Jürgen Breuste · Stephan Pauleit · Dagmar Haase · Martin Sauerwein

Urban Ecosystems

Function, Management and Development

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This book is dedicated to Prof. Dr. Herbert Sukopp, the pioneer of urban ecology, on his 90th birthday.
In gratitude and appreciation

Jürgen Breuste
Dagmar Haase
Stephen Pauleit
Martin Sauerwein

Foreword

Cities and thus urban ecosystems are the most important habitats for us humans. Their continued expansion cannot be given enough attention. This is reflected in an annually growing number of international publications, including numerous textbooks. We have deliberately decided against placing the young science of urbanecology at the centre of the book, but rather the urbanecosystems themselves that it investigates. Our perspective here was an urban ecology, but with a focus on biophysical and social functions, management and development, in short, with a focus on nature and humans. To this end, we have selected eight questions that we know are of great importance for research, management and development of cities. We do not claim completeness. Many more questions are waiting for answers!

However, we hope to be able to show that understanding urbanecosystems is a key to sustainable, ecologically orientedurbandevelopment. Urbanecosystems - technically designed, socially used and economically valued - are a functional focal point of urban development in the present and the future. We are deliberately aiming at a future-oriented urban development which, given the high dynamics worldwide, is also setting itself ecological goals right now and asking: How can urban ecosystemsbe designed and managed? Where are nature-based solutions and their ecosystem services most needed? Where is the need to reduce risks from natural hazards? How can cities develop resilience by relating to urban nature in order to better cope with future crises? The "eco-city" is thus not an utopia, but a real goal that can be pursued step by step in a targeted manner, taking into account local and regional contexts.

We hope that this book will meet with a broad interest in the ecological basics of life in cities and towns, but also in their consideration in the preservation and continuous improvement of them asliving space for urban dwellers. It will thus contribute to the preoccupation with the topic of "Man and Nature" in the city.

This translation into English takes into account new developments in recent years since the book was published in 2015, and supplements English literature. Nevertheless, it is a translation and not a new concept as such. Despite many international examples from outside of Europe, the focus of the book remains on Europe. This can be seen twofold: as a disadvantage, but also as an advantage. The new discipline urban ecology, which examines urban ecosystems, has its roots here; many of the first practical applications of knowledge about urban ecosystems and ecological reorientations in urban development took and still take place here. Even today, Europe is an important research field for urban ecosystems and an experimental field for more nature in cities. English-speaking readers can thus benefit from this focus and at the same time take note of the new developments in research on urban ecosystems and their application.

Although the authors have carefully checked and corrected the automatically translated texts, minor translation errors cannot be ruled out. If this has happened, we apologize.

Salzburg	Jürgen Breuste
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in autumn 2021	

Contents

1 Urbanisation and Its Challenges for Ecological Urban Development

Stephan Pauleit, Martin Sauerwein and Jürgen Breuste

Abstract

Cities are characterised by a high concentration of human population, dense development and a wide range of human activities. Urban development finds its spatial expression in area growth, densification, but also in the phenomenon of "shrinking". These spatial processes are not mutually exclusive, but can take place simultaneously and are also interrelated. What impact do these processes have on the ecological structure and functioning of the city, and how do they relate to the three major challenges for ecologically oriented urban development - promoting a high quality of life and environment in the city, reducing the use and consumption of natural resources by cities, and urban adaptation to climate change?

1.1 The World is Urban

1.1.1 Population Development and Urbanisation

At the beginning of the twenty-first century, not only was the threshold of seven billion people on earth crossed, but now more than 50% of the human population lives in urban settlements (UN 2010) - compared to 13% at the beginning of the twentieth century (UN 2006). The trend towards global urbanization will continue over the coming decades. By the middle of this century, according to United Nations forecasts, 70% of the population, which will grow to around 9 billion people, will already be living in cities. This means an increase of another 2.8 billion people (UN 2010, see also UN Habitat 2006). In Europe and North America, but also in countries on other continents, such as Japan and Argentina, more than 70% of the population already live in urban settlements. For Europe, however, a further increase in the urban population from 75 to 80% was

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expected by 2020 (EEA 2006). In Germany, too, the proportion of the urban population is still rising. However, not every city will benefit from this, because there are also many cities that are losing population, the so-called "shrinking cities" (Oswalt and Rieniets 2006).

Megacities such as Shanghai (case study: four examples of different urban development) provide particularly impressive images of the urbanization of the earth, but overall the majority of the world's urban population lives in small and medium-sized cities. In Europe, for example, there are nearly 1000 cities with more than 50,000 inhabitants, but only 7% of the population lives in cities with more than 5 million inhabitants (EEA 2006). In Germany, about 31% of the population live in large cities, 28% in medium-sized towns and 12% in small towns (BMVBS 2009).

The future growth of cities worldwide will also take place predominantly in small and medium-sized towns and cities, even if the number of megacities with more than 10 million inhabitants has now grown to 33 (UN 2019). The number of cities with more than one million inhabitants has increased from one city (Beijing) to over 400 from 1800 to the present day. Forty-six of these are in China alone (Seto et al. 2013).

These facts must be taken into account when talking about the consequences of urbanization in the following chapters of this book, such as the heat island effect, the strength of which depends on the size of the city (Oke 1973). Ecological phenomena can thus differ between small and medium-sized towns and large cities or even megacities, and their relevance to urban development can also differ.

Definition

Cities are first of all politically defined territorial units. This definition is handled differently in different countries. In Germany, municipalities with municipal law and a population of at least 2000 inhabitants are referred to as cities; in Iceland, the threshold value is only 200 inhabitants; in Switzerland, on the other hand 10,000 inhabitants; and in Japan, even 50,000 inhabitants (Gaebe 2004). Cities are also defined by population and building density as well as the predominant land use and are distinguished from rural settlements (Gaebe 2004). Differences also exist in the degree of functional and socio-spatial differentiation, in settlement and economic structures or even in characteristics of centrality, without this allowing for the identification of sharp boundaries for cities. The range of scientific definitions of the city as a spatial phenomenon is also very wide (Table 1.1).

Ecological characteristics such as energy and material turnover, climatic features or even biodiversity play no role in the usual definitions of the term city based on statistical characteristics. In the later chapters of this book, however, we will show that the city has a number of special ecological characteristics, such as the composition of flora and fauna or thermal conditions (Chapter 4). It therefore makes sense to speak of an ecology of the city (urban ecology), even if the boundaries of the city can never be clearly drawn.

Table 1.1 Examples of the definition and demarcation of urban spaces (According to McIntyre et al. 2000; modified from Haase 2011)

Discipline	Source	Definition of "urban"
Ecology	Emlen 1974, Erskine 1992	Built-up area
Ecology	Odum 1997	Area that consumes at least 100.000 kcal/m^2 per year
Sociology	U.S. Bureau of Census	Area with > 2500 inhabitants*
Sociology	UN (1968)	Area with > 20,000 inhabitants
Economy	Mills and Hamilton (1989)	Area with a minimum number of inhabitants and population density
Environmental Psychology	Herzog and Chernick (2000)	Area with high traffic and high sealing rate and buildings
Planning	Hendrix et al. (1988)	All areas with a population density of > 100 inhabitants per acre, including commercial areas, highways and public facilities

Regardless of how cities are demarcated, one ecologically relevant feature of cities is particularly noteworthy: cities are dependent on the constant import of energy and materials to ensure the lives of their inhabitants. The emergence of cities was only made possible by the development of agriculture that produced surpluses and thus allowed people in urban settlements to live on what other people produced "in the countryside" (e.g. Elmqvist et al. 2013). This is a paradox of urbanization: the more people moved into cities and thus supposedly decoupled themselves from the constraints of agricultural life, the more dependent the city ecosystem became on regional to global imports of energy and materials.

Because of these dependencies, cities are often located in fertile areas and/or in places that were or are favourable for trade and the supply of goods, such as rivers and seas. As much as these locations promoted the development of cities, they are also associated with environmental problems, for example when it comes to the expansion of settlement areas on agriculturally productive soils or the protection of cities against natural risks such as flooding along rivers and seashores (Chapter 6).

Cities are often closely networked with other areas on a global scale (Seto et al. 2012a) and urban lifestyles have also spread far into supposedly rural areas. Instead of a sharp difference between city and countryside, as was once the case historically (Fig. 1.1), today gradients of different forms and intensities of urbanity prevail (Boone et al. 2014; Chapter 3). Characteristics of urbanity are not only physical structures such as building density, surface sealing or city-specific natural features, but also urban lifestyles and associated consumption patterns, as well as functional relationships between cities and their (global) surroundings.

An impressive picture of urbanization is provided by satellite images, which record the nighttime light radiation of the cities of the earth (Fig. 1.2). While Europe and the

Fig. 1.1 Historical map of the city of Munich 1623: The city and the surrounding area are sharply separated. (Munich City Archive, Collection of Plans, Birkmeyer Collection, B 2; digital signature: PS-NL-BIRK-001)

Fig. 1.2 Night view of the earth. It shows the radiation of light from settlements. (http://earthobservatory.nasa.gov/)

northeastern United States each appear bright, almost like a continuous urban area, it is still largely dark on the African continent south of the Sahara. It would be wrong, however, to draw conclusions about urban dynamics from this picture of the situation. Cities are experiencing particularly rapid growth spurts in the less urbanised emerging countries such as China and India, as well as in the countries of Africa and Asia. In China, more than half of the population now lives in cities. An urbanisation rate of 78% is expected there for 2050 (Wu et al. 2014). In Africa, the proportion of the population living in urban settlements is expected to rise from 40% today to over 50% by 2025 (Tibaijuka 2004; UN-HABITAT 2006). By the middle of the century, the cities there are expected to grow by a further 900 million people (UN 2012). In view of the often weak economic, institutional and technological capacities in the developing countries, it is difficult to imagine how this urbanisation can be steered into sustainable paths. Nevertheless, urban development is also being sought here because it is expected to generate economic growth and overcome urgent poverty problems.

Four Examples of Different Urban Development

Munich (Germany) lies at the centre of an economically prosperous region. The population will increase by another 200,000 inhabitants from today's 1.4 million to 2030 (LH München 2011). In its search for suitable sites for urban development, the city has benefited over the past two decades from the conversion of former barracks sites, railway areas and the relocation of the airport with subsequent development of the former airport site (Fig. 1.3a). However, these land reserves have now been largely used up, which is why major urban development projects are currently being planned and implemented on the outskirts of the city. The possibilities and limits for further densification of the city are controversially discussed.

After reunification in 1989, the city of Leipzig lost almost 100,000 inhabitants due to emigration to West Germany or the surrounding area. Today, the population in the core city, which has also grown territorially, is increasing again (Stadt Leipzig 2009), because the city has stabilised economically and has succeeded in increasing the attractiveness of the residential areas through urban redevelopment. The housing vacancy rate fell from over 69,000 dwellings in 2000 to around 34,000 dwellings in 2010 (Stadt Leipzig 2011), but demographic change is expected to result in a high amount of brownfield sites in the longer term (Stadt Leipzig 2009; Fig. 1.3b). These are both a risk and an opportunity for sustainable urban development (Sect. 1.2.2 and Chapter 7).

Shanghai (China) is one of China's major economic centers. The city region is forecast to grow from already 27 million inhabitants in an area of 6341 km^2 (World Population Review 2020) to 50 million by 2050. Shanghai is characterised by very dense high-rise construction in the centre (Fig. 1.3c, Chapters 2 and 7). The enormous settlement development (Fig. 1.3c), for which valuable farmland is sacrificed, as well as the environmental pollution in the city pose great challenges for urban planners. The new urban district of Dongtan was an attempt to respond to these challenges with the model of an eco-city (Chapter 7).

With a continued annual population growth rate of over 5%, the population of Dar es Salaam would double its current population from 6.7 million in 2020 in less than 15 years (World Population Review 2020). About 80% of the city consists of so-called informal settlements, which are not planned by the city administration. They mostly consist of corrugated iron huts or clay (brick) buildings (Fig. 1.3d). The infrastructural supply is very poor. Here, too, urban growth leads to a great loss of agriculturally valuable soil. The settlement of river valleys increases the risk of many people being affected by flooding. Climate change will further increase these risks (Chapter 6).

Fig. 1.3 Four examples of urban development processes and their ecological challenges. **a** Munich: The conversion of the former airport into the new Messestadt Riem was an attempt to implement the model of a compact and green urban district. A park of 200 ha in size is not only important for recreation but also fulfils important climatic functions to cool the neighbouring buildings and provide an air corridor for the city. **b** Leipzig: Are brownfields a sign of decay or an opportunity for ecological urban regeneration? **c** Shanghai is characterised by very dense high-rise development. **d** Dar es Salaam: The informal settlement of Suna is located in a floodplain. It is regularly flooded. (Photos © S. Pauleit)

1.1.2 Spatial Processes of Urban Development

Cities as spaces that are physically distinguishable from their surroundings have so far only taken up a share of about 0.2–2.4% of the Earth's terrestrial surface worldwide (Seto et al. 2011). In Germany, however, the proportion of settlement and transport areas was already over 13% in 2012 (Deutsches Statistisches Bundesamt 2013). Although these figures are based on different methods (globally: satellite image evaluations, nationally: land use statistics) and other definitions of urban settlement areas, they do document the high proportion of urban areas in Germany.

Forecasts on the global expansion of urban space vary widely. According to Angel et al. (2005), the expansion of cities will increase by 250% by 2030. Seto et al. (2011) see an increase in urban area by about 1.5 million km^2 by 2030 as a probable value - an area about three times the size of Spain.

Urban development is caused and influenced by different economic, cultural, social and technological processes (Gaebe 2004). Population growth or decline is the result of natural population development and immigration and emigration. The spatial development of cities is related to these social processes (Gaebe 2004), for example when the per capita demand for housing grows as a result of demographic change and increased prosperity.

Theoretical models differentiate between different phases of urban development, describing e.g. a cycle from the growth of urban centres, growth at the periphery, shrinking of cities to the renewed growth of the centres (Champion 2001). According to further model assumptions, such processes can spread from large city centres to smaller cities with a phase shift (Geyer and Kontuly 1993, cited in: Antrop 2004). However, a study of 158 cities in Europe indicated that this cyclical model does not apply everywhere and that phases of re-urbanisation and suburbanisation can occur simultaneously (Kabisch and Haase 2011).

Satellite image analysis also showed different forms of urban growth globally (Schneider and Woodcock 2008). They range from a) slow-growing cities with low levels of urban redensification, to b) fast-growing cities with sprawling, fragmented settlement patterns, and c) sprawling cities with low population density, to d) exploding cities with high population density.

Simplified, three spatial phenomena of urban development can currently be distinguished, which play a major role from an urban ecology point of view:

1. Growth in the Area of Cities and Urban Regions:
Globally, the city area is growing about twice as fast as the number of inhabitants, i.e. more and more land is being taken up per capita (Seto et al. 2011). In the 120 cities studied by Angel et al. (2010), the population density decreased by 2.0% annually. If this trend continues, a doubling of the urban population would increase their urban area fivefold by 2050 when compared to the year 2000 (Angel et al. 2011).

For Europe, a study of 26 urban regions by the European Environment Agency found that their area grew by 78% between 1950 and 1990, but the population grew by only 33% over the same period (EEA 2006). This trend continued in the following decade (Jansson et al. 2009, Annex I). In the countries of Europe, but especially in North America, Australia and New Zealand, this development has led to *urban sprawl*, which is not only relevant because of the associated "consumption" of land (land can hardly be consumed, but only changed in its properties) - i.e. the conversion of mostly agricultural land - but has also led to less effective spatial structures from an energy and economic point of view, for example because the distances between work and home become longer (travel times, energy consumption, Sect. 2.2; Gayda et al. 2004; Nilsson and Nielsen 2013) and necessary supply and disposal infrastructures must be provided over large, relatively sparsely populated areas. The growth of urban areas can also result in the loss of semi-natural habitats and the fragmentation and degradation of the remaining habitats. Last but not least, the distances from the city to recreational areas on the outskirts of the city are increasing. Accessibility by environmentally friendly means of transport, such as the bicycle, is thus reduced.

In the cities of North America, Australia and New Zealand, the urban sprawl has led to urban structures in which a small and densely populated city centre is often surrounded by an area of single-family housing spread over many square kilometres. The availability of cheap oil combined with rapidly increasing prosperity made it possible to fulfil the desire for a house in the countryside. Lower land prices in the urban hinterland, motorisation and the rapid accessibility provided by the expansion of transport infrastructure are promoting the expansion of urban settlements. Politics and planning also play an important role by promoting home building and supporting car journeys to work, to name but two examples. Spatial planning cannot directly influence fundamental social developments, such as the increasing per-capita housing demand, which rose in Germany from an average of 39 m^2 to 45 m^2 between 1998 and 2013 alone (BIB 2013), but it can help to reduce land consumption by steering, for example through concepts for long-term settlement development at urban and regional level with the prioritisation of development within existing settlements over urban expansion, land management and cooperation between municipalities for the joint development of industrial estates, etc.

Cities do not only expand strongly at their edges due to the construction of loosely built-up single and multi-family housing areas (suburbanisation), but they have also developed into often extensive urban regions, which consist of a conglomerate of urban settlement cores, suburban zones, commercial and shopping centres along the major traffic routes, as well as areas used for agriculture and forestry.

Figure 1.4 shows a structural model for "rural-urban regions" from the EU research project PLUREL (Ravetz et al. 2013). The name "rural-urban region" was chosen because the sphere of influence of cities still extends well beyond the "functional urban region" (OECD 2002), which is defined by one-hour travel times, and also includes rural areas, for example in terms of local recreation or the supply of water to the city.

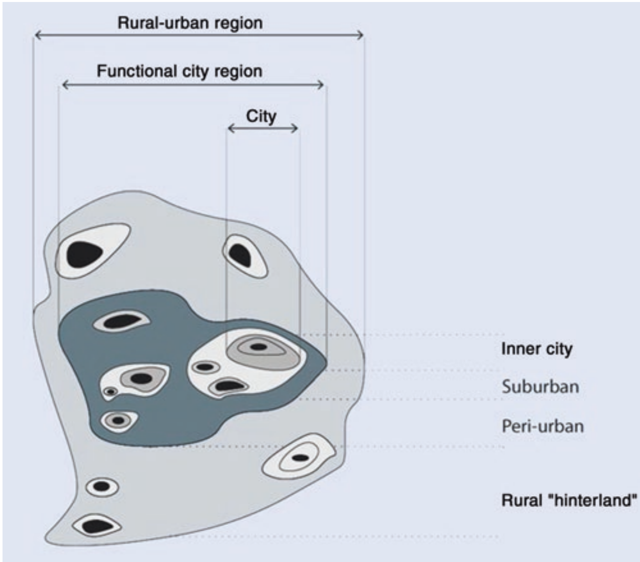

Fig. 1.4 Model of the rural-urban region. Zones within the regions are: city centres, inner conurbation zone, suburban zone, peri-urban areas, rural hinterland. (According to Ravetz et al. 2013, modified)

New forms of landscapes have emerged, which the urban planner T. Sieverts (1997) has described as "Zwischenstadt" (intermediate cities), and which comprise both: city and countryside. Another term for this type of landscape is "peri-urban" (case study peri-urbanization in the north of Munich). In countries such as Germany, Belgium and Great Britain, they occupy over a third of the country's surface area. In the Netherlands, it is even close to 80% (Nilsson and Nielsen 2013).

Results from scenario models of urbanisation in Europe also indicate that cities, and thus peri-urban areas, will continue to expand in the coming decades, even if economic growth is expected to be rather weak (Nilsson and Nielsen 2013).

Large urban regions have been created, which are linked together by transport infrastructures. For England, Green (2008) has impressively demonstrated the size of these "functional" urban regions on the basis of the areas of traffic interdependence. According to this analysis, the whole of England consists of only six city regions, of which London is by far the largest. A particular challenge for policy and planning is that, due to their size, these city regions comprise a large number of more or less independently planning and decision-making municipalities and do not coincide with planning units and certainly not with ecological entities, such as watersheds or biogeographical units.

For the Federal Republic of Germany, the daily land use for settlement and transport areas was 129 ha in 2000 and between 2007 and 2010 on average 87 ha (Bundesregierung 2012). In its national sustainability strategy, the Federal Government aims to reduce this figure to 30 ha on a daily basis by 2020 (Bundesregierung 2012). However, it still was 56 ha in 2018 (UBA 2020). This growth in the area of cities and infrastructure has a number of effects on the environment and the ecological functions of the landscape.

First of all, every expansion of a city means a change in the landscape: natural areas as well as agricultural and forestry land are converted into urban areas. The comparison of satellite image data on surface cover in Europe for the years 1990 and 2000 showed that during this period, the proportion of so-called artificial surfaces increased by about 8000 km^2 (EEA 2006), while conversely less than 1% of settlements were converted into agricultural and forestry or near-natural areas. According to the results of the PLUREL research project, this trend is expected to continue and by 2025, 5% of the agricultural land in Great Britain, Central Europe and the coastal areas of the Mediterranean region will be turned into settlement and transport areas (Nilsson and Nielsen 2013).

The consequence is the loss of often valuable agricultural land in the vicinity of the cities. These soil losses are particularly dramatic in countries with explosive urban growth such as China or Tanzania. In Dar es Salaam, for example, the population is still dependent to a considerable extent on its own food production. “Urban agriculture” in the city and on the outskirts is necessary here and serves to secure food supplies, but it is also an economic factor (Halloran and Magid 2013). This is unlikely to change in the foreseeable future in view of the rapid population increase without corresponding economic growth. If the current trend of urban development in Dar es Salaam, which consists mainly of informal settlement growth on the periphery with low density, were to continue, the settlement area would expand by 14% to then 798 km^2 by the year 2025 when compared to 2008, leading to the loss of 100 km^2 agriculturally used land and scrubland (Pauleit et al. 2013; Chapters 4 and 6).

Near-natural areas, which are of great importance for the preservation of biodiversity, are also under threat. In Europe, 13% of urban areas are already located in protected areas (Seto et al. 2013). According to Seto et al. (2012b), cities currently occupy around 1% of the area of so-called global biodiversity hotspots and it is to be expected that cities will expand into a further 1.8% of hotspot areas by 2030. However, the effects of this urbanisation will go far beyond the immediate loss of biologically valuable areas. Hotspots and protected areas in developing countries and emerging economies such as China and Brazil will be particularly affected (Seto et al. 2013; Müller et al. 2013; Güneralp et al. 2013 for detailed descriptions of the effects of urbanisation on biodiversity).

The expansion of cities not only decimates near-natural areas, but these are also increasingly fragmented by settlement, transport and other infrastructure areas (e.g. power line roads), thus impairing their functionality (Antrop 2004; Irwin and Bockstael 2007). Last but not least, the approach of cities means that the intensity of disturbances in semi-natural areas is increasing, for example due to people seeking recreation, but also due to increased inputs of air pollutants, noise, or the modification of the microclimate (Güneralp et al. 2013). The expansion of cities also has a strong impact on flora and fauna, for example through the introduction of non-native and invasive species (McKinney 2006; Müller et al. 2013; Chapter 4).

Further consequences of the expansion of urban areas and thus the increase in built-up or otherwise sealed areas are changes in local climatic and hydrological conditions (Bridgeman et al. 1995; Seto et al. 2013; Chapter 3).

In order to counter the problems of urban sprawl, which are only briefly touched upon here, politicians and planners are calling for "compact" urban development (Westerink et al. 2013). Features of this model are in particular dense construction, close neighbourhoods and the mixing of urban land uses and functions in order to shorten travel distances, the promotion of environmentally friendly means of transport such as the bicycle, and the development of multifunctional green space systems that ensure sufficient open space in the compact city, promote biodiversity and provide important regulating ecosystem services, for example to reduce the urban heat island effect. The second spatial process of urban development to be addressed here is therefore the densification of inner city areas.

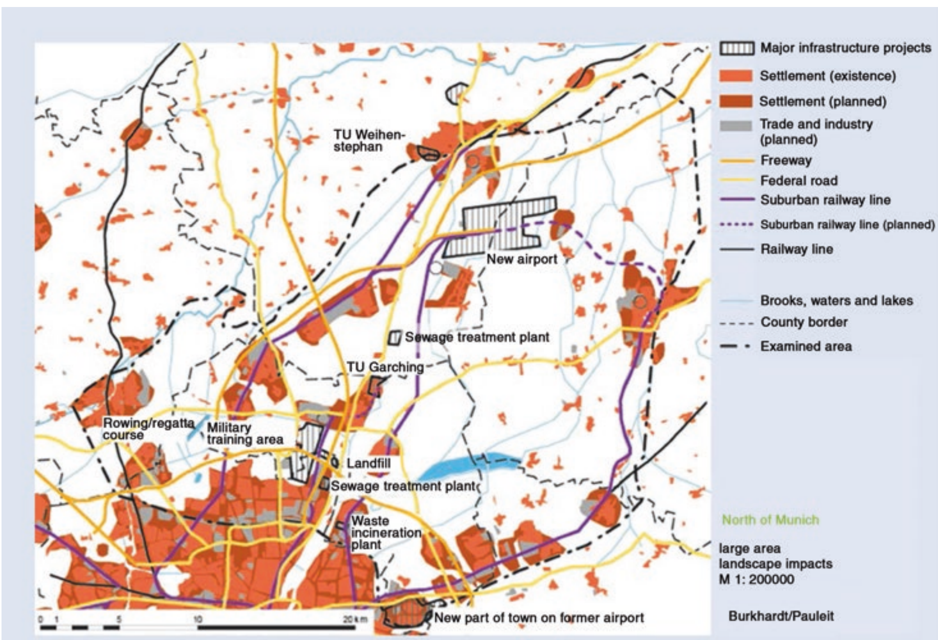

Fig. 1.5 Settlement development in the north of Munich. (Burkhardt and Pauleit 2001)

Peri-Urbanization in the North of Munich

The term "city region" was already coined by E. Howard (1902) in his book "Garden Cities of Tomorrow". He associated it with the idea of urban settlement and open space systems to be developed in an orderly manner (Chapter 7). The current development of urban regions in Europe, especially since the beginning of globalisation, looks different. The map of the north of Munich in Fig. 1.5 - only a small section of the entire urban region - can give an idea of this: Motorway and suburban railway networks connect formerly small settlements that have grown strongly since the 1970s. The new Munich Airport, whose surface area has grown several times larger than that of its predecessor, is located 35 km north-east of the city center and has led to a tremendous surge in development in the neighboring communities. In a short time, small villages have become large and prosperous locations for logistics companies and a variety of other types of business. Service companies, high-tech enterprises, as well as universities and colleges shape the economic and settlement structure. Last but not least, there are waste disposal facilities such as landfills and sewage treatment plants. All this is embedded in an agriculturally shaped landscape. Also the blue-green band of the Isar with its accompanying forests, as well as near-natural remains of moors and semi-dry grasslands, which are important for nature conservation and recreation, can be found here.

2. Densification:

Cities do not only grow outwards. At the same time, processes of internal development can be observed, which lead to more intensive land use and building densification. Strategic measures of inner development are deliberately aimed at a more intensive use of inner-city areas in order to reduce external development. Individual measures by property and house owners resulting from private wishes and needs (e.g. to increase the size of the house) also lead to structural densification in the existing stock.

In Munich, for example, larger military or railway areas have been converted into residential and commercial areas in recent decades (Fig. 1.6). At the same time, individual densification measures have taken place in many places, such as the more intensive use of land in attractive inner-city locations, the enlargement of existing buildings or the construction of new commercial buildings. In loosely built-up single-family house areas, there was a steady densification through the enlargement of residential buildings or the division of plots of land with subsequent development. Not to be underestimated are also measures such as the paving over of front gardens as parking spaces or the construction of garages. As individual cases, these measures are often not particularly conspicuous, but overall they can add up over the years and then lead to considerable environmental effects and consequences for ecological functions of the urban landscape.

In the urban region of Liverpool (Merseyside, England), the densification in eleven residential areas was investigated from 1975 to 2000 (Pauleit et al. 2005). In total, an

Fig. 1.6 The new settlement "Am Birketweg" on a railway wasteland in Munich as an example of "double inner development". Spontaneous vegetation was preserved and integrated into a new green corridor as part of the settlement. (Photo © S. Pauleit)

increase of about 5% in surface sealing was found. In none of the eleven residential areas was there a decrease in surface sealing, regardless of whether these were villa areas with large garden plots or residential areas already densely built up in 1975. The increase in surface sealing was inevitably at the expense of green spaces and, in particular, tree populations. An increase in sealed surfaces by 5% over such a long period of time may not seem dramatic. However, model simulations showed that they led to a significant increase especially in summer air temperatures, surface runoff of rainwater and a reduction in the quality of residential areas as habitats for flora and fauna. These developments may not only affect the quality of the environment in cities, but also limit their ability to adapt to climate change (Pauleit 2011; Sect. 1.2.3). The model of the densely built-up city has also been critically discussed from other perspectives, for example with regard to social sustainability (Breheny 1997; Jenks and Burton 1996; Westerink et al. 2013). Under the magic word of "double inner development", urban planning attempts to combine the development of inner-city densification with an adequate supply of open space, thus countering criticism of densification (DRL 2006; Chapter 8).

3. Shrinkage:
The term 'shrinkage' refers to the loss of residential population (Gatzweiler and Milbert 2009). Different spatial forms of shrinkage can be observed, such as a decrease of built density in previously very densely built-up inner cities, exodus shrinkage with the

emergence of large areas of wasteland as a result of economic structural crises, or even the death of entire cities when the economic basis for existence is no longer available (e.g. oil-producing cities after oil reserves have been exploited).

Apart from catastrophes, the causes of shrinkage are primarily economic crises and structural change (e.g. the loss of the coal and steel industry in the Ruhr area), but also suburbanisation, which is leading to population migration to the urban hinterland, and the general population decline as part of demographic change (Oswalt and Rieniets 2006). This loss is accompanied by housing vacancies and the under-utilisation of infrastructure. Contrasts between neglected neighbourhoods with a socially deprived population and well-maintained neighbourhoods with a wealthy population are increasing.

The phenomenon of shrinking cities could be observed in Germany especially after reunification, when the economy in the new federal states collapsed within a short time (Gatzweiler and Milbert 2009). Other urban regions that are in a longer-term economic crisis, such as the Ruhr area and cities in Saarland, are also affected. But shrinkage is a global phenomenon. In 40% of European cities with more than 200,000 inhabitants, the population was shrinking (Rink 2009). Shrinkage also affects many cities in North America, Asia and Japan. It can even be observed in Africa (Oswalt and Rieniets 2006).

Shrinking cities are characterised by a high proportion of wasteland. In 2004, their share was 176.000 ha, which is 4% of the total settlement and transport area in Germany (Umweltbundesamt 2008). There is therefore a danger that cities will "perforate" (Lütke Daldrup 2001), i.e. in the long term, that they will lose their contiguous urban structure and thus many of the qualities associated with urban density (case study: Four examples of different urban development: Leipzig). Moreover, brownfield sites are considered unattractive by the majority of the population and are avoided because they are regarded as unsafe and unclean places. Previous industrial use can also result in soil contamination (Hansen et al. 2012). On the other hand, brownfield sites in formerly densely built-up urban quarters offer the possibility of creating new green spaces and thus improving the supply of open space for the population, as well as promoting biodiversity and ecosystem services (Chapter 5) (e.g. Reduction of heat loads in densely built-up inner cities, Fig. 1.7, Chapter 5) (Hansen et al. 2012; Burkhardt et al. 2009; Bonthoux et al. 2014). The example of the city of Detroit in the USA has become particularly well-known, where the collapse of the automobile industry has left a third of the city area fallow and where both individual and large-scale commercial forms of *urban farming* have now gained a foothold (Häntzschel 2010; Chapter 5).

However, the decline in population does not necessarily mean that the urban area will also shrink (Haase et al. 2013). On the contrary: the city of Leipzig, for example, has experienced strong growth on the outskirts of the city and in neighbouring communities in the first two decades after German reunification despite a declining population (Bauer et al. 2013). This was due to the development of new residential areas, logistics and shopping centres, as well as industrial companies. Many of these external developments were a consequence of the upheavals in political and social conditions following the reunification of the two German states. The increase in the demand for housing, realisable aspirations of living in the countryside and the efforts to attract companies to settle

Fig. 1.7 Fallow land is even reclaimed for agricultural use and forests. The picture shows the example of an "urban forest" of the city of Leipzig, which was created in 2010 on the site of a former nursery. The trees were planted as small saplings. (Photo © I. Burkhardt) (Chapter 4)

here, for which space should be found quickly in accordance with their needs, are reasons why even with a declining population, space can grow in the long term.

1.2 Ecological Challenges for the City of the Twenty-First Century

Cities are centres of cultural, social and economic progress. For example, 90% of global gross domestic product is currently generated in cities (UN 2011). From an ecological point of view, however, a differentiated assessment is required. There are three main challenges to be met by ecologically oriented urban development:

1. To safeguard and promote the quality of the environment and life for the growing urban population.
2. Reducing the use and consumption of natural resources in order not to overtax the ecological carrying capacity of the earth in the long term.
3. The adaptation to climate change.

These tasks can be of different importance for cities. Environmental problems such as the supply of clean drinking water or the supply of food are certainly particularly pressing in cities in developing countries. In cities of highly developed countries, such problems are solved or at least much less so, while here issues of quality of life and healthy lifestyles are becoming increasingly important. Therefore, the possibility of reducing stress and promoting physical activities in attractive open spaces are objectives of urban development. What role does the opportunity to experience nature play in this context (Chapter 5)? In cities in highly developed industrialised countries, but also in the major cities of emerging economies, a strong reduction in the demand for natural resources and greenhouse gas emissions is an additional objective.

1.2.1 The Livable City

Environmental pollution, such as polluted air, poor drinking water quality or inadequate sewage disposal, have been problems that have accompanied cities for as long as they have existed. Urban development also leads to more or less serious modifications of natural processes (Sukopp and Wittig 1998; Bridgeman et al. 1995; Chapters 2 and 5). Buildings and paved areas partly replace vegetation, and surface waters are altered. In cities such as Munich or Leipzig, 30–50% of the surface is sealed (Pauleit 1998; Haase 2009; Artmann 2013). In the most densely built-up districts, the proportion of sealed surfaces even rises to over 80%. The removal of vegetated surfaces has effects on biodiversity, the ecological functionality of urban soils, the water balance and the climate in the city. This is described in more detail in Chapters 2, 4 and 5.

The solution of environmental problems in Europe became particularly urgent with the onset of strong urban growth during the Industrial Revolution in the nineteenth century. The development of sewage systems and other technical infrastructures were innovative achievements of urban development and technical environmental protection, which was developed at that time. However, the success of these measures also led to a reliance on technical and dirigiste solutions "from above", which are not based on a holistic understanding of the "ecosystem" of the city and often did not adequately address problems by only "solving" them for a short time or only shifting them in space, such as is the case for waste and sewage disposal outside of the city.

These and other infrastructures are ultimately based on the free availability of natural resources, such as water, and permanently available cheap energy. As a result, cities have become increasingly independent of their local natural resources, and urban "landscape" has been designed primarily from an aesthetic point of view, rather than as a necessary basis for urban life.

The limits of these approaches can often be seen today, for example when sewer networks are no longer able to cope with the increasing number of heavy rainfall events caused by climate change and are overflowing more and more frequently. Attempts to counter these problems by further increasing the capacity of the technical infrastructures are becoming more and more difficult to implement for economic and technical reasons. Increasingly, therefore, approaches are being sought that see natural processes as part of the solution, for example by promoting rainwater retention, infiltration and evaporation in green areas. These techniques of local rainwater management can also enhance the quality of green spaces by providing open water areas or attractive planting. Such approaches are now widely discussed under the terms "green infrastructure" and "nature-based solutions" (Pauleit et al. 2011, 2017).

In addition to the physical services provided by open spaces, such as cooling the city on hot summer days, it is also particularly important for the urban population to have access to green spaces for recreation and nature experience. Environmental psychological studies point to differences in the emotional perception of "artificial" and "natural" environments, which can be proven e.g. by measuring brain waves and heartbeat frequencies (summarised in Flade 2010). Regular contact with "nature" and the opportunity to move around in green spaces promote health and human well-being (Flade 2010; Rittel et al. 2014, excursus "Social change - framework conditions for urban ecology", Chapter 4).

How should the urban landscape as a whole and its "green infrastructure" in particular be planned in order to enhance natural processes and their services to mankind? Which open spaces are needed in what quality and to what extent and how should they be arranged? How should individual green spaces be designed and maintained in order to provide as many of the ecosystem services mentioned above as possible and to promote the health and well-being of people as well as possible (Chapter 5)?

Social Change—Framing Conditions for Urban Ecology

By 2060, the population of Germany could decline from the current level of just under 83 million to around 74–83 million (Deutsches Statistisches Bundesamt 2019). In 2060, about 30 % of the population will be 67 years or older (2018: 19 %). The proportion of people with reduced mobility and health problems will increase.

A growing number of people - above all large families with low income, single parents and their children, increasing numbers of migrants, people with low qualifications and the long-term unemployed - live in financially precarious conditions. Socially disadvantaged sections of the population usually have less "urban nature" (Chapter 4) of lower quality at their disposal, their opportunities for recreation and experience of nature are consequently fewer and they are exposed to higher environmental burdens (Claßen et al. 2012). In Los Angeles (USA), for example, the supply of green space in urban districts with a white population is 20 times higher than in districts with an African-American population (Wolch et al. 2002). The diversity of plant and bird species is also correlated with the socioeconomic status of residential areas (Kinzig et al. 2005). For example, Irvine et al. (2010) for Sheffield (Great Britain) found that the number of bird species is lower in socially disadvantaged urban neighbourhoods due to differences in the amenities and quality of the greenery.

Family forms such as single-person households and patchwork families, different housing needs, new patterns of employment (e.g. unregulated forms of employment, spatial and temporal flexibility of employment that mixes with private life), and changed leisure and consumer behaviour shape our society. A lot of time is spent on sedentary activities (especially in front of the computer,) and less outdoors. Due to the increasing number of overweight people as well as stress, an increase in "civilization diseases" such as cardiovascular diseases and diabetes as well as mental illnesses can be expected (Flade 2010; Rittel et al. 2014). There is now ample evidence that access to green spaces, the physical activities they promote, but also the associated experience of nature have a positive influence on human health and well-being. They are very important not least for childhood development (see e.g. Flade 2010). The health-promoting effect of green spaces and the creation of better access to urban nature in order to achieve greater "environmental justice" (Claßen et al. 2012) will therefore become increasingly important in open space planning (Chapter 7).

On the other hand, the use of open spaces is characterised by new forms of activity. A comparison of the user behaviour of urban forests around Munich between the 1980s and today, for example, showed that the proportion of cyclists in the forests has increased significantly (Lupp et al. 2014), and sports activities such as jogging have also increased. On the other hand, the average length of stay in the forest is shorter and is currently about two hours. Effects of trends in sports such as the increase of mountain biking may lead to conflicts with nature conservation (Heuchele et al. 2014).

The pluralisation of social milieus and the individualisation of lifestyles pose further challenges for urban open space planning and nature conservation. Social milieus" are defined as "groupings of people with similar values, mentalities and lifestyles and a shared spatial-objective environment (such as neighbourhoods, regions, professions, education and training, politics, culture)" (Müller 2012, own translation). Repeated studies by the Federal Agency for Nature Conservation, in which the nature awareness of ten different social milieus was examined, show that milieus such as the "conservative-established milieu", the "performer milieu", the "socio-ecological milieu" or the "hedonists" differ from one another in terms of their value systems, but also in terms of their information needs and their interests in nature conservation (Kleinhückelkotten et al. 2012, own translation). None of the ten social milieus comprised more than 15% of the total population. The protection of nature, for example, is very important for people with a social-ecological orientation. They are often already well informed about nature conservation issues and are also actively engaged in nature conservation. For the hedonists as the "fun and experience-oriented modern lower middle class" (ibid., p. 16, own translation), on the other hand, nature conservation plays a minor role. They have little interest in nature- and environmentally compatible consumption and are hardly willing to work for nature conservation.

The social developments outlined above are in turn closely linked to technological change, triggered by the revolutionary development of information technologies. "Life in a swarm" (e.g. Lause and Wippermann 2012) is leading to a fundamental change in the relationship between producers and consumers. The latter want to play an increasingly active role in the design of products - also in terms of freedom of choice (Wippermann 2013). Phenomena such as "urban gardening" indicate this change (Chapters 5 and 8). It is still difficult to assess the impact such developments will have on the ecology of the city. However, they do place demands on the development of new forms of cooperation between citizens, administration and politics in the development of open spaces through participatory or communicative approaches to their planning, design and management.

1.2.2 The Resource-Efficient City

From an ecological point of view, cities can be described as “parasites” because of their concentrated consumption of resources (Haber 2013; Elmqvist et al. 2013; Fig. 1.8). In contrast to terrestrial nature-based ecosystems, urban ecosystems have only comparatively low plant and animal biomass production (Endlicher 2012). While the latter ecosystems almost exclusively use solar radiation as a direct energy source in their energy balance, urban ecosystems/urban industrial ecosystems make extensive use of energy from fossil fuels. The turnover of secondary energy reaches a level that is generally 25 to 50% of the irradiated solar energy and can be four times as much in heavily urbanized areas (Endlicher 2012; Kuttler 1993). Material flows hardly ever close cycles, so that both urban ecosystems and especially those in the surrounding area are heavily polluted with a wide variety of waste materials (Sect. 3).

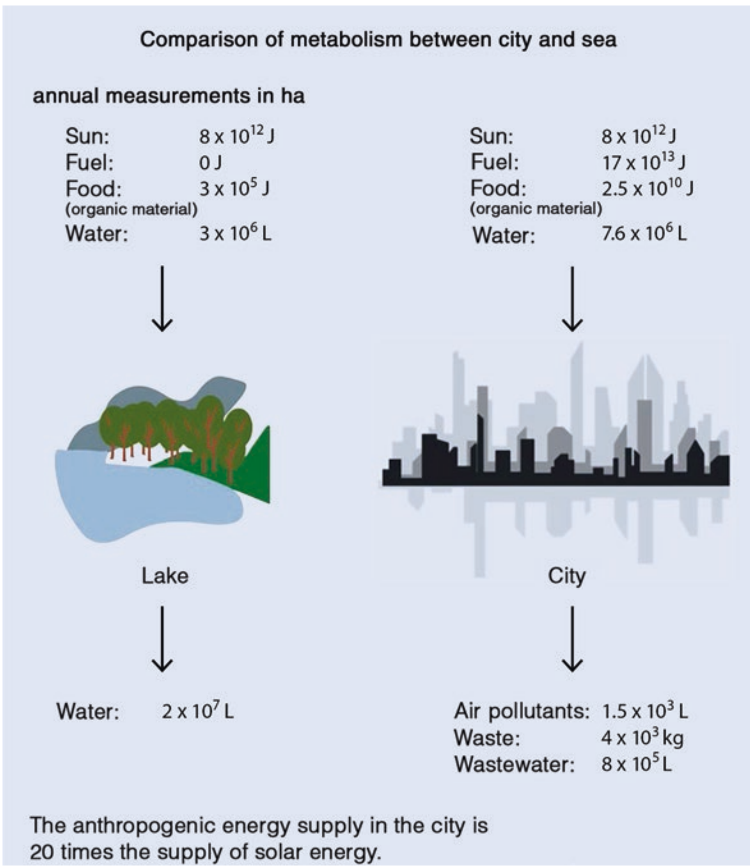

Fig. 1.8 Comparison of the metabolism of a city with that of a lake. (according to Odum 1975, modified)

The first attempts to analyse the metabolism of the city date from the 1960s and 1970s (Wolman 1965; Duvigneaud 1974). The metabolism approach was further developed in the form of energy and material balance analyses (Baccini and Brunner 2012; Ngo and Pataki 2008; Pincetl et al. 2012). In the 1970s, a quantification of energy and material flows of Hong Kong was carried out within the framework of the UNESCO research programme Man and Biosphere (MaB) (Newcombe et al. 1978; Boyden et al. 1981). A somewhat more recent study showed the enormous material imports and exports of this metropolis (Warren-Rhodes and Koenig 2001; data from 1997; Fig. 1.9). Materials amounting to 46.5 million t were imported annually (7027 kg per inhabitant). Building materials alone accounted for over half of the imports, followed by fossil fuels, food and other goods and commodities. Only 41% of these materials were of local origin. The city produced 14 million tonnes of solid waste (2081 kg per inhabitant), of which 66% was construction waste and refuse.

The concept of the "ecological footprint" relates the use and consumption of natural resources to the ecological capacity of the earth. In relation to cities, this refers to the area that would be required for their supply with all necessary resources and the assimilation of their waste products by nature (Wackernagel et al. 1997). For the city of Hong Kong

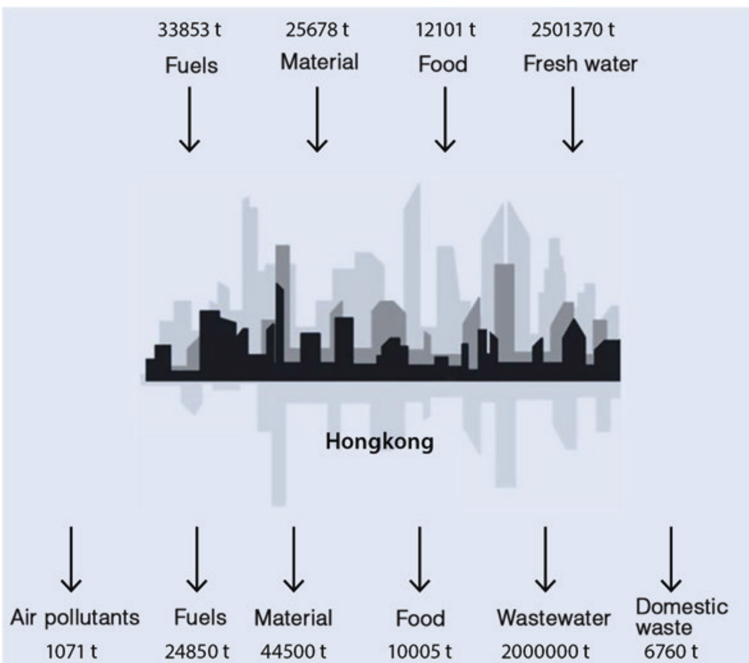

Fig. 1.9 Major material flows into and through the city of Hong Kong for the year 1997 (Data are from Warren-Rhodes and Koenig (2001) and have been aggregated. They represent only a part of the actual material and substance flows. For example, the quantitatively very significant use of seawater for cooling purposes and the evaporation of water is missing)

with its seven million inhabitants, one of the most densely populated cities in the world with an average of 58,000 inhabitants per square kilometre, an ecological footprint of 6.0 ha per inhabitant was calculated (Warren-Rhodes and Koenig 2001). This value is well above the 2.0–2.2 ha of productive land and sea area, which theoretically is the maximum available to every human being on earth (Wackernagel et al. 1997). The ecological footprint of London is even 254 times its urban area (Girardet 2004). This area would be far larger than the whole of Great Britain. Viewed globally, consumption of this magnitude is not sustainable or is only possible through an unfair distribution of resources. Reducing resource consumption is one of the greatest challenges for ecologically oriented urban development in the twenty-first century. However, it is important to note:

1. It is not the built city per se, but the activities carried out in the city and the lifestyles of the urban population that lead to the high use and consumption of natural resources. The level of consumption of the population is dependent on wealth. In Western countries, the ecological footprint of the urban population is often lower than the national average, because their per capita consumption of energy is lower than that of the rural population (e.g. Dodman 2009). However, a Finnish study showed that the greenhouse gas emissions of the inhabitants of Helsinki, 10.9 t, were significantly higher than those of inhabitants of so-called semi-urban areas (9.6 t) and rural municipalities (8.9 t). This was explained by the higher consumption levels of the more affluent city dwellers, the higher supply of services, more leisure activities and more frequent air travel (Heinonen et al. 2013).
2. As the density of a city increases, the energy requirement decreases mainly because of the shorter distances, and increases correspondingly with decreasing density. In reality, the relationships between the shape of a city and its energy consumption are certainly more complex (Baker et al. 2010) and, as indicated, the efficiency gains of compact city shapes can be neutralised by the behaviour of city dwellers.
3. Today, more than ever, cities can only be understood as part of a global system of energy, goods and material flows. Decisions made in one city, for example on consumer behavior, have global effects on other cities and rural areas. The boundaries between town and country are blurring not only within the rural-urban region but also globally. Even the lifestyles of people in seemingly rural areas can be urban ("hidden urbanization", van den Vaart 1991; Antrop 2000). Ecological research will therefore also have to deal with the understanding of these long-distance relationships ("Teleconnections", Seto et al. 2012a). However, research on this is still in its infancy (Boone et al. 2014).

Last but not least, cities contribute significantly to global climate change. The International Energy Agency (IEA 2008) ascribed to them 70% of global greenhouse gas emissions caused by energy consumption. Cities in industrialised and emerging countries are primarily responsible for these emissions. For Shanghai, greenhouse gas emissions were estimated by Hoornweg et al. (2011) at 11.7 t CO_2 equivalents per inhabitant. For Kathmandu (Nepal), the corresponding figure was 0.12 t CO_2 equivalents, i.e. one hundred times lower. The level of greenhouse gas emissions depends not only on the level of prosperity, but also strongly on the climatic conditions (number of heating and cooling days), the share of renewable energies in the energy supply, the importance of cities as transport hubs, but also on the population density of the city (Kennedy et al. 2009). Hoornweg et al. (2011) therefore found that the densely built-up Barcelona scored significantly better than North American cities such as Los Angeles, Denver or Toronto.

Climate protection in cities is thus another challenge for ecologically oriented urban development that is closely linked to metabolism (Chapter 8). Precisely because of their high consumption of resources and energy and the resulting greenhouse gas emissions, cities should not only be seen as the cause of local to global environmental problems, but also as a possible key to their solution. As already mentioned, however, the focus will not only be on questions of the future form of the city, but especially on changing urban lifestyles.

1.2.3 The Resilient and Versatile City

Cities are not only contributors to climate change but are also affected by its effects. In addition to long-term changes in average climate conditions, cities are particularly vulnerable to the increase in extreme events such as droughts, heavy rainfall, heat waves and storms, as evidenced by many recent disasters - such as hurricanes Katrina and Sandy, which hit New Orleans and New York, the heat waves in the summer of 2003 with up to 70,000 additional deaths in Europe (Robine et al. 2008), or the floods in Germany in the summer of 2013 (which does not imply that these events were caused by climate change). All these severe weather events resulted in loss of human life and major economic damage.

