingly important role. However, area enhancement through new and high-quality green spaces (for example, the High Line Park in NYC, Tempelhofer Feld in Berlin or Lene-Voigt-Park in Leipzig) also quickly and consistently leads to higher land prices and rents and promotes—in part not unintentionally—increasing social and income segregation in our cities (Gruehn 2010).

Of equal importance—against the background of climate change, the increase in heat days and heat waves in cities—is local climate regulation, that is, the cooling function through urban nature. It can be determined with the proportion of shaded and tree-covered areas, the surface temperature or radiation, but also evapotranspiration as an expression of latent cooling heat (Schwarz et al. 2010).

However, the urban production function in the sense of urban agriculture in a broader sense is also gaining in importance: classic allotment gardens are supplemented by backyard gardening, temporary uses (Lorance Rall and Haase 2011)*community gardens* with a strong social component, but also short-rotation plantations on fallow land and new forms of peri-urban agriculture such as solidarity-based agriculture or the "Ackerhelden" initiative around Berlin.

There are basically two ways to assess urban ecosystem services in terms of their usefulness to humans—monetary and non-monetary approaches. The latter can be quantitative and qualitative. However, there is currently far better knowledge about the supply of ecosystem services in the functional sense than the demand in the empirical sense.

Due to urban multi-functionality, synergy effects as well as *trade-offs* (conflicts) occur between ecosystem services in the city (Haase 2012), which require a balancing of different goals.

8.6 It is About the Resilience of Urban Ecosystems!

Urban ecosystems are sensitive to disturbances and natural hazards due to changes in energy, material and water flows. Decisive factors are denaturation through sealing and dependence on other ecosystems in the immediate and wider surroundings. Sealing can be regarded as an ecological complex variable, as it alters both energy and material and water flows. Developing resilience to vulnerability is an important task of ecological urban development. Urban ecosystems can make a significant contribution to this. Resilience should not be understood as inertia, but rather as the ability of the urban ecosystem to change and learn. Resilience refers to the ability to react to crises and disturbances, to strive for a dynamic balance of self-renewal and design possibilities (self-regulation). To achieve resilience, existing structures must be transformed into adaptable forms (Vale and Campanella 2005; Walker et al. 2006; Newman 2010). Cities are not only vulnerable as a whole but differ considerably in the resilience of their internal structures, their urban ecosystems. From a resilience perspective, the macrosystem city and urban region can be divided into microsystems, for example, urban structures, and subdivided into the relevant subsystems of economy, environment, infrastructure, *governance* and social affairs (Jakubowski 2013). Certain vulnerable population groups are exposed to environmental stress factors or natural hazards such as heat, floods, drought or tsunamis in their urban habitats and have difficulties in coping with them. These difficulties result not only from a lack of material resources but also because those affected are denied equal participation and access to wealth and income and because they are not sufficiently integrated into social networks (Bohle 2001).Urban ecosystems are thus vulnerable or resilient to external influences of natural events in different ways. To this end, concepts for vulnerability reduction need to be developed that build on the characteristics and performance of urban ecosystems. The Elbe floods of 2002, 2006 and 2013 have shown that vulnerabilities of very specific urban ecosystems, here those of the urban river floodplains, lead to a high degree of resilience (floods from 9 m can now be tolerated!) through technical measures such as raising the dikes. However, they also show that such adjustments reach technical and financial limits and, if they fail, lead to even greater damage. As an alternative or complementary measure, urban structures and their uses should therefore also be adapted (Chapter 2), for example by (re)creating retention areas for floods and by unsealing them to reduce rainwater runoff. These measures promote ecosystem services and thus increase resilience. Compact cities in green networks, vegetation, especially trees integrated into the urban structure and networking of the built city with the surrounding area of the urban region can contribute to this (*nature-based solutions*). The idea of the city as a purely social-technical system must be abandoned in favour of the integration of these social-technical systems in and the resulting urban ecosystems. Understanding these ecosystems, using and consciously shaping their properties and thus contributing to increasing the resilience of cities is an important future task of ecologically oriented urban development, in which citizens must be actively involved as co-designers of their urban living environment.

8.7 It is All About Eco-Cities!

In order to achieve goals, it is good to have a vision as a guiding principle. The eco-city model or similar names provide orientation. The fact that such visions are generally helpful is shown by the numerous national and international initiatives on the broader topic of "*City of Tomorrow*". Dynamic urban development requires management in order to develop structures that are stable in the long term but also flexible enough to meet future requirements. The city of the future is rarely built from scratch but must develop from existing cities. The model must be adapted to many, very different conditions and requirements. Only in China, and in a few examples elsewhere, are new cities actually being built. Here, it could be shown that innovations are taken up and eco-cities are created.

The city of the future is generally a very comprehensive concept in all its sub-areas, eco-city (sustainable city etc.) is a part of it. Its basic principle is to be a city that is in balance with nature and that benefits from nature and its processes and structures (*nature-based solutions* without destroying them (Cities in balance with nature) (Register 1987; Ecocity Builders 2013). This basic principle is multifaceted and should not be pursued in one area alone. Often a selective focus is placed on the eco-city (e.g. energy use and efficiency) and other areas are completely neglected. This dissolves the necessary complex picture and makes "eco-" appear as merely "energy efficiency". On the other hand, eco-city is understood as a technological field of experimentation (e.g. CO_2 emission reduction, low-energy houses, transport technology, rainwater technologist etc.). This is also a possible approach when it comes to what is ultimately most important: the people in the city. Cities are first and foremost people's living space. Enabling them to enjoy better living conditions in them, while taking nature and its processes into account, can be a viable approach. This includes not restricting the opportunities for the inhabitants of other settlements on this earth and future generations to meet their own needs in an appropriate manner. This also means involving city dwellers as co-designers of their urban environment, giving priority to their perspective. The eco-city can thus also be created as eco-city development "bottom up". This participatory approach leads to exemplary small ecological city elements, districts, green spaces etc. They can be used as mosaic pieces to further advance the eco-city idea. Such innovative individual projects describe the path to the eco-city as a target idea.

The approaches in China are different. New cities are designed, planned and built with the latest technology and innovation, often in cooperation with architects from Western countries. People then move in, but often many of the buildings are empty. The eco-city idea remains rather strikingly reduced to certain areas (e.g. CO_2 emission reduction) and is not exemplary. Reality lags behind its claim. In Europe, too, a process to promote future-proof, sustainable urban development began with the Aalborg Charter in 1994 (ESCTC 2013).

It can be seen that there are still no measurable criteria for eco-cities that could affect the individual aspects in detail. However, there is an urgent need to check eco-towns measurably by means of indicators of these partial aspects. The criteria to strive for depend on social, cultural and natural problems. Climate adaptation, energy efficiency, nature integration (ecosystem services) are generally worth striving for, and the achievement of these goals is measurable. The most frequently mentioned areas of eco-cities are Energy (especially concerning buildings), general resource consumption, mobility, water, waste, open space and green spaces. Work, economy, social/cultural issues, participation are rarely taken into account. Urban structure and open space, especially green infrastructure, must play an important role. However, it is important to develop a livable, functional and resource-efficient whole.

Eco-cities are never "finished", but should be able to develop further; the newly developed status can then be measured and compared with the initial situation.

Eco-cities should not be eco-islands, but starting points for ecological development and integration of the surrounding area. Together with their surroundings, they form an innovatively developing urban region.

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