The extent to which cities will be affected by climate change depends very much on their vulnerability (Chapter 6). Cities in the developing countries, which have so far hardly contributed to climate change due to their low greenhouse gas emissions, will suffer particularly from climate change due to their low economic and institutional capacities, unregulated settlement development and infrastructural deficits. The ability of cities to adapt to unavoidable climatic changes must therefore be strengthened. The protection and enhancement of natural processes play an important role in this context, for example by preserving coastal mangrove forests to protect against storm surges, by renaturing inner-city river floodplains to strengthen their flood retention capacity, and by ensuring that urban districts are well greened to alleviate heat waves and allow water from heavy rainfall events to seep away.

A particular challenge for urban development is the uncertainty of climate scenarios and social developments. What should cities such as Munich and Leipzig prepare for if the climate at the end of the twenty-first century could either resemble that of today's cities like Bordeaux or Naples, which are located in different climate zones (Hallegatte et al. 2007)? How will society and technologies evolve, and what does this mean for the vulnerability of the city of the future (Chapter 6)? In the discussion on how to deal with uncertainties in planning, a number of principles are mentioned (Ahern 2011; Hallegatte 2009; Pauleit 2011; Table 1.2). The demand to increase the "resilience" of cities, i.e. their ability to maintain basic functions even after catastrophic events,

Table 1.2 Strategies for dealing with uncertainty in climate change and for strengthening urban resilience. (according to Hallegatte 2009; Ahern 2011)

Strategies	Features/examples/explanations
"No-regret" strategies that will always lead to a "win" regardless of whether or not climate change occurs	- Energy saving through improved thermal insulation of buildings - Greener attractiveness and environmental quality in a city through green spaces
Reversible strategies	- (Provisionally) refrain from urban development in areas that may be at risk of flooding in the future
Strategies to increase flexibility	- Multifunctional spatial structures - Redundancy, i.e. protection of apparently "superfluous" structures (e.g. protection of several biotope areas of a habitat type) - Diversity, e.g. of biological diversity with species that may be better adapted to future climatic conditions - Modularity (e.g. combination of sewerage system with local rainwater infiltration), in order to be able to limit the frequency and extent of damage in terms of space and time - Connectivity at different scale levels, e.g. between habitats, to enable the migration of species into future suitable habitats. Preservation of green corridors to retain large amounts of rainwater and channel it out of built-up areas
Increase of safety margins	- e.g. higher standards for new sewer networks or dikes. It is cheaper to dimension them already now larger than to adapt them afterwards
"Soft" strategies before "hard" strategies	- Introduction of early warning systems - Control of developments through insurance policies (e.g. higher tariffs for insurance policies in areas at risk of flooding) - Standards, for example for the adaptation of buildings to climate change
"Adaptive" planning	- Institutionalisation of long planning or forecasting horizons (>25 years) in order to take into account possible climate impacts that will not occur for 25, 50 or 100 years - Monitoring for the cyclical adjustment of plans based on new findings and framework conditions - Combining strategic planning with a project-based approach ("*learning by doing*") - Cross-sectoral and participatory planning approaches
Interventions with shorter investment periods and life cycles	- Preference for modular infrastructures that can be gradually replaced or adapted over large-scale facilities that can only be replaced as a whole and have long payback periods

Fig. 1.10 Ecologically oriented urban development in the field of tension between the goals of the compact, resource-saving and climate-protecting city on the one hand and the livable, green city adapted to climate change on the other. (according to Nilsson 2009, modified; Photo © I. Burkhardt)

is based on findings of ecosystem research (e.g. Wu and Wu 2013; for application in planning Ahern 2011). Resilience is not to be understood here as inertia, but on the contrary should increase the ability of the city ecosystem to change and learn. What should the urban landscape look like to enable adaptation to climate change and resilient behaviour? How can the recognisable conflicts of objectives between the compact, densely built and therefore resource-saving and climate-protecting city and the green and resilient city with a high quality of life be resolved (Fig. 1.10)? In Sect. 6.5, we will further explore the issues of resilience and climate change adaptation.

1.3 Urban Ecology as a Research and Solution Approach

Ecology is the science of the interactions between organisms and their inanimate environment. Originally coined by Ernst Haeckel, the term describes in its origin the science of the household of nature. Accordingly, even in classical ecology, in addition to the study of organisms, the understanding and linking of the entire biocoenosis and its habitats (biotope) are of central importance. Ecology can thus be understood as a biological discipline, but it necessarily includes the study of abiotic environmental compartments. This requires knowledge of e.g. climatology, hydrology and soil science (Fig. 1.11). Landscape ecology extends this approach to include the spatial dimension.

With regard to the object of investigation of the ecology of cities, ecosystem research is of great importance. Although cities may also be concerned with the observation of

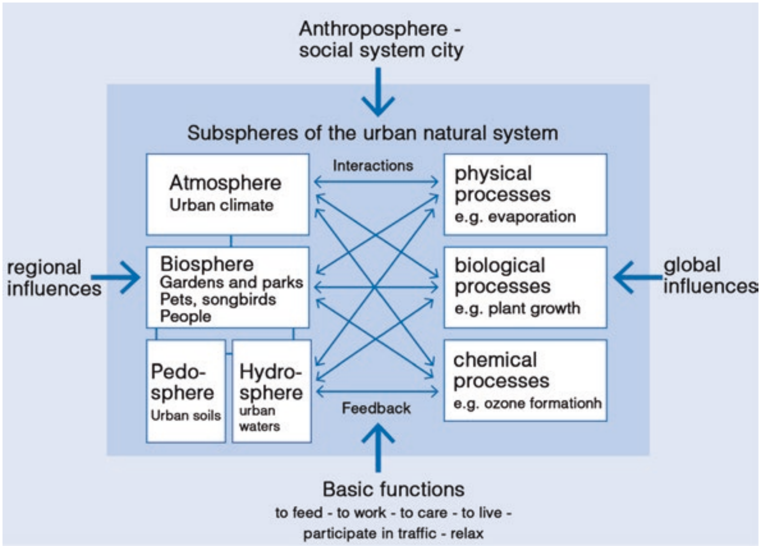

Fig. 1.11 Subspheres in the urban ecosystem. (Breuste et al. 2011)

individuals of a species (auto-ecology), of populations (population ecology) or of biotic communities (syn-ecology), many studies focus on the investigation of biotic communities in their environment - i.e. ecosystem research (Wittig and Streit 2004).

It is therefore appropriate to define urban ecology from an ecological point of view in a narrower sense, and also in a broader sense from today's perspective with a view to sustainable development (Fig. 1.12). In the English language literature, the terms "Ecology in the City" vs. "Ecology of the City" have been used more frequently in recent years to distinguish these two perspectives of research in urban ecology (Cadenasso and Pickett 2013). Studies on "ecology in the city" deal with the effects of the living conditions changed by humans on different organisms, populations and biotic communities. In these studies, human actions are only considered as an external factor affecting the organisms or biotic communities, for example through air pollutant immissions. On the other hand, there are research approaches that regard humans as part of the ecosystem and are interested in the interactions between humans and other organisms and biotic communities (Fig. 1.13). In this sense, the city is also referred to as a social-ecological system (Ecology of the City; Cadenasso and Picket 2013; Wu 2014). Engineering, social sciences, humanities and cultural studies such as medicine and psychology, anthropology and ethnography should be included in urban ecology research, depending on the issue at hand, since the city is the "product" of human society.

The discussions on Local Agenda 21 and the current environmental analyses from the point of view of sustainability have led to urban planning also being increasingly viewed from an ecological perspective. Wolfgang Haber (1994, 1999) can be mentioned as a

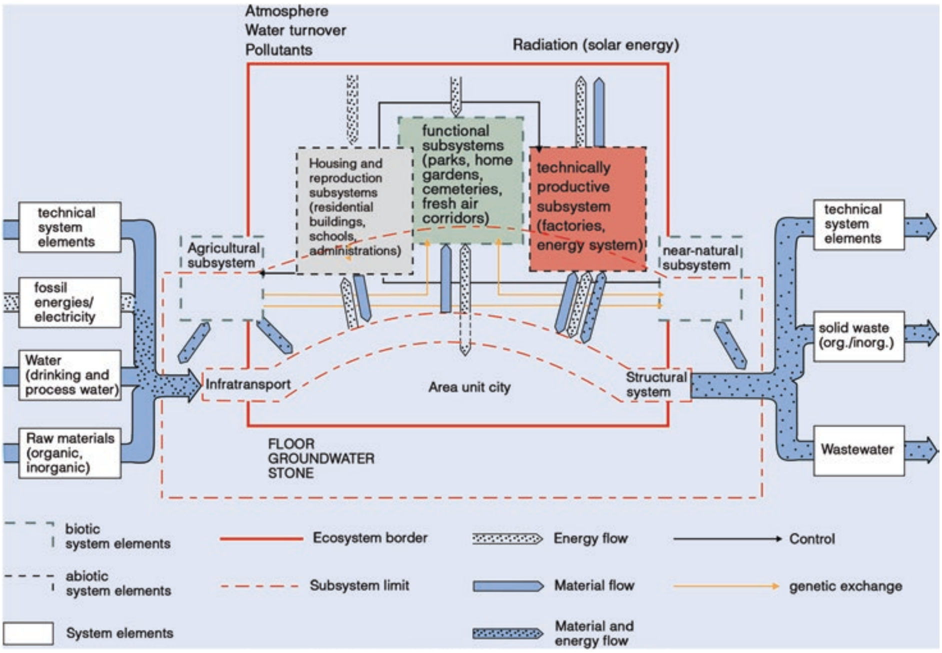

Fig. 1.12 Model presentation of an urban ecosystem. (Sauerwein 2006)

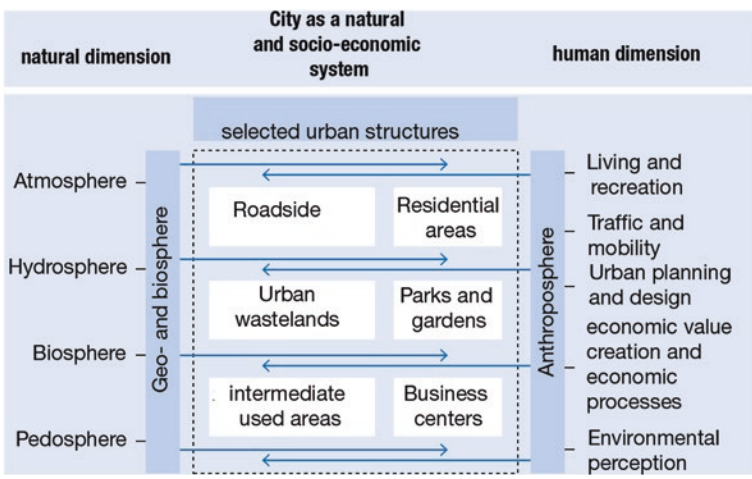

Fig. 1.13 The city as a natural and socio-economic system with geo-, bio- and anthroposphere. (Endlicher 2012, p. 21)

pioneer in this respect. Urban ecology must therefore also involve the various interest groups - from politics and administration, associations and other organizations to the individual citizen - along with their experiences, in order to design strategies and measures for ecologically oriented urban development that are also implemented. The aim is not only to promote ecologically oriented planning "from above", but also to include bottom-up initiatives of civil society, for example for "urban gardening" or the "Transition Town" movement, which promote a shift towards ecologically oriented lifestyles (Chapters 5 and 7).

Since the end of the last century, urban ecology has thus been understood from two perspectives: On the one hand, it is a science related to basic research, and on the other hand, it makes important contributions to sustainable development. In both perspectives, it is still a science in the making and in development (see definition of city).

What is urban ecology?

Urban ecology can be characterised - quite controversially - on several levels.

1. Urban ecology in the narrower sense is the sub-discipline of ecology that deals with urban biocoenoses, biotopes and ecosystems, their organisms and site conditions as well as with the structure, function and history of urban ecosystems.
2. Urban ecology in a broader sense is an integrated field of work of several sciences from different areas with the aim of developing the basis for the improvement of living conditions and a sustainable environmentally sound urban development (Sukopp and Wittig 1998).
3. Last but not least, urban ecology is also understood as a political field of action. "Urban ecology in this sense is not a description of a scientific rule, but a programme and an illusion at the same time" (Koenigs 1994); "it … is at the same time a programme of action and urban design" (Trepl 1994, own translation).

"The urban ecosystem is the reality of the city" (Leser 2008, p. 15). As a model, it can be analysed and conceived in various degrees of detail and scale. As the "reality of the city", however, the urban ecosystem is of key importance when it comes to understanding, analysing, balancing, evaluating and designing the processes and structures of the city. These are no longer just natural processes or even natural structures, as in natural ecosystems. In this respect, urban ecosystems as ecosystems designed by humans are not independent ecosystems that maintain themselves. Nevertheless, they are the basis of life and habitat of urban dwellers, even if awareness of this must first be rebuilt. Incidentally, this applies not only to the consciousness of city dwellers, but also to that of urban planners and designers. This book is committed to contributing to this process.

Global development of urban ecology

Urban ecology as a science has a rather short history of development (Sukopp and Wittig 1998). In German-speaking countries, there is a special tradition of urban ecology, for example through the research of the city of Berlin by Prof. Sukopp and many employees at the TU Berlin (Sukopp 1990). Parallel to this, but often only following on from it, urban ecology also developed in other countries, for example in the USA and England. In the USA, cities have been the subject of long-term research programmes for some time, which have led to significant new approaches and findings on the ecology of cities (Cadenasso and Pickett 2013). In China, urban ecology has been developing particularly dynamically since around 2000, while Africa (with the exception of South Africa) is still in its infancy (Cilliers et al. 2013). In Latin America, urban ecology research groups with a clear application focus are already being organised in Brazil, Argentina, Colombia and other countries. Today, urban ecology is thus a growing discipline that is also present at scientific conferences internationally, is networked in the international "Society for Urban Ecology" (SURE, www.society-urban-ecology.org) and publishes its results in a variety of ways.

Selection of recent scientific books on urban ecology (in alphabetical order)

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Forman RTT (2014) Urban Ecology. Science of Cities. Cambridge University Press, Cambridge

Gaston K (2010) Urban Ecology. Cambridge University Press, Cambridge

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▶ **Definition**

Urban ecosystems are functional units of a real section of the biogeosphere. In addition to the geosystem and biosystem as subsystems, they also represent the anthroposystem that shapes them (economic, social, political and planning). While the geosystem and biosystem are formed by natural factors, but are regulated and controlled anthropogenically (i.e. by the anthroposystem), the anthroposystem provides the regulatory and control objectives to shape the human habitat city as optimally as possible. In a holistic view, the three subsystems cannot be separated in their mutual interactions. In this sense, cities are the most important habitats (living spaces) for people.

Cities can be regarded as urban ecosystems (Chapter 3). However, they consist altogether of a mosaic of completely different, but reciprocally mostly functionally connected (sub)urban ecosystems. These urban ecosystems, such as parks, industrial plants, urban forests and residential areas, together form an ecological structure of the city (Chapter 2). The design of this ecological structure of the city, taking into account its ecological functionality and the needs of its inhabitants (Chapter 3), must be the goal of the city of the future (see also Leser 2008; Adler and Tanner 2013).

1.4 Conclusions

Cities are very successful settlement systems from a social, cultural and economic point of view. Through the concentration of population, there are greater chances of organising the consumption of resources more efficiently than if the same population is distributed over large areas in other forms of settlement. They are therefore the key to global solutions for more sustainable and climate-friendly development. This also applies to developing countries, despite the enormous problems of the rapid urbanisation currently observed, because in cities, there are greater opportunities to concentrate small amounts of capital sensibly and use them efficiently.

However, the current lifestyles of the population in highly developed countries stand in the way of potential efficiency gains for the city. Strategies for ecologically oriented urban development can therefore not be limited to questions of urban form, but must also have an effect on substantial changes in the behaviour of the urban population, as well as of commercial enterprises, administration and politics.

Cities - and thus the politicians and administrations responsible for their development, but also all other actors who contribute to the development of the city - from business and environmental organisations to the individual citizen - need thorough knowledge to be able to make the “right” decisions. Urban ecology has the task of supporting decision-making with the necessary information, but also of helping to design solutions (Chapter 7).

Questions

1. Name the three essential spatial processes of urban development!
2. What are the negative ecological effects of urban sprawl?
3. What opportunities and risks for ecologically oriented urban development do you see in brownfields?
4. Give three reasons for a densely built-up city and three arguments against it!
5. What does social change mean for open space planning?
6. Name three strategies for dealing with uncertainty in climate change and for increasing urban resilience!

Answer 1

- *Urban Sprawl*, i.e. the expansion of cities into the surrounding area.
- Densification, i.e. the additional increase of the building density in the city.
- Shrinking, i.e. building vacancies and wasteland in the city caused by population loss.

Answer 2

Urban Sprawl leads to

- land consumption and thus the loss of often agriculturally used land,
- destruction, fragmentation and degradation of semi-natural habitats,
- changes in local climatic and hydrological conditions,
- spatial structures that are less effective in terms of energy and economy, especially because of the longer travel distances
- increased reliance on the private car, resulting in higher traffic volumes, longer journeys and higher levels of air pollution
- less open space for recreational use and longer distances to the recreational areas on the outskirts of the city, which are less easily accessible by environmentally friendly means of transport such as the bicycle

Answer 3

Opportunities:

- New green spaces can be created in formerly densely built-up districts, which can also accommodate new uses such as urban gardening.
- Increase urban biodiversity.
- Fallow land can provide important ecosystem services, e.g. climate regulation services.

Risks:

- Too many brownfields can lead to fragmentation of the city.
- Fallow land is often perceived as unattractive and as a sign of decay.
- Fallow land can be contaminated.

Answer 4

Speaking for a dense city

- the greater density of urban functions such as social and cultural facilities,
- the lower land use on the outskirts of the city,
- higher energy efficiency through compact building structures and short distances.

Speaking against a dense city

- the high degree of surface sealing and the low proportion of green space,
- the increase of air temperature and surface runoff of rainwater as well as a reduction in the quality of residential areas as habitats for plant and animal life,
- the reduced ability to adapt to climate change.

Answer 5

- The increasing need to compensate for socio-spatially induced differences in access to urban nature.
- The diversification of the demands for open space through pluralisation of social milieus and individualisation of lifestyles.
- The increasing importance of green spaces for the health and well-being of the urban population

The growing desire for participation in the design and maintenance of green spaces, for example in the form of urban gardening.

Answer 6

- "No-regret" strategies that, regardless of whether climate change occurs or not, will in any case lead to a "win".
- Strategies to increase flexibility.
- "Adaptive" planning.

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2 What Are the Relationships Between the Spatial Urban Structure and the Ecological Characteristics of the City?

Stephen Pauleit

Abstract

The spatial form and the ecological features of the city are closely related. Not only biodiversity, urban soils, climate, and hydrology, but also the energy and material flows of the city are influenced in different ways by the spatial composition of different land uses, built-up area, the degree of surface sealing, the proportion and type of green spaces, and other factors. Their analysis through approaches such as biotope and structure type mapping as well as gradient analysis is, therefore, a key to the ecological understanding of cities and city regions for an ecologically oriented urban development.

2.1 Spatial Urban Structure

The size and form of the city significantly influences its ecological features. As an example, refer to Chap. 1 for the studies on the relationship between population density and energy consumption by Newman and Kenworthy (1989). Climatic studies have also shown that the strength of the urban heat island, that is the increased air temperatures in the city compared to the surrounding area, is related to the size of a city (Oke 1973). In megacities such as London, average annual temperatures can be 2–3 °C higher than in the surrounding area, whereas in smaller cities they are only slightly higher. The number of spontaneously occurring plant species also increases with their size (Pyšek 1998). The evaluation of floristic data for 21 German cities showed a logarithmic relationship between human population size and the number of vascular plant species (Werner 2008). One explanation for the increase in species diversity is that with the increasing city size, the variety of land uses also increases, each of which offers different habitats for flora and fauna (Chap. 5; on other factors influencing species diversity).

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Seen from the air, cities appear like a mosaic of areas that can be distinguished by the type of development and associated open spaces, for example, dense inner-city development, single-family housing areas, or industrial estates; also green areas such as parks and forests (Fig. 2.1). At even higher resolution, elements of the development such as individual buildings and garages, and open space elements such as streets, parking lots, backyards, front and house gardens can be recognized, which consist of individual trees, shrubs, hedges, lawns, and flower beds.

Urban form

The form of a city can be defined as the spatial arrangement of certain elements, such as different types of settlement (Andersson et al. 1996, cited in Dempsey et al. 2010). Related terms such as "spatial city structure" or "urban morphology" are also used to describe the physical characteristics of the city or its spatial configuration. Geographer Conzen (2004) distinguished three components of the urban landscape: the spatial pattern of development and open spaces, the building forms, and the patterns of use. However, the urban form can be described not only

Fig. 2.1 Seen from the air, the city is a heterogeneous mosaic of built-up areas and open spaces. (Data source: Bavarian Surveying Authority www.geodaten.bayern.de)

for the city but also at more detailed scale levels, down to the building materials, facade types, etc., (Fig. 2.2).

However, when defining urban form more broadly, it can mean not only the physical structure of the city, but also socioeconomic factors such as population density and distribution (Schwarz 2010).

The topography, especially mountains or hills, still and running waters, and coasts, can have a significant impact on the urban structure and its ecological characteristics. Even ecological differences in location, which may not be easy to identify at first glance, can have a significant influence on urban development (case study “Influence of natural location factors on urban development and the green structure of Munich”). It is precisely these natural features that often make cities, and in particular the spatial structure and characteristics of their green spaces (“green structure”), distinctive (Fig. 2.3). Although they are often heavily modified by settlement development, they influence the urban form as an “open space structure” alongside the “building structure". This structure, often referred to as “urban landscape” is thus the result of an intensive and complex interplay of natural and human processes (Fig. 2.4).

Classical geographic models of urban form describe its emergence through socioeconomic processes on a high level of generalisation and distinguish, for example, between the concentric zone model, the sector model, and the multicore model (Gaebe 2004). However, when it comes to explaining urban ecological phenomena such as the distribution of plant and animal species in the city or the climatic conditions in the city (Chap. 5 and 6), high-resolution spatial models that include further explanatory variables are required.

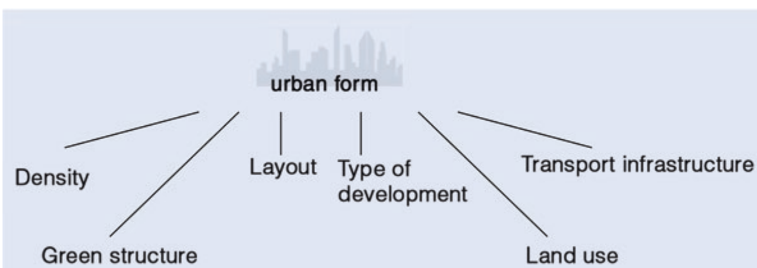


Fig. 2.2 Elements of urban form (according to Dempsey et al. 2010, modified): *Density*: Population density and building density; *Type of development*: Different types of residential development (e.g. single-family houses, terraced houses, multistorey buildings, and commercial development); *Layout*: Spatial arrangement of buildings, streets, and open spaces; *Land use*: e.g., residential, commercial, industrial, public green spaces; *Transport infrastructure and accessibility* (e.g. travel time between home and place of work); *Green structure and natural features*: Topography, green spaces, still and running waters, and coasts

Fig. 2.3 The grasslands on the northern outskirts of Munich are a formative element of the green structure in this urban agglomeration. (Photo © S. Pauleit)

Fig. 2.4 The urban landscape as a result of the overlapping of natural conditions, settlement, and infrastructure. (Pauleit 1998, modified)

Influence of Natural Location Factors on Urban Development and the Green Structure of Munich

Munich is located in the natural area of the Munich plain. The latter is inclined from south to north and is characterized by gravel deposits from the last ice age (Würmeiszeit). The medieval city was built on a late Ice Age river terrace. Thus the city was close to the water, but at the same time protected from the floods of the wild Isar. Munich owes its original meaning to its location at a crossing over of the Isar river, where important trade routes crossed. Since the nineteenth century, the Isar has been heavily regulated by hydraulic engineering. The parks laid out in the floodplain, including the English Garden, were already created in the eighteenth and nineteenth centuries. In 2012, an extensive river restoration project on the southern Isar was completed in order to combine an increase in flood protection with the improvement of the ecological status and the quality of open spaces (Chap. 8).

On the western edge of the old town there is another terrace edge. It forms the transition from the river terrace of the Old Town terrace to the lower terrace of the

Würmeis period. It is clearly visible on the western edge of the Theresienwiese, where the annual Octoberfest takes place. On the eastern side of the Isar river, the river floodplain is directly bordered by a steep slope, which is lined by a strip of forest that crosses the entire city area from south to north, the so-called "Leitenwälder" ("Leite" meaning a steep hillside). Here, on the edge of the slope, there are breweries that built their beer cellars in the Nagelfluh gravel that came to light and used the spring water (Sommerhoff 1987). On the east side of the Isar, an old moraine from the penultimate ice age ("Riß" glaciation) has also been preserved. It overtops the lower terrace by a few meters and is covered by loess loams, which provided the raw material for the brick buildings in Munich's old town.

The gravel deposits of the lower terraces thin out toward the north and are slightly less inclined than the underlying water-storing layers. A few kilometers north of the old town, the groundwater reaches the surface. Although the differences in terrain are very small, the transition from the "dry" to the "wet" Munich plain marked for a long time a sharp boundary for settlement, which can still be seen today. In dry locations with particularly poor soils, species-rich grasslands were established through centuries of sheep grazing. Even larger remains of these grassy heathlands have been preserved. In part they remained "protected" by their use as military training grounds. They are not only very valuable biotopes but also important recreational areas today. In the fenland areas, on the other hand, only small remnants of near-natural wet meadows remain due to the intensification of agriculture.

These examples show the great influence of natural conditions on Munich's urban development and green structure—and this, despite the fact that the city appears to be built on a largely uniform plain. Formative natural green structures such as the Isar floodplains, the adjacent "Leitenwälder" or the fenlands on the outskirts of the city contribute to the city's identity with their particular flora and fauna.

2.2 Land Use and Land Cover as Key Ecological Features of the City

Definition

Land use is the current use of an area of land for human purposes such as living, working, education, health, recreation, food production, and also nature conservation.

Elements of the **land cover** can be distinguished, for example, buildings, streets, vegetation, and water bodies. The physical structure can be recorded, for example, by evaluating satellite or aerial images. They have different spatial and spectral resolutions. An overview of the possible applications of remote sensing in urban areas is given by Taubenböck and Dech (2010).

Areas are shaped by the respective human use. The use of an area is therefore not a static condition, but a process of appropriation of land, which leads to a change in its surface (Breuste 1994). The arrangement and characteristics of these different land uses are not random. They are particularly influenced by economic factors, which are not least reflected in land prices, and by regulatory systems such as planning, land, and tax law (Gaebe 2004; Jones et al. 2010).

The same land use can have different physical features in different areas. Residential development includes, for example, single-family houses, terraced houses, multistorey residential buildings, and other forms. Conversely, a particular type of development can also accommodate different uses, such as flats, shops, and offices. Land use and features of the physical structure should therefore be recorded separately.

Although land use determines the respective physical features of an area, for example, through building, this often changes much more slowly than land use, which can change, intensify or extensify at higher speed. In the residential buildings of the old town areas, for example, the densely developed quarters of the Wilhelminian period, and the villa house areas of that time, the houses may still be largely the same on the outside, although their use has changed. For example, the population density in residential areas of the interwar period has usually changed considerably. In small apartments today, there are often single older people where once families with many children used to live. The population density, as a measure of the intensity of use, has therefore fallen sharply in these residential areas, although the buildings have remained largely the same on the outside. In other districts with large old town villas, law firms and other services have often settled. This change of use in turn leads to adjustments in the physical structure, for example when (front) gardens in these villa areas are converted into parking spaces for employees and customers, thus increasing the amount of surface sealing (Pauleit et al. 2005).

Land use and the physical structure of the area are of decisive importance for urban ecology as influencing factors (Richter 1984; Breuste 1987, 1994; Pauleit 1998). From an ecological point of view, they essentially determine the prevailing “disturbance regime” that characterizes the ecological structure, function, and dynamics of areas (Cadenasso et al. 2013). The composition of flora and fauna, the expression of climatic and hydrological characteristics, or even the properties of urban soils, can differ significantly between individual land uses (e.g., Gehrke et al. 1977; Henry and Dicks 1987; Gilbert 1989; Sukopp and Wittig 1998; Breuste 1994; Pauleit 1998; Sauerwein 2004; Stewart and Oke 2012; Chap. 3, 5, and 6). The expression of the physical structure, which can be measured using features such as the building density, surface sealing, etc., is closely related, for example, to the hydrological and climatic characteristics of the various land uses (Chapter 6).

The type and intensity of land use and physical structure also influence the energy and material flows of a city (“metabolism”, Chap. 1). The total energy consumption of an urban district used primarily for residential purposes, for example, can correlate with population density and the type of development—but social, cultural, and economic factors may play an even greater role (Baker et al. 2010).

Land use and physical structure determine and influence each other. As indicated in Fig. 2.5, both are influenced by social and environmental processes and vice versa. This figure illustrates the theoretical approach used for the integrated study of the urban ecosystem within the framework of large-scale urban ecology research programmes in the American cities of Baltimore and Phoenix (so-called *Long-term Ecological Research Programs* (LTER), Grimm et al. 2000).

2.3 Ecological Analysis of the Urban Form

2.3.1 Mapping of Biotopes and Urban Morphology Types

In statistical surveys in municipalities, for example, on land use, information on the ecological features of a city is not specifically collected. Therefore, own investigations are necessary for their analysis. According to Breuste (2006, modified), suitable approaches for ecological analysis and evaluation of the urban landscape should meet the following requirements:

- Provision of comprehensive information,
- Fast and cost-effective data collection,
- Knowledge of the relationships between environmental quality and urban form, function, and dynamics,
- Reference to planning instruments and hierarchies,
- Possibility to develop and apply evaluation procedures.

In the Federal Republic of Germany, urban-ecological maps have been drawn up since the 1970s in the course of recording habitats for flora and fauna (so-called urban biotope mapping). Biotope mapping has been carried out for more than 200 German cities (Werner 2008). These biotope maps form an important information basis for urban nature conservation, for nature conservation programmes and plans (e.g., urban species and biotope conservation programmes, landscape, and green space planning), or they also serve as a basis for assessing the effects of human intervention in nature and the ecological compensation of planning projects. Various procedures are applied, from the targeted recording of habitats deemed worthy of protection ("selective" surveys) to area-wide surveys. The working group "Methodik der Biotopkartierung im besiedelten Bereich" ("Methodology of Biotope Mapping in Settled Areas") endeavored to standardize these procedures (Schulte et al. 1993; Chap. 5).

In these surveys, land use is regarded as an essential ecological determinant for urban flora and fauna (Sukopp et al. 1980, p. 565), in order to divide the city into habitat types on this basis (case study "Biotope type map of Berlin"). Since a complete survey of the plant and animal species occurring in large cities is not possible for the many spatial units, in-depth studies are limited to selected areas in order to conclude from

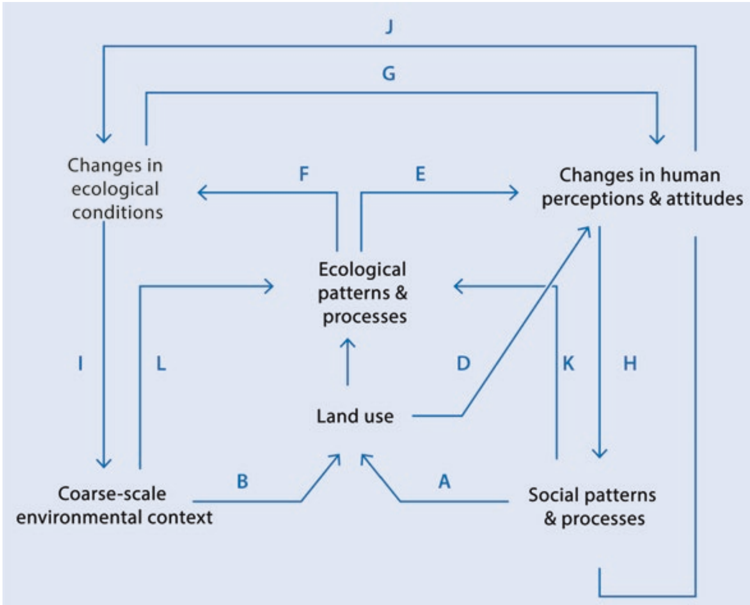


Fig. 2.5 Conceptual scheme for integrating ecological and social systems in urban environments. Variables are in boxes; interactions and feedbacks are arrows: A, environmental context sets the range of possibilities for land-use–land cover; B, societal decisions and human behaviour (incorporating their suite of determinants) are the direct drivers of land-use change; C, the pattern of land-use (whatever the driver) determines ecological patterns and processes; D, humans perceive and react to land-use change (independent of any ecological effects); E, humans also perceive and react to ecological patterns and processes; F, in this interaction, ecological processes as affected by land-use change result in a change in ecological conditions; G, such changes in ecological conditions may result in changes in attitudes (even if human perception previously ignored ecological pattern and process), and changed ecological conditions are perceived as good or bad by humans; H, changes in perception and attitude feed back to the societal system (patterns and processes of society) to influence decision-making, and this part of the cycle begins anew; I, in some cases, changed ecological conditions can alter the coarse-scale environmental context (example: urban heat island), resulting in feedback that is relatively independent of human response. J, K: when a societal response to changed ecological conditions is deemed necessary, the society can act directly on the changed conditions (J) or on the underlying ecological patterns and processes producing the problem (K). Finally, the environmental context of course influences ecological patterns independent of land-use (L) (Grimm et al. 2000). Used with permission from American Institute of Biological Sciences (Grimm et al. 2000, modified; copyright with the publisher of the original publication)

here on the totality of all areas of the same type (so-called area-representative biotope mapping).

Urban morphology mapping represents a similar approach. A distinction is made between areas that are uniformly shaped in terms of their development and green structure and should therefore each have distinctive ecological features. This approach was developed and applied in parallel in the former Federal Republic of Germany and the

German Democratic Republic in the 1980s (Richter 1984; Duhme and Lecke 1986; Breuste 1987). In contrast to biotope mapping, however, the aim here is not “only” to survey the habitats for plant and animal life, but to enable a comprehensive landscape-ecological analysis of the urban ecosystem, including its energy and material flows (Fig. 2.7).

There are various examples of urban morphology type mapping, for example, from Halle, Leipzig, Munich, Linz, Sofia, Manchester, Dar es Salaam, and Addis Ababa (Duhme and Lecke 1986; Breuste 1987; Pauleit 1998; Terzijski 2004; Gill et al. 2008; Henseke 2013; Cavan et al. 2012). In several studies, the degree of built development and surface sealing, the proportion of green space, and also data on open space use and intensity of use were collected for the various morphology types (Duhme und Lecke 1986; Pauleit 1998; Gill et al. 2008; Cavan et al. 2012), in order to analyze the relationships between these features and the climatic and hydrological conditions in the morphology types. The following example of urban morphology type mapping for the city of Munich illustrates this approach.

The approach of urban morphology type mapping briefly presented here draws a picture of the urban landscape that is not otherwise discernible from normal land use mapping or the recording of public green spaces. For example, the surveys in Munich show the distribution of habitats of special importance for plants and animals (Table 2.2). A key finding of such surveys is that these habitats are usually not public green spaces, but rather the remains of near-natural areas such as forests and heathlands. There are also many brownfield sites that have been created as a result of abandoned uses (e.g., industrial plants, railway facilities) or construction projects that have been started or later abandoned. Agriculturally used areas and forests, which characterize the outskirts of the city, are also part of the green structure of a city. The importance of these green structures for ecosystem services and nature conservation is further elaborated in Chapt. 5 and 6 (Table 2.1).

Biotope Type Map from Berlin, Germany

After a first comprehensive biotope mapping for West Berlin, which served as an important basis for the species protection programme of the city of Berlin (AG Artenschutzprogramm Berlin 1984), and led to a map of the ecological spatial units of Berlin (Sukopp 1990), a new biotope mapping covering the entire city was created from 2003 to 2008, which is also available in digital form (http://www.stadtentwicklung.berlin.de/natur_gruen/naturschutz/biotopschutz/de/biotopkartierung/karte.shtml).

All forest, wooded areas, Natura 2000 areas, nature reserves, and other areas of Berlin already known to be of particular value in terms of nature conservation were surveyed by inspecting the areas. The built-up areas were encoded into biotope types using existing information on building structure types and a green space cadastre. The biotope type code comprises a total of no less than 7,483 biotope types, which in turn were assigned to 22 biotope type groups. Figure 2.6 shows a section of the biotope type map for an area of the inner city. Predominant here are "residential and mixed development", "commercial and service areas", and the streets designated as "traffic areas".

There are also various green areas with the zoo in the center. The biotope type mapping provides a differentiated picture of the characteristics of these green

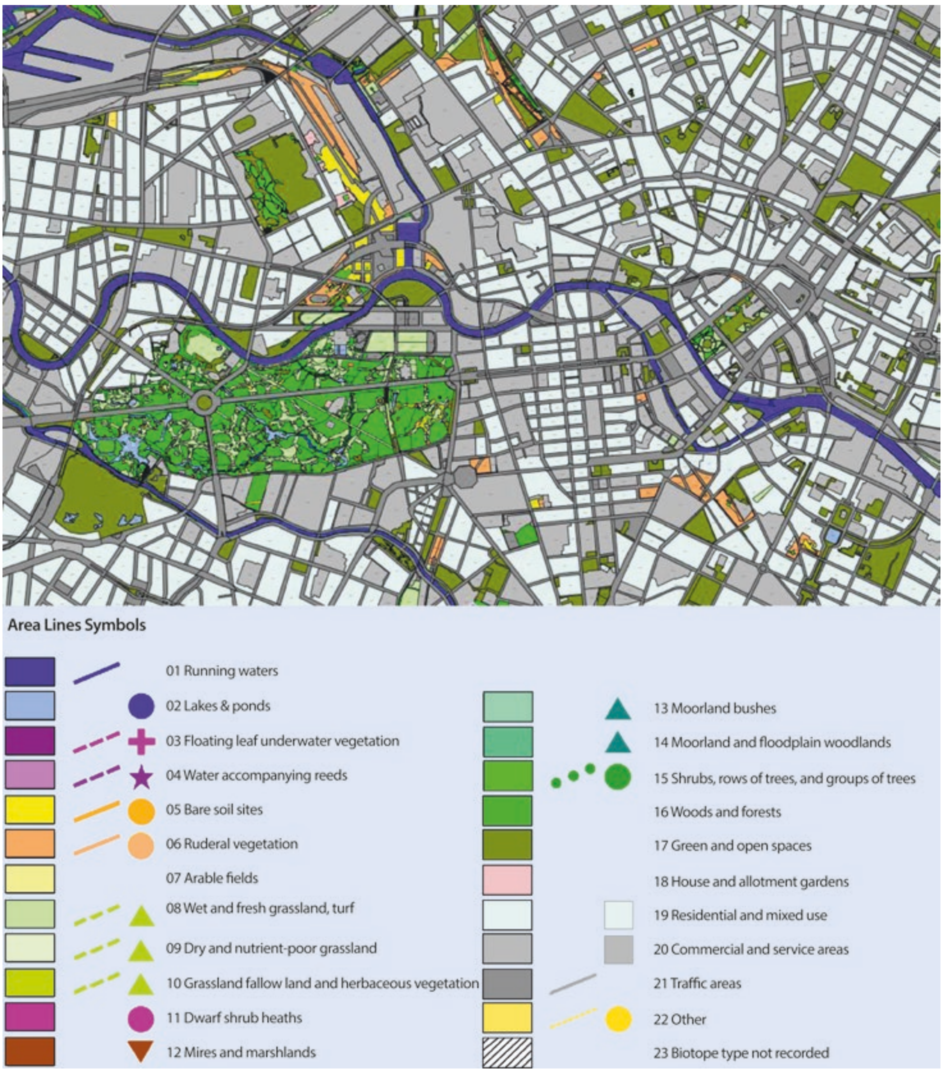


Fig. 2.6 Section of the biotope type map for Berlin. (Senate Department for Urban Development and Environment o. J.)

areas. For example, on this aggregated level of the biotope groups in the zoo, a distinction is made between “forests and woodlands”, “green and open spaces”, “wet and fresh grassland, ornamental and treaded grass”, and “standing waters”. The map section also shows “raw soil sites” and “ruderal corridors” along railway lines and “running waters”.

The biotope types serve, for example, as a basis for determining the extent of compensation measures for interventions under the Federal Nature Conservation Act (Köppel et al. 2013). The determination of the biotope value of the various habitat types is based on an assessment of their closeness to nature (so-called “hemeroby levels”, Chap. 4) and other value-determining features such as the occurrence of rare or protected species, the diversity of the flora and fauna (insofar as recorded in field surveys), an assessment of the rarity of the biotope type, the time required to restore the biotope type, and the risk that the restoration will fail. In this way, the analysis of the main ecological structure of Berlin by the biotope type mapping in conjunction with further surveys provides the basis for landscape planning, the application of the impact mitigation regulation, for environmental reports and environmental impact assessments.

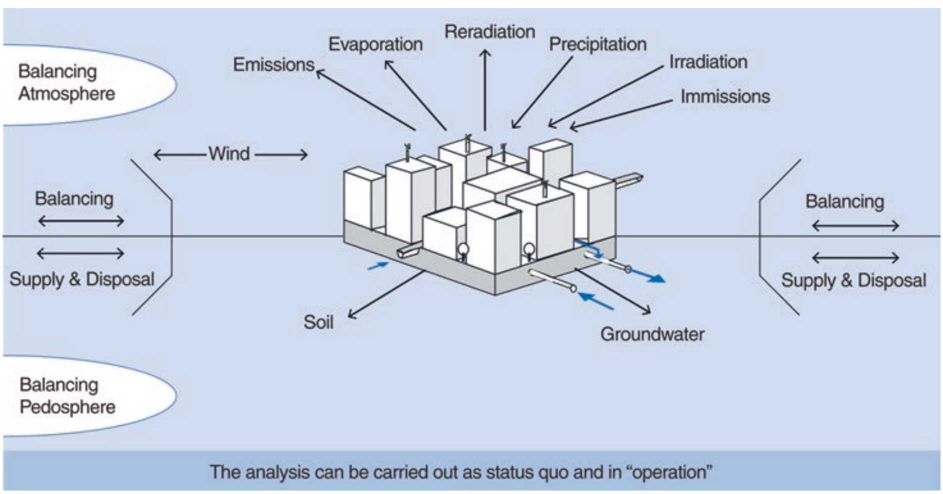


Fig. 2.7 Urban morphology units and types as a spatial-integrative reference system for the analysis of the urban ecosystem. (Pauleit 1998, modified)

Mapping of Biotopes and Urban Morphology Types in Munich, Germany

The first biotope mapping for Munich recorded the habitats for plant and animal life that were considered worthy of protection (LÖK 1989). It was the basis for a nature conservation strategy for the city of Munich (Duhme and Pauleit 1992).

The overwhelming majority of rare or endangered species were found in biotopes recognized as worthy of protection, but they only made up about 10% of the city's area and were highly fragmented. They represented only a small part of the different urban land uses and the agriculturally used urban peripheries. To provide basic information for urban planning and nature conservation about the ecological features and values of the settlement areas with their characteristic architectural features, an urban morphology type mapping was carried out, in which morphological units were distinguished and categorized into morphology types by interpreting aerial photographs (Fig. 2.8).

For each individual area, features of the buildings and open spaces were included, such as the proportion of built-up areas, asphalt or paved areas, trees, shrubs, meadows and lawns, and open soils. The respective area percentage was estimated by a visual inspection of the aerial photographs. These features were collected because a) they are directly related to ecosystem services such as temperature regulation or precipitation infiltration, and because b) they can be influenced by urban planning instruments, for example, by setting building density or the amount of green features in development plans.

The surveys enabled a detailed presentation of the urban morphology types, including the green structures of the city, and an analysis of their importance for nature conservation (Table 2.1). Spatially, the diversity of urban morphological types was aggregated into broader zones (Table 2.2), ranging from the densely built-up inner city with a high degree of sealing and correspondingly low proportions of vegetation and woody plants and island-like green areas, through zones of dense and low density residential development, where the largest proportion of vegetation and woody plants are to be found, to commercial and industrial zones with a higher proportion of wasteland. While the inner city area is homogeneously characterized by old town and block development, the surrounding belt of residential, commercial, and industrial areas is characterized by a high mix of different morphology types occupying smaller or larger areas. Large historical parks and cemeteries are also embedded in this zone. In contrast, the urban fringe area, which is dominated by agriculture and forestry, is again less diverse and the individual areas are considerably larger. Large connected green structures such as the Isar and its adjacent forests and parks can also be seen (Table 2.2).

The maps of surface sealing and trees and shrubs (Figs. 2.9 and 2.10) show features of the urban structure that are closely related to biodiversity and regulating ecosystem services such as the reduction of stormwater runoff from paved areas into the sewerage system and the reduction of thermal loads on hot days (Fig. 2.11; Pauleit 1998; Pauleit and Duhme 2000).

The abovementioned urban zones have specific characteristics, potentials, and deficits that require adapted objectives and measures for ecologically oriented urban development. In the densely built-up inner city, for example, measures to increase the vegetation stock will be a priority. But how can this be done when space is limited? Where can additional trees be planted? Where is the potential to unseal areas for this purpose? How much green space can be created by greening roofs and facades and is it sufficient to increase the ecosystem services in inner cities? In well greened residential areas, the question often arises—especially in growing cities such as Munich—of how the green stock with its important ecosystem services can be preserved in the event of densification.

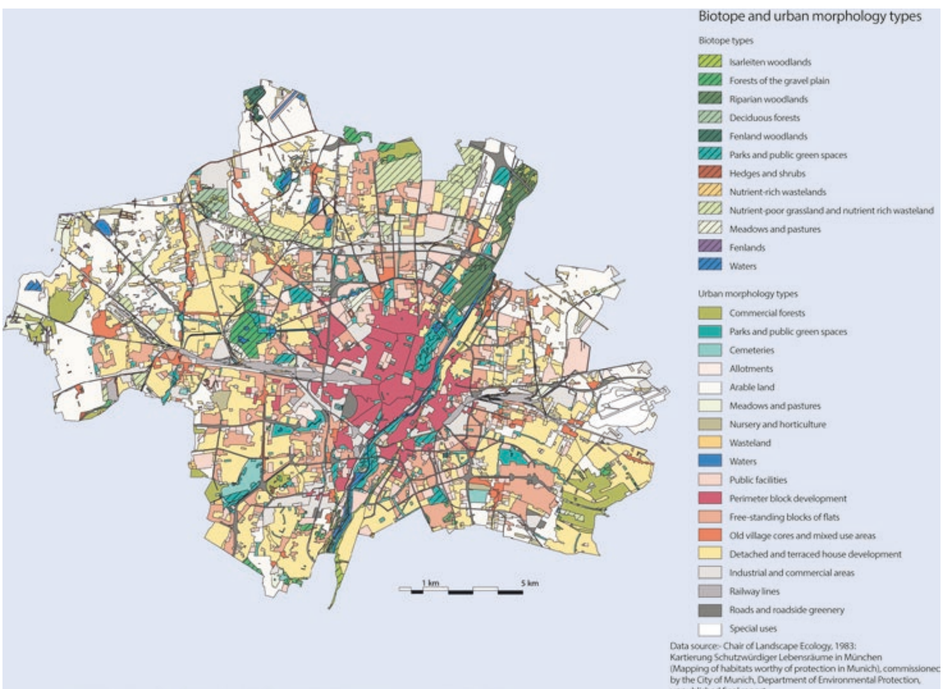
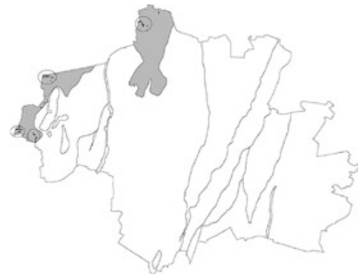
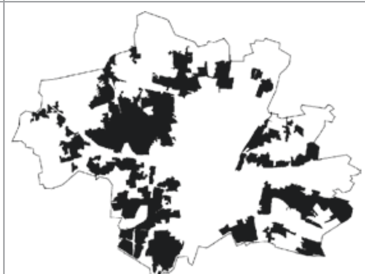


Fig. 2.8 Biotope and urban morphology type map for Munich. It shows the diverse mosaic of different land uses and green structures that make up cities. (LÖK et al. 1990)

Table 2.1 Old villa areas and the city center have very different ecological characteristics (according to Breuste 2009, changed; Photos: © S. Pauleit)

	Old villa areas	City center
		
Land use	Housing	Housing with business, services, and offices
Urban morphology type	Single house development	Dense block development
Degree of development	20–30%	>70%
Open space types	Extensive home gardens	Small backyards, squares, streets
Type of vegetation	High proportion of vegetation, especially trees	Very low vegetation content
Surface sealing	<40%	>70%

Table 2.2 Green structures of the city of Munich. (Source: Pauleit 2005)

			
Running waters: Isar as the most important green corridor with near-natural habitats	Fens: Only small remains of near-natural wet meadows (*arrows*) (*grey*: original extension of the fens)	Forests: Different near-natural forest types, highly fragmented	Lean grass: Remains of formerly grassy heathlands. Fallow land in commercial and industrial zones and along railway lines. Heavy losses due to settlement development
			
Parks: Scattered in the built-up area. Old parks with important habitat features	Low density residential development: Largest proportion of green space within the urban area. Older villa gardens with significant woodland	Agriculture: Intensively cultivated areas, accessible only via paths	Railway lines: Partially significant corridor function for nutrient-poor grassland habitats

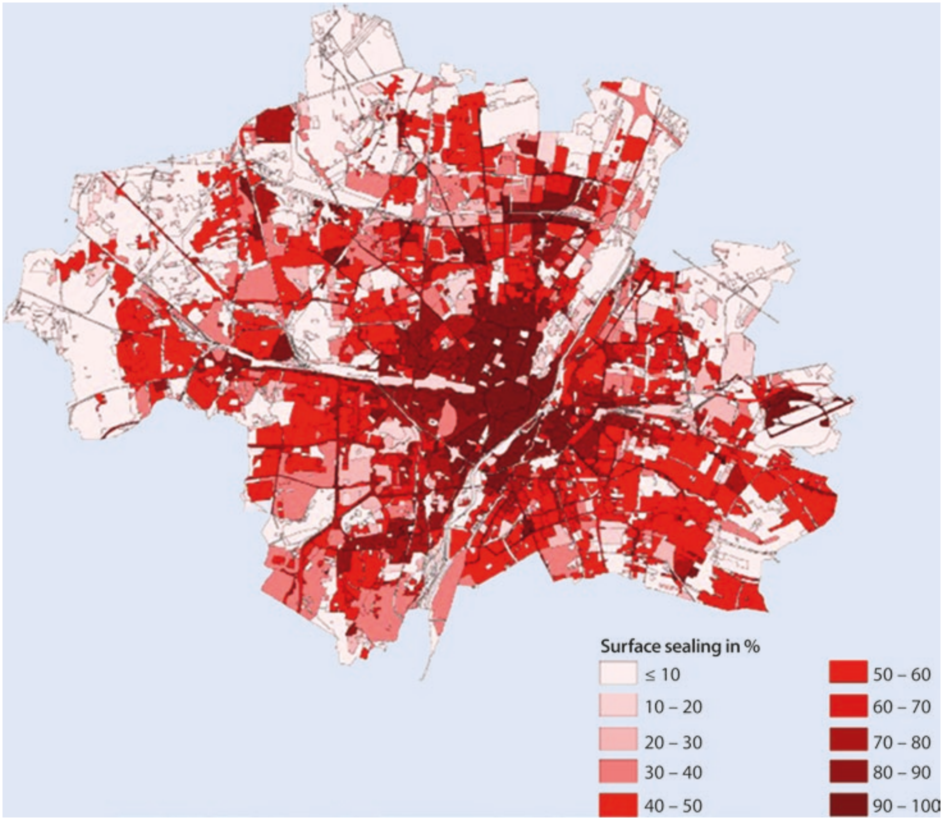


Fig. 2.9 Surface sealing map for Munich. (LÖK et al. 1990)

▶ **Definition**

Surface sealing refers to the permanent building-up or reinforcement of the soil surface (e.g., by asphalt) with more or less air and water impermeable materials (Wessolek 2010 and Prokop et al. 2011 with further definitions).

It is also possible to analyze the ecological performance of or the pressures from urban land use, such as the various forms of residential development, commercial, and industrial areas or even transport infrastructure such as railway lines. In this context, it is important to record features of the physical surface structure such as the degree of surface sealing, the proportion of vegetation, and woodland.

Surface sealing is a key ecological feature in cities. It means the impairment or complete loss of the living soil surface and soil functions (Chap. 3). In cities, surface sealing depends on the type of development and the structure of green spaces. In the Munich urban area 36% of areas were sealed (Artmann 2013). In the densely built-up inner city, however, sealing accounts for over 70% of the area. Residential development shows very

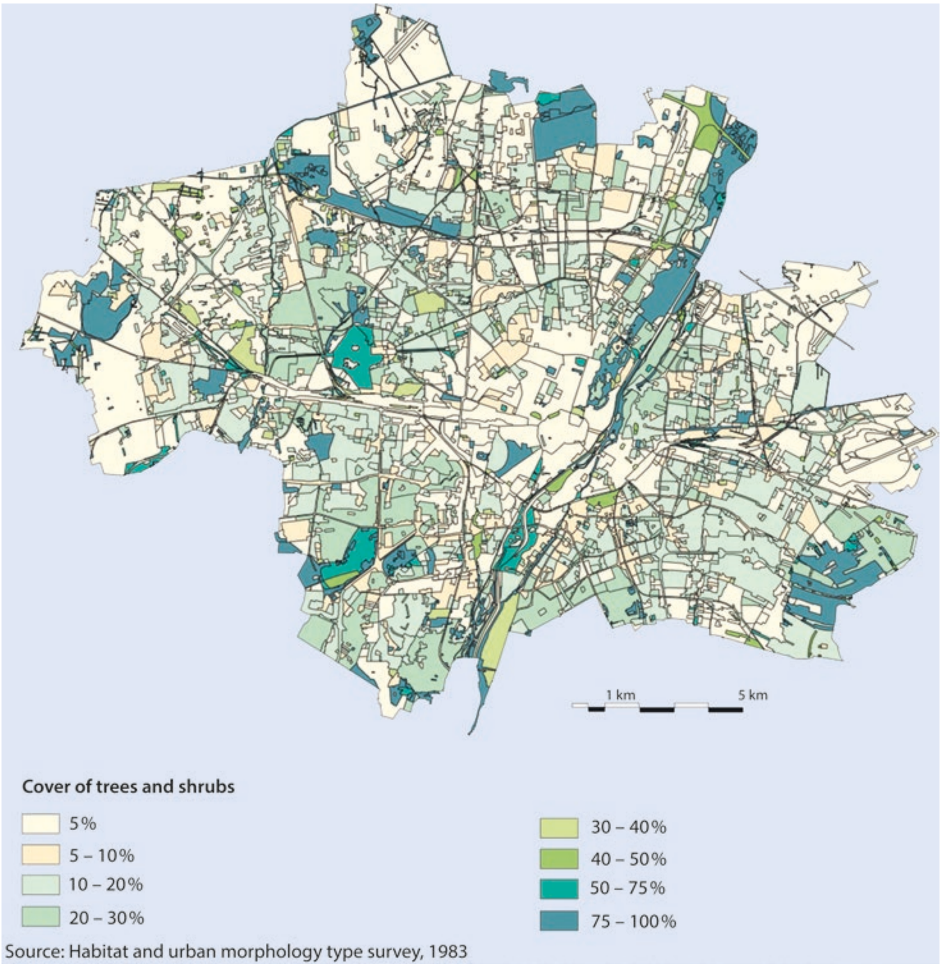


Fig. 2.10 Woody parts for structural units in Munich. (LÖK et al. 1990)

different sealing percentages of 20–60% (Fig. 2.9, Table 2.3). Large commercial and industrial areas can also have a degree of sealing of up to 80% or in individual cases even higher. In contrast, the degree of sealing on the outskirts of towns and cities characterized by agriculture and forestry is below 20%.

Table 2.3 shows from a study for a subarea of the city of Munich the average degree of surface sealing of urban morphology types and other land cover features such as the proportion of vegetation and trees and shrubs (Pauleit 1998). Average values for important environmental properties of the morphology types, such as surface temperatures and the proportion of precipitation that seeps away, are also given. For example, an increase in surface sealing of 10% correlates with an increase in surface temperatures of 1.0 °C (ibid.). According to another study in Munich, a 10% increase in the sealing of open spaces increases the air temperature by an average of 0.7 °C (Bründl et al. 1986). The environmental effects of surface sealing are also shown by other studies (e.g. Haase and Nuissl 2007; Scalenghe and Marsan 2009).

The recording of green areas, vegetation, and tree and shrub cover thus offers further information for urban ecological analysis. The proportion of green and water areas in European cities ranges from less than 2% to approximately 50% (Fuller and Gaston 2009). However, only green and water areas that could be distinguished as individual areas on Landsat satellite images with a resolution of 25 m could be recorded in this survey, but not the vegetation-covered areas within residential, commercial and industrial areas. Cities in Southern and Eastern Europe had on average lower proportions of green areas per inhabitant than cities in Northern and Northwestern Europe. Interestingly, the proportion of green areas increased with the size of the cities, while population density remained the same. As expected, however, the proportion of green spaces per inhabitant dropped with increasing population density.

In 1982, a total of 58% of the area of Munich was covered by vegetation (LÖK 1989). This figure includes the vegetation stock of residential buildings, industrial estates, transport infrastructure, and also the agricultural outskirts of the city. However, the proportion of vegetation can vary between the morphology types (Table 2.3), from 20% area share in the dense block development of the city center and commercial and industrial development to over 60% in the single-family house development.

Investigations in other cities in Central and Northern Europe on the proportion of areas covered by vegetation come to similar results. In Manchester, for example, the total proportion of vegetation-covered areas was 72% and in the built area (i.e., excluding the agricultural peri-urban areas) 59% (Gill et al. 2007). In Linz, it was 53% for the entire urban area, including the agricultural and forested land (Henseke 2013).

While the urban morphology type mapping shows vegetation and sealing in contrast, the map provides new information on the areas covered or sheltered by trees and shrubs (Fig. 2.10). The different quality of vegetation stocks in the different land use structures can now be recognized. Forests and woody vegetation (trees and shrubs) are of particular importance for the urban landscape, the recreational suitability of open spaces and ecosystem services such as the reduction of air temperatures and surface water runoff after heavy rainfall events. Moreover, dense, old woodland stands are valuable as habitats for flora and fauna. Their role as carbon stores is also worth mentioning in the course of climate change (Nowak 2002; Tyrväinen et al. 2005).

The proportion of woody plants in Munich in 1982 was 17% (a more recent survey was not available). It is thus about the same as the share of built-up areas, which was 18% in 1982. It is therefore not without good reason that the entire urban wooded area was termed the “urban forest” in North America (Nowak 2002). As expected, the proportion of woody plants is high in forests and large old parks with wooded areas. Old cemeteries can also have dense stands. In low density residential areas, the share of trees and shrubs can be high, too. On average, the crowns of trees and shrubs in Munich’s single-family housing developments cover 24% of the total area (Table 2.3). In villa areas,

Table 2.3 Features of the physical structure and ecosystem services (Chap. 5) of urban morphology types in Munich. (Source: Pauleit and Duhme 2000)

	Number of cases	Surface sealing[a]	Built-up areas	Vegetated area[b]	Trees and shrubs[c]	Surface temperatures[d]	Precipitation infiltration[e]	Surface runoff[f]
Ranked according to surface sealing		In %	In %	In %	In %	in °C	In %	l/m²
Roads	76	88.7	0	9.5	4.3	37.4	10.5	33.0
Perimeter block development	54	85.4	45.2	13.9	6.1	36.6	10.3	30.1
Multistorey and factory buildings	56	81.3	38.2	9.3	3.7	38.6	12.0	28.4
Parking spaces	9	69.6	5.2	13.7	7.5	39.2	19.0	18.7
Special constructions	4	54.2	23.5	36.6	11.3	34.7	19.4	13.0
Free-standing multistorey blocks	219	52.3	28.5	43.5	14.9	34.1	19.5	18.2
Factory buildings	43	50.4	27.0	23.3	6.7	37.1	23.4	15.9
Terraced houses	25	49.1	26.7	49.9	19.9	33.6	19.4	20.1
Mixed development	11	43.6	26.6	52.6	26.1	33.6	20.4	16.5
Detached houses	83	35.2	16.5	62.0	23.9	32.9	23.4	13.1
Sports facilities	30	24.3	7.4	65.4	12.0	32.8	28.6	4.0
Horticulture/nurseries	32	22.3	16.3	71.4	6.3	32.7	30.9	14.3
Allotments	35	18.2	12.9	72.3	22.4	30.4	30.0	6.3
Hedges	46	18.1	1.0	77.2	55.3	27.1	22.2	7.2
Gravel areas	28	14.2	5.8	15.5	5.1	37.5	41.7	5.0
Parks	100	8.8	1.0	81.2	25.5	29.9	31.2	18.1
Railway lines	10	6.1	1.8	5.6	0.5	40.1	55.0	2.0
Running waters	23	4.3	0.1	40.6	22.2	22.7	15.0	0

(continued)

Table 2.3 (continued)

	Number of cases	Surface sealing[a]	Built-up areas	Vegetated area[b]	Trees and shrubs[c]	Surface temperatures[d]	Precipitation infiltration[e]	Surface runoff[f]
Cemeteries	3	3.0	2.8	84.7	44.3	25.9	32.8	1.1
Wasteland	55	2.8	1.0	80.2	22.6	31.2	33.8	0.7
Meadows	18	1.9	0.1	94.1	3.8	28.3	34.2	0.2
Arable land	37	1.0	0.1	97.3	1,2	28.5	38.9	1.0
Forests	24	0.9	0.2	94.7	86,4	24.1	21.8	1.0
Still waters	7	0	0	0	0	20.7	0	0
Total/average	1028	42.3	18.2	45.0	16.9	33.8	23.1	16.1

The data refers to a study area that covers approximately 15% of the city area. Agricultural urban fringe areas are underrepresented.

Note: The sum of sealed and vegetation-covered areas is smaller than 100%. The remaining areas are open gravel areas (e.g. on railway lines) and water areas.

[a]Surface sealing = buildings, asphalt, and paved areas.

[b]Vegetation = areas of trees, shrubs, meadows, lawns, herbs, beds, and arable land.

[c]Woody proportion = areas covered with trees and shrubs.

[d]From a thermal flight of August 8, 1982, 12.30–14.00 h (Baumgartner et al. 1985).

[e]As a percentage of the annual precipitation of 948 mm (Station München-Riem). Calculation: see Pauleit 1998

[f]With a 1h precipitation of 40 mm (return frequency 10 years). Calculation: see Pauleit 1998

however, the proportion of shrubs and bushes can be much higher and show a high proportion of old, large-crowned trees. Ornithological surveys in Munich showed that bird species such as the wood warbler which were otherwise only found in forests in the city area, also nested in these villa areas (LÖK 1990). Residential areas with woody stands of this quality were, therefore, assessed as corridors for the habitat network of the forests.

In other cities, too, the special importance of green spaces in residential development was noted. According to Loram et al. (2007), for example, in five British cities between 22 and 27% of all vegetation-covered areas are in home gardens. In the Greater Manchester area, about 20% of all vegetation-covered areas and even 30% of all woody plants are in residential areas (Gill 2006).

For cities of the Unites States, the proportion of woodland ("urban forest") and sealed areas was determined for all areas classified as urban for the year 2005 (Nowak and Greenfield 2012). The average percentage of trees and large shrubs was 35%, ranging from 9 to 67% in urban areas in the different states. An analysis of aerial photographs from different years showed for 20 American cities that the tree population decreased by an average of about 0.3% annually, while the proportion of sealed areas increased accordingly (Nowak and Greenfield 2012). For European cities there are no comparable data available to date on the proportions and dynamics of tree stands.

Figure 2.11 illustrates the importance of the woody fraction for regulating ecosystem services by using the example of surface temperatures. According to this study, an increase in the proportion of woody plants by 10% means a reduction of surface temperatures by 1.4 °C (Pauleit 1998), while a 10% increase in the total proportion

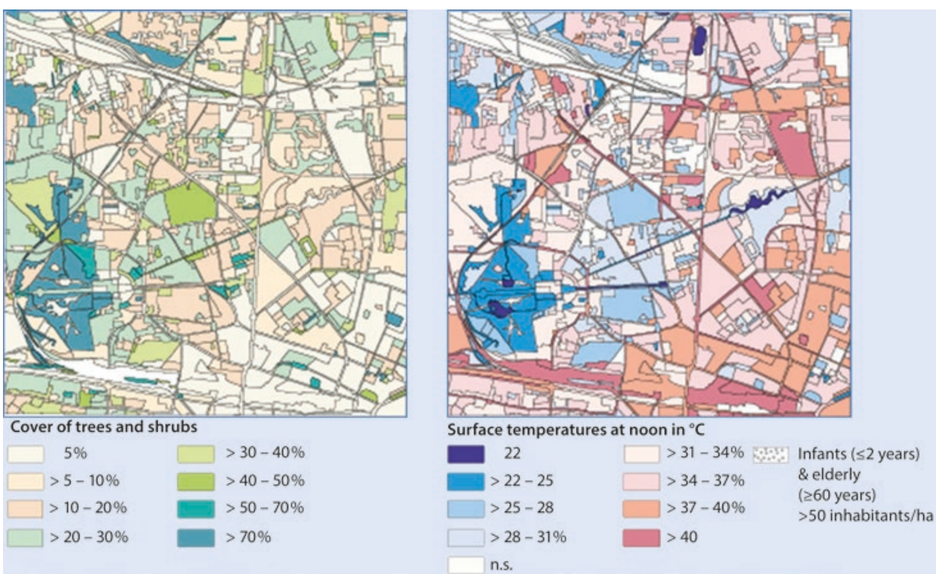


Fig. 2.11 Wood content and surface temperatures in a Munich study area. (Pauleit 1998)

of vegetation-covered areas (trees, shrubs, meadows, and lawns) led to a reduction of surface temperatures by “only” 1.0 °C (Chapter 6 on similar results of other studies). The reason for the particular effectiveness of trees for climate regulation or for reducing surface stormwater runoff is their three-dimensional structure and the high leaf surface. Measures for the vegetation volume or the so-called leaf area index are therefore also used as parameters to determine or simulate the ecosystem services of woody stands (e.g., with the i-Tree Tool of the US Forest Service, Nowak et al. 2008; King et al. 2014; Rötzer et al., 2020; see also Hardin and Jensen 2007). Remote sensing methods such as LiDAR will, in the future, enable a comprehensive survey and regular updating of such inventory data (MacFaden et al. 2012).

The Study of the Land Use and Green Structure of Dar es Salaam, Tanzania

The Dar es Salaam case study is intended to provide a brief insight into the land use and green structure of a city that is fundamentally different from European cities such as Munich or Berlin (Chap. 1). The following information comes from an EU-funded research project *Climate Change and Urban Vulnerability in Africa* (CLUVA). An urban morphology type mapping was an important basis for this project (Fig. 2.12, Cavan et al. 2012).

Dar es Salaam was only founded in the colonial era. Especially in the last decades it has developed almost explosively, and today has over 6 m inhabitants. With

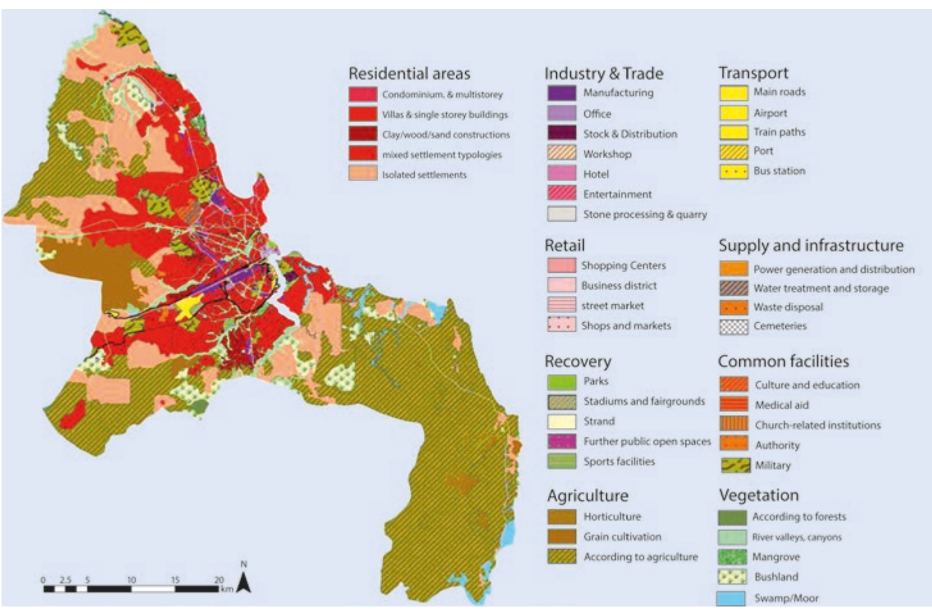


Fig. 2.12 The land use and green structure of Dar es Salaam. (Cavan et al. 2012)

Fig. 2.13 Structural types in Dar es Salaam: **a** densely built-up city center, **b** River valley with informal settlement in the background, **c** informal settlement on the outskirts of the city. (Photos: a, b: © S. Pauleit, c: © A. Printz)

a continuous annual population growth of about 5%, the population would double within less than 15 years. Urban growth in Dar es Salaam takes place mainly informally, hence the settlements are not planned by the city administration and do not have a legally secured status.

Dar es Salaam's densely built-up, but small city center in relation to the total settlement area is therefore surrounded by spreading low-rise settlements, which develop mainly along major arterial roads (Fig. 2.13).

Main green structures in the city are the river valleys, in which informal settlements have also spread. The rivers are heavily polluted by waste deposits and sewage (Fig. 2.14). Parks and other public green spaces have only been created to a very limited extent in Dar es Salaam. One of the largest green spaces in the city center is a golf course, which is not open to the public. A significant part of the green is located in loosely built up settlements. In the scattered settlements on the outskirts of the city which in total take up 25% of the city area, 20% of the vegetation-covered areas are located.

Urban agriculture and urban gardening take place in various forms in the informal settlements, in the river valleys and other undeveloped areas in the urban area and are of great importance for the self-sufficiency of the population (Afton and Magid 2013).

The settlement area and the proportion of sealed surfaces increased by 2% between 2002 and 2008. The rapid settlement development on the outskirts of the city has resulted in the loss of appr. 5,000 ha of agricultural land in this period—the local supply of the residential population through urban agriculture is endangered by this development. The extent of forests, scrubland, and wetlands decreased by one third. In the city, too, many green spaces disappeared due to the built densification of settlements. The annual loss of woody plants was particularly high at 11% of their area. As a consequence, the ecosystem services of the green structure are dramatically reduced and the vulnerability to climate-change-related natural hazards such as flooding is further increased. The application of a spatial scenario model in the CLUVA research project showed that the densification of existing settlements would make a significant contribution to securing agriculture close to urban areas by reducing urban sprawl (Pauleit et al. 2013). Securing or reclaiming river valleys as green corridors is another key task for ecologically oriented urban development. However, the implementation of such goals would require a substantial strengthening of urban planning.

2.3.2 The "patch" Model, Landscape Dimensions and Landscape Gradients

The "*patch corridor matrix model*" of landscape ecology (Forman and Godron 1986; Forman 1995) opens up a further perspective on the urban landscape by focusing on the spatial relationships of its elements.

Accordingly, landscapes can be understood as a structure of different "patches", each of which is created by ecological differences in location and/or certain "disturbance regimes". The spatial heterogeneity of landscapes has a significant influence on ecological processes such as material flows or the distribution of plant and animal species (Pickett and White 1985). "Corridors" are to a certain extent the transport routes for energy and matter and the distribution routes of plants and animals. "Patches" and "corridors" are in turn integrated into the matrix, which as a whole determines the ecological character of the landscape (e.g. "forest" landscape, "agricultural" landscape, and "urban" landscape).

With a *High Ecological Resolution Classification for Urban Landscapes and Environmental Systems* ("Hercules"), an approach was developed in the *long-term ecological research* project in Baltimore (Pickett et al. 2009; Cadenasso et al. 2007) to apply the "patch" model in the city. Not unlike the urban morphology type maps already presented, areas were delimited and classified that can be distinguished from each other based on their configuration of built and open spaces (Cadenasso et al. 2013). The area proportions of features of the physical structure such as built-up area, paved area, wooded area, and area of herbaceous vegetation were also estimated.

In addition to the physical structure, features such as size and shape also determine the ecological properties of the "patches". For example, the size of the patch can influence the quality as a habitat for plant and animal life. For small forest bird species, such as the Golden Oriole or the Wood Warbler, for example, a minimum forest size of about 10ha seems to be necessary for their occurrence (van Dorp and Opdam 1987). The climatic features of green areas are also size-dependent. The difference between the average air temperature in green areas and their built environment started to differ, for example, only from a size of about 3ha and became bigger with increasing size in a study carried out in Berlin (Stülpnagel 1987). In addition to the size of the area, however, the geometric shape of the individual "patches" also plays a role in their ecological properties, for example, through the shape-related size of the edge areas.

Spatial characteristics of the landscape can be described by various so-called landscape metrics. Alberti (2008), for example, distinguishes metrics for "form" (spatial configuration), density (e.g., population density, building density), heterogeneity (variety of different physical structures), and connectivity (e.g., of green links). For a climatic assessment of urban form, measures such as "porosity", "compactness" of the development, and "surface roughness" were also used (Adolphe 2001; Steemers et al. 2004). As an example for the application of landscape metrics, the following case study for the South Korean urban region of Kwangju shows how the effects of urban growth and related processes of intensification of agriculture and development of the surrounding mountains for tourism affect the structure of the forests in this region. However, the ecological relevance of such landscape metrics has rarely been verified by independently collected data on flora and fauna or even ecosystem services (Leitão and Ahern 2002; Li and Wu 2004; Corry and Nassauer 2005, but see for urban climates e.g. Li et al. 2012; Lin et al. 2016).

As the example from South Korea already indicates, landscape measures can also be used to describe urban–rural gradients. The aim of such studies is to analyze the effects of varying degrees of urbanization on ecological processes (e.g., McDonnell et al. 1997; Luck and Wu 2002; Hahs and McDonnell 2006; Pickett et al. 2009; Alberti 2008). For Leipzig, for example, the development of surface sealing along an urban–rural gradient from 1870 to 2006 was investigated and the effects on hydrology were analyzed (Haase and Nuissl 2010). In other studies, the effects of urbanization (e.g., the heat island effect, land use and other anthropogenically caused "disturbances" (McDonnell et al. 1997) on biodiversity, successional processes or nutrient cycles in forests from the city center to the outskirts and rural areas were analyzed. The gradient approach has also been further developed to analyze polycentric urban structures and the overlay of multiple natural and anthropogenic gradients (Fig. 2.14).

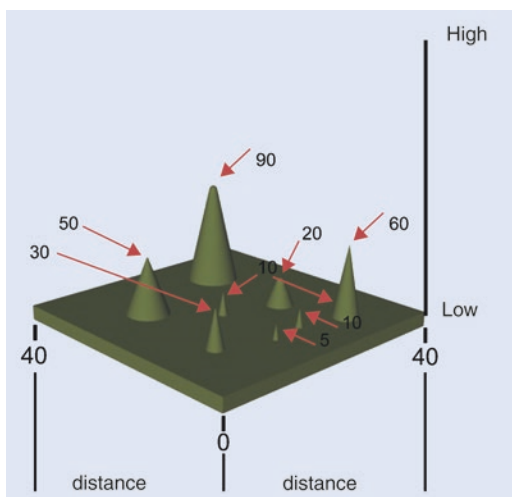


Fig. 2.14 Schematic representation of complex urbanity gradients in the urban region. The height of the mountains symbolizes the intensity of urbanity. (After McDonnell and Hahs, unpublished Powerpoint presentation, Urban Ecology Workshop, Duluth, May, 18–20 2006)

Perhaps the greatest potential of the gradient approach for research on urban ecology lies in the fact that it: a) Does not start from preconceived notions of what is being regarded as city and countryside—a distinction that is no longer applicable in today's urban regions with their large peri-urban areas and far-reaching functional interdependencies, and b) Sharpens awareness of the fact that urbanity gradients result from various physical-structural, sociodemographic, and economic factors which, in their specific interaction, shape the ecological characteristics of the urban landscape (Sect. 5.2.1). 1; Boone et al. 2014).

Analysis of the Spatial Characteristics and Dynamics of Kwangju Forests, Südkorea

Kwangju is a fast-growing city in South Korea with 1.4 m inhabitants (2002). It is embedded in a mountainous landscape, which is mainly forested, whereas they mostly use the valley areas for rice cultivation. The strong growth of the city, agricultural intensification in the urban environment, and also the increasing development of tourism in the mountains lead to the loss and fragmentation of forest areas and woodlands.

In four landscape types, representing a gradient from the mountainous landscape, over the agricultural zone, the outskirts of the city to the city center, the landscape change and its effects on the forests were analyzed by means of landscape measures, three of which are presented below (Kim and Pauleit 2009).

- The "forest patch shape" index is a dimensionless number that indicates the ratio between the extent and area of forests. Biotopes with more complex forms and a higher proportion of edge areas can have a higher biodiversity. However, since plant and animal species specialized in the interior of forests cannot occur in small forests with a high proportion of edge areas, the index was additionally weighted according to the size of the area;
- The "mean nearest-neighbour distance" is a measure of the distance between forest habitats to determine their isolation; and
- "Patch density" index (number of forests per 100 ha) is a measure of the spatial heterogeneity or connectivity of the landscape (McGarigal et al. 2002). In addition, the change in surface cover in the respective landscape matrix was also analyzed, as it can influence the possibility of species spreading.

Altogether between 1976 and 2002 almost 14% of the forest stand in the urban region of Kwangju was lost. The landscape metrics (Table 2.4) show the very different nature and the specific dynamics of the forest stands on the gradient from the city center to the outskirts, from the agricultural landscape to the mountains. In the city center, the proportion of forest was lowest overall, the individual forests were on average the smallest and their geometric shape the simplest. Between 1976 and 2002, the proportion of woodland in the city center was reduced by

Table 2.4 Analysis of forest dynamics in the Kwangju agglomeration, South Korea. (Source: Kim and Pauleit 2009)

Landscape type	Year	Land use (share of total area in %)				Forest features					
		Settlement	Agriculture	Forests	Miscellaneous	Forest area (ha)	Number of forests	Average size of forests (ha)	Area-weighted mean patch-shape Index (AWMPSI)	Mean nearest-neighbour distance (MNND (m))	Patch density (PD) (number of forest areas per 100 ha)
City	1976	77.9	12.3	8.9	0.9	80.5	41.0	1.9	1.66	263	4.4
	2002	87.0	7.8	4.3	0.9	38.7	13.0	2.9	1.44	264	1.5
Outskirts of town	1976	33.8	29.6	32.8	3.8	195.3	32.0	6.1	2.62	188	5.3
	2002	48.1	21.0	27.1	3.8	161.0	28.0	5.7	2.66	287	4.9
Agriculture	1976	5.6	75.7	12.1	6.6	121.3	97.0	1.2	1.70	182	9.7
	2002	6.7	76.4	10.3	6.6	103.1	96.0	1.0	1.67	185	9.6
Mountainous land	1976	5.6	48.1	44.5	1.8	706.3	86.0	8.2	3.81	232	5.3
	2002	12.3	44.8	41.1	1.8	652.0	91.0	7.1	3.63	221	5.9

almost half, leading to a further decline in density. Their isolation did not increase any further because the remaining forests were preserved mainly in two subareas of the inner city. In the outskirts of the city, the forests on the steep hills were still close together. Their geometric shape was much more complex than that of the forests in the inner city. However, due to the strong growth of the city, the suburban landscape showed the second largest loss of forests and woodland area after the city center. The average distance to other forests increased most in the suburban landscape.

The intensively farmed agricultural landscape had a comparatively low proportion of predominantly small forests. The loss of forest area was similarly high as in the outskirts of the city, but the number of forests remained the same. In the mountains the best habitat conditions for plants and animals of the forests prevailed. However, between 1976 and 2002, the development of the mountain landscape for tourism led to the largest absolute area losses of forests and to a significant increase in their fragmentation. Based on this analysis, different protection and development objectives were proposed (Kim and Pauleit 2009).

2.4 Conclusions

The spatial structure of cities is characterized by a particularly intensive and complex interplay of natural processes and human actions. Nevertheless, the natural conditions, in particular the topography, the location on rivers or coasts, but also climatic factors such as the prevailing wind direction still influence the form of the city and especially the green structure.

As a result of its development, the urban landscape is a diverse mosaic of different land uses and green structures. Biotope and urban morphology type mapping and the recording of features such as surface sealing and the proportion of trees and shrubs, and landscape metrics, enable the analysis of the relationships between the urban form, biodiversity, and ecosystem services (Chapt. 5 and 6).

Urban morphology types are also characterized by a specific composition of the human population with different socioeconomic features. They are therefore suitable spatial interfaces for the linking and integrative consideration of ecological, social, and economic characteristics of the urban landscape. The relationships between these socioeconomic features, such as income levels and the quantity and quality of green spaces, biodiversity and ecosystem services have been shown in various studies (e.g., Iverson and Cook 2000; Hope et al. 2003; Strohbach et al. 2009). Approaches such as the biotope and urban morphology type mapping presented here therefore also make it possible to link an ecological with a socio-spatial dimension and thus, for example, to answer questions about the “environmental justice” (Chapt. 1) of urban development.

In particular, they are tools that help to prepare ecological information for urban planning (Fig. 2.15). In a German context, urban planning can use instruments such as strategic urban development plan, land use plan, and building construction plans on different scale levels to control the spatial structure of the city and thus influence its ecological characteristics. For example, the arrangement of different land uses with their respective physical features, such as the proportion of green space, can influence biodiversity or the extent of the heat island effect in the city. Specifications at more detailed scale levels, such as for the number and arrangement of trees in the building construction plan, can influence the microclimate.

An understanding of the ecological properties of land uses and their physical structure is therefore a prerequisite for designing and implementing ecologically oriented urban development strategies adapted to the different urban morhology types. The promotion of urban nature, local stormwater and service water management or adaptation measures to climate change require a holistic view of the urban landscape. The protection of urban biodiversity, for example, cannot be limited to the few remaining seminatural habitats, but must also take into account the often high importance of urban land use structures

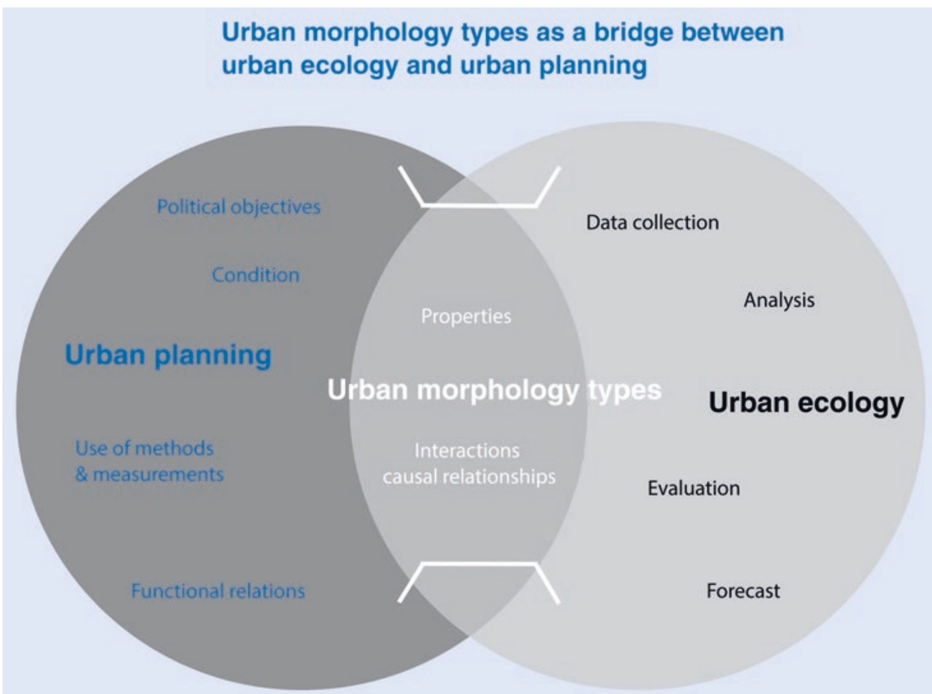


Fig. 2.15 Urban morhology types as a bridge between urban ecology and urban planning. (after Breuste 2006, modified)

such as home gardens with old trees and shrubs or industrial estates and abandoned land accompanying railways as habitats and distribution corridors for flora and fauna (Chap. 4). This also applies to strategies to promote ecosystem services (Chap. 5) in multifunctional green infrastructures. They must incorporate urban nature in all its diversity and with its various services, from parks and forests, through home gardens and street trees to green roofs (Chap. 7).

Questions

1. What are the key features of the ecological city structure and why?
2. Name at least three important requirements to be met by spatial approaches to the ecological analysis and evaluation of the city!
3. What is surface sealing? Name the ecological effects of surface sealing in the city!
4. Why are woody stands a particularly important element of urban green structures?
5. What aspect does the "patch-corridor-matrix" model bring to urban ecological analysis?
6. Why do urban morphology type maps form suitable spatial interfaces for the linking and integrative consideration of ecological, social and economic features of the urban landscape?

Answer 1

- Land use, that is, the current use of an area for human purposes such as living, working, and recreation, is particularly related to functional features such as energy and material flows.
- The expression of the physical structure, which can be measured via features such as the building density and the sealing of surfaces, influences, for example, the hydrological and climatic characteristics of various land uses.

Answer 2

- Provision of comprehensive information.
- Fast and cost-effective data collection.
- Knowledge of the relationships between environmental quality and urban structure, function, and dynamics.
- Reference to planning instruments and hierarchies.
- Possibility to develop and apply evaluation procedures.

Answer 3

Surface sealing means the permanent building over or covering of the ground surface (e.g. by asphalt) with more or less air and water impervious materials. Surface sealing can lead to:

- An impairment or complete loss of animate soil surface,
- Loss of habitats for plant and animal life,
- Increase of air temperatures and,
- Lead to increased surface runoff of precipitation.

Answer 4

Woody vegetation (trees and shrubs) is of great importance for:

- The cityscape and the recreational suitability of open spaces,
- Flora and fauna as a habitat (especially dense, old stands of woodland),
- Ecosystem services such as the reduction of air temperatures and surface water runoff after heavy rainfall events and carbon storage.

Answer 5

Importance of spatial form for functional properties and relationships between different urban structures ("patches").

Answer 6

Urban morphology types also allow socio-spatial considerations and the analysis of interactions with ecological characteristics features of the city. For example, it can be used to show the clear relationships between the proportion and quality of green spaces in residential areas and their socioeconomic status.

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What Are Urban Ecosystems and Why Are They Special?

3

Dagmar Haase and Martin Sauerwein

Abstract

Chapter 3 defines urban ecosystems and elaborates the specifics of these compared to other ecosystems, especially agricultural or forest systems, in terms of their properties and basic functionality. The abiotic bases and properties of urban ecosystems are described in detail. Different ways of delimiting urban ecosystems including their advantages and disadvantages are also discussed. In addition, Chapter 3 introduces and critically evaluates different concepts of urban ecosystems. Information boxes inform about current topics, methods and case studies.

3.1 Urban Ecosystems and Their Special Features

3.1.1 Ecosystem Research and City

Ecology refers to the interactions of organisms both among themselves and with their inanimate environment. Originally coined by Ernst Haeckel, the term describes in its origin the science of the household of nature. Accordingly, even in classical ecology, in addition to the study of organisms, the understanding and linking of the entire biocoenosis and its habitats (biotope) are of central importance. Ecology can thus be understood as a discipline that necessarily involves the study of abiotic environmental compartments in interaction with organisms. With regard to the object of investigation, i.e. the ecology of cities and thus the urban or urban ecosystem, ecosystem research is of great importance. Although on the organismic level in cities it can also be about the observation of individuals of a species (auto-ecology), of populations (population ecology) or of biotic communities (syn-ecology), many studies focus on the investigation of biotic communities in their abiotic and biotic environment - i.e. ecosystem research. This is also closely

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related to humans themselves and their environmental demands. This approach, which is characterised by the description and understanding of material and energy flows, requires the knowledge of neighbouring sciences such as hydrology, geology, pedology, chemistry, physics or statistics. The integration of the social sciences, humanities, social and cultural sciences as well as economics is of central importance, especially with regard to the ecology of cities, because the city is both product and the projection surface of human society.

It is therefore appropriate to define urban ecology and urban ecosystems from an ecological point of view in a narrower sense, but also in a broader sense with a view to sustainable development.

3.1.2 Urban Ecosystems

Urban ecosystems are ecosystems that were created by man and are strongly influenced by him (Sukopp and Wittig 1998; Endlicher 2012) (for definition of urban ecosystems, see Chapter 1). Various authors also speak of urban-industrially shaped ecosystems, where the natural biotic and abiotic geofactors are dominated by anthropogenic components (Leser 2008). Such a human-shaped system is therefore dependent on intensive material and energy input and exchange with the surrounding area (e.g. surface heat and waste disposal, drinking and fresh water and fresh air supply, supply of energy and food). In contrast to forest and agricultural ecosystems, closed material and energy cycles are virtually non-existent in open urban ecosystems (Haase 2011). Similarly, a natural regulation of ecosystem functions and processes in the city is largely absent (Elmqvist et al. 2013). Natural ecosystem functions are being replaced by various anthropogenically influenced economic, political, planning and social control and regulation mechanisms such as energy supply, night-time lighting, various transport systems, the housing market or the health system, to name but a few (Haase 2014).

Urban Ecology

"For more than a century, urban theorists have struggled to understand urban systems and their dynamics. During the second half of the last century, ecological scholars started to recognize the subtle human-natural interplay governing the ecology of urbanizing regions. Both social and natural scientists concur that assessing future urban scenarios will be crucial in order to make decisions about urban development, land use, and infrastructure so we can minimize their ecological impact. But to fully understand the interactions between urban systems and ecology, we will have to redefine the role of humans in ecosystems and the relationships between urban planning and ecology" (Alberti 2008, p. 28).

Urban ecosystems are unique in their close interdependence and the interactions between natural and man-made structures; and as a result they are also extremely complex: The multitude of factors in urban ecosystems—geological subsoil, soils, land cover by artificial surfaces, various residential structures, retail structures, industrial and commercial parks and their economic values, urban trees, parks, urban waters, flora, fauna and the urban population, to name but a few important ones—and their interactions are linked in various spatio-temporal hierarchies, offer many habitat niches and provide space for emergence (e.g. the emergence of species adapted to the urban space, mass movements or swarms and communication networks, or the specific microclimate of urban matrices of biotic, abiotic and building components) (Figs. 3.1 and 3.2).

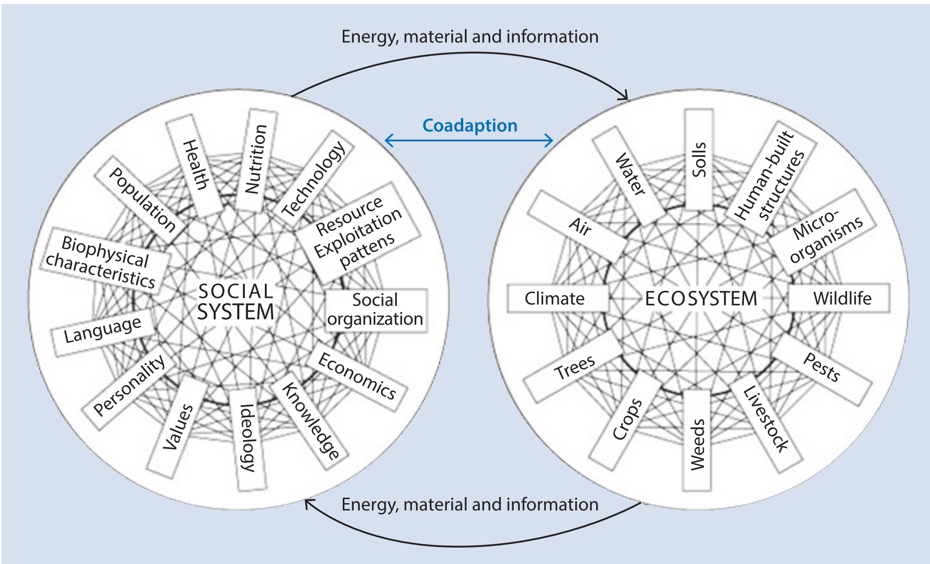

Fig. 3.1 The two sides of our environment, which the urban ecosystem unites as a social-ecological system. (according to Marten 2001)

Fig. 3.2 Three different rural-urban gradients from three continents: compact Leipzig (610,000 inhabitants), Germany (**a**), Tokyo (9.2 million inhabitants), Japan (**b**), and the metropolis of Tirana (420,000 inhabitants), Albania (**c**). The three photos show how different urban structures and densities can be along the three rural-urban gradients, and how high the density of urban systems is compared to open land systems, despite existing inner-city open spaces. (Photos © Haase)

Urban ecosystems have their own typical urban climate (Fig. 3.3) due to dense development and sealing, the displacement of flora and fauna in niches, and acidic and toxic emissions as a result of industry and traffic, which in turn influences the formation of a typical urban flora (Chapter 4) (for example, ruderal areas and other ecological niches, adaptation and mutations and thus even the emergence of new species).

The urban ecosystem has been studied for about 50 years by the still young scientific discipline of urban ecology (Chapter 1). Currently, the *Cities and Biodiversity Outlook* (CBO) and the *Urban Planet* both deal with numerous facets of cities and growing urbanisation worldwide, urban ecosystems in small towns and megacities, corresponding urban ecosystem functions and services, and urban biodiversity (Elmqvist et al. 2013 and 2018; http://www.cbobook.org).

Urban ecosystems as integrative social-ecological systems, in short the "urban habitat", can best be considered on different levels of organisation and scale, on the social side from the apartment or the individual household or building to an entire urban region, as well as on the ecological side from the individual plant to the urban heat island along a rural-urban gradient (Fig. 3.2). Urban ecosystems are characterised by small-scale varying, often extreme biotic and abiotic factors compared to the surrounding area, e.g. surface temperatures >80 °C or acidic or basic substrates of only a few centimetres thickness. These factors create completely new ecosystems, which often have little in common with the original open land ecosystems from which they originated (Fig. 3.3).

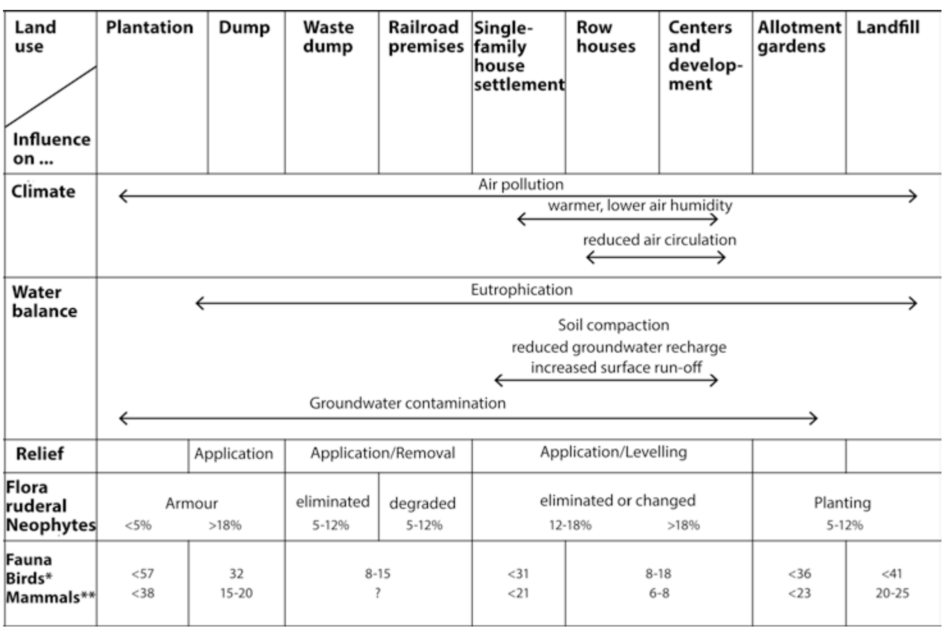

Fig. 3.3 Urban land uses and their ecosystem properties. (According to Weiland and Richter 2009; modified in Haase 2011)

3.2 Which Abiotic Characteristics Define Urban Ecosystems?

3.2.1 Urban Climate and Radiation Balance

The characteristics of urban ecosystems have consequences (Fig. 3.3): On average, the soil surface is covered with artificial building materials and highly compacted to 3% (this can vary greatly between 40% in single-family house settlements and up to 90% in industrial estates) (Haase 2011; Haase and Nuissl 2010). This has consequences both for the microclimate in cities and for the local water balance: direct runoff is greatly increased (up to 500% at low tide) compared with intermediate and base runoff; resistance to surface flooding is consequently low, as is humidity due to lack of evapotranspiration (Chapter 5). Buildings, which are generally densely built, have a strong influence on solar radiation (lower) and albedo (specific reflectivity of surfaces). By using concrete and stones for the construction of buildings, the heat storage capacity of urban surfaces is higher and the ability to retain moisture is lower compared to the open landscape (Schwarz et al. 2011). Cities therefore also have a mean daytime temperature that is 1–2 K higher than in their surrounding areas (Haase 2011). In cities, large parts of the soil are sealed and highly compacted (Haase 2009). For this reason and due to targeted drainage measures, urban soils are drier than those in the open countryside. Thus, the microclimate in cities is also drier than in the surrounding countryside (Stewart and Oke 2012). The dense development reduces wind speeds and thus the exchange of air masses.

The climatic changes brought about by cities are always dependent on the overall climate, but near the ground they are exposed to numerous microclimatic influences that vary over a small area. The urban climate is therefore a special small-scale climate or local climate, which arises under the influence of urban development below and above a height of the air layer of two metres (Henninger 2011).

Compared to the rural environment, the urban climate in Central Europe is characterised above all by higher temperatures and greater drought (Chapter 4). High building density and changing building heights result in an increased surface area and roughness of the earth's surface, so that the flow obstacle city reduces the wind speeds near the ground between 10 and 30%, in individual cases even up to 50%. Compared with the surrounding area, there are 5–20% more calm winds and just as much fewer gusts in the city (Table 3.1).

As a result, air exchange processes are reduced or even stopped altogether, resulting not only in an accumulation of air pollutants but also in the accumulation and accumulation of warm air masses in the city. If, however, the surfaces are very uneven due to the alternation of streets and parks, etc. and especially due to different house heights, much more turbulence is created above the city, which can counteract inadequate or missing ventilation and increased temperatures.

Probably the most important aspect concerns the building materials. They usually have a lower albedo than the natural environment, which in built-up areas leads to a lower

Table 3.1 Characteristics of the climate of urban ecosystems compared to open land ecosystems. (Compiled and modified according to Leser 2008 and Kuttler 2000)

Climate elements	Changes compared to undeveloped open land
Global radiation	≤ – 10% (in early stages of industrialisation in Europe and urban regions in developing countries today partly significant > – 10% reduction)
Albedo (and emission coefficient)	+/– depending on the type of surface and exposure (e.g. meadows have an albedo of 0.15–0.25, deciduous forests of 0.15–0.2, asphalt has an albedo of 0.05–0.2 and bricks of 0.2–0.4)
Atmospheric back radiation	≤ 10%
UV radiation (summer and winter)	≤ – 5%
Sunshine duration	≤ – 8 … 10%
Heat Perceptible heat (*L*) Latent heat (*V*) Bowen ratio ($Bo = L/V$)	≤ 50% ≤ – 50% > 1 (on average)
Heat storage	≤ 40%
Air temperature Annual average Winter minima	+ 2 K + 15 K (in individual cases until + 15 K)
Wind speed **Calm**	≤ – 20% ≤ 13%
Humidity	+/–
Fog City small town	less more
Precipitation Rain Snow	more less
Evaporation	– 60 … – 30%
Bioclimate Growing season in human terms	~ 10 days Straining for the cardiovascular system
Frost period	≤ – 10 … 25%
Air pollution CO, NO_x, AVOC[a], PAN[b] O_3	more less (but concentration peaks)
Global radiation	≤ – 10% (in early stages of industrialisation in Europe and urban regions in developing countries today partly significant > – 10% reduction)

(continued)

Table 3.1 (continued)

Climate elements	Changes compared to undeveloped open land
Albedo (and emission coefficient)	+/− depending on the type of surface and exposure (e.g. meadows have an albedo of 0.15–0.25, deciduous woods of 0.15–0.2, asphalt has an albedo of 0.05–0.2 and bricks of 0.2–0.4)
Back radiation	$\leq 10\%$
UV radiation (summer and winter)	$\leq -5\%$

[a]Anthropogenic hydrocarbons, [b]peroxyacetyl nitrate

reflection of the sun's rays and this in turn leads to a higher heat storage in the building masses. The warm air masses resulting from an increased heat storage capacity and delayed heat release of the urban building masses with their numerous materials and shapes, as well as radiation modification through emissions, house fires and other anthropogenic energy input, cause a delayed cooling of the air at night and an equally delayed rise in temperature in the early morning hours (Lauer 1999). The rise in air temperature is also followed by increased convection and cloud formation over the city.

On average, a city is 1–3 K warmer than the surrounding area (depending on the size of the city), but this value varies depending on the macroclimate, the size and location of the city, the density of the built-up area, the time of year and day, and wind speeds. Thus, the difference in temperature can disappear completely as the wind increases or reach its maximum in calm weather, which in cities with millions of inhabitants is often 10 °C. But even in much smaller cities or districts, considerable overheating can occur, provided that the majority of the buildings are tall. This is because every reflection of solar radiation always results in the absorption of part of the radiation, so multiple reflections on high-rise buildings lead to correspondingly greater energy absorption and thus to greater thermal radiation. The city is therefore also referred to as a heat island or "heat archipelago" or "multi-core heat island", since spatially differentiated analysis leads to a resolution into several smaller heat centres (Lauer 1999).

As the temperature level in cities rises, so does the relative humidity; it always remains below that of the surrounding area and, like the mosaic of heat islands, varies over the urban area. The general dryness of cities is largely due to the high degree of sealing, with more or less impermeable surfaces. This is because sewage and drainage systems do not infiltrate the precipitation, and evapotranspiration is considerably reduced by the rapid runoff and the reduction of the transpiring plant cover. The result of reduced evapotranspiration is a reduced conversion of heat into latent energy and lower humidity in the city.

The overheating in the city is particularly noticeable in summer and then especially at night. This period can be a great strain for people, since only a nightly cooling down to below 18 °C guarantees a physiologically restful sleep. A further health risk arises during such strong overheating phases when they occur in conjunction with high water vapour pressure (>14 mmHg). This leads to sultriness, which occurs not only during the day, but also during the night hours ("tropical nights" with > 20 °C). In the mid-latitudes, it impairs the circulation even in healthy people, causes sleep disturbances and reduced performance and concentration. In extremely pronounced phases of sultriness, it can even lead to an increased susceptibility to infectious diseases (Fellenberg 1999). The trace substances contained in city air, which come from a wide variety of sources, influence the urban energy balance, which is made up of the radiation balance and the heat balance.

Overall, the urban radiation balance is characterized by the fact that, depending on air pollution, the short-wave radiation flux densities decrease in comparison to the surrounding area, while those in the long-wave range increase. This results in somewhat lower values for the sealed and unsealed areas. At the same time, the short-wave albedo of the city, which is often characterized by dark surfaces and multiple reflections in the three-dimensional structure, is lower.

The urban heat balance is dominated by QH and QB, whereas QE dominates in the undeveloped surrounding area. Since evaporation is limited in urban areas, latent heat flows QE are usually low, resulting in Bowen ratios (Bo = QH/QE) of > 1 on average. This results in a warmer urban atmosphere compared to the undeveloped surrounding area, the above mentioned urban heat island.

Radiation and heat balance

Radiation balance: $Q^* = K\downarrow - K\uparrow + L\downarrow - L\uparrow - L\uparrow_{refl}$

Heat balance: $Q^* + Q_{anthr} + Q_{Met} + Q_H + Q_E + Q_B = 0$

with

Q^*: radiation balance,

$K\downarrow$: direct and diffuse global radiation,

$K\uparrow$: short-wave reflection,

$L\downarrow$: long-wave atmospheric counter radiation,

$L\uparrow$: long-wave charisma,

$L\uparrow_{refl}$: long-wave reflection,

ε: long-wave emissivity,

α: short-wave albedo.

as well as:

Q_{anthr}: anthropogenic heat flux density,

Q_{Met}: metabolic heat flux density,

Q_H: turbulent sensible heat flux density,

Q_E: turbulent latent heat flux density (evaporation),

Q_B: soil heat flux density.

(all units in W/m^2, α and ε are dimensionless).

3.2.2 Water Balance

Soil sealing or the type and intensity of sealing change the runoff regime and infiltration around the sealed areas as well as the ecosystem properties of the soils. These changes influence important control variables of the soil water and groundwater balance such as evapotranspiration, water storage, groundwater recharge, capillary rise, surface runoff and material displacement (Renger 1998). In particular, the still increasing proportion of sealed areas and the associated construction of sewerage systems lead to a reduction in groundwater recharge and evapotranspiration, to a change in the heat balance and to an increase in flood runoff in receiving waters. Due to the rapid runoff, hardly any purification processes take place, which leads to additional pollution of the water bodies (Fig. 3.4).

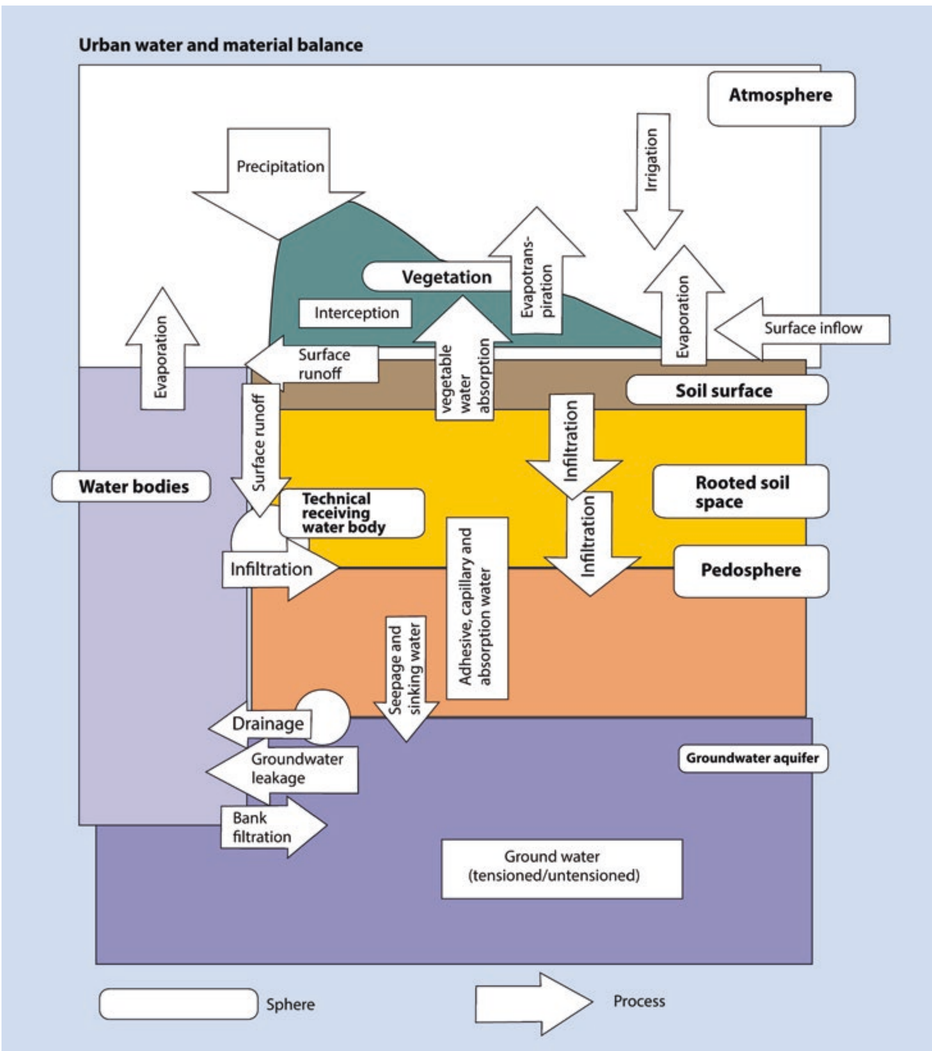

Fig. 3.4 Elements of the water balance. (© Sauerwein)

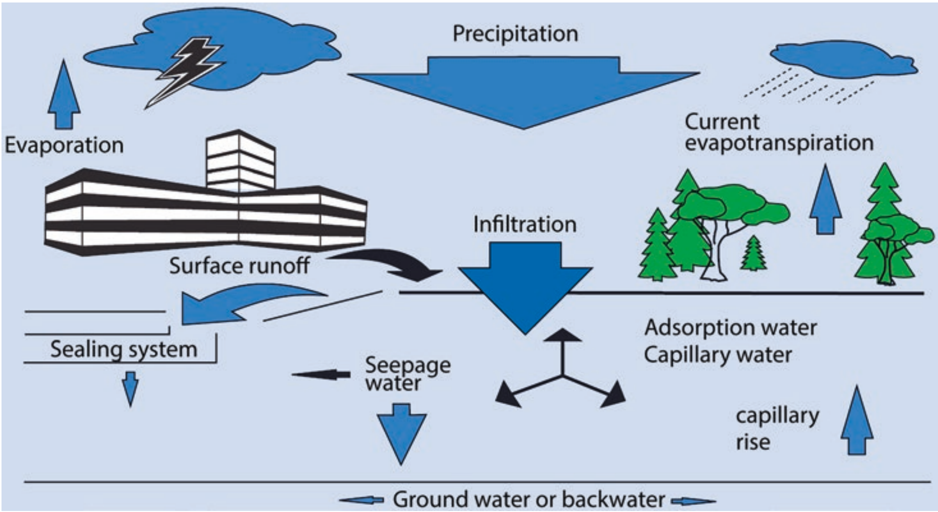

Fig. 3.5 Infiltration and soil water balance in urban soils. (according to Burghardt 1996; © Sauerwein)

In the urban water balance, infiltration and surface runoff play the decisive roles (Fig. 3.5).

In comparison with non-urban spaces, there is on the one hand an increase or concentration of infiltration on the remaining unsealed or only weakly sealed surfaces. This in turn means that the increased infiltration can also lead to an increased pollutant load being introduced into the soil. On the other hand, a part of the surface runoff is partly collected locally with different sealing systems in order to allow precipitation to seep away and not enter the sewerage system. But even with this, concentrated material inputs into the soils of these locations can be detected.

Relief change in the large housing estate Halle-Neustadt, Germany

Halle-Neustadt was built from 1965—planned as the largest large housing estate in the GDR at the time—in several stages (so-called housing complexes) with a population of almost 100,000 in 1989. The pre-urban area was mainly used as arable land. Depending on the original substrate, the Saaleaue areas had developed as quasi-natural soils in large areas of floodplain soils, on the loose-embossed mottled sandstones and shell limestones mainly black loess-black earth/cover sand loam-black earth or black stagnent gleye. Due to the relatively young, documented and usually only unique overbuilding, it is possible to make statements about the (horizontal) soil distribution as well as the vertical distribution of individual material balance and pollutant parameters or their changes.

In the course of the construction measures, levelling measures of the relief were carried out. This clearly shows areas that were backfilled as well as areas that were partly removed. The largest class with 37.6% is made up of areas that are described as almost unchanged, i.e. whose relief change cannot be detected by the method used (plus/minus half a meter). The fact that the net backfill outweighs the excavation must be justified by the material of the basement/foundation excavation and the supply lines (including the partly underground suburban railroad). Approximately 5.7% of the area underwent a relief change of more than 2.50 m (Sauerwein 1998; Fig. 3.6).

3.2.3 Soils as Subsoil for Urban Ecosystems

Soils in settlement areas usually differ significantly from the soils surrounding the settlements. This is particularly true for urban landscapes, since in these areas, there is a marked change in the soil-forming factors due to the usually long-lasting, diverse and intensive anthropogenic overprinting (Burghardt 1996). Urban soil research is a comparatively young scientific discipline. The first soil mapping in urban areas took place in the early 1980s (Blume 1982). So far, no uniform mapping concept has been able to establish itself either nationally or internationally. This has led to a multitude of approaches for the classification and typification of soils in urban areas and to a corresponding lack of clarity. The German and international classification has so far been unsatisfactory (Sauerwein and Geitner 2008). It is astonishing that soils in settlement areas are not or hardly ever treated in most German-language textbooks on soil geography, soil science, urban and landscape ecology.

Urban soils

According to Blume et al. (2010), urban soils (often synonymous with urban-industrial soils, soils of urban-industrial conurbations, urban soils, settlement soils) can be defined as “the totality of all soils in urban areas. These are (to some extent small-scale socialised) soil units of natural, anthropogenically rearranged natural and technogenic substrates, which, due to anthropogenic overprinting (e.g. sealing) through intensive use, show a change in their properties in particular” (Sauerwein 2006).

Global approaches to the typification or classification of soils do not or not sufficiently consider the functions and importance of soils as part of the urban ecosystem. This means that although a differentiation of soils in urban landscapes is possible in different ways, the previous approaches do not lead to a comprehensible categorisation based on ecosystem theory and with a spatial impact on the ecosystem.

With the development of urban ecosystems, the natural site conditions have been modified or even completely changed in many ways. This is especially true for soil substrate, but also for relief conditions (see above). In such anthropogenically strongly

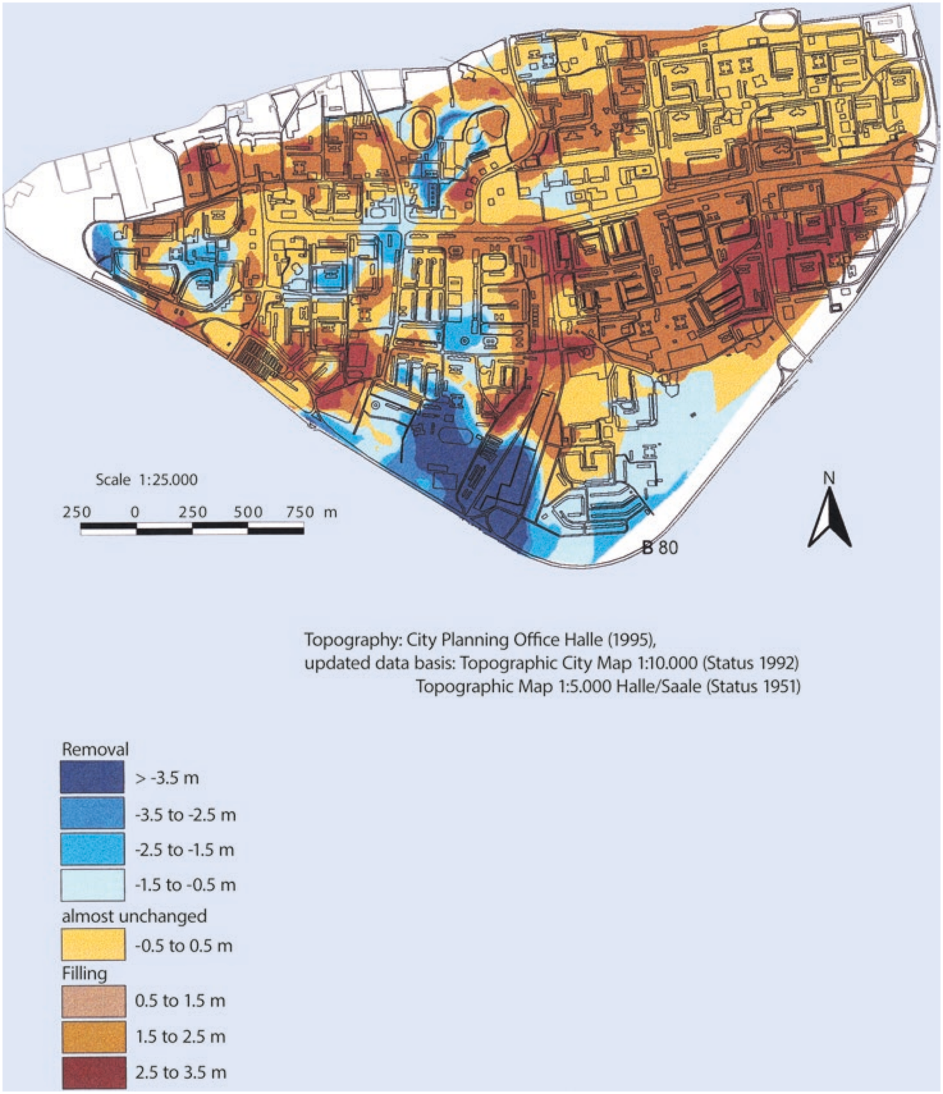

Fig. 3.6 Relief change in the large housing estate Halle-Neustadt. (© Sauerwein)

formed ecosystems, the storages and regulators determining the material and energy balance (in the sense of Leser 1997) were influenced and modified in various ways. These changes are particularly clearly reflected in the horizon and substrate structure. In comparison to hardly or not anthropogenically influenced sites, urban soils show a much higher horizontal and vertical heterogeneity (Pietsch and Kamieth 1991; Burghardt et al. 1997). This is determined by the time- and space-differentiated course of urban development, but also by the natural, i.e. “pre-urban” relief, substrate and soil water conditions.

In urban-industrial agglomerations, the following three basic groupings of soils can be distinguished: a) modified soils of natural development, b) soils of anthropogenic application of natural substrates, technogenic substrates or mixtures thereof, and c) sealed soils.

The soil-forming substrates in urban ecosystems are both autochthonous and allochthonous (natural and artificial). They determine not only the type, intensity and speed of pedogenesis, but also to a large extent the ecological potential of these sites. This can be demonstrated particularly clearly by the soil water and nutrient balance characteristics. Their dimensioning and spatial (as well as temporal) variance not only decide on the success or failure of various “open space utilization variants”, but also regulate other material and energetic processes in urban ecosystems that take place via the soil (see also Infiltration and groundwater recharge potential) (Fig. 3.7).

A special “characteristic” of urban soils is that they often occur in small areas and can therefore hardly be shown separately in medium-scale soil maps, but only as soil complexes. The above-mentioned large horizontal, but also vertical heterogeneity has a considerable influence on the ecological quality of these soils, which is reflected in a partly abrupt change in the character-determining site characteristics (humus content, pH-value, soil moisture regime, water permeability etc.).

In addition to the changes in the (formerly natural) soil structure, the material and energy balance in “urban soils” is also changed. These (direct or indirect) impacts on urban soils and the resulting changes in pedo-ecological properties or soil functions are

Fig. 3.7 Examples of urban soils. (Photos© Sauerwein)

partly intentional, but also occur as unintentional, usually negative effect. They particularly affect the heat balance, but above all the soil water balance. The latter applies to a large extent to (deliberate) groundwater lowering, which frequently occurs during urban development in or on the edge of larger floodplains (Tables 3.2 and 3.3).

A particular problem of urban soils arises from their function as "substance sinks". Although this also applies to (quasi-)natural soils, the ecological properties of soils in urban ecosystems are often impaired by (pollutant) pollution to a greater or lesser extent, depending on the immission conditions. To a large extent—especially in the recent past— this is certainly due to atmospheric input. In addition, there are other, additional

Table 3.2 Material influences on the urban pedosphere

Stock of substances	Solid applications of natural and technogenic substrates or mixtures thereof, Material inputs: gaseous, dissolved or solid from the atmosphere, production and settlement sites, transport, infrastructure facilities, Pollutant transfer, Humus formation and groundwater lowering
Material exchange between the spheres	Climate change, Soil compaction and sealing, Changes in water catchment areas and Changes in the distance between soil surface and groundwater
Overprinting of natural characteristic and process structures	Anthropogenic spatial patterns, vertical and horizontal heterogenization, anthropogenically controlled relief change
Period of their formation and frequency of land use change	
Changes in the storage and transfer functions of soils for pollutants	

Table 3.3 How urban soil formation is influenced

	Floor type
Humus enrichment	Regosols (lime-free) and pararendzinas (calcareous)
Carbonate enrichment	Mainly from building rubble, formation of pararendzinas
Mixture of substrates of technical origin with natural soil	Phyroliths
Deposits of substrates of technical origin (building rubble, ashes, etc.)	Technoliths

material, but also energetic effects on the soil-substrate complex. In many cases, the admixture of allochthonous, above all anthropogenically produced substrate components with an increased pollutant base load has already severely impaired the site ecology.

In contrast to the environmental media air and water, the above-mentioned accumulations of (harmful) substances in soils are, at least in the early stages, hardly perceptible, i.e. tangible or visible to humans. In many cases, these pollution effects are only noticeable once the so-called *point of no return* has been exceeded and damage to soils or the maintenance of soil functions can hardly be guaranteed (Scheffer and Schachtschabel 2010). Since natural decontamination, e.g., is hardly effective for heavy metal contamination and technical cleaning is only possible to a limited extent, but is very costly, the ecological potential under these conditions must be regarded as extremely problematic.

However, it is not only the direct impairment of (in-situ) site characteristics that makes the "soil problem" in urban ecosystems so explosive. Due to the integral position of soils within a landscape—also within an urban landscape—the restriction or even complete suspension of the (natural) soil functions in cities leads not only to a direct reduction of the ecological potential at the "source", but also to (negative) effects on the material and energy balance of the entire urban ecosystem through modifications of their storage, control and regulation functions. In many cases, an "ecological long-distance effect" even extends beyond the immediate urban area. In the literature, there is a wide range of examples in this respect, including the impairment of the infiltration or groundwater recharge potential, microclimatic influences or the habitat for urban vegetation and fauna (Sukopp and Wittig 1998).

Properties of Urban Soils in Brief

In summary, the characteristics of urban soils can be characterised as follows (Sauerwein 2006): It is a small-scale soil mosaic of the urban settlement area, which can vary greatly from metre to metre. As urbanisation progresses, interventions in the soil structure increase, particularly through construction measures, mechanical loads and the introduction of foreign substances and pollutants, and there is a decline in the surface-forming soils or open spaces.

Since soils act as the "memory" of a landscape, information on soil development or pollution and its causes can also be obtained from urban sites. This is undoubtedly a very difficult issue in a large part of our cities, some of which have grown over several centuries, as here there was usually not only a unique overprinting of the pre-urban soil conditions. In some cases, several soils or their remnants are superimposed on one another, each of which is composed of different compositions and characterized by different pedo-ecological conditions (fossilized). Often, however, their processing products or (newly added) allochthonous substrates form the basic material of today's surface soils.

The preurban relief played an important control or regulator function here, as in "normal" pedogenesis. In the "interest" of urban development, attempts were made to compensate for "unfavourable" relief properties, i.e. to carry out levelling tendencies through soil/substrate capping or filling. The associated pedo-ecological changes are often only relevant to current issues if they still have a surface effect today. Certain exceptions are e.g. physiological barrier layers caused by historical settlement and occurring in today's – deeper—subsoil or serious accumulations of pollutants, which quantitatively or qualitatively impair the groundwater recharge rate—or capillary rise.

In open spaces (front yards, house gardens, allotment gardens, green areas), the range of soil types is very wide, from humus-poor loose and backfill soils to dark substrates rich in humus and nutrients (through intensive, artificial fertilization). At the same time, the majority of urban soils are low in humus, which is due to the removal of leaves and litter (humus producers) through intensive care measures on the green areas (especially parks).

The most important physico-chemical parameter—the pH value—is in the neutral range for the majority of urban soils as a result of calcareous building rubble and blown up dust; pH above 7.5 are found, for example, in the pararendzinas of the ruderal surfaces on rubble debris.

The reduction of the pore volume simultaneously lowers the water storage capacity of the soil, so that suddenly occurring large amounts of water (due to heavy rainfall and increased surface runoff due to sealing) can only partly seep into the soil. The water that runs off on the surface and is rich in fine material additionally silts up the topsoil.

Pollution of urban soils can be caused by airborne pollutants, by rain/rainfall, by floods (especially alluvial soils), by contaminated sites, de-icing salts, pipe leaks, accidents, improper storage of environmentally hazardous substances or over-fertilisation. Types of pollution can be increased acid pollution due to acid rain or substance pollution due to heavy metals typical for cities (lead, copper, zinc, nickel, manganese, cadmium)

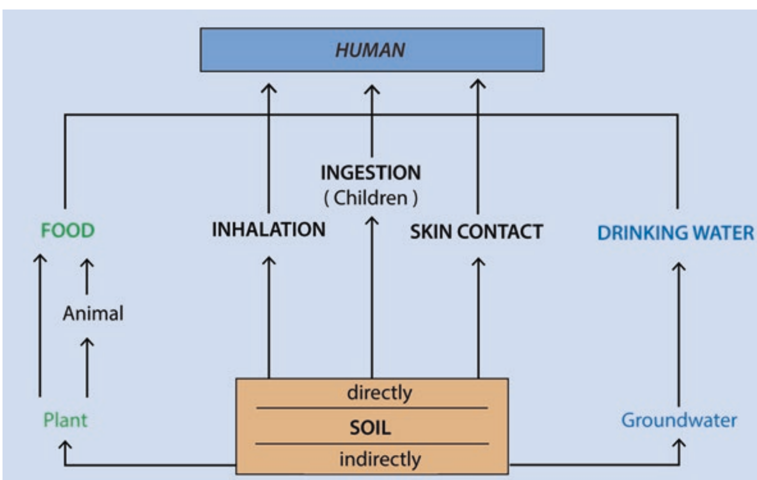

Fig. 3.8 Soils as a source of pollution for humans. (© Sauerwein and Scholten 2011)

and organic pollutants (PAH, PCB), which accumulate in considerable quantities over the years. The group of persistent problematic substances, i.e. substances that are not degradable or only degradable over long periods of time in the soil, thus constitutes a growing hazard potential. Accumulation can lead to latent impairments of soil flora and fauna, which can be significant if certain exposure limits are exceeded, and even to acute hazards for humans through direct contact or via the food chain and groundwater. Hazard pathways for soil pollutants to the protected human being are (Fig. 3.8):

- Load path ground-air-human (pulmonary/direct absorption),
- Soil-human exposure path (oral/direct intake),
- Load path ground-to-human (cutaneous/direct exposure),
- Pollution path soil-groundwater-drinking water-human (oral/indirect uptake),
- Exposure pathway soil–plant-food-human (oral uptake via the food chain).

With regard to the functions of urban soils in the urban ecosystem, it is of crucial importance that a city not only needs the soil as a location for infrastructure facilities, but that the soil as an open system represents the throughput space for a variety of substances and that the urban water balance is closely linked to that of the soil. All in all, urban soils can be regarded as heavily disturbed, with only limited fulfilment of soil functions.

Urban settlements are mostly complexes of residential quarters, commercial and industrial areas, but also parks, forests and water areas (Haase 2014). In particular, residential, industrial and traffic areas generate specific emissions or waste such as heavy metals, road salt, polycyclic aromatic hydrocarbons (PAH), urine and musk, drug residues, etc. Dense road traffic in cities generates noise and exhaust fumes, which in turn have an impact on flora and fauna and on people (Leser 2008).

3.3 Demarcation, Classification and Presentation of Urban Ecosystems

The abiotic environment, which is partly man-made in the city (e.g. buildings, streets, dumps, embankments, ponds), has a significant impact on the habitat of flora and fauna in cities (Chapter 4). Cities have a low plant mass and cover with high soil sealing as open land ecosystems. The resulting lower amount of evaporation and transpiration also works towards a drier microclimate. Soil sealing also hinders the settlement of plants. The chemical milieu of urban soils and air in cities has changed, either to acidic (through SO_x/NO_x emissions) or alkaline fly ash from coal combustion to alkaline, the latter being a decreasing trend due to gas, oil and renewable energy-fired heating systems.

In cities, certain plant communities that are less common in the open landscape can be found, such as treading communities (in frequently frequented places), ruderal corridors (in the area of building rubble accumulations, in railway tracks and industrial wastelands, on landfills), cut turf (in parks), plants on walls (in wall crevices, also climbing plants), and plant communities of pavement cracks (Sukopp and Wittig 1998; Marzluff et al. 1997; Grimm et al. 2008). These play an important role above all in parks, cemeteries, allotment garden settlements, leafy courtyards, villa districts and partly also in botanical gardens (Chapter 5). In terms of land cover, tree and green space, many cities show a clear urban-rural gradient, i.e. the density of green space increases towards the outside (Figs. 3.9 and 3.10). However, new studies on carbon storage in trees and

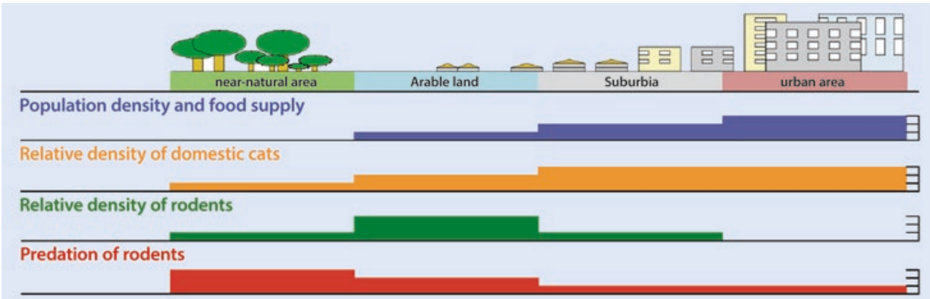

Fig. 3.9 A typical rural-urban gradient of population density, domestic cat and rodent density. (Gilot-Fromont et al. 2012)

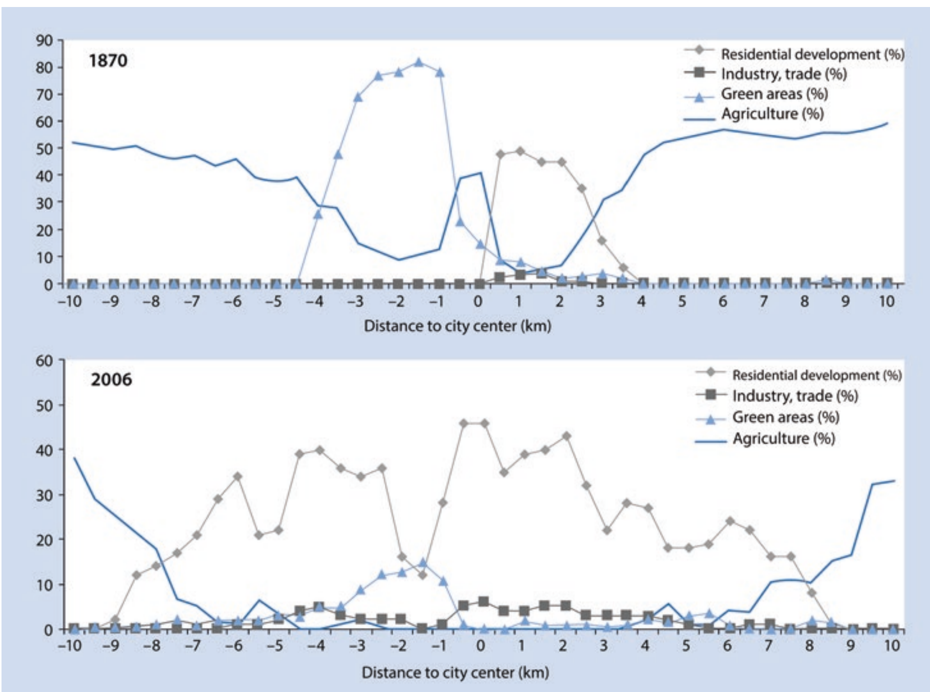

Fig. 3.10 Spatio-temporal change in the rural-urban land use gradient using the city of Leipzig as an example over a period of 140 years. A clear decrease in the compactness of the built-up areas can be observed, which is at the expense of an expansion of the urban area. (Haase and Nuissl 2010)

breeding bird diversity in cities show that even mature built-up areas close to the city centre with many niche habitats and old tree population, e.g. typical old building areas, have comparatively high wood biomass and species richness.

It is therefore of great importance for urban ecologists to delimit the system of interest. However, urban ecosystems and cities are defined and delimited very differently depending on their purpose. Table 3.4 and Fig. 3.11 present different views on the question "What is an urban landscape or what is an urban ecosystem? Urban landscapes are urban or urbanly shaped spaces in which the three dimensions social, economic and environmental overlap, compete and interact" (Ravetz 2000, McPhearson et al. 2016 offer the SETs concept: social-ecological-technological systems). Urban ecosystems are characterised by a high density and competition of different land uses—living, working,

Table 3.4 Examples of the definition and demarcation of urban spaces and their strengths and weaknesses. (According to McIntyre et al. 2008; and Haase 2009, modified)

Discipline	Definition of "urban"	Strengths of the definition	Weaknesses of the definition
Ecology	Built-up area	Very short	Does not include population density
Ecology	Built-up area	Very short	Vaguely
Ecology	Area that consumes at least 100,000 kcal/m^2 per year	Internationally very well comparable	Difficult to measure
Sociology	Area with > 2,500 inhabitants	Precise and takes population density into account	Arbitrary
Sociology	Area with > 20,000 inhabitants	Precise	Arbitrary and neglects the density
Economy	Area with a minimum number of inhabitants and population density	Includes both population size and density	Defines no minimum density
Environmental psychology	Area with high traffic and high sealing rate and buildings	Explicitly includes the transport sector and the built-up area	Neglects people and population density
Regional research and landscape planning	Population size and share of residential land use	Applicable to all regions worldwide; includes population and land use	Data availability is essential; not applicable if data are not available
Planning	All areas with a population density of > 100 inhabitants per acre, including commercial areas, highways and public facilities	Takes into account the complex supply and demand relationships and the density of settlement	Demarcation difficult

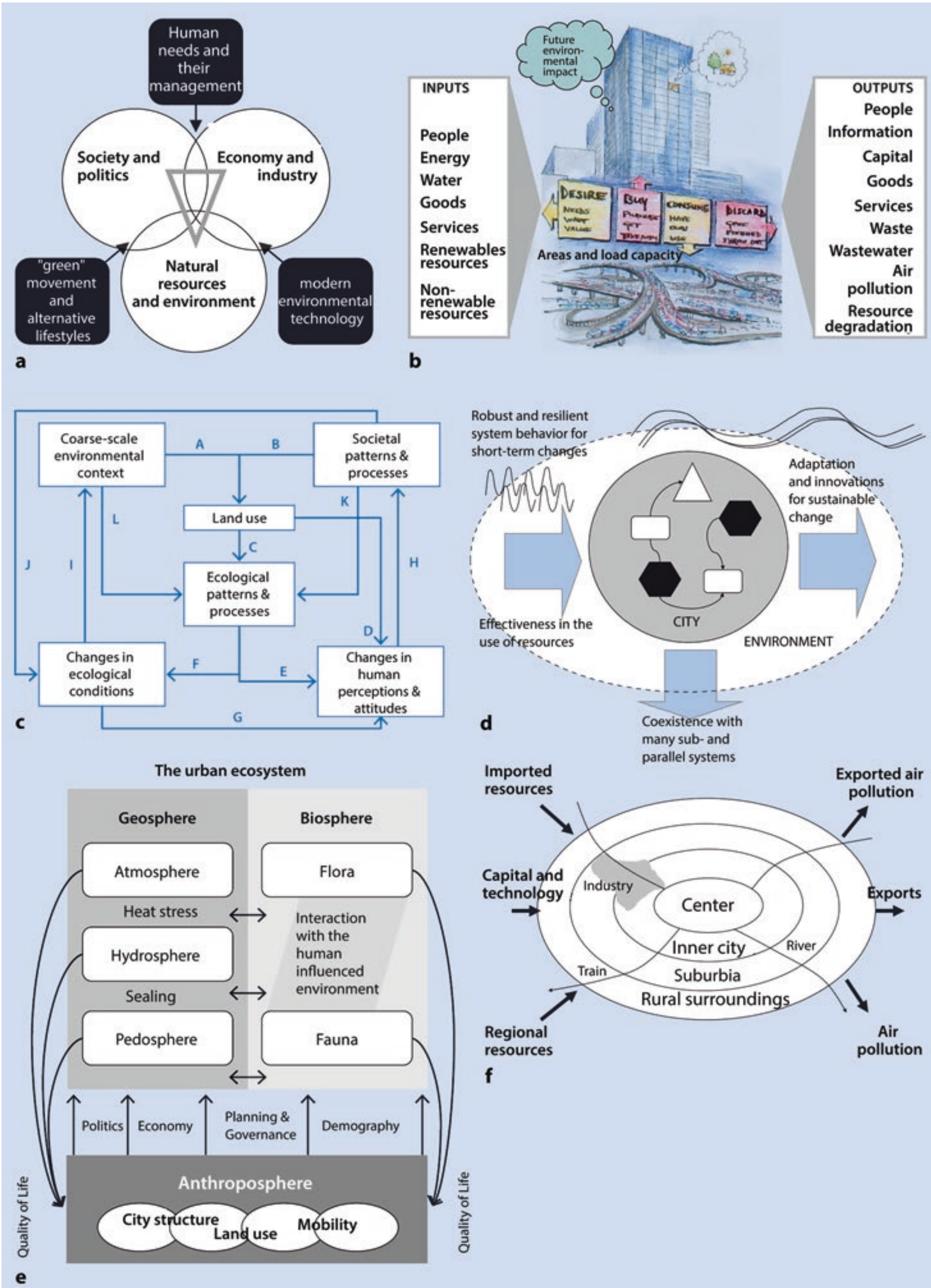

Fig. 3.11 **a–f** Graphical representation of an urban landscape or an urban ecosystem and views of it. (Own design based on the sources mentioned above)

transport, recreation, communication etc. —which often lead to an extreme strain on natural resources such as air, water, soil and biodiversity.

The Urban Landscape

"Fundamentally, a landscape defined as urban shows some effects of human influence. Taken literally, this could mean that most remote sites could be called urban simply because humans have influenced a portion of their area at some point in time. (…) Clearly, this description of urban is too broad to be very useful, and it confounds the differences between human dominated and truly urban ecosystems. There is thus an evident need to remove the uncertainty with which ecologists define urban ecosystems and to correct oversights regarding definitions (or lack thereof) of what it means to be urban" (Ravetz 2000, p. 85).

3.4 Conclusions

In summary, a large number of scientific papers from different scientific disciplines on the question of the definition of an urban ecosystem conclude that the high proportion of built-up or sealed areas and the high population density are two essential characteristics of urban systems compared to rural systems. Table 3.4 also shows the diversity of definitions and understandings of the "urban" or an urban ecosystem from the perspective of different scientific disciplines.

From Fig. 3.11, it becomes clear that there are different dimensions, systematics and views of the city from an ecological point of view. Common to all classifications or schemes of urban landscapes is that an urban system contains abiotic as well as biotic elements and that it is dominated by humans. Its components are strongly interlinked (Leser 2008).

A high population density (see Population densities worldwide, Fig. 3.12) and a high proportion of sealed soil are associated with "city" or "the urban". There is no abrupt transition from city to country, but rather a rural-urban gradient (Haase and Nuissl 2010). An urban ecosystem, for example, is seen by Ravetz (2000) as a large metabolism that carries out a kind of "material and information turnover" over a range of input and output variables. Grimm et al. (2008) and Langner and Endlicher (2007) rather emphasize the integrative character of urban ecosystems, which are characterized by a wealth of interactions and feedbacks between nature and society as well as between natural and "built" environment.

As shown in Fig. 3.11, the energetic, material and biotic exchange processes generated by urban settlement areas have a considerable influence on the ecological processes of all other areas, not only locally or regionally, but also globally (Ravetz 2000). The process of communication, which exchanges information and knowledge, including about ecological processes in cities, limit value transgressions and risk situations

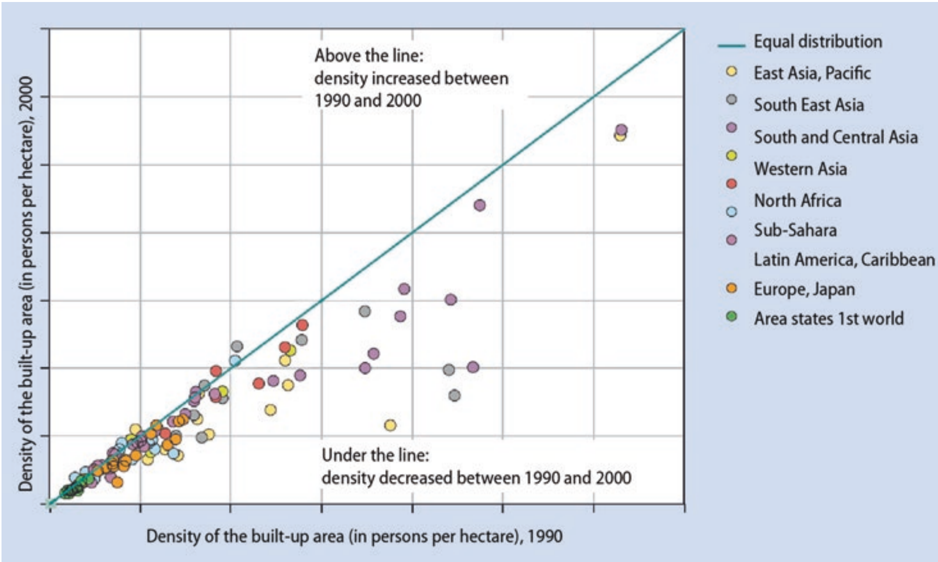

Fig. 3.12 Population density of 120 cities in a global sample in the period from 1990 to 2000 (Angel et al. 2011)

(smog, flooding) within the city and between cities, is also becoming increasingly important. The "actual area" which a city needs for the production of the necessary food and energy, if it had to supply itself self-sufficiently, is many times larger than today's urban space. This area is also known as the "*ecological footprint*" (Elmqvist et al. 2013; Chapter 1).

The dynamics of urban development constantly force new processes of adaptation between anthropogenically determined social and economic systems and the natural systems of the landscape, with the most diverse environmentally damaging consequences (Elmqvist et al. 2013). Many environmental problems and the high consumption of resources on earth are more or less linked to the urban-dominated form of society and urban settlements, because already today over 50% of all people live in cities and forecasts predict an urban population of 75% in the middle of the twenty-first century (Kabisch and Haase 2011). If these problems are not solved, they can lead to serious and sometimes irreversible consequences for humanity (examples include anthropogenically induced climate change, natural disasters such as heat waves in Paris in August 2003, landslides such as those in Brazil's coastal megacities Rio de Janeiro and São Paulo, or flooding of medieval cities such as Passau or Dresden on the Elbe in 2002, 2006 and 2013 or 2015 in the Philippine city of Tacloban). Ecological research on and in urban settlement areas, i.e. urban ecology research, is a fundamental foundation for analysing and evaluating the above-mentioned ecological consequences and the associated risks (Haase 2011, 2014; Meeus and Gulinck 2008).

Questions

1. How do urban ecosystems differ from open land ecosystems?
2. How to describe or delimit a city?
3. What is a typical rural-urban gradient and does it change over time?
4. Is the following statement true: cities have a higher surface runoff than open land ecosystems? Justify your answer!
5. Where do we find the highest sealing rates in cities?
6. Which cities have a higher per capita sealing rate: compact or urbanised cities?
7. How can urban geoecosystems be labelled?
8. Which phases of urban development since industrialisation and which models characterise the majority of Central European cities?
9. What are typical properties and characteristics of the urban energy balance?
10. What is the effect of urban development on the water balance?
11. What are the consequences of anthropogenic changes in the natural relief and natural soils?
12. What conditions determine the local ecological impact on cities?

Answer 1

- Urban ecosystems are characterised by a high population and building density.
- Their soils are more heavily sealed than open land ecosystems.
- Urban ecosystems are sources of various pollutant emissions from industry and traffic.

Answer 2

- There are various criteria for delimiting cities from their surroundings—e.g. by population density, building density (morphological structure), commuter networks, but also simply by the administrative boundaries of the municipality "city".

Answer 3

- Urban-rural gradients characterize the change of parameters with increasing distance from the city centre: sealing is often decreasing, population density is also decreasing, open land shares as well as the share of arable land or forest are increasing. Often, however, urban-rural gradients are not continuous; in dense peri-urban settlements, for example, the residential and population density often increases again after lower values in the outer urban area.

Answer 4

- This is generally true, but there are also low sealed areas with low surface runoff in cities as well as highly sealed commercial areas with very high surface runoff in peri-urban and rural areas.

Answer 5

- Traffic areas and commercial areas are the most heavily sealed.

Answer 6

- Often *sprawling* cities and cities with a lot of *urban sprawl* have higher per capita sealing rates, because although the seal/density in compact cities is very high in the central areas, less area is sealed overall. In sprawled cities and urban regions, areas with much lower population density are also sealed, and overall the (partially) sealed area takes up much more space.

Answer 7

- Overprinting of the natural energy, material and water balance.
- A complex control variable is the sealing (type and intensity).

Answer 8

- Typical phases of recent urban development in Central Europe are Wilhelminian style urban expansions, construction of workers' housing estates, the garden city movement, the Athens Charter and suburbanisation.
- Guiding principles in chronological order: modern, functional city—urbanity through density—car-friendly and mass transit city - compact city—intermediate city—sustainable urban development.

Answer 9

- Compared to the surrounding area, it is warmer in cities (heat island).
- Depending on air pollution, the short-wave radiation flux densities in cities are lower than in the surrounding areas, while the long-wave ones are higher.

Answer 10

- The type and intensity of sealing changes the flow regime, the infiltration into the soil and the groundwater balance.
- As a result, the flood runoff is increased and additional pollution of water bodies occurs.

Answer 11

- In the course of construction work, levelling of the relief and in many places filling up.
- Overprinting of natural soils up to the development of anthropogenic soils with partly considerable pollutant loads.

Answer 12

- On the one hand, the regional conditions (climate zone),
- Furthermore, local physical-geographical conditions (example: location by the sea) as well as internal structure, age, proportion of informal structures and dynamics.

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What Are the Special Features of the Urban Habitat and How Do We Deal with Urban Nature?

4

Jürgen Breuste

Abstract

This chapter discusses the specific features of urban habitats for plants and animals, with which we are living together. Cities are extraordinary, differentiated habitats with many special offers, but also with restrictions for animals and plants. Urban flora and fauna and its habitats are in many ways special. Their development and their ecological characteristics are presented and illustrated through examples.

4.1 The Urban Habitat is Different

4.1.1 Urban Nature

Ecological site characteristics of the cultural landscape can be found in peripheral urban areas or special urban relief positions, for example, on hills or in river floodplains in the city (Fig. 4.1 and 4.2).

Nevertheless, the predominant locations in cities are special features that do not occur in the cultural landscape of countryside outside cities.

Ecological steering features such as temperature, humidity and water balance, light, air chemistry, soil condition, competition and disturbance are often significantly changed in contrast to the surrounding areas of cities. Their diverse, small-scale, often abruptly changing conditions and combinations of characteristics make up the diversity of urban site and habitat conditions and explain the special features of urban biodiversity (Breuste et al. 2020).

Urban biodiversity

As everywhere else, the climate (water supply, energy supply through light, temperature, chemical milieu, in part also nutrient supply through dust and precipitation) and the

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Fig. 4.1 Elisenhain urban woodland in Greifswald. (Photo © Breuste 2006)

Fig. 4.2 Meadow in the landscape protected bog Leopoldskroner Moos in the urban area of Salzburg. (Photo © Breuste 2003)

soil (mineral supply, water supply, chemical milieu) are the most important site characteristics for plants in the city. The important water supply is dependent on climate and soil. The interspecies competition, in which man intervenes deeply through use, care and planting, is ultimately decisive for the composition of vegetation (Wittig 1998).

The locations of the city are usually less favourable for plants in comparison with surrounding areas:

- The chemical milieu of the soil is often less favourable.
- The chemical milieu of the air is usually less favourable (gases, dust etc.).
- The enjoyment of light is reduced at many locations.
- The water balance is usually in imbalance. Higher temperatures cause water losses, soils are often reduced in their water storage capacity (low soil moisture content due to soil compaction).
- Soil sealing and compaction impede the colonisation by plants (Wittig 1998; Leser 2008).

The natural distribution of plants on urban sites is thus linked to the habitat requirements of the plants and the existing site characteristics. However, the real distribution of plants deviates from this relationship because humans limit competing species, exert disturbances, unconsciously improve site characteristics for target species, and consciously or unconsciously introduce non-native and non-site adapted species into the flora of the city.

While plants usually have a very close dependence on certain site factors, individual animal species or animal groups show a less marked dependence on certain ecologically relevant conditions, as their plasticity (morphological, physiological and ecological adaptability) is high (Leser 2008). Artificial sites and their "new" characteristics are often quickly accepted and colonised as attractive new habitats and replace natural habitats. From an animal-ecological point of view, buildings are artificial rocks (exterior) and artificial caves (interior). For missing natural structures (e.g. wood), technical replacement structures are used as residence, visit and nesting sites (Klausnitzer 1993).

The urban climate is less important for animals than for plants. Heat-tolerant species occur, but often in connection with nutrient plants. "Light pollution" (large and continuous supply of light) affects animals with a strict day-night rhythm (Eisenbais and Hänel 2009). Soil changes affect mainly the soil fauna. Unlike plants, water shortage is not a limiting factor. Since plants are the decisive basis of their occurrence for many animal groups (species spectrum, frequency, and physiological state), changes in flora and vegetation have impacts on their occurrence (e.g. insects - longer vegetation period) (Klausnitzer 1993). Rich food supply, diversity of nesting and habitats, lack of competition and displacement from extra-urban habitats are the most important factors for the occurrence of many animal groups.

Werner and Zahner (2009) and Möllers (2010) provide a detailed summary of the characteristics of urban spaces with explained criteria. Further references can also be found in Leser (2008) and Tobias (2011).

Humans are the decisive factor for the occurrence and distribution of species in the city (Wittig 1998, p. 220, 2002). Cities provide new habitat qualities for plants and animals, and in some cases, they also replace natural habitats outside the city. Urban space consists of a habitat mosaic of high heterogeneity (building structures, uses, unused spaces) and high area dynamics (pioneer species). Since the habitat conditions are directly dependent on urban structure and land use, this information is often used to develop an urban ecological biotope classification (Chapter 2) (Klausnitzer 1993; Table 4.1).

The urban habitat offers new environmental conditions, especially in connection with disturbance and stress factors, to which living beings react by their patterns of distribution and movement, but also by evasion or habitat preferences and changes as well as physiological (e.g. endogenous adaptation).

The reasons for the species richness and attractiveness of cities as habitats are

- urban landscape rich in structure,
- nutrient-poor, dry and warm biotopes/habitats,
- protected and safe habitat (see also Reichholf 2007).

Urban Biodiversity

Cities often have unique habitats whose characteristics and structures are the result of urban use (type, intensity and frequency of use and management). Land use (land use, land use, see Breuste 1994b) determines the structures and processes of the urban habitat. Its sub-habitats are not only characterized by new land conditions. They are complex ecosystems (biocoenoses) with special ecological characteristics, often influenced by anthropogenic factors. Diversity and smallness of the structures created by use are characteristic. They also offer many plants and animal habitats that have become rare outside of cities in Central Europe, especially due to intensive agriculture. Cities are thus also rich in species, including often a high proportion of non-native species, and different habitats. Cities are therefore often characterised by a high level of species diversity, for which humans are the decisive factor (Wittig 1998, p. 220, 2002) Cities offer new habitat qualities for plants and animals and in some cases also replace natural habitats outside the city. Since habitat conditions are directly dependent on urban structure and land use, this information is often used to draw up an ecological classification of the city (Chapter 3) (Klausnitzer 1993).

Table 4.1 Effects of human influence from the "point of view" of plants (from Wittig 1996, modified after Wittig 2002, p. 17)

Human influence			Effects from the "point of view" of plants*
Type	Object	Effect*	
INDIRECT	Climate	Warmer (especially also milder winters), drier, Air more polluted	Favouring thermophilic and drought-resistant species; increasing the chances of survival of frost-sensitive species; hardly any possibilities of existence for strongly (air-) moisture-dependent species (hygrophytes); extending the growing season Favouring toxitolerant species; disadvantageous to sensitive species
	Floor	More nutritious, basic more polluting, less water	Promotion of nutrient-loving, basophilic species, Competitive advantage for pollutant-resistant species, Advantage for water savers and/or extreme deep-rooting plants; hardly any possibilities of existence for hygrophytes
	Water	Groundwater lowered, surface water runs off more quickly	
	Waters	Framed, ducted or piped, dirty	Hardly any chance for marsh and aquatic plants (helophytes and hydrophytes)
	Entire location	Disruption, destruction, creation	Favouring annual species (therophytes) with a short generation cycle (several generations per year), high seed production, Effective dispersal mechanisms (e.g. wind dispersal), long-lasting seed bank; reducing competition; better chances for new arrivals (neophytes)
DIRECT	Plant	Combat	
		Mechanical damage	Advantages for species with strong regeneration capacity; disadvantages for delicately built and fragile species

* Compared to the surroundings of an urban area

4.1.2 Flora and Vegetation of Urban Habitats

Flora and vegetation in cities are largely determined by planted species. They dominate gardens, parks, tree stock, urban woodlands and accompany streets. Crops and even more so ornamental plants, whose species offered in nurseries and garden markets can hardly be surveyed. Fashion trends and sense of beauty determine even more than the urban ecological conditions (nutrient supply, water balance, soil conditions, climatic conditions, etc.), the species offered and planted. The favourable economic situation in many developed countries has significantly reduced the dependence on the cultivation of crops in cities or the urban surrounding, which is still high in many cities in Asia, Latin America and Africa. Planted ornamental plants, particularly perennial and low-maintenance species dominate. In the course of urban beautification and urban expansion, landscape gardening designs oriented to aesthetic ideas were implemented on a large scale in public and private spaces in Central European cities from the second half of the nineteenth century at the latest (Table 4.2). These urban gardens, which are in public areas maintained by urban garden departments, correspond to the social ideals of order, beauty and cleanliness. Many urban spaces created in this way by planted vegetation require intensive care (soil cultivation, pruning, removal of competing vegetation, increasingly also irrigation). Natural succession is hardly ever, if at all slowly, allowed, partly because of a lack of public funding for maintenance.

Flora
The totality of all plant species that occur in a certain distribution area (e.g. flora of Central Europe) and are systematically described. The term is species-related. There are also floras of urban areas (e. g. flora of Zurich). Zurich has one of the best-documented floras of ferns and flowering plants worldwide.

Vegetation
All the plants that cover an area and form plant formations and communities. The term refers to structures and communities of plants. Climate, soil, relief, rocks, water balance and the influence of fire, animals and humans shape the vegetation.

The flora of Zurich (ferns and flowering plants) includes 213 indigenous species, 119 neophytes and 84 archaeophytes (ten species are unassigned, 67 are lost or extinct; Landolt 2001).

Urban trees, the majority of which have also been planted, form an *urban forest* of numerous islands, rows of trees and individual trees of different sizes. The small areas create large marginal zones and the use and maintenance of missing undergrowth. Large cities alone have tens of thousands of planted and maintained trees along public roads (Wittig 2002; Chapter 6).

Table 4.2 Overview of the flora of the city of Zurich (according to Landolt 2001)

Native and naturalized species	1400
Occurring today	1210
Extinct over the last 160 years	190
Other species	600
Occurring only in the immediate vicinity	50
Introduced by chance and only occurring for a short time	150
Frequently cultivated, but hardly overgrown	400
Total number of species recorded	2000

However, geobotanical objectives of the investigation are usually not the planted and cultivated vegetation and flora, but primarily the spontaneous and possibly extensively cultivated vegetation and flora (Wittig 2002, p. 94). The spontaneous urban flora is composed of indigenous (native) and hemerochorous (non-indigenous) species. The indigenous species that have adapted to anthropogenic settlement sites are called apophytes. Among the non-native species, a distinction is made between those that immigrated in prehistoric times up to about the year 1500 (archaeophytes) and those that only immigrated after the year 1500 (neophytes). The proportion of neophytes in the urban flora is higher where the degree of disturbance (use, maintenance, emission etc.) is high (Lenzin et al. 2007). For some plants in cities no natural sites are known (anecophytes) (Table 4.3 and Fig. 4.3).

The urban flora can be divided into three categories according to the three main types of spontaneous plant distribution in cities - urbanophobic (urban sprawl, hardly ever found there), urbanoneutral (distributed in cities and surrounding areas) and urbanophilic (preferred in cities).

Typical urban species are usually no indigenous species, but predominantly neophytes. Only 5–6% of the flora of Central and North-eastern Germany are urbanophilic species (Klotz 1994).

Cities have significantly more species per km^2 than in the surrounding area only in the case of seed plants (especially representatives of the Asteraceae and Poaceae families)

Table 4.3 Increase in the proportion of non-native species in the fern and flowering plants of Central European cities by increasing settlement size (Sukopp 1983; in Leser 2008, p. 179)

City size	Total number of species	Percentage share Non-native species
Villages	No information	30
Small towns	500–600	35–40
medium-sized towns	650–750	40–50
Large cities	900–1400	50–70

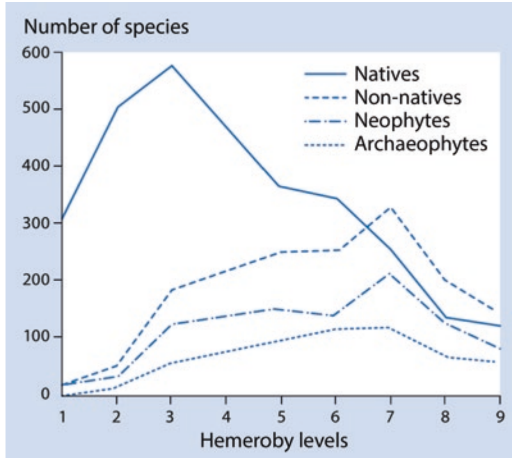

Fig. 4.3 Occurrence of native plant species as well as archaeophytes and neophytes (summarised as non-native) on differently disturbed sites in Berlin (hemeroby level 1: very slightly disturbed, hemeroby level 9: very strongly disturbed). (Data source 5136 vegetation surveys in: Kowarik 1988; from Kowarik 2010, p. 112)

do. This is due in particular to their high adaptability to warm and dry locations (well-developed water balance). Urbanophilic species are well adapted to urban drought by sclerophytic construction, life cycle and/or ecophysiological mechanisms. They often originate from warmer regions (Cornelius 1987; Wittig 1998). Within the same climate zones, there is a worldwide tendency towards the unification of urban flora due to increasing international exchange, disturbance adaptation, comparable thermal conditions and the occupation of vegetation gaps by pre-adapted newly establishing plants settlers (Sukopp and Wurzel 1995; Table 4.4).

Due to the ecological quality of certain urban sites, plant communities of spontaneous urban vegetation have developed in a mosaic-like pattern over the urban area, often sharply delineated from each other by use. They are characteristic of the respective structure or type of use (Chapter 2) or the respective urban zone (Wittig 2002). There is a close relationship between social structure, building structure and use on the one hand and vegetation patterns on the other (Hard 1985; Gilbert 1991; Wittig 2002). For this very reason, any inventory of urban flora and vegetation represents only a section of a dynamic development process, in which urban flora and vegetation can be interpreted ecologically (Fig. 4.4).

Table 4.4 Differences between urban and peri-urban flora in temperate climate zones. (Herbaceous vascular plants only, according to Wittig 1996; in Wittig 1998, p. 231)

Feature		Differences (compared to the surrounding area)
Number of species/ km^2		Higher
Non-native species (Hemerochoric plants)		More
Location requirements		More light-, heat-, base- and nitrogen-loving and drought-bearing species, less moisture-loving species
Family membership	Spectrum	Little one
	Percentage share	Asteraceae, Poaceae and Polygonaceae significantly increased, other families (e.g. Orchidaceae and Cyperaceae) reduced
Malfunction indicator		More
Life form		More Therophytes
Building plan		Less hygro- and helophytes, no hydrophytes
Dissemination mechanisms		More species with wind and adhesive or velcro dispersal
Flower	Size	More species with small flowers, lack of large-flowered species
	Quantity	More multiflowered species
	Duration	More species with a long flowering period (entire vegetation period)
	Pollination	More species with self-pollination and parthenogenesis, absence of species with complicated or specialised pollination mechanisms
Resistance to pollutants		More resistant species

Urban Biodiversity – Network BioFrankfurt

The Frankfurt area is home to 1675 fern and flowering plant species. This is about half of all known species in Germany on only 0.06% of the German territory. The close-by Taunus hills, which is 11 times larger, can only show 1250 species (Lehmhöfer 2010).

Cities are also *hot spots* of regional biodiversity. This is indicated by the high number of plant species found there and the high species density. Werner and Zahner (2009) found for Central Europe that for urban areas above 100 km^2 and over 200,000 inhabitants, 1000 plant species and 30–600 plant species per km^2 can be expected. This exceeds by far the intensively used cultural landscape. The

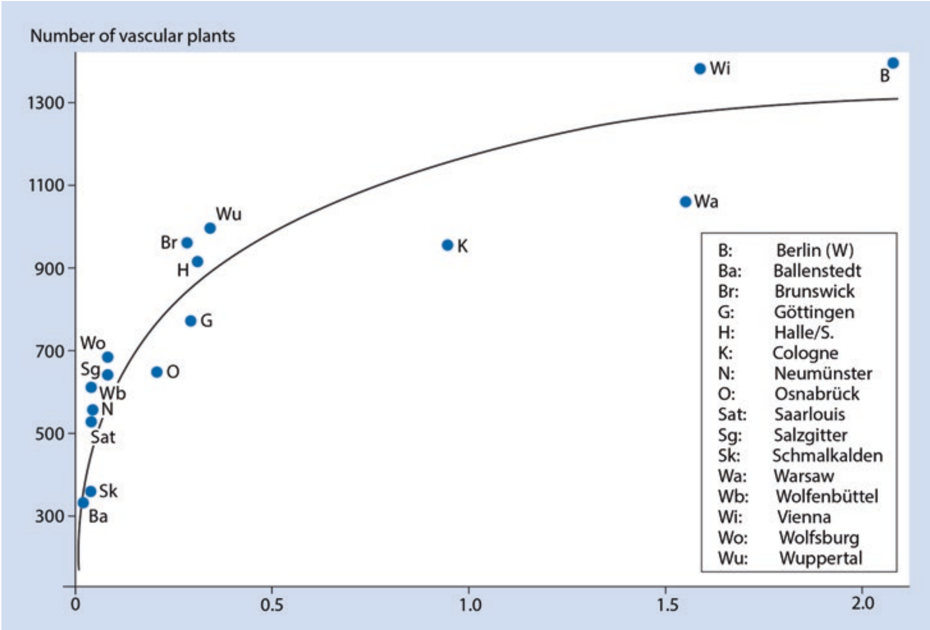

Fig. 4.4 Number of vascular plants in relation to the population of cities (according to Brandes and Zacharias 1990; Klotz 1990; quoted after Wittig 2002, p. 63)

high number of species in the city is explained by a variety of ecologically different sites. Usually, only spontaneous vegetation is included without differentiating between indigenous and hemerochoric species. A comparison with near-natural ecosystems, in which mostly only indigenous species occur, shows that urban biodiversity is not insignificantly caused by immigrated species and extreme and special ecological site conditions. This does not lead to the conclusion that nature conservation should concentrate on cities in the future since many species can be preserved or even protected with little effort in a small area, while in extreme cases protection measures outside cities can be reduced.

4.1.3 Animals of Urban Habitats

The importance of animals in urban ecosystems is often underestimated or less considered than that of plants. Although their biomass is much lower, their number of species is much higher than that of urban plants (by about 10 times; Tobias 2011). There is a considerable diversity of relationships with humans:

- Disposal of organic waste,
- Removal of insect pests from crops,
- Flower pollinators,

- Bio-indicators,
- Observation and encounter with animals as part of the contact with nature,
- Pests on plants, supplies and materials,
- Vector and exciter of diseases,
- Producers of troublesome waste (Klausnitzer 1993).

Livestock farming is still associated with settlements and also with cities. Not only in Indian cities you can find cattle breeding for milk production up to the city centres, but also in Salzburg, two kilometres away from the historical UNESCO world heritage city centre. The city is still home to agricultural land, also used for animal husbandry, whose importance is increasingly recognized today.

The keeping of pets without an economic but with an emotional benefit (dogs, cats, birds, small animals etc.) is becoming increasingly important. Insofar as they are active outside the home, they influence urban ecosystems to no small extent.

However, special object of investigation in urban zoological ecology are the wild animals (wildlife) in the city, which - due to the loss of habitats outside the cities and the attractiveness of the cities as a habitat - permanently colonise them. Their occurrence is also directly dependent on human uses (disturbances, food, etc.). Little research has so far been done on the soil animal world. Mammals in the city quickly come into the focus of general interest (wild boars, foxes, martens, squirrels, etc.). Here, too, the level of knowledge about populations, adaptation to habitat, dispersal, endangerment, etc. is still insufficient. They colonise replacement habitats with comparable, but also new characteristics to which animals adapt relatively quickly.

Best known is the avifauna of cities. The reason for this is - besides the widespread interest in observation (emotional attention) - the manageable number of species of this animal group and the relatively easy observability.

Big Garden Birdwatch

The special advantageous conditions of the city (rich food supply, winter feeding, hiding and sleeping facilities) are contrasted by disadvantages such as frequent disturbances, technical dangers such as traffic and light traps for insects. Many species from warmer countries are restricted to warmer building interiors as intramural fauna (Wittig and Streit 2004). In addition to parasites of humans and domestic animals, these include storage pests and species adapted to special habitats such as wood, roofs and damp cellars.

The following zoogeographical development trends can be generalized for animal groups and animals in the city:

- Reducing the diversity of their communities,
- Higher population density,
- Sudden changes in species numbers and urban distribution areas,
- Selective, species-specific preference of urban ecosystems against other ecosystems (“urban animals”),
- Development and expansion of familiarity and tameness,
- Change in food ecology,
- Change in the nesting method,

- Extension of the daily rhythms,
- Extension of the reproductive period,
- Behavioural changes (e.g. reduction of the migratory behaviour of birds),
- Extension of the average life span of individuals,
- Development of site stability of certain species (reproduction without exchange with surrounding populations)

(see Müller 1977; Klausnitzer 1993; Gilbert 1991; Klausnitzer and Erz 1998; Leser 2008; Tobias 2011).

Animals with urban colonization advantage

Especially those wildlife species are preferred which have the following characteristics:

- Short escape distance,
- No dependence on large open spaces,
- Adaptation to diverse structured, rocky terrain (z. B. former rock and cave dwellers, z. B. House Redstart, House Swallow),
- Similar food requirements as humans (omnivores, e.g. rats and mice),
- Specialists in certain foods or materials that are part of human needs (flour beetle, clothes moth),
- High reproduction rates (many offspring and short reproduction time),
- Low height,
- No great competition or disturbance to humans,
- Independent of high air or soil moisture,
- Not dependent on water or clean water,
- Not very sensitive to immissions (Wittig 1995; Wittig and Streit 2004).

Urban Blackbirds—Woodland Blackbirds

The woodland bird blackbird (*Turdus mercula*), which was still exclusively shy two centuries ago, became now an urban bird. The development of urban garden culture (Sect. 4.2.4) has opened up new habitats for blackbirds in the cities. The blackbird thus stands for the plants (apophytes) and animals (apozoes) of the forests that have become native to cities.

The breeding population of blackbirds in Nymphenburg Park in Munich fluctuated between 53 and 75 breeding pairs, about 30 per km^2, until 1982. In Munich's West Cemetery and the English Garden, this was as high as 86 and over 100 breeding pairs per km^2 respectively at the end of the 1970s and beginning of the 1980s. Natural sites such as the bog Murnauer Moos, on the other hand, had only 3.6 breeding pairs per km^2, forests in the vicinity of Munich even less (1–32 breeding pairs per km^2).

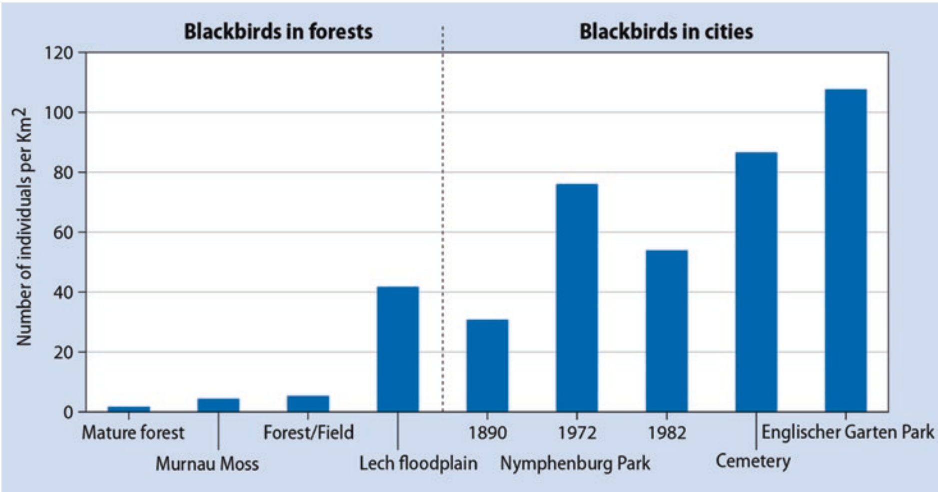

Fig. 4.5 Urban blackbirds—wood blackbirds in Munich's urban and suburban habitats (modified after Reichholf 2007, p. 104)

The blackbird reaches its highest population density ever in large urban open spaces (large parks, cemeteries, places where the ground remains accessible for foraging). The frequency of the species has been increased by a factor of about 10. The habitat change from woodland to urban also led to behavioural changes, so that today "woodland blackbirds" are distinguished from "urban blackbirds". The blackbirds often spend the winter in the city and take advantage of the wide range of food available. They are ecotypes of the species. The two-century advance from the forest into urban areas is an evolutionary process and is still ongoing (Bezzel et al. 1980; Wüst 1986; Reichholf 2007; Fig. 4.5).

Pet Ownership in Germany - One in Three German Households Has a Pet

22.6 million pets lived in German households in 2009. The majority of them lived in cities. Animals are kept in more than a third of all households. The numbers of animal groups are more or less constant. Cats and dogs have long been the most popular and most kept pets. The proportion of pet owners (over fifty years of age) has been growing slightly in recent years. But 53% of pet owners are younger than fifty years. The proportion of pet owners in multi-person households of the middle generations is also large. 74% of pets are kept in two-person and larger households. The proportion of pet owners up to 29 years of age (11%) and from 30 to 39 years of age (18%) has decreased. The share of 40-49-year-old pet owners remained unchanged at 24% compared to the previous years. Even though about a quarter of all pet owners live alone, pets are still predominantly family members (IHV 2010; Table 4.5).

Table 4.5 Pets in Germany (IHV 2010)

	Number of animals in million	Percentage of total pets kept
Cats	8,2	16,5
Dogs	5,4	13,3
Small animals	5,6	5,4
Ornamental birds	3,4	4,9
Animals in garden ponds	2,1	4,0
Aquarium animals	2,0	4,4
Terrarium animals	0,4	1,2

Ecological consequences on the native fauna can be observed especially with cats and dogs. The cats, most of which also run free, reduce the indigenous bird population. Free-ranging dogs considerably disturb ground-breeding birds and small mammals, but also game, especially in city forests and in nature reserves. Dog excrements in green areas are a hygienic burden, especially for children.

Big Garden Birdwatch

The *Royal Society for the Protection of Birds* (RSPB) organises the annual "Big Garden Birdwatch" in Great Britain, the world's largest organised bird survey. All citizens who carry out bird watching in their gardens or urban parks are invited to observe, record and report to the RSPB. This is a national event in which 590,000 people took part in 2013. On the basis of these observations, it has been established that most bird species are in decline. For example, the number of starlings recorded decreased by 16% compared to the previous year, and house sparrows by 17%. This is interpreted as a sign of a threat to the species and as a call to strengthen their protection. The house sparrow is already on the Red List of Threatened Species in Great Britain!

The RSPB states: Gardens are important habitats for the most endangered birds. However, they only cover 4% of the UK's land area (RSPB 2013).

4.2 Urban Habitats, Condition, Use and Maintenance

4.2.1 The Concept of the Four Natural Types

What is urban nature? This question can be answered very differently. The positions on this issue are shaped by different understandings of nature (Breuste 1994a; Brämer 2006, 2010). Nature is usually not sought in cities, but in "untouched" landscapes (forests, mountains, etc., often distant to urban areas). The public rediscovery of “nature” (e.g. Müller 2005), “wilderness” (e.g. Rosing 2009) and “landscape” (Küster 2012, also 1995, 1998) in Europe is only just taking place. The “sense of nature” of the Romantics often mixes with scientific analysis and knowledge.

The realization is gaining ground that nature should not be understood as “untouched” and that everything created by man should not be understood as “non-nature”. Leser (2008) justifiably demands that the concept of nature in the city should be defined so openly that “spontaneous to anthropogenic nature” is also included (Leser 2008, p. 214).

What is nature?

Kowarik (1992a) attempts a simple and pragmatic approach to urban nature by dividing it into four “nature types” based on the characteristics of urban flora and vegetation (but also indirectly of fauna). These natural species allow the diversity of anthropogenic shaped natural conditions in the city to be grouped into just four major groups, from which the habitats that shape them can be examined more closely.

Nature of the first type (Kowarik 1992a) are remnants of pristine landscapes, comprises woodland/forest and wetlands remnants, which are somewhat idealized as “pristine natural landscape”, although they too have usually lost their “originality” through anthropogenic design (water balance influence, eutrophication, immissions, species changes, etc.). What is meant is their low urban character.

Nature of the second type, remnants of the cultural landscape, comprises agricultural areas, meadows, pastures, arable land and associated landscape elements such as hedges, heaths, drifts and dry grassland. This type of nature is characterised by varying degrees of intensive, often anthropogenic, influence, also in cities, through intensive farming. Their design is often already determined by the urban environment.

Nature of the third type, designed landscapes, refers to the “ornamental nature of the gardening facilities”, the urban nature usually perceived as urban greenery, nature specially created for the design of the city and use - economically and aesthetically - in it. It has come into being as a kitchen garden for economic reasons or as a decorative garden (city garden or park), as an aesthetic structuring and design element, in the expanding and beautifying city. It combines very different, but very typical urban habitats such as house gardens, allotment gardens, traffic greenery, urban parks, large recreational parks, individual trees, avenues, etc. Their anthropogenic design through care and use varies greatly and is subject to temporal fluctuations, fashions and economic justifications. The designation of habitat, for example, park, can therefore provide rough indications, but does not yet say anything about the actual ecological status.

The **nature of the fourth type**, novel urban wilderness, enjoys special attention in urban ecology research as a “specific nature of urban-industrial areas”, as it is not seeded or planted vegetation. This type of nature arose through spontaneous development under the more or less anthropogenic influence, but always in close relation to the strongly anthropogenic changed site conditions (soil, water balance, microclimate etc.) after the abandonment of previous uses. In accordance with the typical urban flora, pioneer communities, spontaneous bush communities up to urban pre-forests develop as stages of succession and adaptation to site conditions and disturbances. They are frequent objects of study in urban ecology research and have been the focus of botanical interest since the 1970s and 1980s (see Rebele and Dettmar 1996; Wittig 2002 and others). Today this type of urban nature is also increasingly seen in its importance for humans (see Kowarik 1993; Wittig 2002 and others).

Urban habitats are all habitats within the city (Gilbert 1991; Aitkenhead-Peterson and Volder 2010). They are not just ecosystems shaped by gardening and spontaneous urban flora and fauna, that is, the nature of the third and fourth kind (green spaces and fallow land). Urban habitats should be understood as ecosystems that are located in the urban area (e.g. in an urban area or the area of urban development and its surroundings) and thus have a relationship to the city by urban utilization. Thus, the urban area is first and foremost a spatial dimension with a strong urban utilisation gradient, from intensive to low urban use (qualitative dimension). This use by urban dwellers and the design for urban dwellers always also influence the ecosystem state of ecosystems that are originally not specifically urban, such as woodland in a city (Gilbert 1991; Aitkenhead-Peterson and Volder 2010). In the following, some essential urban habitats of the four natural types and their management are presented as examples.

"Nature Obscure - How Young People Experience Nature Today"

Rainer Brämer, sociologist, at the Institute of Educational Science at the University of Marburg (Institut für Erziehungswissenschaft der Universität Marburg) with a research focus on the relationship between nature and man, has published numerous publications on empirical studies of nature relationships among young people (Brämer 2006). The Youth Report Nature 2010 (Brämer 2010) received special attention. The report notes that, among the 3000 sixth- and ninth-graders in six German federal states, the distance to nature already established in the previous studies appears to go further than expected. Contact with nature is only reduced. Brämer (2010) calls this "forgetfulness of nature" and "natural distance". Conservative ideals as cleanliness, order, tranquility and care also unite in children and young people transferred to nature and form an abstract image of nature that is shaped less by the school than by the media. Nature on the (urban) doorstep does not take place. Nature now functions only as a backdrop, although the sense of discovery, even for unknown landscapes, is still present and can be used for educational purposes.

Contact with nature takes place to 47% of the questioned scholars outside the city ("out in the country"), to 35% in the city and 28% in their own room (Table 4.6).

In the USA, Louv's (2005) report "Last child in the woods" has triggered a widely supported backlash against the remoteness of young people from nature, on a par with activities to tackle major environmental problems. This social reaction is still missing in Germany.

Table 4.6 Nature contact of young people (Brämer 2010)

Where do you prefer to spend your free time?	
Out in the country	47%
In the city	35%
In your own room	28%
I'm happy to do it, or would I like to do it!	
Discover unknown landscapes	74%
Mountain biking in the forest	53%
Walking through the forest	56%
Observe deer in the wild	49%

What is Nature?

The original total concept for the "totality of things of which the world consists" has meanwhile dissolved into various individual terms and made way for different "natures" (Leser 2008). Although the term "natural" still means "not influenced by man", it can hardly define this content ("pure" nature). Trepl (1983) states that this "good" nature is perceived in a diverse, decentralised, uncontrolled and spontaneous way and thus has the sympathetic features of a social role model.

Isolated nature (partial nature) - The nature of science remains a "mental isolate" of an unrecognizable wholeness of reality (Trepl 1983, 1988, 1992). The abstract "all-nature", the nature of philosophy, has today hardly any significance for the social image of nature. The symbolic nature ("culture-nature") of cultural history still determines our image of nature.

The admiration of nature led to a new and varied integration into social life. From this grew the longing for an ideal state, the view of nature as "good" nature, which, by turning back to it, would enable the solution of many social problems. Transfigured was the "lovely" agricultural landscape of the river-drained floodplains, which became the utopian shepherd's land of Arcadia and entered the cities through castle gardens, public parks and landscape gardens in the nineteenth century. This is contrasted by the woodlands/forest, which documents the power and primeval nature of the landscape (also applied to the individual tree). As a symbol of the primeval landscape "uninfluenced" by man, it showed the limits of human control over nature. Designed agricultural landscape and natural landscape as "pristine nature" formed the opposites of cultural appropriation of nature. Both can be found as symbols everywhere in the cities (sheared lawns from the cultivated floodplains, urban kitchen gardens from the village-agricultural environment, trees and shrubbery from the natural forest, pine and rock bushes as the fringe areas of ecumenism). Urban nature thus has a cultural-historical basis and is still accepted as a symbol (Breuste 1994a, p. 2–3, Breuste1999; Hard 1988).

4.2.2 Urban Forests

Urban forests can be assigned to all four nature types depending on the type of.

Urban forests are not only typical (remnant) elements of the agro-forestry cultural landscape into which cities have expanded and which are now located directly on their periphery, often near buildings, but also embedded in them (Jim 2011). They are also “park forests” of loose mixed structure, newly created by succession on fallow land. What is meant in the following is not the often common property designation “urban forest” as forest owned by the city, regardless of its location.

Large municipal forests in Germany are in Berlin (a total of 28.500 ha Berliner Stadtforsten) the Tiergarten (210 ha), the Grunewald (approx. 3000 ha) and Köpenicker Forst (approx. 6500 ha), the Frankfurt Stadtwald (3866 ha), the Dresdner Heide (6–133 ha), the Eilenriede in Hannover (650 ha), the Rostocker Heide (6004 ha) and the Duisburg Stadtwald (approx. 3000 ha). Baden-Baden has the largest municipal forest in Germany with 8578 ha and a share of 61% of the city's total area. The Leipzig floodplain forest (approx. 2500 ha) is one of the largest floodplain forests in Central Europe.

Since the late 1960s at the latest, there has been a continuous rethinking of forest management of urban forests, away from timber production and towards *urban and community foresty* (Johnson et al. 1990; Kowarik 2005; Burkhardt et al. 2008; Jim 2011) with multiple forest functions.

In the European research project “Urban Forests and Trees” (1997–2002), a systematic overview of the planning, management and use of urban forests and urban trees was compiled (Konijnendijk et al. 2005). For Germany, summarizing and special studies on the management and redevelopment of urban forests are available in Kowarik (2005), Kowarik and Körner (2005), Rink and Arndt (2011).

In the USA and increasingly also in Europe, the term *urban forest* is understood to mean the entire stock of all trees in the urban area, mixed according to species, age, ownership and density. It has no individual owner and is not subject to joint, coordinated management, but serves human needs in its entirety and its parts (Breuste and Winkler 1999; see ecosystem services, Chapter 5).

The urban city forest consists of woodlands of different sizes and many individual trees, rows of trees and avenues. Large contiguous forests (more than 60 ha) are rather rare, and there are the ecologically relevant border effects of small woodlands (Fig. 4.6).

The urban forests cover a whole spectrum of forests from successional woodlands to planted forest plantations. Forests with a species composition that deviates from the ecological site conditions are called forests. In the case of a site-appropriate combination of woody species, the term forest can be used regardless of whether it was created by original natural development or planting (Kowarik 1995; Table 4.7).

Urban forests are divided according to their functions. In addition to wood production, which can even take a back seat in urban forests, new tasks such as recreation, nature experience, environmental learning and others are being set.

Studies on species diversity of urban woodlands are often available, at least for urban planted forests. However, species diversity depends very much on the type of forest,

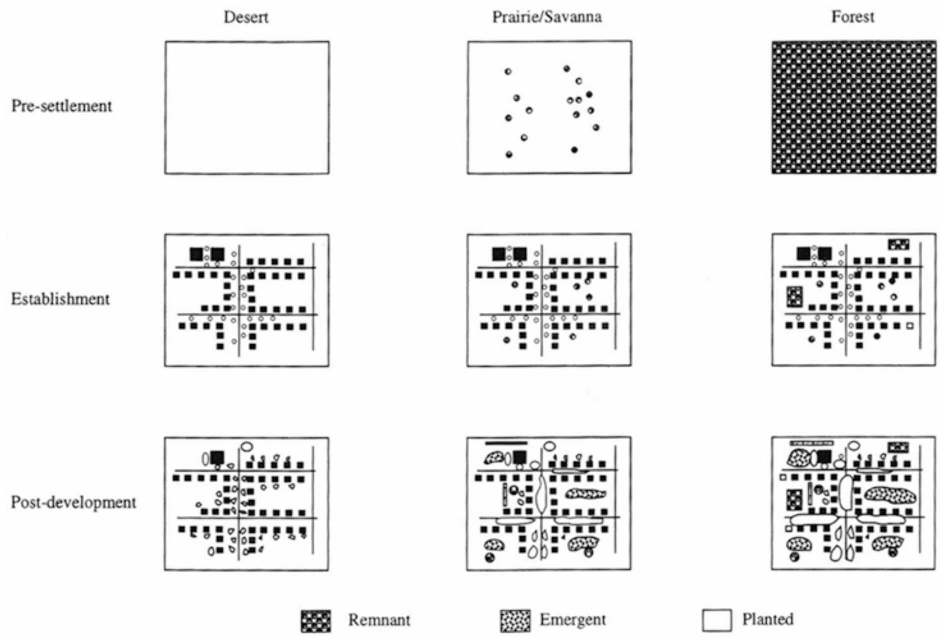

Fig. 4.6 Development of the *urban forest* through forest remnants, emerged and planted forests in three ecoregions (Zipperer et al. 1997, p. 235)

Table 4.7 Types of an urban forest (according to Kowarik 2005, modified)

Nature 1	"Old Wilderness"	Natural forests or their remains
Nature 2	"Traditional cultural landscape"	Forest, strongly influenced by traditional forestry
Nature 3	"Functional Green"	Park forest, planted trees in green areas and residential areas
Nature 4	"Urban Wilderness"	Succession forests on fallow land

its use and its maintenance, and therefore cannot be generalised. All in all, it can be expected that urban forests with near-natural tree stock and low disturbance will provide habitats for a large number of native plant species. For park forests and successional forests, this is only incompletely the case. Kowarik (1992a) lists 77 woody species for the spontaneous forests Berlin, including three tree species and four climbing plants. 50% of the woody plants are indigenous. In the remaining 50%, the shrubs are predominantly neophytes. 13% are also archaeophytes. Black locust (*Robinia pseudoacacia*, neophyte from America) dominates the tree and shrub layer, in which the native black elder

(*Sambucus nigra*) also occurs. The pioneer woody plants of the tree and shrub layer are too weak in competition with black locust (*Robinia pseudoacacia)* to displace it. The relative stability of this successional forest is assumed. Maple forests with beech could replace the black locust (*Robinia pseudoacacia*) after a longer period of time (Kowarik 1992b).

New planted forests - example Leipzig "Stadtgärtnerei Holz" (BfN 2010; Rink and Arndt 2011)

The higher the structural diversity of an urban forest, the higher the species diversity and population density. Tree species composition, habitat diversity (dead wood, earth and tree cavities, disturbed edge areas, hiding places, resting and reproduction areas) contribute to the quality of the habitat (Otto 1994). The settlements, agricultural use and conversion of forests into productive commercial forests have usually reduced the area of natural forests in urban areas of Central Europe to an extreme extent and changed their habitat quality. Their rare, little disturbed remains are often under strict protection as nature reserves in forests otherwise usually only protected as landscape protection areas.

The urban forests are the least impaired habitats for animals over large areas. Compared to other habitats, they are usually less affected by land fragmentation and reduction and high intensity of use (Gilbert 1991; Fig. 4.8).

The urban forest of Salzburg rises on hills to 190 m (up to 640 m height) above the city of Salzburg. The 75.5-hectare beech forest on limestone was designated as a landscape conservation area in 1981. After a long phase of open scrub formation by grazing, the hill was reforested with site-adapted beech trees, typical for the location, but as a secondary forest.

A large number of plant communities have been identified and determined for Central European cities (see Wittig 2002). Although Central Europe used to be a forest country, forests are no longer dominant components of the cultural landscape here. This is

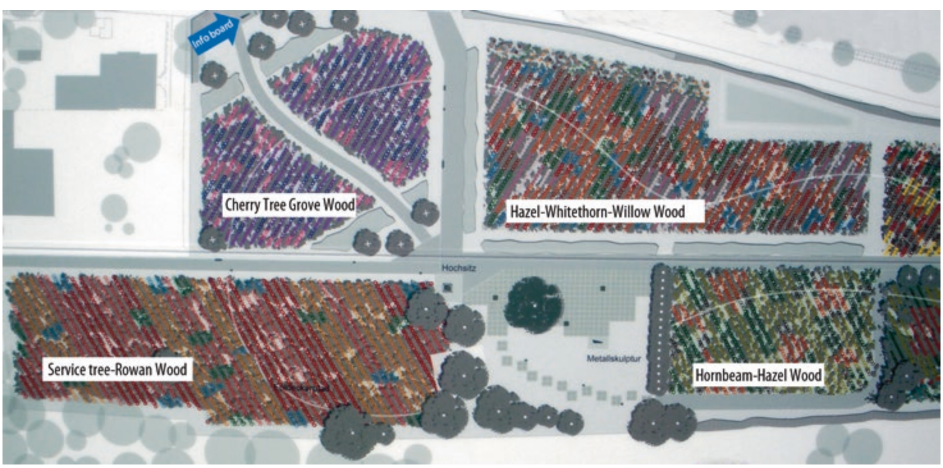

Fig. 4.7 Stadtgärtnerei-Holz, "urban forest" in Leipzig. (Photo © Breuste 2012)

Fig. 4.8 The Kapuzinerberg hill in Salzburg is a forest island in the midst of the city. (Photo © Breuste 2003)

Fig. 4.9 **a** Butterfly bush (*Buddleja davidii*) on a former industrial site Phoenix West, Dortmund (Photo © Breuste 2012), **b** Tree of the heaven (*Ailanthus altissima*) as a street tree in Bratislava, Slovakia (Photo © Breuste 2015), **c** black locust (*Robinia pseudoacacia*)as a spontaneous tree on the railway premises of the Zollverein former coal mine in Bochum. (Photo © Breuste 2011)

especially true for cities where often bush and forest plant communities of spontaneous vegetation have not been understood as typical for settlements (Diesing and Gödde 1989). Black locust (*Robinia pseudoacacia*) as single trees and Robinia forests are spreading to suitable locations in the warm continental area, for example, in the Upper Rhine area and the Vienna Basin. In northwestern Central Europe (e.g. Ruhr area), butterfly bushes (*Buddleja davidii*) - societies (neophyte from China) (Fig. 4.9a) are particularly characteristic (Kunick 1970). In the central and south-eastern area of Central Europe urban tree of heaven (*Ailanthus altissima*), a neophyte from Eastern China appears (Fig. 4.9b).

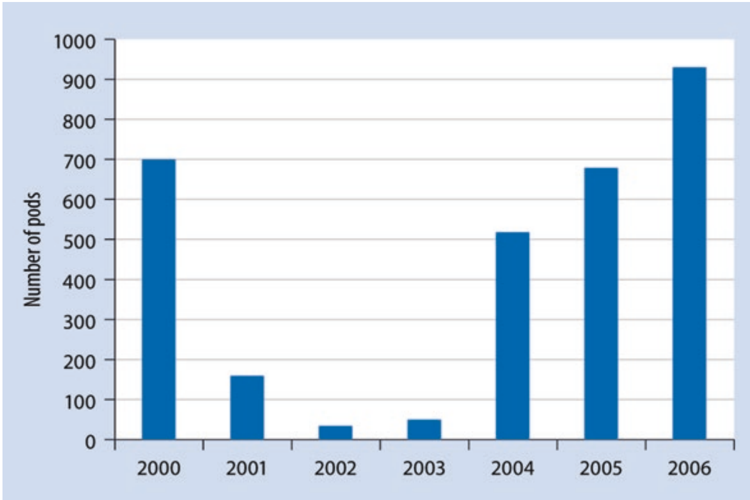

Fig. 4.10 Longer-term cycle of seed attachment (number of pods) of *Robinia pseudoacacia* in the garden of the State Zoological Collection Munich (Zoologische Staatsammlung München) (Reichholf 2007, Fig. 96, p. 1991)

Not only thermal adaptation enables these species to distribute in cities. In addition, other adaptations make them competitive, such as in the case of the black locust (*Robinia pseudoacacia*), the formation of root runners that make even closed plant stands possible to colonie, long-lived seeds, budding on underground runners (bud bank) etc. (Kowarik 1992a; Reichholf 2007; Fig. 4.9c, 4.10, and Fig. 4.11).

Arndt and Rink (2013) see to develop urban forests as innovative urban open space development strategies, especially in shrinking cities, where the opportunities for their implementation arise.

Structure of Urban Forests in Germany

Burkhardt et al. (2008, p. 32, modified) divide city forests functionally.

Neighbourhood forest

- Relatively small forests in the residential area,
- Particularly important for user groups with reduced mobility, such as children, elderly, disabled people
- Positive effects on the local climate, possibly on the immediate surroundings,
- Bright, transparent and inviting forest structure, gradation of the tree stock in height and density,
- Often insufficient care and disturbing waste disposal.

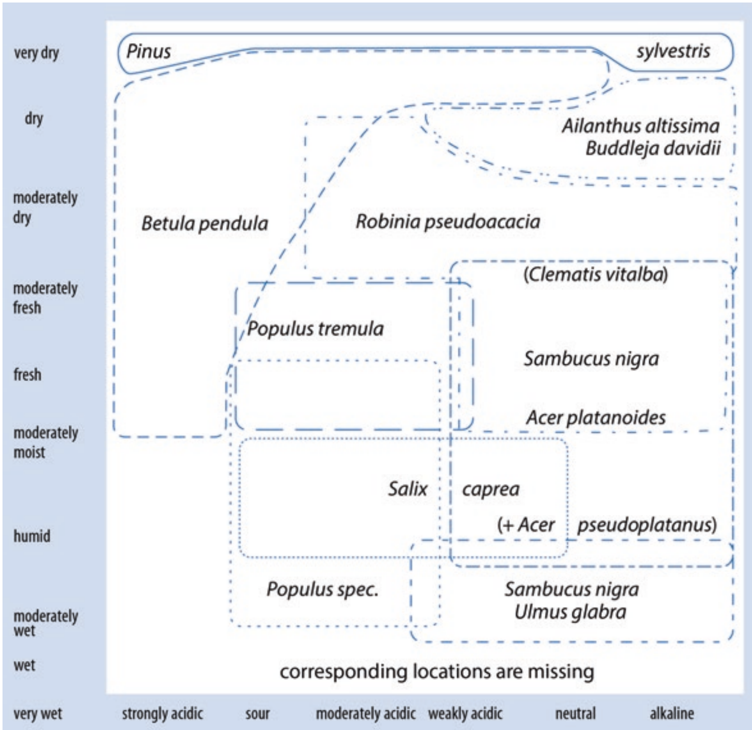

Fig. 4.11 Preference of the spontaneous woody plants common in the Berlin city centre with regard to soil moisture and soil acidity (according to Sukopp 1990; cited in Wittig 2002, p. 169)

District forests
- Multifunctional, medium-sized forests,
- Often located between city districts or in connection with new construction areas on the outskirts of the city,
- Use by residents and passing pedestrians and cyclists,
- Information and public participation are particularly important,
- Graduated management based on the intensity of use.

Recreational forests (mostly on the outskirts of the city)
- Mostly bigger than 60 ha,
- Different forest structures possible as a mosaic pattern,
- High diversity and closeness to nature are possible,
- Various possibilities for experiencing nature,
- Equipment with paths, meeting points, seats, information boards etc.

Productive forest

- Forest areas outside of cities,
- Focus on timer production,
- With additional functions as required (e.g. nature conservation, recreation).

Newly Planted Forests - Example Leipzig "Stadtgärtnerei Holz" (BfN 2010; Rink and Arndt 2011)

In the Leipzig district of Anger-Crottendorf, a city nursery that has not been used since 2005 was converted into an urban forest after the demolition of the building. The "Stadtgärtnerei Holz" was handed over to the public on 23 June 2010. The 3.8 ha large "Stadtgärtnerei-Holz" is the first completed sub-project of the test and development project (E+E) "Ecological urban renewal by planting urban forest areas on inner-city sites in a change of use - a contribution to urban development", which was funded by the German Federal Agency for Nature Conservation with funds from the German Federal Ministry of the Environment, Nature Conservation and Nuclear Safety. Using Leipzig as an example, the new creation of various types of inner-city forest areas is to be tested. These forest areas are to be an instrument of innovative urban development and at the same time contribute to the preservation of biological diversity. The action in Leipzig is also part of the implementation of the German National Strategy on Biological Diversity and the German Strategy for Adaptation to Climate Change.

More than forty percent of the surface of the location had to be unsealed. Fruit-bearing wild shrubs, which are reminiscent of the former horticultural use, can be found next to forest trees. Areas for playing, lingering and walking were created. The plantations consist of 30–50 cm high forest plants, which must be fenced in for the first five years.

Experiments are being carried out with different forest variants in relation to natural forest formations (oak-hornbeam forest, *Carpino-Quercetum*) and by admixture with fruit trees in relation to previous use (Fig. 4.7).

Nature Park Schöneberger Südgelände

In 1952 the railway operation at the Anhalter Bahnhof in Berlin was stopped. The natural succession of the railway wasteland began. The "Bürgerinitiative Natur-Park Südgelände" (Citizens' Initiative Nature Park Südgelände), founded in 1987, was able to prevent a reuse of the 18 ha large area by proving its ecological value, which has since been proven. In 1995, the Deutsche Bahn AG transferred the Schöneberger Südgelände to the Berlin Senate as compensation for interventions by its transport facilities elsewhere. The state-owned Grün Berlin Ltd., supported with 1.8 million marks by the Allianz Environment Foundation, took over the further development of the forest park, which was placed under nature and landscape protection and symbolically opened in 1999. In 2000 it became an official German EXPO project.

In 61 years of more or less undisturbed succession, after pioneer stages of herbaceous vegetation and bushes, a new urban (pre-)forest developed, dominated by birch (*Betula pendula*) and black locust (*Robinia pseudoacacia*) as a new form of "urban wilderness" - a scientific and aesthetic object of experience of independent habitat development after the abandonment of use.

The spontaneous vegetation and the corresponding fauna are well studied. Thus, 366 different species of ferns and flowering plants, 49 species of large fungi, 49 species of birds, 14 species of locusts or crickets, 57 species of spiders and 95 species of bees can be seen there. A part of the area is designated as a nature reserve. It is not allowed to leave the paths here, especially to protect ground breeding birds. A 600 m trail above the ground, build by elevated steel grid paths, fixed to the old, still existing railway tracks, lead through the area. Grün Berlin Ltd. is currently developing further concepts for combining new urban nature with concerts, readings, as well as theatre and cultural projects. Guided tours of the flora, fauna and history of the area are held regularly. The combination of forested urban wilderness and urban culture and recreation seems to be a complete success (Kowarik and Langer 2005; Senatsverwaltung 2011; Grün Berlin GmbH 2013; Cobbers 2001; Table 4.8, Fig. 4.12).

Table 4.8 Differentiation of forests in relation to settlements (after Kowarik 2005, p. 9, modified in Burkhardt et al. 2008, p. 31)

Forest type	Subtype	Spatial situation	Function		Urban influence
			Social function	Production	
Urban forests	Forests within and on the outskirts of urban areas,	Insulated in the built-up area, Between the built-up area and open landscape			
Semi-urban forests	Forests near cities	Part of the cultural landscape near or adjacent to urban areas			
Non-urban forests	Forests far away from cities	Part of the open (semi-natural) landscape, far away from cities			

Fig. 4.12 Nature Park Schöneberger Südgelände. (Photo © Breuste 2011)

4.2.3 Urban Waters

Urban waters are running and still waters that are subject to characteristic urban influences (commercial use, flood protection, aesthetic design, pollution, eutrophication, etc.) (Schuhmacher 1998). They show considerable changes compared to waters of the same type outside cities. Still, waters are naturally occurring small waters, ponds, lakes, but also park waters and rainwater retention basins. Running waters are rivers, streams, canals and drainage ditches (Gunkel 1991). With their peripheral areas, they are important habitats for plants and animals (Gilbert 1991).

The following, in particular, have changed for urban waters

- Hydrology and hydraulics (flow dispensation/dynamics, flow velocity),
- Watercourse structure (width, course, profile, bank),
- Species spectrum of plants and animals, abundances,
- Waterbody use (e.g. recreational and leisure use) and water status (Endlicher 2012, p. 87).

Urban waters can thus take over functions in the city (Chapter 5)

- Habitat for flora and fauna (ecological potential),
- Urban climate improvement (climatic potential),
- Industrial and commercial use (utilization potential),
- Absorption of wastewater (disposal potential),
- Embellishment of the urban human habitat (recreational and aesthetic potential) (Endlicher 2012, p. 89).

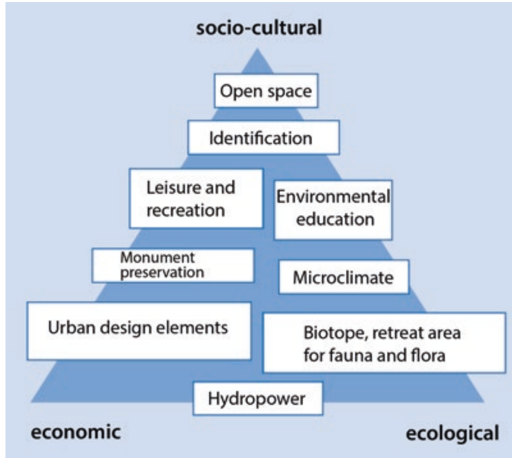

Fig. 4.13 Functions of urban waters (DVWK 1996)

Table 4.9 Nature Park Schöneberger Südgelände. The decline of herbaceous vegetation and the increase of woody vegetation in a 10-year period (Kowarik and Langer 2005, p. 289)

	1981	1991
Area under investigation (in ha)	22,4	20,0
Investigated vegetation area (in ha)	21,6	19,1
Cabbage vegetation (in %)	63,5	30,9
Forest vegetation (in %)	36,5	69,1
Dominated by:		
Robinia pseudoacacia (%)	11,2	21,3
Betula pendula (%)	13,7	23,8
Betula pendula & *Populus tremula* (%)	?	5,3
Populus tremula (%)	1,3	2,3
Acer platanoides, *A. pseudoplatanus* (%)	0,2	1,4
Other (%)	10,1	15,0

In 1996, the German Association for Water Management and Cultural Construction (DVWK) assigned them socio-cultural, economic and ecological functions (Fig. 4.13; Table 4.9, Table 4.10).

Water quality: Pollution of urban waters by material inputs is decreasing, at least in Central Europe, but still exists. They must be reduced at the source. Kausch (1991) distinguishes two groups of substance inputs, substances that directly or indirectly affect the oxygen content of water bodies, and substances that accumulate in organisms and can have toxic effects.

Due to the frequent loss of the filter function of ecosystems in the water environment, the oxygen content is often reduced, which is partly to be counteracted by technical means (weirs, etc.). Constant monitoring of water quality is necessary to detect and prevent pollution at an early stage.

Table 4.10 Change in the functions of water bodies and waters in Central European inland cities due to anthropogenic use and perception (Kaiser 2005, p. 22)

	Before 1750	1750–1850	1850–1915	1915–1950	1950–1980	Since 1980
Protection			–	–	–	–
Food, fisheries, irrigation					–	–
Route of transport						
Energy supplier						
Drinking water supply						
Service water supplier						
Disposal						
Leisure and recreational use	–	–	–			
Upgrading the living environment	–	–	–	–	–	
Habitat for plants and animals	–	–	–	–	–	

High significance,
Medium significance,
Low significance, - No significance

Due to the large urban sealing areas, a large part of the precipitation water does not seep away and is largely drained through the sewerage system and fed to nearby watercourses. This poses additional risks in the event of flooding there and lowers the groundwater level. Technical construction very often leads to the isolation of the habitats. The urban physical, chemical and biological conditions reduce plant and animal specialists and promote ubiquists (reduction of the species spectrum).

As a consequence, the often highly advanced technical expansion, especially of the watercourses for flood risk reduction, has destroyed many water-related habitats in the city or considerably impaired their habitat functions. Especially the river floodplains in cities as natural retention areas hardly fulfill their ecological functions anymore by straightening rivers to canals and lowering the groundwater table (Fig. 4.14). Where there is still a floodplain forest, the disturbance-influenced softwood floodplain habitat

Fig. 4.14 Salzach in Salzburg - a river canal with good water quality and recreational function. (Photo © Breuste 2003)

has largely given way to a mixed stand that has emerged from the hardwood floodplain (Gunkel 1991; Kasch 1991; DVWK 1996, 2000; Schuhmacher and Thiesmeier 1991; Schuhmacher 1998; Leser 2008; Endlicher 2012).

Waterbody renaturation is intended to restore the lost functions at least partially and in certain often only small areas. In most cases, the original condition cannot be the reference target. Instead, a "near-natural state" is redefined and supported by initially technical measures. The priority is to improve water quality by purifying the discharged water. The increase of low water discharge and the combination of flood protection with renaturation measures are current challenges in urban water management (DVWK 2000). Nature conservation and nature development on the one hand and recreational use on the other can also be brought together again using urban water bodies as highly attractive recreational areas in cities.

Renaturation of the Isar in Munich (2000–2011)

With its islands, gravel banks, meadows, floodplain forests and parks, the Isar river floodplain is an attractive recreational area for the whole of Munich and especially for the almost 200,000 people who live in the districts close to the Isar river. Cycling, walking, jogging, sunbathing, barbecuing, playing games and in winter sometimes even cross-country skiing are possible.

In 1988 the Isar Plan was created, a renaturation project that has been developed with the participation of citizens, associations and political committees since 1995 as part of the planning process. In February 2000, the exemplary Isar renaturation project began in Munich, with three objectives: improved flood protection, more space and closeness to nature for the river landscape, improvement of the leisure and recreational function.

The river bed was widened and the flood dikes were repaired. Flat, partly terraced, accessible banks were created. Gravel areas and natural bank formations with recreational opportunities and new, interesting visual relations to the river are part of the project.

Sufficient water supply and quality support the developing near-natural habitat of fauna and flora. The river will continue to shape its river bed in the course of time. In eleven years, the Isar Plan was implemented over a length of eight kilometers by 2011. Unique in Europe were the successful efforts to achieve bathing water quality on the Isar river.

The first Award for Water Development for exemplary measures for the preservation, natural design and development of water bodies in urban areas was awarded to the Munich Water Management Office and the City of Munich for the Isar Plan project in 2007 by the German Association for Water, Wastewater and Waste (DWA).

The widening of the river bed improved the flood flow. Flat banks, offshore gravel banks, gravel islands and shallow ramps of large stone blocks with basins in between (“dissolved river bed ramps”) make it a semi-natural river in the city again today. This improved the habitat diversity for the animal and plant species typical of the Isar river. Nature development, urban and recreational use can go together.

The costs for the project (flood protection and renaturation measures) amounted to approx. 35 million euros, 55% of which were borne by the Free State of Bavaria and 45% by the City of Munich (Wasserwirtschaftsamt München 2011; Fig. 4.15).

Fig. 4.15 Section of the renaturalized Isar river in Munich. (Photo © Voigt 2013)

4.2.4 Urban Gardens

Urban gardens in various forms are as nature of the third type (Kowarik 1992a) the typical and desired natural forms and habitats in cities. They are and were part of the urban beautification that began in the nineteenth century. Ignatieva (2012) sums up that these were influenced worldwide by the English garden idea ("Victorian Gardenesque" 1820–1880) and have led to similar garden (park) forms in different cities of the world. While private decorative greenery in the cities had previously been reserved for elites as a manorial park, the "greening" of the rapidly growing cities according to landscape gardening ideals has now begun. Public parks, avenues, decorative small green spaces, lawns and hedges became an element of the new urban development (Schwarz 2005a). To these was added in the second half of the nineteenth century the allotment garden (Schrebergarten), which was not concerned with the need for decoration but with the need to be active in dealing with nature and to profit from it (fruits, vegetables), thus bringing elements of our rural character into the city. This "symbolic nature of allotment gardens" can at least be divided into two large groups, the mostly public parks and the mostly privately used gardens, connected to houses or independent. In addition, there is a variety of small green structures such as roadside greenery, single trees, avenues, playgrounds, vest-pocket parks, etc. From these two groups, public city parks and allotment gardens will be treated here as examples.

4.2.4.1 Public Urban Parks

Different habitats belong to this urban nature category:

- Small neighborhood parks,
- Big city parks,
- Very large recreation and adventure parks, mostly on the outskirts of the city,
- Botanical and zoological gardens (theme parks),
- Cemeteries,
- Forest parks (transitions to the urban forest, see above).

The transitions to the urban forest are fluid, especially when the park is laid out in the forest (e.g. in many Scandinavian cities).

Key ecological features are:

- Equipment of the park with natural elements (trees, bushes, lawn, water etc.),
- Size (marginal effects of small parks reduce ecological functionality),
- Disturbances (especially noise, but also dogs running free, number of visitors and visitor activities, presence of less disturbed retreat areas)
- Tree stock (density, species spectrum, degree of canopy cover, age, etc.),
- Management (intensity, frequency, timing).

The typical features of a public park consist of large open spaces with sheared lawns, individual trees, sometimes ornamental shrub beds and flower beds that require more care. Small woody areas are often integrated with larger parks (see also Gilbert 1991). Park maintenance is mostly a public affair (e.g. in the USA also private) but is becoming increasingly expensive for the municipalities. Ways are being sought to reduce these costs, for example, by staggering the maintenance and allowing natural succession in parts of the park. Out of conviction for the spontaneous development of nature, eco-parks on urban wasteland (e.g. in Great Britain) have now also been created (Sect. 4.2.5).

People's parks (Volksparke) as public parks were created in Germany, for example, in Berlin, Hamburg, in the Ruhr area, in Düsseldorf, Leipzig or Munich, mostly only in the twentieth century (Endlicher 2012). The parks are used for recreational purposes. This has changed from a more contemplative use to active elements of use in recent years. In an open society, different culturally determined interests of use are added (e.g. sports on park lawns, camps and barbecues with large numbers of people on grass). Nevertheless, most parks are still natural cells of peace and relaxation. Children's play areas, sports fields or even dog meadows can be integrated. Their users are predominantly older people, young families with children at weekends; a cross-section of urban society (e.g. Krause et al. 1995).

Public parks offer opportunities for a variety of nature observations and allow an emotional or even intellectual approach to nature. For the majority of our children who live in cities, they are the most important places to learn about nature. In addition to recreation, parks can also take on important functions as meeting places with nature for learning from and with nature (nature experience spaces, nature experience spaces). This is particularly important when public parks are the only easily and quickly accessible nature elements in large cities. They are currently only partially fulfilling this important task (Breuste et al. 2013a).

Public urban parks are important habitats for plants and animals. The avifauna of urban parks is usually well studied. It is in Central Europe characterized by characteristic species composition. Blackbird (*Turdus merula*), starling (*Sturnus vulgaris*), greenfinch (*Carduelis chloris*), collared dove (*Streptopelia decaocto*), great tit (*Parus major*), chaffinch (*Fringilla coelebs*), blue tit (*Cyanistes caeruleus*) and wood pigeon (*Columba palumbus*) were frequently observed in Leipzig and Chemnitz (Wittig et al. 1998). Breuste et al. (2013b) show considerable differences in avifauna in the Linz parks and can prove the connection between low disturbance and high structural richness on the one hand and high breeding bird numbers on the other hand (Breuste et al. 2013b).

The "People's Park" for democracy: Central Park in New York

The rapidly growing metropolis of New York was to be given a new center in the middle of the nineteenth century, Central Park - a revolutionary new idea in modern urban planning. In 1858, 4000 men began the landscape design work of the creative visionary and father of the American landscape architects Frederick Law

Olmsted. Central Park became his masterpiece and "the greatest American work of art of the nineteenth century" (Schwarz 2005b, p. 135). The "artwork urban park ", completed in 1873, was also intended to combat the escalating problems of the rapidly expanding metropolis. The public urban park was literally assigned a therapeutic and healing effect for the social and health problems of the urban population. It is undisputed that Olmstedt's primary motive is to make it a place where all strata of urban society can meet nature. In such a park for the people, the different social classes were to meet and the "rowdies" and "ruffians" of the lower classes were to learn from the behaviour of the middle and upper classes. This social illusion resulted in a myriad of rules for visitors, including dress codes and controls. Ultimately, however, Central Park remained a park for the rich in the nineteenth century, who had time alone to visit, used it for their carriage rides and enthusiastically welcomed and promoted it as an enrichment of their elitist lifestyle.

Only today, Central Park is a park for everyone, visited by 25 million people every year, on some days more than 500,000, and at 349.15 hectares it is the largest of New York's 1700 parks. The park is first and foremost the habitat of New Yorkers, who have one of the few opportunities here for contact with nature.

Central Park has its website (www.centralparknyc.org) and its own funding organisation, the private *Central Park Conservancy* which was founded in 1980. The *Conservancy* staff maintains 250 hectares of meadows, 24,000 trees, 150 hectares of lakes and streams and 80 hectares of forest. They look after the annual plantations, 9000 benches, 26 playgrounds and 21 ball fields. All this is done with the help of donations. Since its foundation, 60 million US dollars in donations have been collected, 536 million from private sources. The highest single private donation was registered in 2012 with US$100 million from the John A. Paulson's Foundation. In 150 years, the park has been worth US$150 million to the city of New York (Central Park Conservancy 2013; Fig. 4.16) (Schwarz 2005b).

Shanghai (China) is building a new "national park city"

Hardly any other city in the world has expanded its urban green space as much in such a short time as Shanghai. The 761 ha city green in 1978 was extended to 30.609 ha by 2006. 37.3% of the space of the megacity are green spaces. In 1990 this was 3 m^2 per inhabitant, in 2006 already 22 m^2 per inhabitant. This is internationally unprecedented and shows the city's efforts to give itself a face as a modern metropolis as a "park city". The largest new green spaces are not first and foremost classic urban parks, but a network of tree plantations and forest parks in the city's surrounding area that accompany streets and waterways (Fig. 4.17, 4.18 and 4.19).

New parks were created in urban expansion areas such as the Pudong district (e.g. Century Park 140 ha). But also in the densely built-up city, space was found

Fig. 4.16 Central Park New York. (Photo © Zepp 2011)

Fig. 4.17 Area of the future urban park Yangzhong Greenery, Yan'an Road in Shanghai, state 2000 (display board on site)

for urban greenery. The solution here was the demolition of old residential buildings to make space for parks. The Huangpu section of the city park on Yan'an Road was completed after a one-year planning and construction period in 2001 at 11.85 ha. Previously, 17.07 ha had to make way for old residential buildings and 4837 families who were resettled in other parts of the city. With a stock of old trees transplanted there, it does not give the impression today that it is only thirteen years old on Fig. 4.18 (Shanghai Municipal Statistics Bureau 2006).

Fig. 4.18 Yangzhong Greenery City Park, Yan'an Road in Shanghai, the state in 2001 (display board on site)

Fig. 4.19 Yangzhong Greenery City Park, Yan'an Road in Shanghai. (Photo © Breuste 2011)

4.2.4.2 Allotment Gardens

In the last quarter of the nineteenth century organized allotment gardening developed in Central European cities. The allotment garden sites were mostly leased land for a limited period of time, which was located close to the residential areas with multistoried houses and rented apartments and often built on later. Only in unfavourable locations, unsuitable for building development did the gardens of the initial period last longer.

The origin of the allotment garden and the allotment garden association is the industrial society. At the same time, the allotment garden is a part of the pre-industrial country life, which has been preserved until our time and has thus also grown out of the industrial society. This persistence of individual urban allotment gardens testifies to a special significance of this "second urban nature type" (Kowarik 1992a). Many accents of the allotment garden have changed in the course of its development, its core, the creative interaction with nature, have remained and is as relevant to modern urban life today as it was in the past. From the point of view of ecologically oriented urban development, the maintenance of human health, leisure activities in the urban space and especially in the big cities, the allotment and leisure garden system is still of great importance at the beginning of the twenty-first century (Breuste 2007). With the *Urban Gardening movement,* the spectrum of design and appropriation of urban green spaces has expanded.

In many cities, especially in northern and central Germany, allotment gardens were created in particularly large numbers between the two world wars and still characterise the green structure of the cities today. In some former industrial cities, they now occupy as much space as all other urban green spaces (except municipal forests) combined (e.g. Halle, Leipzig) (Breuste 2007).

Allotment gardens in Germany are about 300–400 m^2 in size and have fruit trees, vegetable beds, flower beds, lawns and a summer hut. In recent decades, there has been a marked change from a pure utility garden to a recreational garden (less labour-intensive vegetable beds, more lawns) and a nature meeting place (Breuste 2007).

Many older allotment gardens are now located in the middle of the city and part of the district like other facilities. At present, however, it is precisely here that a process of displacement is taking place in favour of building uses.

Allotment gardens are important green elements of the city and living spaces (Gilbert 1991). They are the last links between the urban and the countryside life. Mostly the allotment gardeners in allotment garden estates (from a few dozen to several thousand allotments) are organized as associations. The allotment garden is an important green space, cultural factor, place of learning, recreation and meeting. Allotment garden estates in the city are green spaces that make the built-up areas habitable (Schiller-Bütow 1976). Considerable parts of the urban population spend their leisure time as tenants or their family members in allotment gardens. A study by the BMVBS (2008) assumes 4.5 users per allotment garden. The majority of allotment gardeners are pensioners with a relatively large amount of free time. Co-users are their younger family members. No other public green space is only remotely as intensively visited and used as the allotment garden. On weekends in summer, 7–9 h a day are spent here.

As part of the green system of large cities, allotment gardens can, among other things, a. improve the urban climate and air hygiene, increase biodiversity through habitat provision and provide more contact with nature (see also Wittig et al. 1998, pp. 347–348; Endlicher 2012, pp. 197–199; Table 4.11).

Table 4.11 Allotment gardens organised by associations in Germany. (Breuste 2010)

	Number of allotments	Number of allotment garden estates	Area in km^2
Germany BDG	About 1,000,000	14.000	466,40
1. Berlin	67.363	738	31,37
2. Leipzig	40.000	290	9,63
3. Hamburg	36.000	311	14,00
4. Dresden	23.400	366	7,67
5. Hanover	20.063	102	0,94
6. Frankfurt am Main	16.000	115	0,80
7. Magdeburg	16.000	236	0,85
8. Rostock	15.559	155	0,66
9. Chemnitz	15.100	181	0,54
10. Bremen	13.900	160	4,79

4.2.5 Urban Brownfields

Urban brownfields are areas in the city that are temporarily (a few years to decades) unused but previously used. They can be found in industrial areas or on railway sites, but also as independent areas due to the abandonment of use. War destruction, reserve land provision and socio-economic reasons (e.g. de-industrialisation, demographic change, land speculation etc.) are the causes of abandonment. Brownfields are found worldwide, especially in the context of urban-industrial shrinkage (e.g. in Germany, Great Britain, USA, Korea).

Urban brownfield sites have primarily urban-industrial prior uses. Agricultural wastelands on the urban territory are often found on the outskirts of the city as "farmland". They are rather untypical urban wastelands.

Some brownfields are designated according to their previous uses - for example, Housing, agriculture, industry, etc. (e.g. Rebele and Dettmar 1996).

Urban brownfield sites are habitats of intensive anthropogenic changes (e.g. industry), which have often come to a sudden standstill. They are therefore often relatively undisturbed areas for years, on which a natural secondary succession can take place via pioneer stages to pre-forests. They are therefore among the few urban habitats where no management takes place and where their natural development can be scientifically observed. Early on, this has turned urban wastelands into an experimental field for ecology and objects of scientific investigation (Gilbert 1991; Sukopp and Wittig 1998; Rebele and Dettmar 1996; Wittig 2002). Urban brownfield sites are valuable habitats with plant and animal species often only found there.

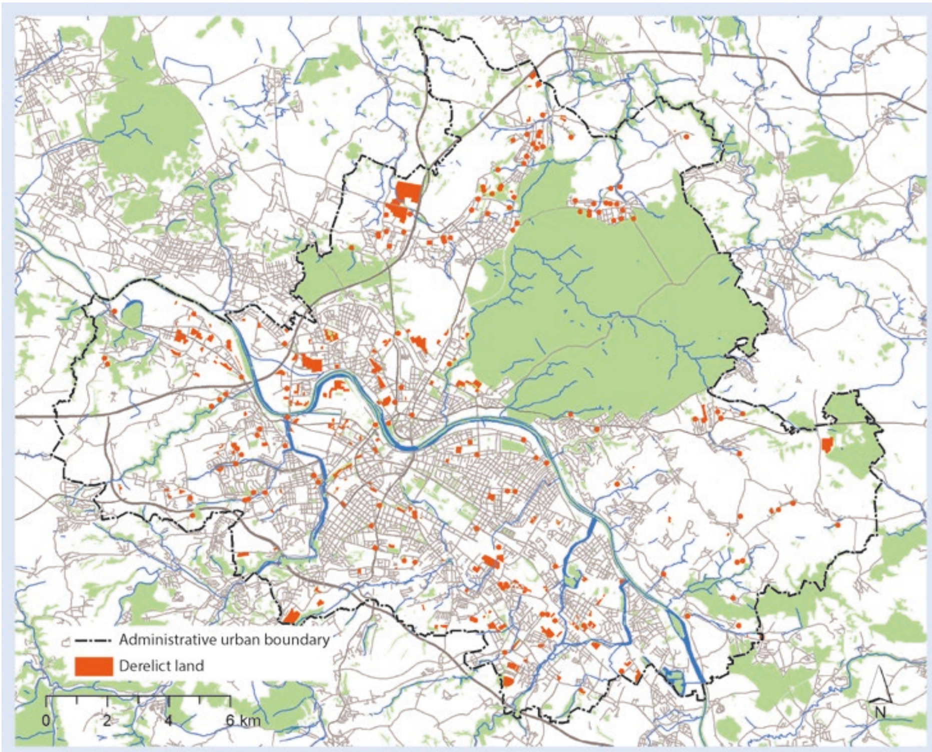

Fig. 4.20 Brownfields in Dresden 2004 (in red), total 1550 ha. (Korndörfer 2005)

On the other hand, nature observations can be made on them and experiences of nature gained that would not be possible anywhere else in cities. This importance of urban wastelands will increase, but it is still not sufficiently recognised and appreciated. Instead, the reuse of brownfield sites is the focus of efforts almost everywhere. This is quite understandable in view of a large number of urban wastelands in some cities (e.g. in Dresden 2004, 1550 ha) (Fig. 4.20).

Particularly long-standing undisturbed brownfields, brownfields in different stages of succession, as well as easily accessible and accessible brownfields in residential areas must be at least partially preserved as a natural experience area and are developed in a targeted manner. To this end, necessary agreements can be made with the owners (in some cases, especially in eastern Germany, these are the municipalities themselves) on temporary (co-)uses simple infrastructural accessibility and exclusion of risks of use (risk of injury).

The acceptance of the "forth nature type" (Kowarik 1992a) and its new possibilities for the experience of nature and the possible integration of succession areas into traditional parks will depend to a large extent on whether it will be possible to overcome existing reservations about "unkempt", "messy" and "unattractive" natural succession

Fig. 4.21 Thüringer Bahnhof district park, developed since 1991 on former railway brownfields. The railroad gardens depicted here show the industrial traces of previous use. (Photo © Breuste 2008)

nature and to make people familiar with this specific nature. This requires more efforts in environmental education, especially in kindergartens and schools. Banse and Mathey (2013) were able to show in a study that the initial stages of succession with herbaceous pioneer vegetation and the final stages with less penetrating dense woody vegetation are least regarded as pleasant and inviting to use, but the intermediate stages with perennials and single trees are certainly better accepted. It is, therefore, possible that the use of urban brownfields for nature experience or as part of public green spaces may require design intervention in order to control succession in a targeted manner.

Brownfield revitalisation refers to the efforts of municipalities to make reuse possible by demolishing buildings and eliminating the risks of use. For this purpose, public funds are used via subsidy programmes. The reuse of brownfield sites as public open spaces often has the aim of establishing public parks on their areas, sometimes as a new type and with reference to previous use (e.g. parks on railway lines - e.g. Eilenburger Bahnhof in Leipzig or Thüringer Bahnhof in Halle/Saale, Fig. 4.21). As a rule, the new parks allow for a considerable upgrading of residential areas in the densely built Wilhelminian-style neighbourhoods that were associated with industries that have since been closed down (Hansen et al. 2012).

Ecological Parks in London – Brownfields as Public Urban Parks

Ecological parks are intended to enable nature development of all kinds on urban sites and the use of these by people for recreation and experiencing nature (*enjoy nature*). Neither traditional park designs nor costly management is necessary.

Citizens design their parks themselves or receive gardening support while respecting urban nature.

Max Nicholson was a visionary who proclaimed as early as 1976 that he wanted to bring nature conservation into the cities through nature experience and he put this into practice. Nicholson and the Trust for Urban Ecology (TRUE) first realized this idea in 1976 at an old truck park near London Bridge in London with the William Curtis *Ecological Park*. In 1986–88 *Stave Hill Ecological Park* was built in the London Docklands. Further parks as *urban wildlife habitats* in London, other cities in the UK and abroad have since been added. Stave Hill is a nine-meter high mound of rubble and debris from the London Docks with 2,1 ha surrounding land in various stages of natural succession, preserved by management.

TRUE manages Stave Hill*, Greenwich Peninsula Ecology Park, Dulwich Upper Wood* and *Lavender Pond Nature Park*. In 2012 TRUE became part of *The Conservation Volunteers* (TVC).

The TRUE *Ecological Parks* take a new approach to urban conservation by introducing people to the not especially spectacular urban nature. They create new *habitats* for plants and animals (*habitat for urban wildlife*), enable urban ecology research, introduce urban citizens, especially children, to urban nature through their own experience (environmental education) and demonstrate creative urban nature conservation off the beaten track, involving citizens as volunteers in management. The *Ecological Parks* on urban wastelands with natural succession and use-related management has proven to be a new idea to value urban nature (TCV 2013).

4.2.6 Structure and Dynamics of Urban Habitats

Through the urban expansion, the urban nature of first and second type has been displaced to the periphery. The nature of the third type, the parks and green spaces, were created together with the new residential areas and urban expansions in interrelated mixed structures. The large urban parks were either created on the outskirts of the city on former agricultural land or in forests. The dense inner-city development allows only little green space in inner courtyards or as front gardens. The belt of low-density, low-density, loose buildings adjoining the inner cities to the outside is much more diverse, with plenty of garden greenery in individual and terraced housing. In the mixture with commercial and industrial areas, there are also more frequently urban brownfields with nature of the fourth type, and a small-scale structure of nature used with varying intensity leads to a wealth of species in the outskirts of the city, which is caused by the structural richness and often exceeds that of the intensively used inner cities and even that of the intensively agriculturally used surrounding area. It is primarily thanks to these spatial patterns of urban nature and biodiversity that cities are often richer in species than their surrounding areas. Despite this general spatial structure of decreasing building density and increasing natural endowment from the inner city to the outskirts, cities generally have a mosaic structure of the four natural types in accordance with their development and land use. Although the total number of vascular plants in the city is high, there are considerable differences between the individual biotope types and also within the same biotope type (Chapter 1).

Urban habitats were and are subject to dynamic change, determined by changes in land use and intensity of use. The abandonment of land use leads to successions and creates new habitat characteristics and structures. The surroundings of urban natural areas often lead to the isolation of the habitats and the endangerment of their populations due to building development and traffic routes. This influence can be mitigated by networking the habitats in the city. The changing habitat structures in the city require ongoing monitoring in order to be able to carry out protection and development within the framework of complex urban nature conservation. Additional challenges arise from climate change, which will especially affect cities. For example, it is expected that the number of tropical days (average temperatures above 250 °C) in Essen will increase from 22 to 76 days in the years up to 2100 (Kuttler 1998). This, combined with summer drought, will lead to changes in the urban flora, the planting of other ornamental plants and the irrigation of parks. Plants that are better adapted to higher temperatures and drought will gain competitive advantages (Chapter 1 and Sect. 5.3; Sukopp and Wittig 1998).

Urban nature is unevenly distributed in the urban area. Some districts have very few and small green spaces; others have large parks, urban forests or private gardens. In every city, the majority of living space is privately owned (agricultural land, private gardens) and is subject to private decisions in design and management. In built-up urban areas, two-thirds of green spaces are often private. Just like public open spaces, they are living spaces, but are given far less consideration in analysis, evaluation and planning. The public and publicly accessible green spaces of cities are also unequally distributed. Depending on location and distance, not all citizens have equal access to them. While this is a design goal in European cities, it is often ignored or accepted in other countries. The green districts are inhabited by the “richer”, the less green by the “poorer”.

Distribution of Urban Parks in Tabriz, Iran

In a study (Breuste and Rahimi 2015), all 132 city parks of Tabriz (Iran) were examined with regard to their accessibility in distance zones, differentiated by park size and category (from urban green spaces to large urban parks) and their social environment. While the provision of urban green spaces is comparable for all districts and all social groups in the city, this is not the case for the larger regional and urban parks. The larger and better equipped the parks are, the more often they are located in a residential environment with higher social status. In the vicinity of the large urban parks, the well-off middle classes dominate over low-income groups with over 75%. The park environments are at the same time characterised by higher land prices and rents. Public green spaces in Tabriz are far more accessible and accessible to the richer classes of the population than to the poorer classes, who, however, make up the majority of the urban population (Fig. 4.22).

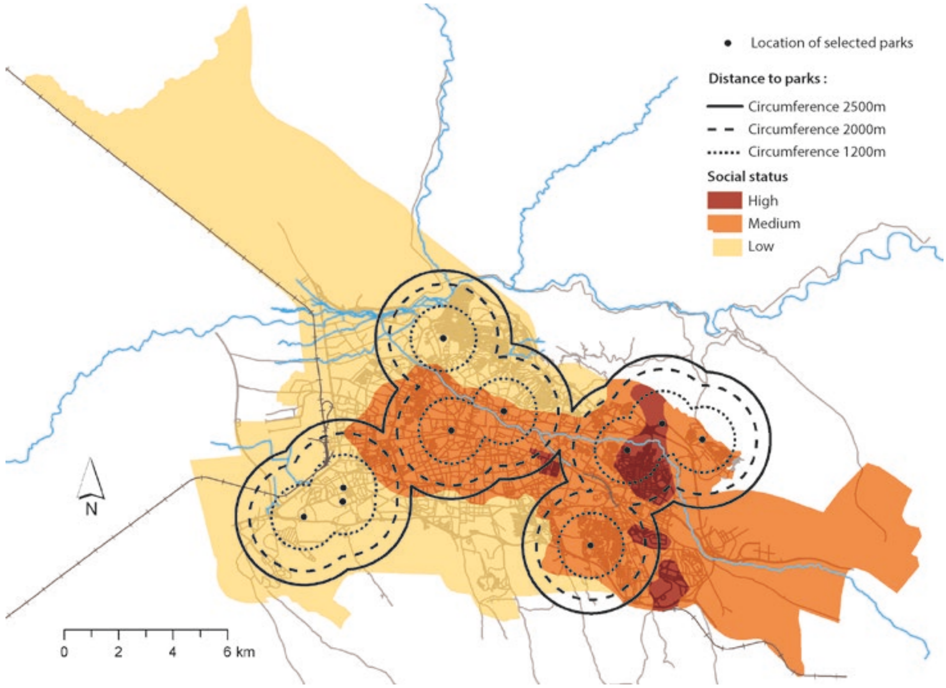

Fig. 4.22 Catchment areas and social status of the residential environment of urban regional parks in Tabriz, Iran (Breuste and Rahimi 2015)

4.3 Management of Urban Nature

4.3.1 Tasks and Objectives of Urban Nature Conservation

Urban nature conservation has special tasks. It protects nature for people in the city. This includes first and foremost making this nature accessible to people and understanding and preserving it as a place for recreation, learning and experiencing nature.

> Nature conservation in the city does not primarily serve the protection of endangered plant and animal species; its task is rather to specifically preserve living creatures and biotic communities as the basis for the direct contact of city dwellers with natural elements of their environment (Sukopp and Weiler 1986, p. 25).

Urban nature conservation can not only make use of scientific approaches and methods, but must also include social science issues, and often even put them in the foreground.

Among the new, urban tasks of nature conservation were

- Recreation,
- Environmental protection and landscape management (water balance, water hygiene, climate, air hygiene, noise protection),
- Educational use as a model and experimental areas,
- Unregulated child's play,
- Identification with the area ("sense of home"),
- Production of agricultural and ornamental plants,
- Bioindication of environmental changes and pressures,
- Ecological research (Sukopp and Weiler 1986; Breuste 1994a).

The urban land use structures are a general, spatial analysis instrument for nature conservation in the city. On their basis, interpreted as biotype types, plant and animal species and their biotic communities are often recorded. Nature conservation management also refers to this urban approach in species and biotope protection programmes.

> In the populated area, it is primarily the uses that shape the distribution pattern of the organism species. The basis of nature conservation work in the city is therefore to systematically record the most important types of land use and to describe their species population and their ecological conditions of existence. The final result shows the extent to which individual uses of certain characteristics contribute to the conservation of species in the populated area. It also becomes clear which uses are characterized by pronounced species poverty and may, under certain circumstances, require measures for 'renaturalization' (Sukopp et. al. 1980, p. 565).

The land use-related biotope survey became in Germany the standard procedure with the 1986 basic programme for area-wide biotope mapping in populated areas (Arbeitsgruppe 1986). This basic programme was revised again in 1993, but in principle corresponds to the methodological approach of 1986 (Arbeitsgruppe 1993). With this basic programme, between 1978 and 1986, area-wide biotope mapping in populated areas had become established as the standard procedure for developing ecological programmes for nature conservation in cities in Germany (Breuste 1994a, b).

Although the "flow chart of biotope mapping in populated areas" (Schulte and Voggenreiter 1986; Schulte et al. 1993; Frey 1999) can also be clearly emphasized as areas of evaluation of the mapped biotope types "experience of nature and nature experience" and "townscape/village/landscape", this area has only recently been dealt with more intensively (Reidl et al. 2005).

In contrast to the scientifically exact recording of plant and animal species and their evaluation according to rarity and endangerment, the social sciences are required here as an important component of urban nature conservation. Biotope mapping, however, is usually done by biologists and landscape ecologists. Social science studies should be involved in nature conservation investigations and justifications right from the start.

Trepl (1991) points to the need to expand the justifications for nature conservation, which also makes nature conservation research an object of social science:

- Importance for urban design (aesthetics, preservation of tradition, etc.),
- Importance for recreation,
- Importance for the "free" use of "open spaces", especially by children and young people,
- Importance for education, training.

Accepted nature can be protected for the urban dweller, unaccepted nature only against the urban dweller. To protect nature in the city against the urban dweller should be the rare exception with special justification (e.g. protection is not possible elsewhere) (Breuste 1994a). The exclusion of humans from nature to be preserved should be the rare exception in the city. What consequences does this have for nature conservation? Which nature should be protected and for what reason?

> In the built-up area ... the focus is not on the identification and preservation of natural vegetation and the fauna associated with it, but rather of those biocoenoses that have spread over large areas with the urban development of the last 100 years (Sukopp 1982, p. 60).

For all urban areas, spatially differentiated nature conservation objectives specific to settlements are to be determined. The same structure, or the same species spectrum of a biotope outside and in areas enclosed by buildings, cannot lead to the same nature conservation objectives applying to them. Even near-natural habitats in the settlement area cannot be treated according to the general objectives for such areas from the outside (Plachter 1990, 1991).

The answers to the questions

- What is the value of a tree in a street?
- From what point of view are small green structures important?
- Can this value be compared with that of a rare insect species in the city's alluvial forest?
- Does rarity increase the worthiness of protection?
- Why do rarities enjoy special protection?

can only be found by taking into account the specifics of development, location, use and functions of nature in the settlement area.

The definition of generally applicable, settlement specific nature conservation objectives has not yet been completed. Ecosystem services and thus the usefulness of nature for humans now seem to provide orientation for urban nature conservation.

4.3.2 Practical Nature Conservation in the City - Worldwide

For urban nature conservation, all levels of scale, from the house and garden plot to the urban landscape, are equally important. They are part of the nature conservation concepts of the cities. Many small changes in use, for example, more near-nature management in a public park or garden or the felling of trees in an avenue, also bring about ecological changes at the level of the city as a whole. Such changes can be essential for animals that operate on this larger scale. Habitat loss and isolation as well as the emergence of new habitat structures must be considered in nature conservation concepts. In a complex habitat mosaic, natural patches can complement each other, unusual ones can be replaced in their function by others, and some are irreplaceable. This eco-functional consideration of habitat patterns and networking of urban habitats is of great importance for practical urban nature conservation.

Auhagen and Sukopp (1983) made the first attempts to define urban nature conservation objectives using the example of Berlin (West) at the beginning of the 1980s (principles of ecotope and species protection).

Guidelines for the implementation of nature conservation in urban planning

In 1987, principles were developed for the "Guidelines for the implementation of nature conservation in urban planning" (Sukopp and Sukopp 1987, pp. 351–354), which are still fully valid today.

Principle of.

1. Priority areas for environmental and nature conservation,
2. Zonally differentiated priorities of nature conservation and landscape management,
3. Consideration of the development of nature in the city center,
4. Historical continuity,
5. Maintaining large continuous open spaces,
6. Networking of open spaces,
7. Preservation of differences in location,
8. Differentiated intensity of land use,
9. Maintaining the diversity of typical elements of the urban landscape,
10. Preventing all avoidable interference with nature and landscape,
11. Functional integration of structures into ecosystems,
12. Creation of numerous channels for air exchange,
13. Protection of all life-supporting factors.

> In short, almost every attempt to protect 'nature' in the city has paradoxical effects. The only sensible way to protect nature in the city is to let the 'weeds' grow where and as long as they do not really interfere with everyday activities (Hard 1998, p. 41).

This drastic formulation by Hard (1998) at least indicates that nature development in the city has an intrinsic value and should not be formally destroyed for reasons of order and cleanliness alone. This way of thinking is slowly beginning to take hold in green spaces and municipal nature conservation administrations, not least with the support of numerous NGOs. Less intervention means more nature development and this without costs, for example, urban forest. What is also missing is the acceptance of spontaneous nature by the urban dwellers, a process that should be promoted in the long term through environmental education.

Species and Biotope Protection Programme Munich

The Species and Biotope Protection Programme (ABSP) in Bavaria is a nature conservation concept. Based on biotope mapping and species protection recording, it analyses and evaluates all areas of importance for nature conservation. It derives from the results goals and proposed measures, which have been developed and applied for more than twenty years for districts and cities. The Bavarian State Office for the Environment coordinates this work. The ASBP is carried out according to a uniform standard by independent planning offices and specialists on its behalf. The results of the ABSP are used for the preparation of landscape and green space plans or in contractual nature conservation. They are an important basis for nature conservation authorities and local authorities.

The dynamic development of the city of Munich in recent decades has led to the designation of new commercial and residential areas. Ecologically significant areas potentially important of nature conservation (e.g. parts of the open forest Allacher Lohe, the railways' yard area or parts of the Panzerwiese heartland) were also taken up by construction measures. Instead of using ecologically significant areas on the outskirts of the city, priority for building developments should be given to (already built-up) areas that are no longer used. Wetlands, rough meadows and dry habitats in the city are legally protected by several nature reserves. 44 areas with a total of approx. 155 ha have been designated as protected landscape components (various types of forest, litter meadow remnants, heath land remnants, hedges and field shrubs, fallow and succession areas, old tree populations and old parks). Since 1964, 18 landscape protection areas (approx. 5150 ha) have been designated. Sealing is to be reduced. In particular, the preservation of historically developed biotopes has priority over a new establishment. For this purpose, conceptual cooperation with the surrounding communities (e.g. regional pool of compensation area) is practiced.

Munich is striving to develop a biotope network system in the settled area with a focus element:

- Development of a dry biotope network,
- Conservation and optimisation of wetland habitats,
- Development of a network of woody biotopes,
- Conservation and development of all forests and woodlands in the urban area, especially those of special importance for avifauna, deadwood-populating insect species, cave breeders, bat quarters,
- Preservation and optimisation of the running water system including the springs with spring streams of the city (Bayrisches Landesamt für Umwelt 2014).

Protection of urban biodiversity—the example of Singapore

The 712 km^2 large island city-state Singapore had 5.7 million inhabitants in 2018 with a very high population density of 7126 inhabitants/km^2. The National Park Board is responsible for four nature reserves (3347 ha), 2269 ha urban green spaces (59 regional and 255 district parks) 2664 ha street green spaces, including more than one million trees and 1679 ha used open land. Only 200 years ago, the island was completely covered in forest (82% tropical forests, 5% swamp forests and 13% mangrove forests). In 1992, a first *Singapore Green Plan* was drawn up, which was continued until 2011. It has since been supplemented by the *Singapore Blue Plan* (Fig. 4.23). Singapore has adopted a *National Climate Change Strategy*, a *National Biodiversity Strategy* and an *Action Plan*. In addition, there are ten-year *concept plans* and five-year *master plans* for urban development, which include the protection of biodiversity. The "City In A Garden" concept envisages the embedding of the city in a natural environment managed by different parties and the protection of the remaining tropical forest. The *Singapore Index of Cities Biodiversity*, which was developed in 2012, is intended to encourage other cities to evaluate and monitor their natural environment and nature management themselves. More than fifty cities around the world are already applying the evaluation concept. Twenty-three quantitative indicators will provide information on urban biodiversity, ecosystem services (water regulation, climate regulation, recreation, education) and their management. Since 1992, Singapore has thus been one of the pioneers in the protection of urban biodiversity worldwide (Davisson et. al. 2012) Fig. 4.24.

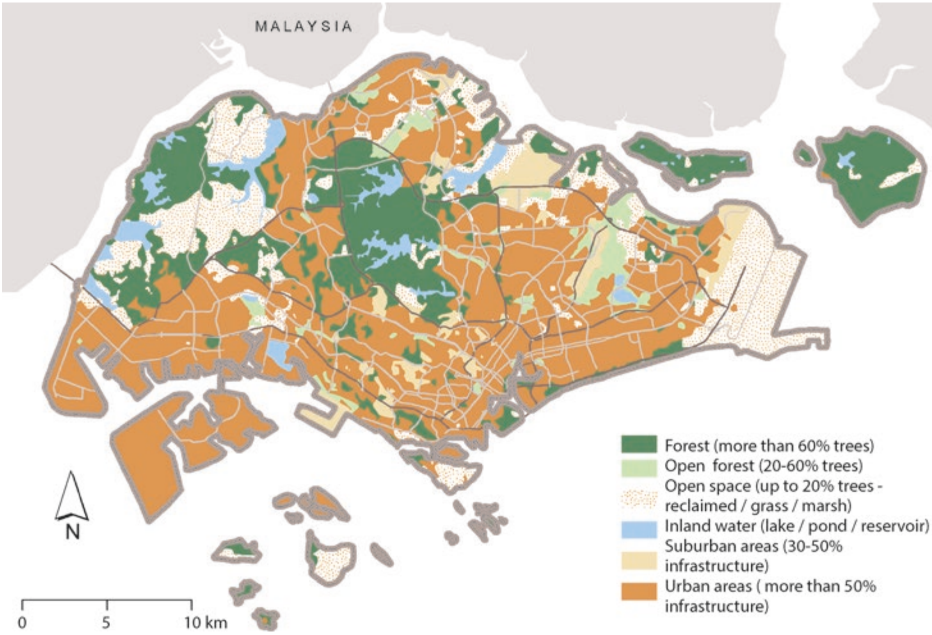

Fig. 4.23 Urban nature as part of the urban structure in Singapore. (© Design: J. Breuste, cartography: W. Gruber; source: Davison et al. 2012)

Fig. 4.24 Table Mountain National Park, Cape Town, South Africa. (© Breuste 2006)

National Park in the City - Example Table Mountain National Park (TMNP) Cape Town, South Africa

The Table Mountain National Park (TMNP) was established in 1998 after earlier conservation efforts (1963 Table Mountain Nature Reserve) to protect the unique endemic flora of the Cape Floral Region (UNESCO Cape Floral Region World Heritage Site), but also because of the special landscape of the Cape Peninsula. On three sides it is surrounded by the growing city of Cape Town with its 3.7 million inhabitants, to whose 2455 km^2 urban area it belongs with 221 km^2 (9%).

The efforts of the park administration consist of organising the large streams of visitors and in the preservation and development of the particularly rich biodiversity (2200 mainly endemic flowering plants, in comparison the whole of Great Britain has 1492 flowering plant species). The National Park is a globally important biodiversity hot spot. Invasive plants are reduced by deforestation (e.g. of commercial *Pinus pinaster* plantations) or fire management to give indigenous flora (fynbos and afromontane forest) development opportunities (Fig. 4.24).

With its educational opportunities, the park plays an important role in nature education for the population of Cape Town. More than one million people visit it every year, many of them international tourists. The National Park in the city is easily accessible through a variety of trails, but especially through the cable car to the 1067 m high Table Mountain (since 1929). The majority of the inhabitants of the large black townships see the mountain every day, but most have never visited it (Yeld and Barker 2003).

4.4 Conclusions

Urban nature is complex, diverse and determined by man. The changes in natural conditions lead to special habitat characteristics that do not occur in the surrounding area. These include more fragmentation, warmer and drier habitats, changing intensity of use and much more. In cities, humans also provide substitute habitats for species that often have few habitats left in the intensively used agricultural landscape of the urban surrounding. This also explains the relative species diversity in cities. Ubiquists, but also specialists, find habitats in cities.

The diversity of urban habitats can be divided into four easily describable nature categories ("nature types"; Kowarik 1993). They all have their justification in the nature spectrum of cities. Urban trees along streets, on squares and in urban forests, for example, enable a wide range of ecosystem services that help people to improve human living conditions in cities (shade, temperature reduction, increase in humidity, light attenuation, habitat for many animals, etc.) They allow an aesthetic and creative enhancement of urban spaces without requiring a lot of space in the competition for space. Especially the self-developing urban-industrial succession nature is still not a valued part of urban nature in the consciousness of the urban dwellers. This urban nature manages without planting and care, is optimally adapted to the conditions of the location and can be an enrichment of the spectrum of habitat spaces in cities. Animals are often less noticed in cities or only perceived when they become pests (health, buildings etc.) or appear as spectacular species (wild boars, foxes, moose etc.). They are, however, permanent inhabitants of our cities.

The habitats are in a constant state of change due to changes in land use and urban expansion. Climate change will also be a particular challenge for flora and fauna. Cities are the first experimental fields to show how flora and fauna react to these changes. The dynamics of urban habitats must be given special consideration in urban nature conservation. Urban nature conservation is not only the continuation of nature conservation efforts from outside the city into the city. It must also take into account a paradigm shift that consists of protecting nature for the urban dwellers and not against them. The task of bringing nature in the city closer to the people in the city and turning urban nature into places of learning and nature experience alongside recreation is of particular importance. For the majority of people in many countries, the city is the most important space for dealing with nature and learning from and about it.

Urban nature is neither primarily fragile nor is it a risk space for people. In this area of conflict, however, it is often perceived in cities. Maintaining nature for the protection of urban nature is only necessary where we have good reasons for wanting to enforce and preserve a very specific nature against its natural development and where we aim for accessibility and risk reduction. Nature maintains itself, even in the city, independently if it is allowed to do so. Nor does it need to be perceived per se as a risk space (dense, dark, confusing). It is a space for recreation, inspiration, relaxation and learning. For this, it is needed as a green infrastructure like other important parts of the urban structure. We need more nature of all kinds in cities, in a better distribution, accessible to all, in order to make their services available to every urban dweller. Species and biotope protection concepts, but also the commitment of the many individual urban citizens to nature in their city helps to achieve this.

Questions

1. What are unfavourable site conditions for plants in the city in comparison to the urban environment?
2. What are the reasons for the richness of species and the attractiveness of cities as habitats?
3. What characteristics do animal species favour when settling in the city?
4. Why in urban ruderal black locust forests only 50% of the woods are indigenous?
5. Why are brownfield sites valuable habitats?
6. What is the main task of urban nature conservation?

Answer 1

- The chemical milieu of the soil is often unfavourable.
- The chemical milieu of the air is usually less favourable (gases, dust etc.).
- The enjoyment of light is reduced at many locations.
- The water balance is usually more difficult. Higher temperatures cause water losses. Soils are often reduced in their water storage capacity (low soil moisture content due to compaction).
- Soil sealing and compaction impede the colonisation by plants.

Answer 2

- Structurally diverse urban landscape,
- Nutrient-poor, dry and warm biotopes/habitats,
- Protected and safe habitat.

Answer 3

- Short escape distance,
- Adapted to small structured areas,
- Adaptation to richly structured, rocky terrain,
- Similar food requirements as humans (omnivores),
- Specialisation in certain foods or materials that are part of human needs,
- High reproduction rates,
- Small body size,
- No great competition or disturbance to humans,
- Independent of high air or soil moisture,
- Not dependent on water or clean water,
- Not very sensitive to immissions.

Answer 4

The pioneer woody plants of the tree and shrub layer are too weak in competition with black locust (*Robinia pseudoacacia*) to displace it.

Answer 5

- High species diversity, especially in the pioneer stage,
- Special site conditions with plant and animal species often only found here,
- Observation of natural processes (succession) is possible (nature experience).

Answer 6

They preserve living beings and communities as a basis for the direct contact of urban dwellers with natural elements of their environment in a targeted manner.

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What Do Urban Ecosystems Do for the People in the City?

5

Dagmar Haase

Abstract

This chapter looks at ecosystems and the services they provide for the well-being of people in cities, so-called ecosystem services, but also at the biophysical processes, structures and functions that contribute significantly to the creation of ecosystem services and their maintenance. For this purpose, selected methods for measuring, monitoring, statistics, modelling and evaluating these structures, processes and functions are presented for these individual components—climate, water, vegetation, and soil. In addition, basic methods for the assessment and valorization of ecosystem services are presented. Using information boxes, case study and excursus, current approaches to the analysis and investigation of components of urban ecosystems and urban ecosystem services will be illustrated.

5.1 Urban Ecosystems and Their Services

Urban ecosystem services (i. a. Boland and Hunhammar 1999; TEEB 2011; Haase et al. 2014) describe ecosystem functions (processes, structures) which are provided by natural components of urban ecosystems (*providers*) and which are used by people/inhabitants of a city or urban region (*beneficiaries*). Ecosystem services describe the direct or indirect benefits that humans derive from various services provided by nature. Examples of urban ecosystem services are the provision of fresh and drinking water through precipitation and natural filtration of soils, the regulation of peak runoff during extreme precipitation events and the resulting reduction of flooding in urban areas, the production of food (fruit, vegetables) in urban (small) gardens, the pollination of fruit blossoms by city bees or the provision of fresh (cool) and unpolluted air in open and recreational areas (see Cowling et al. 2008). Thus, the concept includes data on ecosystem functions in

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space and time (*factual level*, *space level*, *time level* according to Grunewald and Bastian 2015), values (*value level*) and decisions on land use and management (*decision level*).

The concept can be seen as a further development of the approach of landscape functions (Bastian et al. 2012), in which ecosystem structures and processes are quantitatively recorded and evaluated. The evaluation is carried out on the one hand with regard to their performance potential to positively influence human well-being—this already included the principle of landscape functions—but on the other hand also, if possible, in the monetary sense: What does the artificial production/replacement of the natural service cost and how much is this replacement worth to us? How can health costs be reduced by providing clean air and recreational green spaces for people in the city?

The first approaches to the ecosystem services approach date back to the late 1990s and early 2000s in the European research landscape (DeGroot et al. 2002) as well as the groundbreaking publications of Costanza et al. (1997) and Daily (1997). While ecosystem services in the 1990s and early 2000s were primarily a scientific concept that dealt with the service and benefit potential of ecosystems for humans, a number of science policy "science-policy interface" initiatives and organizations have developed over the last ten years, which—and this not primarily for urban areas—have contributed significantly to the introduction and further dissemination and institutionalization of the concept of ecosystem services.

Four groups of urban ecosystem services are distinguished: supporting, supplying, regulating and cultural services (MA 2005; TEEB 2011 and CICES classification under https://cices.eu/; Fig. 5.1). Supporting services describe processes of soil formation, photosynthesis and nutrient cycling, and are thus also basic prerequisites for other ecosystem services. Supportive services include goods produced by ecosystems or with their

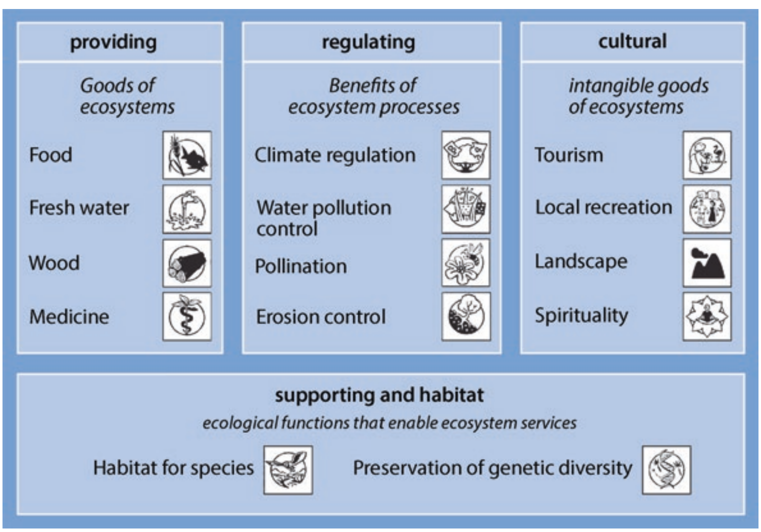

Fig. 5.1 Urban Ecosystem Services TEEB. (TEEB 2011)

help, such as food, freshwater or wood. Cultural services include the functions of green spaces. These provide a space for physical and mental recreation and offer the opportunity to experience nature. They convey a sense of home, but also knowledge about the environment and culture. Regulatory services tend to have an indirect benefit for humans by influencing certain areas and processes of ecosystems. These include the mitigation of flood hazards through the water retention potential of floodplains, the filtering effect of soils for the quality of groundwater or the reduction of concentrations of air pollutants from trees and green spaces in urban areas (Elmqvist et al. 2013; Fisher et al. 2009; Grunewald and Bastian 2015).

Ecosystem services in studies by science-policy initiatives and organisations

1. The **Millennium Ecosystem Assessment (MA** 2005**)** of the United Nations (UNEP), is the most comprehensive study to date on the status of ecosystems and their performance, alongside the TEEB study (TEEB 2011).
2. **The** study **The Economics of Ecosystems and Biodiversity (TEEB)** was launched by the G8+5 with a stronger focus on the economic dimension and valuation of ecosystems for different demand and user groups. For the first time, TEEB also includes a separate study for urban ecosystems.

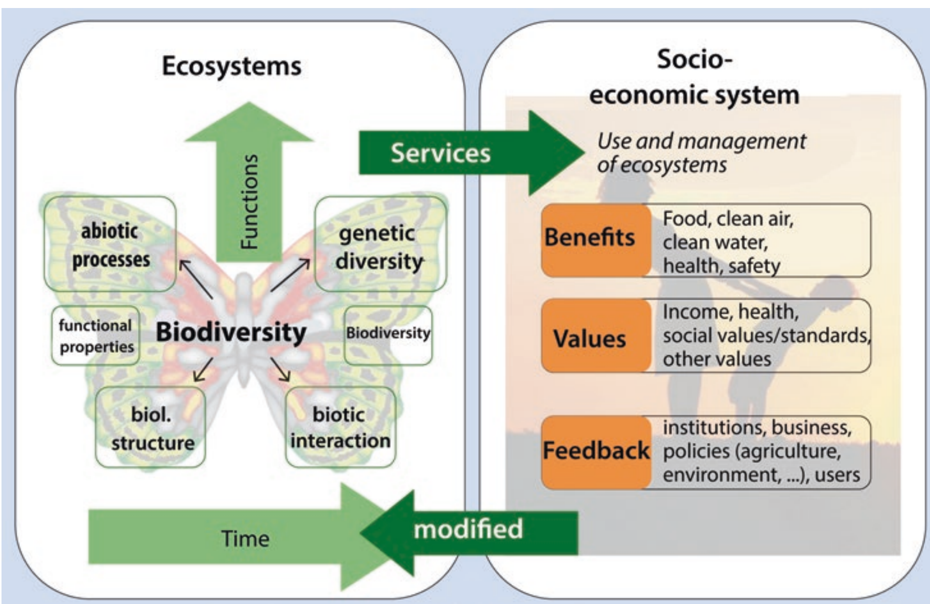

Fig. 5.2 The relationship between urban ecosystem services and human well-being. (Albert et al. 2014; Copyright at the Helmholtz Centre for Environmental Research UFZ, Leipzig)

3. The **Cities and Biodiversity Outlook**, is the first worldwide report on the processes and effects of urbanisation on the natural environment and global biodiversity.
4. **National studies** such as the UK National Ecosystem Assessment in the UK (UK NEA 2009–2012) and the **TEEB Naturkapital Deutschland**, the exploratory study for the implementation of TEEB Germany, currently in progress (Albrecht et al. 2014).
5. **IPBES—International Science-Policy Platform on Biodiversity and Ecosystem Services** brings together global and national activities and interests on ecosystem services in Germany institutionally and provides a platform for discussion.

Regulatory and cultural ecosystem services are particularly important in the city, as they have a direct impact on human health and well-being: Urban trees cool the surrounding air, enrich it with oxygen and water vapor, and also provide an aesthetic quality. Both ecosystem functions can be directly perceived by city dwellers. In contrast, the performance of the urban soil as a plant growth site can only be made usable for humans through an active form of plant production (e.g. Horticulture or urban agriculture). Haase et al. (2014) show this "hierarchy of meaning" of urban ecosystem services in a review article. Here, the number of studies on regulated ecosystem services surpasses all other ecosystem services, followed by cultural ecosystem services in second place.

Table 5.1 Urban ecosystem services and indicators of quality of life in the dimensions of sustainability. (own compilation from Haase 2011, based on the Millennium Ecosystem Assessment MA 2005; TEEB 2011; Fisher et al. 2009 and Santos and Martins 2007)

Sustainability dimension	Urban Ecosystem services	Component of urban quality of life
Ecology	Air filtration Climate regulation Noise reduction Rainwater drainage Water supply Wastewater treatment Food production	Health (clean air, protection against respiratory diseases, heat and cold death) Security Drinking water Food
Social affairs	Landscape Recovery Cultural values Environmental Education	Beauty of the surroundings Recovery, stress reduction Intellectual enrichment Communication Residential location
Economy	Food production Tourism Recovery function	Income maintenance Investments

Without ecosystem services, public health and human quality of life as we know it today would hardly be possible in the city (Rall et al. 2017; Haase 2011; Guo et al. 2007; Fig. 5.2). There are studies that attempt to express urban ecosystem services in monetary terms (by means of *hedonic pricing* or *revealed preferences*, *willingness to pay*, market prices, or *avoided costs*), in order to illustrate the economic significance of dependence on nature on the one hand, but also the economic potential of urban nature especially in cities (Gómez-Baggethun et al. 2010; Bastian et al. 2012). But also, a non-monetary model and valuation approaches, as presented in the following, are very well suited to emphasize the importance of urban ecosystem services.

In terms of content, urban ecosystem services are closely related to the concept of quality of life in cities (Schetke et al. 2012; Santos and Martins 2007; see also the catalogue of indicators for determining the urban quality of life of the Sustainable Seattle Initiative, since 1991,) and the Happiness Index (2015). This concept is based on the three dimensions of sustainability and expresses a "need" of city dwellers for services to satisfy the needs of daily life, which can then be partially met by ecosystem functions. The complementarity and interdependence of the two concepts is shown in Fig. 5.2 and Table 5.1: As long as there is no human demand for the results (*outputs*) of ecosystem processes, water supply, air filtration, carbon storage or plant growth are ecosystem functions and represent potentials for ecosystem services (*potential*). As soon as humans need or use the results of ecosystem processes to secure and/or improve their quality of life, that is, as soon as there is a *demand*, an ecosystem function becomes an ecosystem service (Breuste et al. 2013; Haase 2013). The essential components of human quality of life are presented in Table 5.1 and ordered according to the three dimensions of sustainability (from the perspective of ecology) or vulnerability (from the perspective of man/society):

From this listing, indicators for urban ecosystem services can be derived, which combine the two concepts, for example, the indicator "supply of clean drinking water to the urban population" is a measure for the ecosystem service "water supply" according to the demand for "drinking water". Or the indicators "Green space per inhabitant in m^2" and "Accessibility of the next green space in minutes/meters" are each a measure for the recreational service of urban ecosystems and the health of city dwellers.

Table 5.2 presents approaches and general methods for quantifying and modelling the above-mentioned urban ecosystem services. The quantitative estimation of the services and performance of an urban ecosystem can provide an important basis for urban and landscape planning (Elmqvist et al. 2013). The compilation includes approaches for determining the demand as well as the provision of the various ecosystem services. The approaches to quantification range from surveys or interviews to bio-physical models and are mostly quite data-intensive, which means that there is comparatively little reliable and comparable data on ecosystem services in cities (McDonald et al. 2019; Haase 2012, 2014; Elmqvist et al. 2013; Breuste et al. 2013). Detailed information on the individual models can be found in the continuation of Chapter 5.

Table 5.2 Identification and quantification approaches and models for the quantitative determination of urban ecosystem services. (Haase 2012)

Service	Meaning	Model
Food	Areas for arable farming	Statistical models, agricultural statistics
Raw material	Building and heating materials	Carbon storage models, forest growth models
Water	Surface and groundwater	Physical 2D/3D and empirical water balance models
Medicine	Medicinal plants for the pharmaceutical industry	Habitat models, population models, genomes, DNA sequences
Air pollution control	Trees provide shade, filter pollutants from the air. Forests store precipitation. Vegetation produces latent heat or evaporative cooling by transpiration	Empirical models (Bowler et al. 2010), Tree database i-Tree (i-Tree 2015), CiTree database
Carbon Storage	Trees and other plants bind $_{CO2}$ from the atmosphere through their growth	Tree database i-Tree, CiTree database, tree function evaluation tool UFORE; laser scanning, allometric models (Strohbach and Haase 2012); InVEST (Natural Capital Project)
Moderation of extreme Weather	Ecosystems and overgrown surfaces reduce the damaging effects of extreme events (floods, heat, drought, landslides)	2D/3D flooding models, risk assessment models
Wastewater treatment	Microorganisms in soils and wetlands degrade pollutants and waste	Degradation curves, metabolism models
Erosion control, soil fertility	Vegetation cover retains soil particles and thus prevents their erosion	General soil erosion equation ABAG or USLE (American version), Erosion 3D, SWAT (Soil and Water Assessment Tool)
Pollination	Enables fruit growth and harvest	Empirical models, InVEST (GIS-based modelling tool for the assessment of ecosystem services), Individual-based models (IBM)
Pest control	Regulation of pest infestation	Dissemination models, individual-based models (IBM)

(continued)

Table 5.2 (continued)

Service	Meaning	Model
Habitat	(Surplus) habitat for organisms	Biomapper (a tool for modelling the ecological niche), regression models, habitat models
Genetic diversity	Gene pool for natural and agroecosystems	Genome, genetic footprint, DNA sequences, diversity indices
Soil filter	Purification of water	Soil and Water Assessment Tool (SWAT)
Buffer capacity	buffers acidic and basic inputs to soil and water	Acid and base neutralization capacity
Nutrient delivery	provides nutrients to organisms through mineralization and solution	Soil and Water Assessment Tool (SWAT)
Recreation, physical and mental health	Contributes to physical and mental health and stress management	Distance and accessibility models, network analysis with GIS, Participatory GIS (PPGIS), Maptionnaire (https://maptionnaire.com/), URGE criteria catalogue (URGE-Team 2004)
Tourism	Economic values, source of income	Cost-distance models, hedonic pricing, *willingness-to-pay*
Aesthetics, Inspiration	Source of language, knowledge and appreciation of the natural environment	Hedonic pricing, survey, interview, painting
Spiritual Experience	Religion, local identity, affiliation	Questioning, interview, maps of sacred places

5.2 Urban Ecosystem Services and Urban Land Use

Worldwide, urban land use accounts for a maximum of 4% of the earth's surface, but more than half of all people today live in cities, and the trend is rising (Seto et al. 2011; Haase et al. 2018). As already mentioned in Sect. 1, about 95% of global cumulative gross domestic product (*GDP*) is currently generated in cities and urban/urban settlements. The conversion and sealing of semi-natural areas and farmland into settlement and transport areas is one of the most significant, mostly negative environmental impacts worldwide (Chapter 1). It is often irreversible. The resulting rural-urban gradient is characterised by intensive land development characterised by the high pressure of use, with increasing sealing towards the centre of cities (Haase and Nuissl 2010). Sealing maxima are located

Fig. 5.3 Settlement growth, redensification and land sealing (South Leipzig, *top*) and land use dissolution/perforation through shrinkage (millennium field in Leipzig, *bottom*). (Photos© Haase)

not only in the inner city but also in peri-urban residential parks and commercial areas (Haase 2013). Sealed or partially sealed areas can no longer or only to a limited extent provide the ecosystem services described above (Haase and Nuissl 2007; Fig. 5.3).

In particular, the land use types of urban open and green spaces and forests provide various ecosystem services for urban residents. For example, forest and park areas contribute to the regulation of extreme temperatures by reducing surface radiation and temperature through shading and increased evapotranspiration (Pauleit et al. 2018; Bowler et al. 2010; Kottmeier et al. 2007). In addition, all types of urban green spaces (including urban brownfield sites) and water bodies can contribute to the recreation of city dwellers. Unconstructed alluvial meadows serve primarily to regulate floods (Haase 2003). Unsealed areas are suitable for rainwater retention and infiltration and can thus regulate the rapid surface runoff of heavy rainfall events. In addition, rainwater infiltration systems specially constructed for this purpose in settlement areas can also be used for in-situ rainwater harvesting (Haase 2009). With reference to the recently increasing debate on man-made climate change, urban green spaces (especially trees and forests) can contribute to local carbon storage. Recent studies, however, speak of only 1–2% of emissions from cities that can be neutralized by urban vegetation (Richter et al. 2020 for Berlin; Strohbach and Haase 2012 for Leipzig; Nowak and Crane 2002 for US cities). Despite the small proportion, tree-covered land uses contribute to reducing a city's "ecological footprint".

Currently, in addition to urban growth, another process, often described as contrary, is increasingly coming to the fore: urban shrinkage. Cities characterized by economic problems and population loss are characterized worldwide by a reduction in the intensity of urban land use, vacancies and the fallow of land (Fig. 5.3; Haase and Nuissl 2007). This land-use perforation (Lütke-Daldrup 2003) offers a unique opportunity for the revitalization of (inner) urban areas (Lorance Rall and Haase 2011) and, in connection with this, the "revitalization" of ecosystems and urban nature (Haase 2008). A prominent example of the simultaneity of urban growth and urban shrinkage is the city of Leipzig in the new federal states (Kabisch et al. 2019; Wolff et al. 2016). The following examples of the analysis and evaluation of urban ecosystems and ecosystem services refer primarily to studies conducted in Leipzig.

Population Growth and Land Use in Europa

In most European cities the population is growing. In an increasing proportion of European cities, the population is declining, mainly due to migration and low fertility. In all European cities, however, the number of households is rising, a consequence of increasing individualisation. It is unclear how this population behaviour affects land use in and around cities. It must be assumed that the urban area increases if the total number of persons and/or households and thus the demand for more housing increases. Haase et al. (2013) show that urban area increases if there is an absolute growth a) in the number of households and b) in per capita living space even in cities where the number of households is declining. This means that shrinking cities do not necessarily have a decreasing land consumption, but that it can increase further (Fig. 5.4).

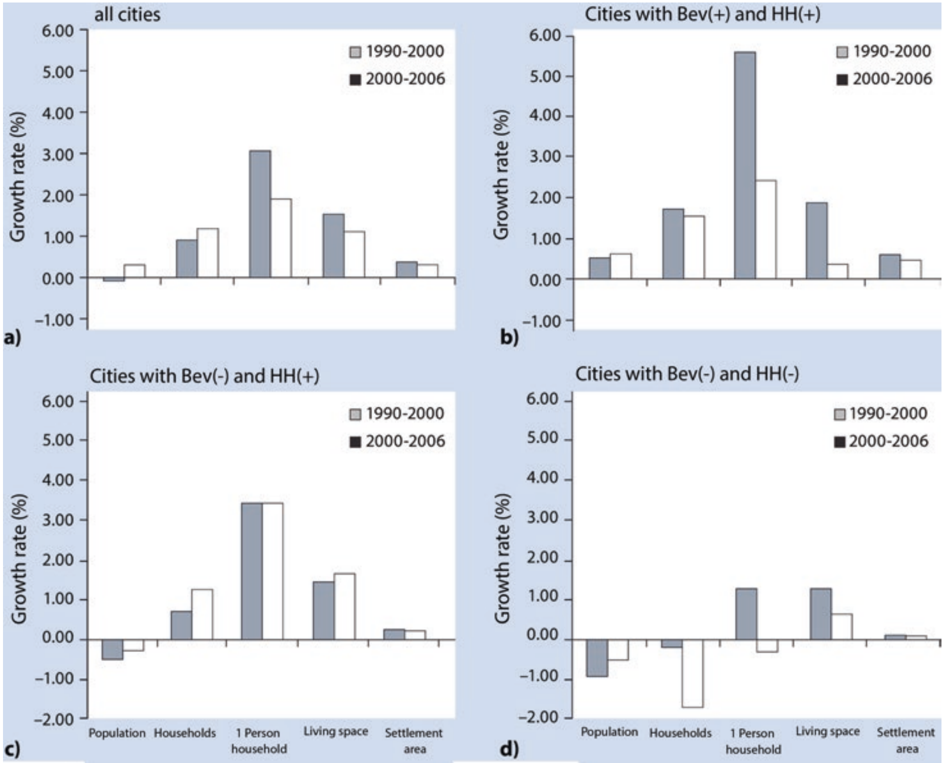

Fig. 5.4 Population growth and land use in Europe. (Haase et al. 2014)

5.3 Individual Consideration of Selected Important Urban Ecosystem Services

In the following sub-chapters, important urban ecosystem services and the ecosystem structures and processes that make them possible are presented and discussed. Particular attention is paid to those services that have been identified as particularly important for cities in international and national review studies (Haase et al. 2014; Kabisch et al. 2014; Elmqvist et al. 2013; TEEB 2011). The following presentations should be examples from a broader spectrum.

5.3.1 Local Climate Regulation Through Urban Ecosystems

Urban ecosystems differ significantly from the surrounding countryside in terms of climate and weather patterns: they are often warmer, have more precipitation, less frost and snow and have a longer vegetation period (Chapter 3) (Table 5.2). The changed anthropogenic albedo values of urban surfaces lead to heat storage and increased long-wave heat radiation of urban surfaces, resulting in the formation of the "*urban heat island*"

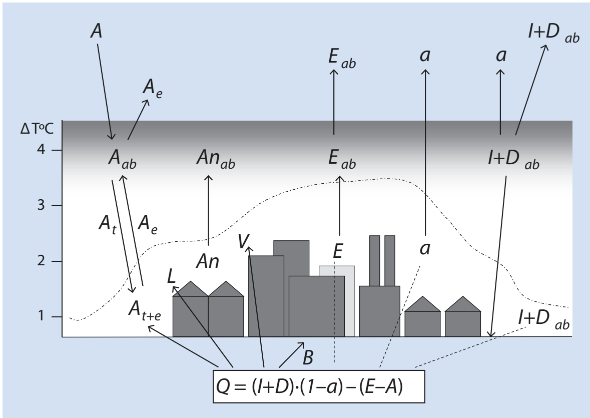

Fig. 5.5 Simplified schematic representation of the radiation and heat balance of a large city. The different parameters represent a simplified radiation balance equation as well as the relations between the atmosphere, land use, soil and the urban haze. The urban haze dome and its absorbing function (*grey*) and the urban heat island are also shown. *Q* radiation balance, *I* direct radiation, *D* diffuse celestial radiation, *a* albedo, *E* thermal radiation from the earth's surface, *A* counter radiation from the earth's surface, *B* soil heat, *L* sensible latent heat, V latent heat, *An* anthropogenic heat production, *ab* absorbed, *t* transmitted, *e* emitted. *Grey* urban haze bell, *dashed line urban heat island* (*UHI*). (Reader 2008; modified in Haase 2012)

(*UHI)* (Fig. 5.5; Kottmeier et al. 2007; Endlicher 2012). Anthropogenically released heat from combustion or energy conversion processes in industry and transport also contributes to this, but in cities at mid-latitudes, this only contributes to approx. 5% of the heat island effect (Fig. 5.5). Nevertheless, particulate emissions (PM10, 2.5 < 1) are particularly involved in the formation of so-called haze bells. In spring 2014, this led to a limitation of passenger traffic in the Paris metropolis, a measure that is applied in Chinese megacities (DIE ZEIT 2013).

Above urban green spaces, the air heats less during the day (1–3 k according to Bowler et al. 2010) than above-sealed surfaces, and in green spaces dominated by open meadow areas it cools down more at night due to the low heat capacity and unhindered radiation - “cold air” is produced. Large green areas are so-called “cold air generation areas” and can counteract high summer temperatures even in the surrounding built-up areas if the topographical conditions and the building structure allow cold air to flow into the adjacent urban quarters (Gill et al. 2007; Bolund and Hunhammar 1999). The roughness of the urban surface, for example on buildings, can also dampen wind peaks up to 20%, which are perceived as disturbing by most people and which produce dusty city air when they are stirred up. Corresponding effects increase with the size of the green spaces; for example, considerable cooling up to the surrounding residential areas could be proven for the 210 ha of the Großer Tiergarten park in Berlin (von Stülpnagel 1987).

DeGroot et al. (2002) in their first papers on ecosystem services include the factors topography, vegetation, configuration of urban water bodies and the specific reflection

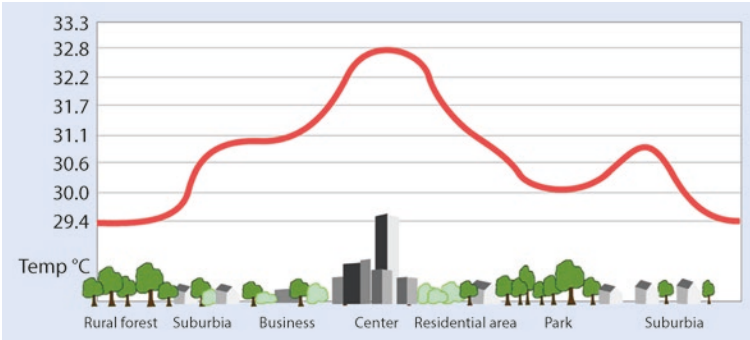

Fig. 5.6 Schematic representation of the urban heat island along a rural-urban gradient taking into account different land uses. (Kuttler 2000)

of urban land cover (albedo) in the urban climate regulation service, but do not provide a model or weighting of these factors (Fig. 5.6).

The current literature on urban ecology (see here Endlicher 2012) lists a number of possible negative effects of climate change on urban ecosystems and cities (Chapter 6): heat waves with high daytime temperatures (>30 °C) and tropical nights (>20 °C), resulting heat stress among the population and material effects of the built environment ("lifting" of asphalt roads, cracks in concrete). Thermal comfort, that is, the temperatures at which city dwellers feel comfortable and healthy, drops dramatically during such heat waves (Burkart et al. 2013), although it varies according to climate zone. In addition, Franck et al. (2013) and Großmann et al. (2012) were able to demonstrate that heatwaves, especially during the day, cause much higher stress among younger age groups, who are unable to organise their daily routines and whereabouts flexibly, in contrast to pensioners who are assumed to be much more exposed.

Due to their high population density, urban areas are also particularly vulnerable to extreme weather conditions, which are becoming increasingly frequent as a result of climate change, and thus to increased natural hazards such as flooding (Menne and Ebi 2006). Endlicher and his co-authors argue "… urban heat waves are among the deadliest of all-weather emergencies". In the summer of 2003 alone, a prolonged heat wave in Europe claimed thousands of lives, especially in Western European urban agglomerations. "Most of the deaths were counted in urban regions Urbanization and urban architecture have a profound effect on heat mortality. High nighttime and morning temperatures characterize the climate of densely populated areas" (Endlicher et al. 2011). The phenomenon of persistent heat waves or extreme weather conditions is already being discussed as a scenario for urban Europe at the end of the twenty-first century (IPCC 2014; Egerer et al. 2020). Exposed population groups (infants, the elderly, cardiovascular disease) will then be particularly at risk. Above all, demographic ageing in European cities further increases their climate vulnerability (Chapter 6 in more detail).

How can urban areas counter the effects of climate change and what role do the ecosystem services of green spaces play in this? The current debate on adaptation to climate change in cities focuses on the temperature reduction performance of existing open spaces (green spaces, water bodies, floodplains) in the city (Bowler et al. 2010; Gill et al. 2007). Urban green spaces and water bodies can produce cold air due to their specific evaporation heat. They can counteract high summer temperatures (Gill et al. 2007; Chapter 6 in more detail).

In addition, shaded areas in the city play a special role: here the temperature reduction can be up to a maximum of 5 k during a day's walk compared to a sunny location. It can be seen in Fig. 5.7 for the city of Leipzig, an increase in the shade (i.e. the proportion of tree-lined parking areas or the number of trees in parks) of urban green spaces has a temperature-reducing effect (for urban green spaces in general Bowler et al. 2010; for Leipzig Breuste et al. 2013). The cooling effect of tree shadows of an average of 3 K in the daily variation of air temperature by shading was empirically determined: It was measured and extrapolated to the urban area using aerial image data of shaded areas in parking areas. The measurement was carried out with simple temperature probes, which

Fig. 5.7 The temperature difference between sun-exposed and shaded areas of urban parks in late summer in Leipzig (own data from a survey campaign in August 2009). The air temperatures were measured with temperature probes and recorded by data loggers. An average temperature difference of 3 k was empirically determined between shaded and not shaded areas for different parks and the shadow percentage of 40% determined from remote sensing data was applied to all parks in the city. Thus, the effect of increased or decreased shading on the local climate regulation (cooling) in public parks could be simulated for a shrinking or urban redevelopment and a reurbanization scenario. In addition, the effect "climate regulation by shading" could be determined for different afforestation measures in urban parks. (Breuste et al. 2012)

have a correction function for direct solar radiation to exclude double measurement effects. Once in the sun and once directly under the canopy in the shade are measured in several daily runs to minimize the uncertainties of the measurements.

Approaches to the Determination of the Climate Regulation Function in Urban Ecosystems

In order to determine the important climate regulation function for larger urban areas and land use composites in cities, without having to carry out complex measurements (temperature, humidity, radiation, etc.), which urban environmental budgets rarely allow, three methods are described in the box below, which can be used to estimate the cooling function of urban land cover and thus land use in comparison to each other and absolute terms (Fig. 5.8).

Determination of the climate regulation function in urban ecosystems

f-Evapotranspiration (evaporation)	Transpiration and evaporation values as empirical values related to overgrown or ungrown or sealed surface or land use → standardized over 12cm high grass; max. value 1.4	Schwarz et al. (2011)
Cooling potential	Tree shadows determined with aerial photo or satellite data; temperature reduction measured with temperature probes	Bowler et al. (2010); Breuste et al. (2013)
Sealing degree and infiltration	Percentage of impermeable material in the respective land use, measured by infiltrimetry and subsequent classification of land use types according to %- infiltration of a defined amount of water	Haase & Nuissl (2010)

Fig. 5.8 Approaches to the determination of the climate regulation function in urban ecosystems. (Haase 2014)

5.3.2 Water Supply and Flood Regulation

The urban water balance (Chapter 3) as one of the basic parameters of the urban ecosystem comprises all processes and variables related to the transport and storage of water in the urban ecosystem (Steinhardt and Volk 2002). The hydrological cycle balance can be described in a highly simplified way with the following Gl. 5.1, in which precipitation N is the sum of runoff A and evaporation V:

$$N = A + V \tag{5.1}$$

Some models add the intermediate storage S to the sum. More specifically, one can define the variables of the water balance as (Gl. 5.2)

$$N = (A_b + A_i + A_o) + V + S \tag{5.2}$$

is the sum of basic ($_{Ab}$), intermediate (*interflow* Ai) and direct outflow (Ao).

In contrast to the water balance of non-urbanised watersheds, the variables of sealing and canalisation play an important role in the urban ecosystem. They decide how much precipitation water is available to the ecosystem via the soil, or what reaches the receiving watercourse directly via direct runoff (Haase 2009). The higher the degree of soil sealing, the lower the basic or intermediate runoff and the higher the direct runoff. Urban ecosystems, therefore, increase runoff peaks and lead to more frequent and stronger local floods (Sommer et al. 2009). In the following, an example of urban water balance modelling will illustrate the relationships between urbanisation and water balance.

As already discussed before (Chapter 3), increasing soil sealing has a negative impact on the fulfillment of natural soil functions. The effects on the urban water balance associated with the increase in sealed surfaces can generally be described as follows (Wessolek 1988; Haase 2009).

- Decrease of real evapotranspiration (ETP) by conversion of vegetation areas and reduction of surface roughness by artificial or sealed surfaces,
- Reduction of the effective seepage rate and thus of the base runoff ($_{Au}$) with increasing degree of surface sealing as well as,
- Increase in (rapid) surface runoff (Ao) with an increase in the proportion of sealed surface area as well as increasing the degree of sealing.

The water supplied to an urban ecosystem by precipitation is divided into the water balance variables evapotranspiration, surface runoff, and percolation or base runoff with different proportions depending on climatic conditions, soil properties and land use.

A well-known method for calculating the base discharge or the seepage rate within an urban area is the discharge formation model ABIMO (Glugla and Fürtig 1997) of the Federal Institute of Hydrology. The ABIMO model was developed for the loose rock area of eastern Germany and modified for the urban area of Berlin. It illustrates the main components of the urban water balance numerically: The main component of ABIMO is the calculation of the total runoff (Q), whereby the real evapotranspiration (ET_a) of an area is first determined using the Bagrov equation (Glugla and Fürtig 1997). The total runoff (Q) is calculated by the difference between real evapotranspiration (ET_a) and the long-term precipitation average (N). With increasing precipitation (N) the real evapotranspiration (ET_a) approaches the potential evapotranspiration (ET_p), while with decreasing precipitation (N) the real evapotranspiration (ET_a) approaches the precipitation. The intensity with which these boundary conditions are reached is changed by the storage properties of the evaporating surface (effectiveness parameter n). The storage properties of an area are mainly determined by the use (increasing storage efficiency in the sequence sealed area, soils without vegetation, agricultural, horticultural, forestry use) and the corresponding soil type. The measure for the storage efficiency of unsealed soil is the usable field capacity FC (Fig. 5.7).

According to this model, direct runoff (A_o) is calculated only for sealed surfaces, since it is only determined via the degree of sealing or drainage of a surface (Glugla and Fürtig 1997). A method developed by Messer (1997; based on investigations by Schröder and Wyrwich 1990) for the urban-industrial Ruhr area considers the direct runoff (A_o) of an area, which can be determined by the factors slope inclination, soil type, groundwater level and land use. The real evapotranspiration is determined in this procedure using empirically determined values that are only valid for the Ruhr area. Direct runoff is calculated by determining the share p of excess water (the difference between precipitation and evapotranspiration). The direct runoff share p is determined using the input parameters slope inclination, soil type, groundwater corridor distance and land use or degree of sealing. The direct runoff fraction p decreases with increasing groundwater level. It is significantly higher in soils rich in clay and silt than in sandy soils. For sealed surfaces, the proportion increases with increasing degree of sealing (Messer 1997; Fig. 5.9).

If one looks at the results of urban water balance modelling with ABIMO and according to Messer (1997) for the city of Leipzig since 1870 (Fig. 5.10; Haase 2009) in contrast to an almost 100% base discharge on the filter-rich sand loess and loess loam blankets, areas with increased surface runoff have increased significantly in large areas of today's urban area as early as 1940 and especially after the Second World War. As early as 1940, the increase in surface runoff corresponds roughly to the decrease in evaporation capacity (see water balance model in Fig. 5.8). After 1990, large areas in the suburban hinterland of the city were sealed, some of them at almost 580 mm%, resulting in surface runoff values of+400 mm/a since 1870, with total annual precipitation

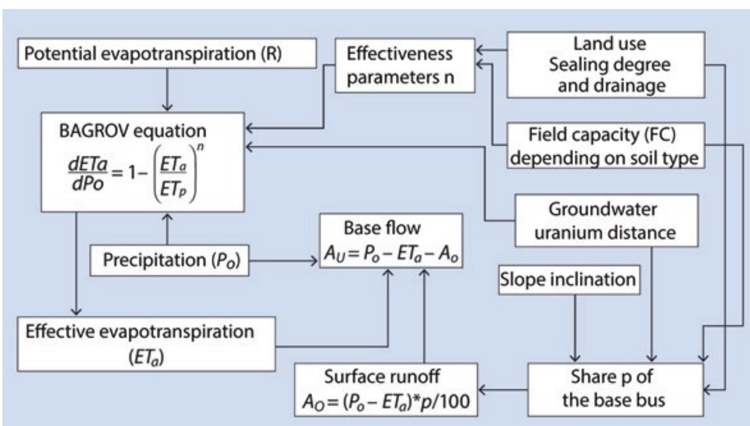

Fig. 5.9 The urban water balance as a function of land use and the degree of sealing. (Haase 2009, modified)

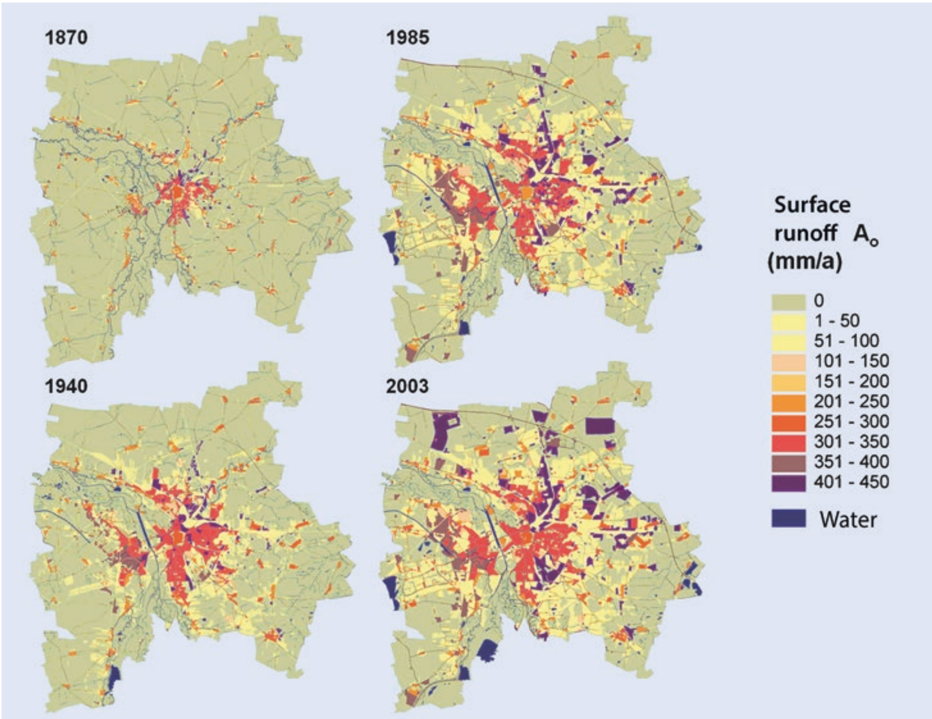

Fig. 5.10 Change in surface runoff A_o in the city of Leipzig since 1870 (Haase 2009; Haase and Nuissl 2007, modified)

of 560–580 mm. In addition, Fig. 5.10 shows that in the period under consideration of approx. 130 years the filter-rich alluvial clay areas in the centre of the city were increasingly built on and thus also canalised or drained. Thus, the discharge regulation capacity in the inner area of the city is low and explains the floods occurring thereafter heavy precipitation events (Kubal et al. 2009).

In addition to the air temperature factor, technical flood protection (dams, dikes, polders) continues to play a major role in adapting to increasing precipitation extremes in cities (Egerer et al. 2020; Krysanova et al. 2008). As places of high population density and the accumulation of many material assets, cities are exposed to increased flood risk if they are in an area with a high probability of flooding (Scheuer et al. 2011). Ecosystems belong to the risk elements according to their tolerance to the amount and duration of supernatant or overflowing water. Urban forests are threatened by prolonged flooding (putrefaction water due to anaerobic conditions and intolerance of typical urban tree species such as the Norway maple *Acer platanoides* to prolonged flooding), as well as by toxic substance inputs from urban commercial, industrial and derelict land (Kubal et al. 2009). An example of an urban multi-criteria flood risk map for the Weisse Elster river in Leipzig is shown in Fig. 5.11.

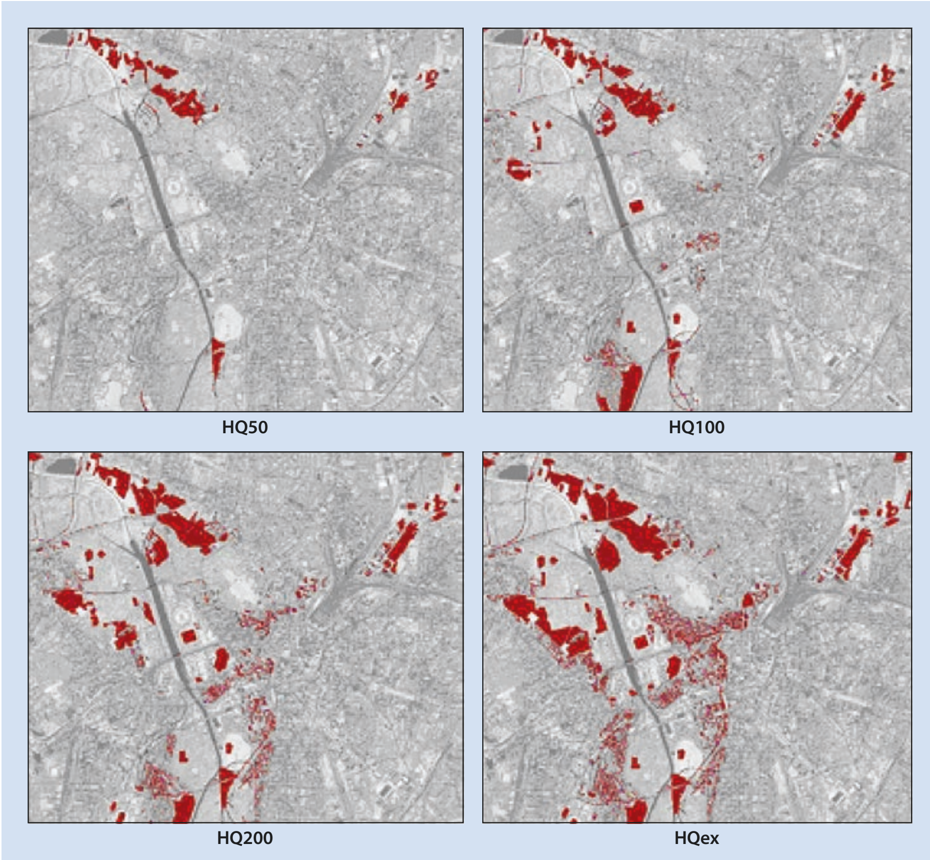

Fig. 5.11 The areas in the city of Leipzig in which floods of the White Elster River can cause economic damage (measured as damage to buildings and household effects/inventory) with different frequencies of return (flood return every 50, 100 and 200 years and extreme floods HQ_{ex}) are marked in *red*. (Kubal et al. 2009)

Urban Vegetation and Urban Soils Promote Climate Protection

Building greenery provides ecosystem services of urban greenery with virtually no soil consumption. In addition to roof greening, permanent greenery without soil and soil–water connection can be created with wall-bound façade systems, for example, in addition to aesthetic enhancement and the promotion of biodiversity, the potential of green roofs for buildings includes above all energy savings and increased energy efficiency. The heat loss through a building component depends on the temperature gradient between inside and outside as well as the thermal resistance of the different layers of the component. Green roofs can improve both properties. An insulating or buffering effect is achieved by a calmed layer of air (protection against cooling by wind and moisture) or by a substrate structure that reduces the heat transmission. This applies to both roof and facade greening. Measurements show that extensive green roofs with a height of 10–15 cm have a 3–10% lower heat loss in winter compared to a gravelled roof structure. This corresponds approximately to a 6 to 16 mm thick conventional insulation (Köhler and Malorny 2009). This results in additional CO_2 savings of ~ 0,13 kg CO_2/m2a. Monetarily, this makes a small contribution to cost savings with approx. 4 ct/m2a (at 8 ct/kWh for heating energy).

For wall-bound façade greening, the substitution of the visible façade offers an additional cost advantage. The greenery of buildings has a high potential in supporting the cooling of buildings by taking over sun protection functions or cooling components via evaporation cooling. Deciduous façade greening can replace non-moving solar shading systems by keeping the solar radiation outside in summer but letting the solar radiation through in winter. The same principle supports the seasonal control of energy collectors such as air collectors or transparent thermal insulation, which use solar radiation to generate thermal energy. Scaffolding climbing plants can protect against overheating in the summer months. The sun protection function is additionally supported by evaporative cooling. As a result, green roofs have lower surface temperatures of up to 25 °C in summer, whereas a bitumen or gravel roof can heat up to 4055 °C (Sukopp and Wittig 1993; Berlin Bauen 2010). Intact greening thus considerably reduces extreme temperature fluctuations of the material surfaces, which also contributes to the durability of the underlying materials, up to twice the life expectancy, for example, of geomembranes (Hämmerle 2010).

Multi-Criteria Flood Analysis in Urban Areas

Cities are complex systems in which a large number of components are affected by flooding, primarily the inhabitants, but also material assets, real estate, industrial sites, traffic and other technical infrastructure, as well as urban ecosystems, that is, city parks, city forests or wastelands. For flood risk assessment in such multi-factorial systems, multi-criteria analyses (MCA) are a very well-suited approach to do justice to the complexity of the system and to be able to examine individual factors in detail and evaluate them in a weighted manner (Gl. 5.3):

$$\mathrm{R}_{\mathrm{MCA}} = \sum_{i=1}^{n} w_i \overline{D'}_{\mathrm{i}} \tag{5.3}$$

Flood risk (R) is always the weighted (w) product of the potential damage (D) and the probability (P) and magnitude of a flood event, that is, R = P D (Scheuer et al. 2012). The damage D refers to the social, economic, and ecological dimension of the urban area and can be calculated/determined for individual risk elements with the aid of *damage functions* (Table 5.3).

Table 5.3 Risk elements for the calculation of damage functions and multi-criteria risk

Social	Economic	Ecological
Population Children Pensioner Hospitals Schools, daycare Homes for the elderly …	Building Household contents Industry Trade Central facilities Art	Rare species Dry grassland Water intolerant trees Contaminated sites Fertilizer store Oil tanks

5.3.3 Recreation Function

The urban ecosystem serves as a habitat for humans, plants and animals (Chapter 4). The habitat function in relation to the health and quality of life of city dwellers, that is, the recreational function, is of particular importance if the city is understood as a "human habitat" (see also Breuste et al. 2013; Reader 2008). In general, the ecosystem services of urban green spaces include biotope formation function (at the site) in the true sense via the nature conservation function (biodiversity), the filter function (for air pollution control), climate regulation (cold air generation and cold air storage), the soil protection function (filter, buffer) and the recreational function that is particularly important for humans. The latter includes aspects such as mental and physical health, noise protection, the cityscape, educational and historical functions (Bolund and Hunhammar 1999; Givoni 1991; Norberg 1999; Coles and Caseiro 2001; for shrinking cities: Schetke and Haase 2008 and Haase et al. 2013).

One of the most important urban ecosystems are urban green spaces (especially parks, allotments, home gardens, playgrounds, meadows, cemeteries, green wastelands, urban forests and to a certain extent green balconies) because they ensure the possibility of recreation for people in the city. They enable both an improvement in physical health and nature experiences (Pauleit et al. 2020; Yli-Pelkonen and Nielema 2005; Chiesura 2004). They thus make a significant contribution to the urban quality of life in the city (Troye 2002; Santos and Martins 2007). In addition, they serve the aesthetic design of the city (Breuste 2004). Green spaces enrich the direct residential environment and can thus improve the image of a city or district and contribute to the identification of city residents with their surroundings. They form characteristic elements of the urban structure and thus give it its own individuality or character (Breuste 2004). In addition, urban green spaces have a broad potential for social functions. They are spaces for free interaction between different population groups, offer sports and play facilities as well as quiet retreats. It is also important to differentiate between publicly usable and accessible as well as private green spaces. The area of private green spaces can account for up to 45% of a city's total green space.

In Germany, there are no binding nationwide limits or target values for urban green supply for recreation, but there are city-specific minimum green supply values. In Leipzig, for example, 5 m^2 is given as the minimum value and 10 m^2 as the target value. For Berlin, 6 m^2 is the guideline for the minimum per capita green supply. The "recreational service" of urban green spaces can be measured with various indicators (Fig. 5.12), for example, with the absolute green area or with the area share (in %) that the green areas occupy, the per capita share of green or the per capita area that can be put into relation with the population. The analysis of the per-capita shares of green space for Berlin, for example, shows that the supply measured by this indicator is remarkably high at 36 m^2 per inhabitant (Kabisch and Haase 2014, 2011). In addition, the direct accessibility of green spaces from residential areas can be calculated by means of a GIS-based network analysis using digital data on population distribution and the road and path network of a city (Comber et al. 2008; Handley et al. 2003; Fig. 5.12 and 5.13). In most cities the population (the users) and existing public green spaces (the supply) are unevenly

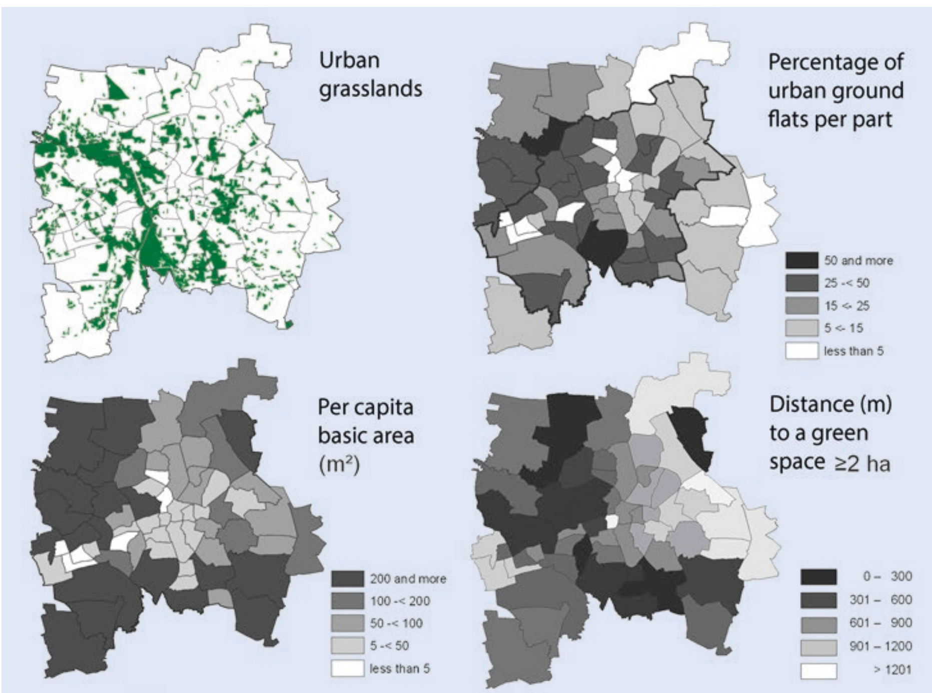

Fig. 5.12 Size, proportion, need and accessibility of urban green spaces (parks, allotments, home gardens, playgrounds, meadows, cemeteries, green wastelands, urban forests), exemplified in the city of Leipzig. Over- and undersupplied districts (per capita green < 5 m^2) can be seen. In addition, a high proportion of green areas does not always mean that the minimum size of green areas is easily accessible. (Breuste et al. 2013)

distributed, that is, a larger proportion of the urban population has more routes to a large parking and recreational areas than the average. This can be quantitatively determined by means of a statistical mass concentration analysis, with Gini or Theil coefficients, which reflect the equal or unequal distribution of variables in space, or by means of a path network distance analysis in a geographic information system (*GIS-network analysis*, Wolff et al. 2020; Kabisch and Haase 2014).

For the city of Leipzig as described above, there is a clear inequity of distribution in the green spaces available per district and an inequity of access. For Berlin, Kabisch and Haase (2013) were able to show that the high per capita proportion of green space in 36 m^2 is distributed very unevenly over the total population and its residential areas (Gini coefficient of over 0.8) and that in the inner south-west of the core city there are undersupplied areas in terms of green space (Kreuzberg, Neukölln, Fig. 5.13). In addition, especially the population with a migration background is less able to access green spaces compared to the city as a whole, a result that is evident for many cities in Europe as well as in the United States, Great Britain and many other countries (Breuste and Rahimi 2014). Access to green is thus one of the fundamental questions of environmental justice in cities.

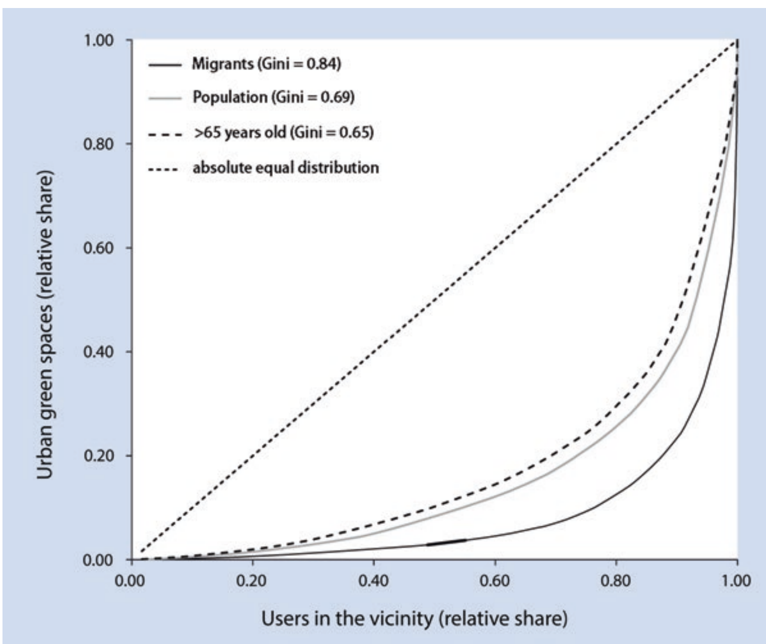

Fig. 5.13 Concentration of the variables parks and users of these parks (all inhabitants, inhabitants over 65 years and migrants) for Berlin, shown with the Lorenz curve, a graphical measure of the equal or unequal distribution of properties (in space). (Based on Urban Atlas data from 2006; Kabisch and Haase 2014)

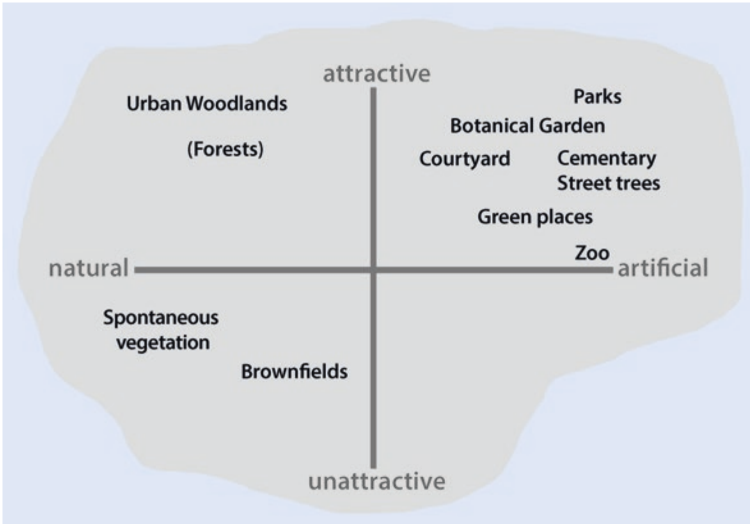

Fig. 5.14 Perception of urban nature by city dwellers. (According to a sociological study by Rink 2005, modified)

In addition to the numerical measurability of the green supply of the urban population, qualitative methods can also be used to determine its perceivable qualities (Rink 2005; Fig. 5.14). A sociological interview- and focus group-based study in the city of Leipzig showed that well-kept green spaces are preferred to unkempt brownfields and succession areas (also known as *urban wilderness*). Within the nature of the first type, it is especially urban forests and floodplain forests which are perceived very positively by the urban population. Another study on the afforestation of urban wastelands showed that successional stages of forests tend to be perceived as negative, while park-like tree areas are perceived as positive by city dwellers (Rink and Arndt 2011; Fig. 5.15).

Social Science Needs Analysis of the Recreational Function

The original assessment of ecosystem services in the context of landscape ecological studies primarily considers the *supply side* as the supply, and less the *demand side*—the demand by the population. The ecological assessment looks at the results of ecosystem processes and whether or how they can be of benefit to humans. Here, they can be linked to sociological or social science methods that ask about these benefits or the usefulness of nature/ecosystems for humans (the users). Methodologically, it is mainly perception analyses or surveys and focus groups that mainly use the classical questionnaire form but increasingly also the Internet. The latter can lead to a certain user- and age-related bias in the answers (Chan et al. 2012). Interviews also appear from time to time in the spectrum of

Fig. 5.15 Examples of revitalised urban brownfield sites that are now used for recreation of the urban population. (Photos © Haase)

methods, especially. when it comes to the implementation of ecosystem services that are considered important (Mäkinen and Tyrvainen 2008). Current studies investigate the importance of certain places and locations for city dwellers (*sense of place*; Schetke et al. 2012) or traditional knowledge and spiritual values about/of ecosystems and nature (Gómez-Baggethun et al. 2013). Other non-monetary valuation approaches analyse the connection between land use management and the provision of ecosystem services (Barthel et al. 2005), whereby strategies and concepts of land use or land use are evaluated or the biophysical equipment of a room is compared with the recreational services perceived by the users (Fuller et al. 2007). A disadvantage of perception-based studies is their cost and time intensity. Moreover, for natural scientists, many of the published results of such "surveys of the benefits of ecosystems" are difficult to include in the measurement or model-based analyses of the *supply side* (Chan et al. 2012). For these reasons, among others, monetary studies are mostly—if at all—used as decision support in urban planning, although it is known that they are often much narrower and less complex than the non-monetary analyses and valuation approaches discussed here.

Interim Uses of Residential and Commercial Brownfield Sites (Licensing Agreement)

To counteract the shrinking of the city, the city of Leipzig started a series of revitalisation projects in 1999. One of these was that of the "Gestattungsvereinbarung" (permit agreement), a form of interim use of brownfield land under existing building laws. In the course of these interim uses, many new green spaces were created in formerly densely built Wilhelminian style districts in the east and west of Leipzig. As an innovative form of using inner-city demolition and brownfield sites while at the same time leaving the ownership structure untouched, the “Gestattungsvereinbarung” was created in 1999. As a kind of informal planning and control instrument, it permits the temporary use of private areas by the public under existing building laws. In this way, temporary green spaces can be created, the surroundings upgraded and the cohesion of the districts affected by shrinkage, vacancy and demolition preserved. It also has advantages for the owners of the areas: Clearance and development of the areas are subsidised by the local authorities, land tax is waived during the permit agreement, and maintenance costs of the site at the time of the contract (waste disposal, green space maintenance) are partly borne by the local authorities.

Leipzig currently has 134 licensing agreements for 235 spaces with a total area of 165.905 m^2. Compared to the total area of urban brownfield land in Leipzig of 7 million m^2 (1942 areas, City of Leipzig, 2014), this area appears small, but by concentrating on the sites of interim use in inner-city areas particularly affected by vacancies and demolition—the Inner East and West—the intervention is certainly visible. The average duration of the permit agreement is eight years. However, the Free State of Saxony has now ordered a minimum period of ten years in order to make the interim use more sustainable. Interest in the measure continues unabated, especially since existing permission agreements are often extended due to a lack of construction demand (Haase and Lorance Rall 2010). Indicators have been successfully used for many years to determine the sustainability of land uses and their “environmental qualities”. Based on a selection procedure according to Combes and Wong (1994) to secure Leipzig’s sustainability strategy and the objectives of the zoning agreement, a study in Leipzig developed a set of indicators which takes into account the three pillars of sustainability as well as the quantitative and qualitative aspects of urban land use.

Recording and evaluation of the ecological and social quality of the interim uses was carried out using the above-mentioned indicators, which were realised by means of a corresponding catalogue and the status levels assigned to the indicators. The condition of the areas (sealing, greenery, variety of plants, waste, benches, etc.) and their accessibility (public transport connection, accessibility, footpaths) played a major role. The factors of security and vandalism were also included. For comparison purposes, near fallow land without interim use, wooded areas and recent demolition sites were also mapped and evaluated. In addition, user activities on the sites were observed. A total of forty sites were examined. A user survey by means of a questionnaire was carried out at six of the forty sites. Care was taken to ensure that the survey covered as representative a spectrum as possible in terms of age, gender and nationality. Inquiries were made as to the assessment of the condition of the sites and their own use. In order to summarise the many data from the survey at the end and to be able to provide a valuable overall assessment for urban planning, the SWOT analysis (*Strengths, Weaknesses, Opportunities, and Threats*) was applied.

The strength of the Land Management Agreement is clearly the better condition of the land compared with other types of brownfield land. The frequency of use exceeds the other types of brownfield land—that is, interim use is assumed. In addition, the framework of a municipally subsidised, temporary green space design and use offers a lot of creative potential. As the responses on self-commitment have shown, the strategy also promotes citizen participation. However, there are also clear weaknesses, above all the poor condition of many areas, the lack of maintenance and moderate equipment. In addition, the current interim uses are still too little oriented to the leisure interests of citizens (too few benches for pensioners seeking recreation, too few opportunities for trend sports such as biking or skateboarding). Moreover, there is little knowledge of the strategy itself. In general, too little ecological emphasis has been placed on diversity and green structures.

Despite these weaknesses, however, the agreement on the temporary use of brownfield land as green spaces could make an important contribution to social integration in the residential area if the areas were used more often and represented a "meeting place" in the district. It also represents the first successes of a PPP (*public–private partnership*) in Leipzig. Of course, this potential stands and falls with the future provision of public funds for the maintenance of existing and the design of new interim uses. The permit agreement as an intervention and brownfield use strategy has many characteristics and potentials, which in the literature are consistently ascribed to the "urban wilderness" in a positive sense: Ward-Thompson (2002) and Chiesura (2004) argue for such poorly designed areas as places for creativity and discovery. Many authors ascribe great potential to such landscaped wastelands as playgrounds and adventure sites. In any case, the Leipzig Conservation Agreement is a creative instrument for the interim use of urban brownfield land, which has great potential for social and ecological sustainability. Especially for shrinking or ageing cities, temporary, flexible measures play a major role. Despite the restriction of possible long-term development, the sites of interim use represent important pillars of the urban green structure—they have a recreational function.

5.3.4 On the Air Pollution Reduction Function of Urban Trees

Urban trees not only increase the quality of living and living space in the city, but they are also involved in the air pollution control function, that is, oxygen production, dust filtration and noise protection (Leser 2008). Particulate matter is one of the most important pollutants in urban air; it has been proven to affect human health and is subject to legal limits [95]. Particulate matter or TSP (*total suspended particulates*) includes respirable particle emissions up to a diameter of < 2,5 µm (liquid and solid matter in the air = aerosol). In addition, there are ultrafine particles with a diameter of < 0,1 µm which can be absorbed into the blood of humans (Table 5.4).

Urban trees filter particulate substances by deposition, sedimentation, diffusion, turbulence or leaching. The plants do not act physiologically but physically by the anatomical-morphological condition of their leaf, branch and stem surfaces as well as their roughness, relief, hairiness, leaf veining, presence of glands, wettability, curvature, leaf edge morphology and leaf pinnules. Woods with steep, firm leaf blades (conifers) and uneven leaf surfaces are more effective at trapping particles from the air than smooth, easily movable, elastic leaves (deciduous woods). In addition, leaf angle, leaf position, the number of leaves per crown volume, the *leaf area index* (LAI) and the absolute foliage duration (leaf-throwing, evergreen) are important for the filter performance. Database-based models such as i-Tree (Nowak et al. 2002) can estimate the air pollution function of urban trees based on the inventoried tree information, which however was compiled for tree species used in North America (Baró et al. 2015; Table 5.5). In order to be able to fulfil the ecosystem services of air pollution control and noise abatement, optimal preparation of a tree site including the expansion of the tree pit and the installation of a special tree substrate, the correct choice of species and varieties, furthermore a planting according to the site and regular maintenance measures are necessary.

Table 5.4 Particulate matter in the city (house dust is made up of both components)

Organic fine dust	Inorganic fine dust
pollen, bacteria, spores, scales, humus, soot, plant fibres, sawdust, VOC (*volatile organic compound* = volatile organic compounds, hydrocarbon, proteins …)	Minerals: sand, sea salt, cement, asbestos, metals and their oxides

Table 5.5 Measuring and modelling the air pollution reduction function of urban trees

Indicator	Model	Sources, literature
PM10/2$_{.5}$ Storage in tree vegetation (Mg ha-1 year-1)	*i-Tree-Eco dry deposition model* using the variables canopy, LAI, air pollution, precipitation, air temperature	Nowak et al. (2006), i-Tree Canopy (i-Tree database for tree crowns) (www.itreetools.org), Database on air pollution of the European Environment Agency EEA (AirBase v7 EEA 2013)

Excursus: Example of Dust Filtration of a Norway Maple (*Acer Platanoides*)

- 9 m high
- Total number of sheets 41,000
- Middle leaf area 68 cm^2
- Total page area 278 m^2
- 2 kg Total dust load (vegetation period), of which 20% fine dust (2–10 μm)
- Particulate matter release on-site (surroundings of the tree) 3,5 kg

5.3.5 Urban Agriculture - Local Food Production and Social Cohesion

Urban agriculture plays a role not only in the cities of the global South (Elmqvist et al. 2013); the cities of the industrialized countries of the West are also experiencing a kind of revival of urban agriculture and thus of the ecosystem services "production of food" on-site as well as the recreational function (Fig. 5.16). Urban agriculture is more than the cultivation of crops and—rather less frequently—the keeping of farm animals in the

Fig. 5.16 Innovative examples of urban agriculture and urban gardening in Chicago and Berlin. (Photos © Haase)

city. Jac Smit, the mastermind of *urban agriculture*, understood it to mean "… agricultural activities as self-help in both the narrow and broader sense", with a wide variety of objectives ranging from community building, environmental protection and education, self-sufficiency, recreation and income generation to the reappropriation of common goods (*commons*). Urban agriculture or urban gardens can take many forms: Allotment gardens (Chapter 4), community gardens, community gardens (Chapter 7), city farms, intercultural gardens, neighbourhood gardens, herb gardens etc. However, against the background of the discussions on local food supply and regional economic cycles, new importance is also being attached to traditional agricultural production in the city. The various projects as well as the actors involved are diverse (www.stadtacker.de).

Besides the pure production of local food, participation, community, appropriation of land and political action are the central elements of urban gardening. The rediscovery of harvesting in everyday urban life is understood as a counterpoint to the globalization and mobility of urban society. Urban gardening is a so-called "low-threshold" entry into participatory urban development. The citizens who are involved in these projects not only want to participate in a garden but also urban development; they want to help shape neighbourhoods and take an interest in their city. In this context, however, urban gardening projects can also lead to conflicts with urban development projects (Smit 1996). In addition, urban gardening itself is also a carrier of innovation, if one thinks of fruit and vegetables from high-rise greenhouses of the future, as is currently already the case in New York's Brooklyn district (Fig. 5.17).

New forms of urban agriculture require cooperation and communication with farmers as indispensable partners on the part of the municipality. Farmers' acceptance of municipal concepts and innovative approaches is an important prerequisite for strengthening

Fig. 5.17 Tomatoes from the raised bed. (Photo © Haase 2015)

urban agriculture. This can be seen, for example, in the case of solidarity-based agriculture around large German cities (Elsen 2011). It is important that urban municipalities with their own farms support the change to organic farming at the national and EU level and can act as a role model. The ecological and social functions of urban farms are becoming increasingly important in view of the growing importance of sustainable and consumer-oriented agriculture and the increased demand for regionally produced agricultural products.

5.3.6 Carbon Storage in the City—A Contribution to Reducing the Urban Footprint?

Urban ecosystems can contribute to global climate regulation by storing carbon. Carbon and carbon dioxide (CO_2) are predominantly stored in soils and tree vegetation. The current state of knowledge about the CO_2 storage potential of urban woody plants goes back to various studies by American researchers since the early 1990s (i. a. Rowntree et al. 1991; Nowak 1994; Nowak and Crane 2002; McPhearson 1998; McPherson and Simpson 2003). In all projects, CO_2fixation is based on allometric regression (the relationship between trunk circumference and total biomass of the tree) between different tree compartments such as the height, diameter or crown volume of the tree. From the comparison of the international studies, the parameters stand density and diameter distribution can be derived as the most important parameters influencing the carbon stock per unit area (McPherson 1998). Important for the carbon storage capacity is the tree species, that is, when considering species-specific characteristics such as lifespan, growth behaviour and wood density, the species composition of urban forests and street trees can influence the CO_2 storage potential. The international literature, especially forestry literature, also provides comprehensive collections of site-specific biomass equations. However, these equations have been developed in forest stands, because the state of research of formulas explicitly developed on urban trees is still in its infancy and contains some uncertainties (Vollrodt et al. 2012).

There are different methods and models to determine the CO_2 fixation in above-ground wood biomass, two common approaches are shown in Table 5.5. The diameter of the chest height (1.30 m; BHD) and the type of tree in the field are determined by random measurements (Fig. 5.18). For the extrapolation of the data due to tree growth, mostly forest yield tables are used. However, annual growth is not only species-specific but also particularly influenced by location, which is uncertainty that should not be neglected, especially for urban trees on unfavorable substrates. Figure 5.19 shows this for copper beech (*Fagus sylvatica*).

During their annual growth, trees absorb $_{CO2}$ during photosynthesis. They store a part of it for a longer period in their wood tissue (Nowak and Crane 1998). One gram of organic dry matter consists of about 50% carbon (Gl. 5.4; Larcher 2001):

$$\begin{aligned} 1\text{ g org. Trockensubstanz } &= 0,42 - 0,51 \text{ g C} \\ &= 1,5 - 1,7\text{g } CO_2 \end{aligned} \tag{5.4}$$

(mass conversion factor 1 g C = 3,67 g CO_2).

Fig. 5.18 Determining the diameter of the chest height (BHD) in the field. (Photo © Strohbach)

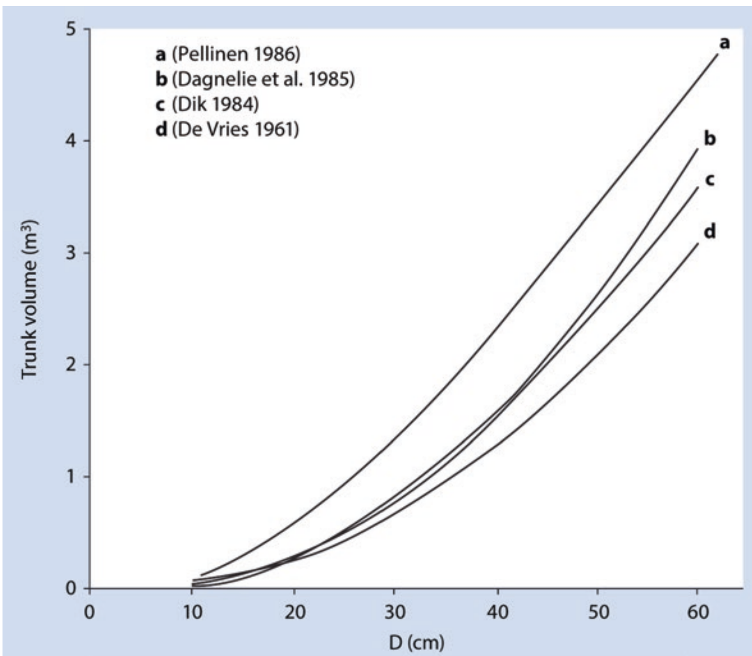

Fig. 5.19 Uncertainties in the determination of the trunk volume or above-ground wood biomass from the BHD for a tree species in the city. (Vollrodt et al. 2012)

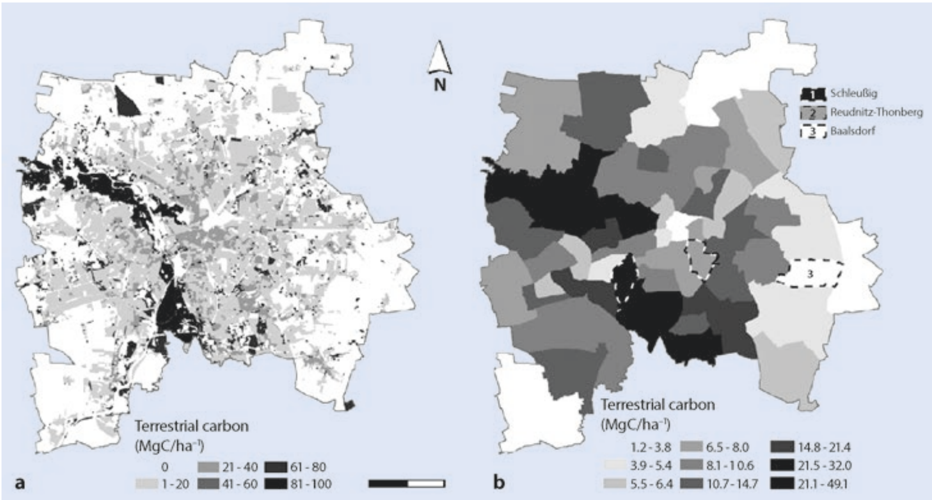

Fig. 5.20 Carbon storage by the above-ground wood biomass in the city of Leipzig, a at the level of individual areas (plots) and b aggregated for the 63 districts of the city. Clearly, the Leipzig river floodplains is a prominent carbon store, but also the high values of the old building areas along the floodplains and in the eastern suburbs. (Strohbach and Haase 2012, picture rights with the authors)

The above-ground wood biomass of a single tree is determined by estimators. The key to this calculation lies in its allometric regression between the tree height/width and the BHD. This allometric function is described with equations as in Gl. 5.5 (Braeker 2008):

$$y = a \times x^b \tag{5.5}$$

with y = above-ground wood biomass (oHB) and x = BHD; a and b are estimation parameters.

Using this field methodology it could be shown for Central European cities like Leipzig that there is no clear urban-rural gradient of carbon storage in the city—that is, an increase in CO_2 fixation with greater distance from the city centre, especially in peri-urban rural areas (Figs. 5.20, 5.21 and 5.22). Comparatively high values in comparison to the city as a whole are achieved in old building areas close to the city centre, as they often have tall old trees that can fix a lot of carbon in contrast to "younger" structures such as terraced houses or single-family house areas. This means that during urban redevelopment in old building areas the felling of these old CO_2 reservoirs should be avoided if possible (Kändler et al. 2011).

5.3.7 Urban Ecosystem Disservices

Ecosystem disservices are understood as undesired effects of ecosystem functions. Lyytimäki and Sipilä (2009) define *ecosystem disservices* as "ecosystem functions that

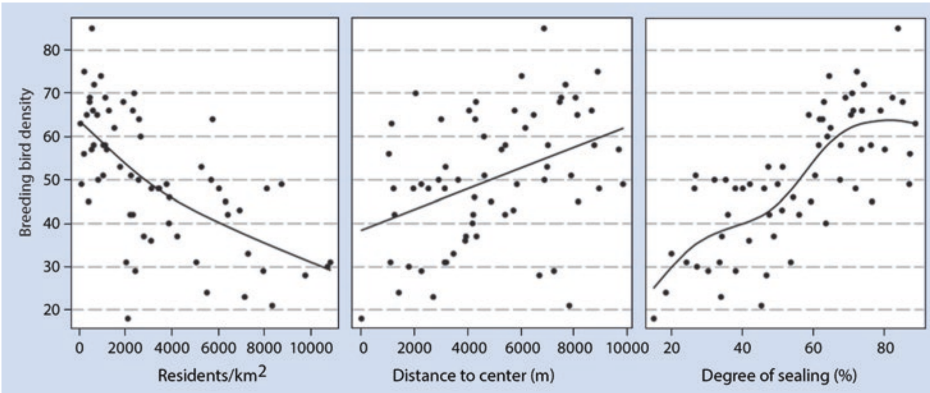

Fig. 5.21 Gradients of carbon storage in Leipzig: It can be seen very clearly that there is no clear gradient and that even comparatively highly sealed areas (>60%) can offer a comparatively high CO_2 binding potential for the city. (Dissertation Michael Strohbach at MLU Halle)

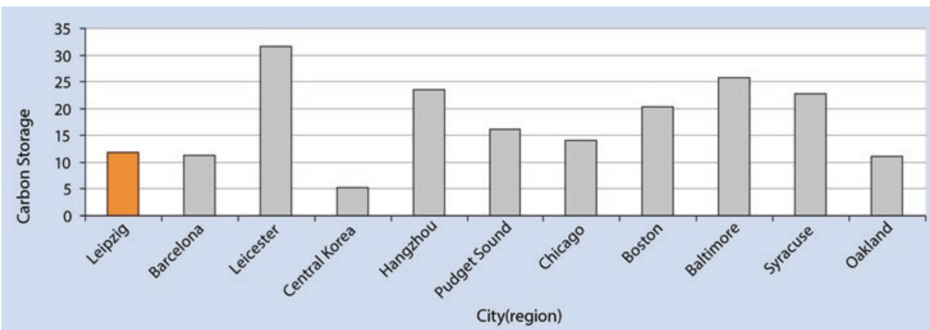

Fig. 5.22 Carbon storage in different cities (in tons of C per hectare). The compact cities Leipzig and Barcelona store little carbon compared to Chinese and US cities, which are less dense and compact in relation to the total city area

cause negative impacts on human well-being”. The concept refers to that of *ecosystem services*, and against this background, *ecosystem disservices* can be described as negative side effects of ecosystem functions. A connection between *Ecosystem Services* and *Ecosystem Disservices* can be seen by looking at the mechanisms of action of ecosystem processes. Ecological processes cause effects, which are evaluated as *Ecosystem Services* or *Disservices* according to their benefit or damage. This evaluation ultimately depends on what the people concerned, under the given circumstances, consider beneficial or detrimental to their well-being. *Ecosystem Services* and *Ecosystem Disservices* are subject to social and economic as well as ecological influences. This is especially true for the effects of urban ecosystems on the quality of life of city dwellers since many people are affected by the effects listed in Table 5.6. The empirical and metrological investigation

Table 5.6 The connection between *ecosystem services* and *disservices is* illustrated by comparison against the background of the respective underlying ecosystem functions

Ecosystem function	Examples Urban Ecosystem Services	Examples Urban Ecosystem Disservices
photosynthesis/primary production	Oxygen production	Production of biogenic suspended solids
Accumulation of biomass (plant growth)	Carbon Storage Cooling effects Aesthetic benefit	Damage to urban infrastructure Restricted visibility A possible source of accidents
Plant reproduction	Conservation of the plant population	Plant allergies
Ecological niches for plants	Preservation/increase of biodiversity	Occurrence of undesirable or dangerous plants Distribution of invasive species
Ecological niches for animals	Preservation/increase of biodiversity	Occurrence of unwanted or dangerous animals Distribution of invasive species
Ecological niches for microorganisms	Preservation/increase of biodiversity	Incidence and spread of dangerous infectious diseases
Photosynthesis/primary production	Oxygen production	Production of biogenic suspended solids
Accumulation of biomass (plant growth)	Carbon Storage Cooling effects Aesthetic benefit	Damage to urban infrastructure Restricted visibility Possible source of accidents
Plant reproduction	Conservation of the plant population	Plant allergies

and recording of urban *ecosystem disservices* is not yet very well developed. *Ecosystem disservices* related to urban green are of particular interest for future quantification and modelling work (Table 5.6). Relevant indicators in this context are VOCs, biogenic suspended matter in urban air, damage to urban plants and the distribution of allergenic pollen.

5.3.8 Synergy and Trade-Off Effects

So far, individual urban ecosystem services have been discussed in detail and their impact on human well-being described. Since urban areas—as described in Sect. 5.2—often face multiple demands, there are also synergy effects between different ecosystem services on the one hand—mutually reinforcing, beneficial effects—and so-called *trade-offs* or conflicts, that is, certain service can only be well fulfilled if another is reduced (Haase et al. 2012; Haase et al. 2014). Classical examples are, for example, the conflict between local production function (Sect. 5.3.5) and biodiversity (Sect. 4) or also partly local climate regulation (Sect. 5.3.1): While the tree population is very important and beneficial for the latter two as well as for CO_2 storage, it is disruptive when the soil is used for urban gardening. There are also *trade-offs* between a—mostly artificial—design of parks and green spaces including the introduction of allochthonous species (Chapter 4) and local biodiversity. Synergy effects, however, can be seen between an intervention-extensive park design using allochthonous species and biodiversity, as well as between recreational function and local climate regulation, both using the presence of trees.

Of course, there are also several conflicts and synergies between urban ecosystem services on the one hand and other demands on urban areas such as housing, industrial and commercial production or social well-being (shopping, entertainment, leisure, etc.) on the other. Thus, as described in Sect. 5.2, ecosystem services and sealing are often mutually exclusive (Nuissl et al. 2009; Haase et al 2014; McDonald et al. 2019). In the built-up area, however, there are so-called indirect climate regulation effects through the greening of buildings and the building environment (Strohbach et al. 2014). Particularly in inner-city locations, where larger tree plantings are not always possible, greening buildings not only has a variety of positive effects but also has the potential to promote energy-related concerns and thus protect the climate (Pfoser 2013).

5.3.9 Conclusions on the Application of the Urban Ecosystem Services Approach in Urban Planning

The sustainable use of natural resources in the city and urban ecosystems is one of the central social challenges of the present day. In order to secure an ecologically and socially compatible economy (e.g. the new way of the *Green Economy*) in the long term, responsible use of the services of urban ecosystems and a reduction of negative impacts of human influence are indispensable. Chapter 5 shows that human well-being depends on a functioning natural balance (Haase et al. 2014). Especially the *green economy*, but also climate adaptation strategies of cities, increasingly relies on ecosystems as providers of important services for society (Breuste et al. 2013). Urban ecosystem services generate benefits for urban society, which can be assessed from a social and economic perspective (Gómez-Baggethun et al. 2013).

However, since the provision of ecosystem services depends on the ecosystem structures and processes of urban nature, as also shown in Chapter 5, the danger of their overuse or destruction is increasingly pointed out (Elmqvist et al. 2013; MA 2005). At the same time, these services are becoming increasingly important as a result of the effects of climate change, which primarily affects cities, on the one hand, and social change processes (such as ageing, energy system transformation) on the other, but their provision is also becoming increasingly uncertain (Albert et al. 2014).

Knowledge of the complex interactions between ecosystems, ecosystem processes and biodiversity on the one hand, and society, the economy and human well-being on the other, is constantly increasing in Germany (WBGU Report 2013). However, this knowledge is available in very heterogeneous groups of experts, and rarely is urban planning directly involved (Daily et al. 2009). And so, at the end of the chapter on urban ecosystem services, the challenges still to be solved in the concept or approach must be addressed:

1. Urban planning—as also shown in the book (Chapter 1 and 6)—often has to make pragmatic decisions based on knowledge. New concepts, especially if they are based on a rather theory-based approach and are discussed and developed in English, find it difficult to find their way into daily urban planning in Germany (Kabisch et al. 2013).
2. For the various ecosystem services, there are a multitude of assessment, modelling, measurement and monitoring methods that are sometimes difficult to compare and integrate—especially in urban areas, where there are very few (Haase et al. 2014). Individual surveys are available in various cities around the world, but their results have not yet been combined.
3. Moreover, little is known about the demand for urban ecosystem services, since social science surveys are often very time-consuming and personnel-intensive, and the concept of ecosystem services has so far found little acceptance in the empirical social sciences. Moreover, as the ongoing demographic and lifestyle changes show, the demand for urban ecosystem services is changing very dynamically.
4. There is a lack of an overarching strategy—that is, above all a national strategy for the first time—on how urban nature can be protected more effectively and uniformly by means of the concept of ecosystem services.

Questions

1. What are urban ecosystem services and how do they relate to urban quality of life?
2. How does the degree of sealing affect the ability of urban surfaces to regulate precipitation?
3. What factors contribute to the development of the urban heat island?
4. What is the reason for whether an urban tree can store much or little carbon?
5. What is the BHD?
6. What factors determine whether trees can contribute to air purification? Are coniferous or deciduous trees more suitable and why?

Answer 1

- Processes of the balance of nature, which people use for their well-being, that is, their physical and mental health, (often free of charge)

- Examples: Air pollution control function, production function, water supply, recreation, pollination, etc.

Answer 2

- The higher the degree of sealing, the lower the absorption of rainwater at the surface and the higher the direct surface runoff.

Answer 3

- Sealing degree,
- Building density,
- Location,
- Proportion of water and green areas,
- Heating behaviour,
- Emissions.

Answer 4

- On the diameter of his chest,
- At its growth rate.

Answer 5

- The diameter of the chest.

Answer 6

- Deciduous trees can filter pollutants from the air more effectively because they have a higher leaf area index (LAI) than coniferous trees.

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6 How Vulnerable Are Urban Ecosystems and How Can Urban Resilience Be Developed with Them?

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and Martin Sauerwein

Abstract

Sensitivity to external disturbances such as floods, heat waves, summer droughts, tsunamis or hurricanes is very high in sensitive urban ecosystems. Urban ecosystems are generally vulnerable due to their open material cycles. In particular, the chapter provides insights which effects the foreseeable climate change will have on cities and how they can be counteracted. In addition, it will be shown which problems urban ecosystems in particular are exposed to under the aspect of global change and which concepts are conceivable for a reduction of vulnerability. Special attention is paid to the development of urban resilience. Urban structure, city size and urban region will be given special attention with case studies.

6.1 What is Vulnerability?

Vulnerability is the propensity or predisposition (of a system) to be affected endangering its stability (Field et al. 2014). In development and risk research, the concept of vulnerability has been used for about 30 years and has undergone various developments since then. Vulnerability is one of the central concepts in development research and represents a kind of extension of the classic research approaches to poverty (Adger 2006).

However, this term is much less clear-cut with regard to the vulnerability of cities and urban regions. Birkmann (2006) defines vulnerability on the one hand as a lack of unmet needs and on the other hand as a social condition characterized by vulnerability, insecurity and defenselessness. Vulnerable population groups are exposed to ecological stress factors or shocks such as heat, floods, drought or tsunamis, among other things, and have difficulty coping with them. These difficulties result not only from the lack of material resources, but also because those affected are denied equal participation and access to

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wealth and income, and because they are not sufficiently integrated into social networks (Bohle 2001). Vulnerability therefore has an economic (poverty), political, social and ecological dimension (Birkmann 2006). Vulnerability therefore means being exposed to stress factors (external dimension), being unable to cope with them (internal dimension) and suffering the consequences of shocks and failure to cope. Vulnerability must be understood as a dynamic process. City dwellers can be or become vulnerable in different ways depending on the situation. Individual phases of this vulnerability process range from the stage of basic susceptibility (phase of coping or arranging oneself) through several intermediate steps to an existential catastrophe, which is characterized by a collapse of life security and total dependence of those affected on external aid. A tsunami/flood catastrophe, as in the case of New Orleans in 2005 by Hurricane Katrina or in the case of New York City which was hit by Hurricane Sandy in 2012, or an earthquake which destroyed large parts of the pre-Himalayan Kathmandu valley in 2015 are all examples of such a collapse (Fig. 6.1).

In urban disaster management, the main focus is on the question of how to improve protection for those potentially affected by damaging events. To this end, indicators are being developed to compare the damage event in urban space with buffer and protection possibilities—safe places, financial compensation, on-site assistance, construction

Fig. 6.1 Typical urban vulnerabilities, illustrated by current case studies of recent years. (Source: Hyndman and Hyndman 2011)

costs. Conceptually, the risk R of a city, a district, but also of an individual city dweller is understood as the probability P with which a certain damage D occurs or will occur (Fuchs 2009; Eq. 6.1):

$$R = P \cdot D \tag{6.1}$$

In the case of urban floods but also heat waves or storms, damage D refers to all negative consequences of the damaging event (Smith and Ward 1998). Following a definition of Cardona (2004), the damage event H itself is understood as the probability P, with which a damage event with a defined intensity I (in a certain space at a certain time) occurs (Eq. 6.2):

$$H \sim (P, I) \tag{6.2}$$

The so-called probability of occurrence P (with $P = 1/t$) is described by factors or parameters such as flood or heat wave extent, duration, intensity, etc. (Merz et al. 2007). The respective damage D is also described by a number of factors (Scheuer et al. 2011; Meyer et al. 2009): 1) event intensity; 2) number of risk elements; and 3) the ratio of the damage to the intensity of the damaging event, also known as susceptibility.

Messner et al. (2007) for Europe and Chinh et al. (2016) for Vietnam in Asia distinguish between different aspects of the vulnerability of an (urban) society in terms of direct and indirect effects: Direct damage thus results from the event itself, e.g. water damage, hurricane injuries or building damage after a tornado. Indirect damage is related to the damaging event, but cannot be classified simultaneously in terms of time—especially different stress reactions and mental-health aspects of an extreme event or losses or bottlenecks in value chains (trade, industry, commerce) and supply services (food, water and energy supply). While direct damages are mostly quantifiable in monetary terms (tangible costs), indirect damages are often not (intangible costs) (Messner et al. 2007). For the latter, semi-quantitative, partly subjective valuations such as *contingent valuation* or *hedonic pricing* must be used (Markantonis and Meyer 2011). The loss of human life due to high urban vulnerability, for example, can neither be expressed in monetary terms nor "counted" in a narrow sense (Kubal et al. 2009).

In summary, vulnerability (V) in cities is the relationship between extreme events (H) and resilience in different dimensions (summarized as risk R) (Eq. 6.3), according to the very often used definition by Downing (1993; Figs. 6.2 and 6.3):

$$R = H \cdot V. \tag{6.3}$$

6.2 Vulnerability of Urban Ecosystems Through Open Material Cycles

Urban systems are open systems. This means that input and output factors must be taken into account in material balance considerations. Since they are dynamic systems, it is not sufficient to record current actual states in order to derive statements about the

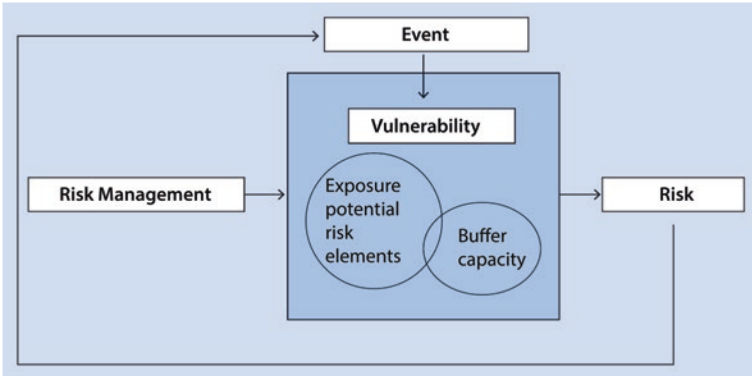

Fig. 6.2 The concept of urban vulnerability according to Cardona (2004) and Birkmann (2006): The urban risk is the function that describes how different vulnerable risk elements are exposed to different damaging events. (Haase in reference to Scheuer et al. 2011)

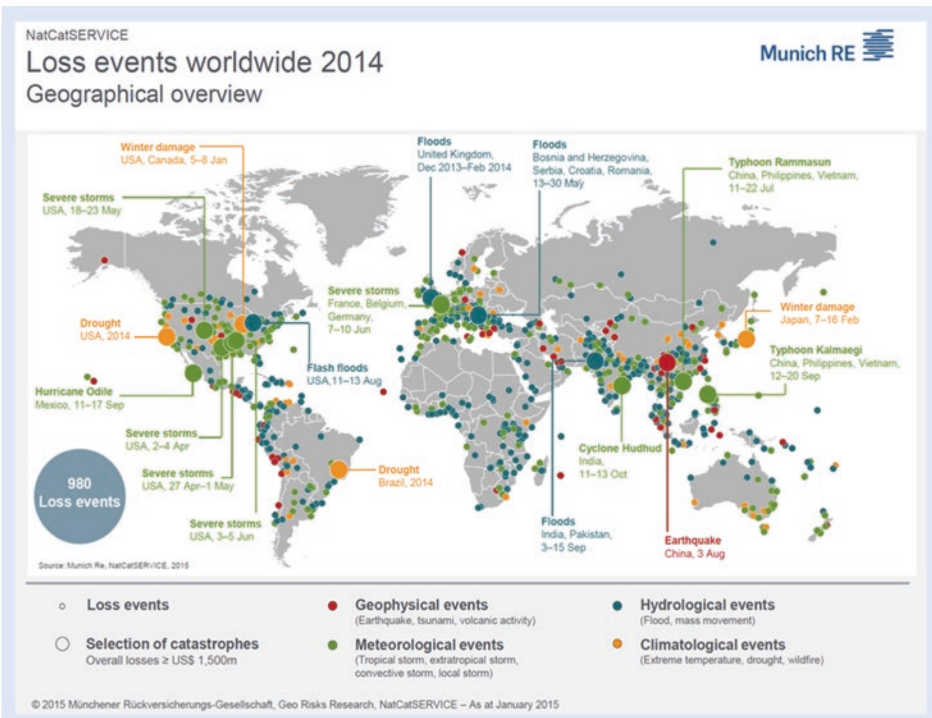

Fig. 6.3 Damage events of the year 2014 according to the Munich RE: Almost exclusively cities and their surroundings or coastal areas are affected. (Munich RE 2015)

"functioning" of the system, but rather the variables controlling and regulating the system must be recorded and then considered in their temporal course (Symader 2001).

Following Leser (1997), urban ecosystems can thus also be defined as functional units of a real existing section of the geobiosphere, in which a self-regulating effect structure of abiotic and biotic factors adjusted to it is spatially manifested, which represents an always open material and energetic system with a dynamic equilibrium (Sect. 2.2). If one tries to instrumentalize this definition, i.e. to make it measurably comprehensible, one quickly encounters the two main problems of spatially delimiting the "functional unit" and of considering the "openness" of the spatial functional unit (input and output) accordingly.

Internal influences on the ecological sensitivity of cities result from the negative, non-sustainable changes in energy, material and water flows. A decisive factor is the sealing, respectively the type and intensity of sealing. Sealing can be regarded as an ecological complex variable, since it changes both energy and material and water flows (Chap. 1 and 3; Fig. 6.4).

The effects of (soil) sealing can be very diverse. For example, after heavy rainfall events, inner-city flooding is possible or the mobilization of pollutants deposited

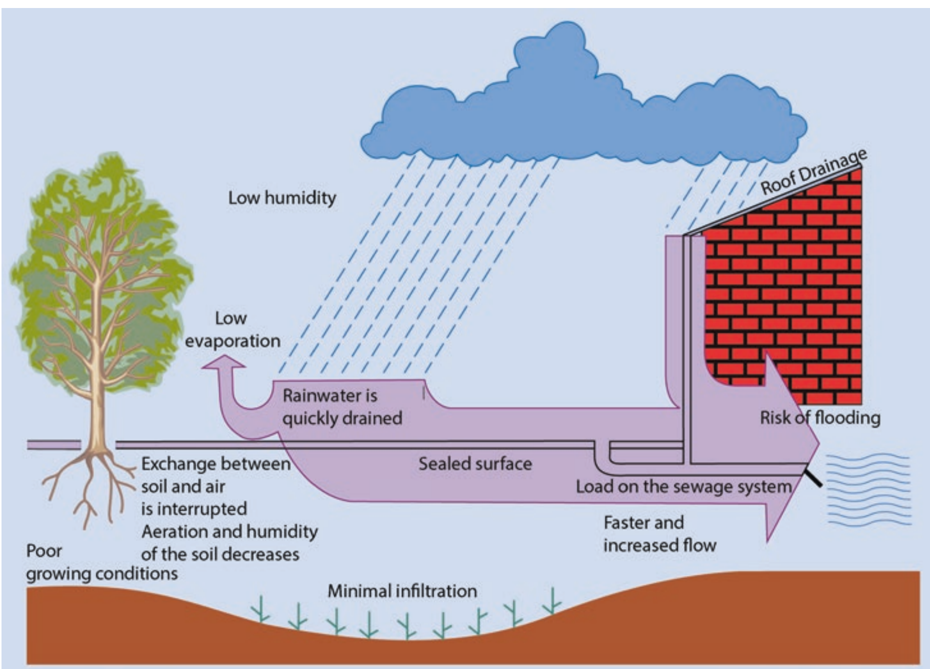

Fig. 6.4 Effects of soil sealing on the water balance. (Sauerwein 2006)

in sediments of inner-city floodplains (Winde 1997). This in turn has negative consequences for the urban biosphere.

Due to their openness, urban ecosystems are subject to numerous external influences in the energy, material and water balance. On the other hand, they themselves influence directly and indirectly the surrounding non-urban ecosystems (geoecological near and far effects). In contrast to terrestrial natural ecosystems, semi-natural and agricultural and forest ecosystems, urban ecosystems have no or only a comparatively low plant and animal biomass production (Bick 1998). While the latter ecosystems use almost exclusively solar radiation as a direct source of energy in their energy balance, urban ecosystems make extensive use of energy from fossil fuels as well as hydropower/wind power and nuclear energy. Food energy for humans is supplied from other areas—regional, supra-regional (and global) agro-ecosystems. Since there is no closed material cycle in urban ecosystems, a considerable portion of the waste produced, for example, ends up in the material cycle of other ecosystems (Friege et al. 1998). The export of compost and sewage sludge to agro-ecosystems is a targeted material return (recycling). In other cases, there is a material impairment, which often affects very remote ecosystems. Air pollutants (e.g. NO_x, SO_2) can be transported over long distances with air currents. The same applies to waste water ingredients or plant nutrients from sewage plant outlets, which are transported over long distances via flowing waters and may eventually end up in the sea. Urban ecosystems are therefore highly dependent on energy, water and material inputs. However, this also makes them very sensitive to a limitation of these environmental factors.

6.3 Vulnerability to Natural Hazards

As early as 2001, Munich Reinsurance reported that the frequency of major natural catastrophes has tripled over the last 40 years. Economic losses have increased eightfold, while insured losses have increased 15-fold (Berz 2001). In recent years, more and more natural disasters have attracted worldwide attention, such as the Sumatra–Andaman quake on December 26, 2004, Hurricane Katrina in the USA in 2005, the earthquake in Haiti in 2010, or the earthquake of Tōhoku in Japan in 2011, which triggered a tsunami that caused major damage and destroyed several reactor blocks of the nuclear power plant near Fukushima.

The United Nations had already reacted to this trend before and, in order to counteract it, proclaimed the last decade of the twentieth century the "*International Decade for Natural Disaster Reduction*" (Dikau and Weichselgartner 2005). A few years later, the years 2004 and 2005 broke new records: Several devastating hurricanes occurred in the USA in 2004, while at the same time the record for tornadoes was broken (Gore 2006), and Japan was also hit by 23 typhoons—more than ever before (Dikau and Weichselgartner 2005). In 2005, the number of major hurricanes in the USA reached a record high, Europe suffered numerous severe floods, and China also recorded more floods than ever before (Gore 2006). This affected cities in particular, especially in exposed coastal areas. Settlement areas, especially many coastal areas, which are particularly exposed to the risk of storms and flooding, have long been considered disaster-prone areas on various continents (Berz 2001; Pearce 2007).

Hazards generally refer to events “that have a significant impact on the structure of society in a larger region, in particular injuring or killing people and damaging goods” (Dikau and Pohl 2007, p. 1031). According to the framework action plan of the *United Nations International Strategy for Disaster Reduction* (UNISDR), human activities can also be classified as hazards if they fulfill the above-mentioned conditions. According to UNISDR, these conditions or consequences of hazards include environmental destruction as well as *social and economic disruptions*, which are described in more detail as impacts on society (UNISDR 2009). UNISDR has established a classification of hazards that distinguishes between natural hazards, technological hazards and environmental destruction (Table 6.1). Natural hazards can be divided into meteorological, hydrological-glaciological, geological-geomorphological, biological and extraterrestrial natural hazards (Dikau and Weichselgartner 2005).

A **natural event** is “the actual occurrence of a natural process". In this sense, a natural event can also be a resource: a flood, for example, can be useful if it brings fertile mud with it (Dikau and Pohl 2007, p. 1034). If a natural event exceeds a certain threshold in terms of frequency of occurrence or extent, it is perceived as a potential danger to life and property and thus becomes a natural hazard. This threshold value is temporarily variable depending on the individual and/or society (Dikau and Pohl 2007; p. 1034, Dikau and Weichselgartner 2005, p. 180).

Natural hazard refers to the impact of a natural event on the structure of society in a larger region, in which people in particular are injured or killed and property is damaged (Dikau and Pohl 2007, p. 1031).

Technological hazards are hazards associated with technological or industrial accidents and infrastructure collapse.

Certain human activities with fatalities and injuries, damage to property, social and economic disruption and environmental destruction are also referred to as **anthropogenic hazards**. Examples: Pollution from industrial plants, radioactive contamination, toxic waste, dam bursts, industrial accidents, plane crash, pipeline rupture, explosions, fire, oil pollution, sabotage, chemical attacks, terrorist attacks (Dikau and Weichselgartner 2005).

In contrast to natural hazards, **natural risk** also includes anthropogenic interactions and is generated or favored by natural processes and phenomena (Dikau and Weichselgartner 2005, p. 180). A natural risk thus arises when people consciously expose themselves to the dangers of natural events in order to achieve certain goals or gain advantages from them (Dikau and Pohl 2007, p. 1033).

A **natural disaster** occurs when an extreme natural event has a direct negative impact on people (or their possessions or the values they create). The term is used anthropocentrically (Dikau and Pohl 2007, p. 1034; Dikau and Weichselgartner 2005, p. 180; Felgentreff and Dombrowsky 2008, p. 13; Plate et al. 1993, p. 2).

Table 6.1 Natural hazards can be classified according to their causes. (According to a proposal of the United Nations International Strategy for Disaster Reduction (UNISDR) based on Dikau and Weichselgartner 2005, p. 22)

Cause	Phenomenon/example
Meteorological natural hazards Natural processes or phenomena of the atmosphere, i.e. the predominantly gaseous envelope of the earth	Tropical cyclones (hurricane, tropical cyclone, typhoon), tornado, winter storm Hail storm, ice storm, freezing rain, snow-storm, sandstorm Extreme precipitation Lightning, heat wave, cold wave Fog
Hydrological and hydrological-glaciological natural hazards Natural processes or phenomena of hydrosphere and cryosphere	Flooding Storm surges Flash floods Drought Snow avalanche Glacier demolitions Eruption of glaciers Permafrost melting Frost stroke
Geological-geomorphological natural hazards Natural processes or phenomena of the earth's crust (lithosphere) and surface (relief sphere). A distinction is made between endogenous causes (e.g. tectonics, magmatism) and exogenous causes (landslides or soil erosion by precipitation)	Earthquakes Volcanic eruption Tsunami Gravitational mass movements Mine subsidence Soil erosion Coastal erosion River erosion
Biological natural hazards Processes of the biosphere in the broadest sense with organic causes as well as those processes that are transmitted through biological pathways, including pathogenic microorganisms, toxins and bioactive substances. Furthermore, processes of interaction of biological systems including human with nature	Epidemics Animal and plant diseases Diseases Forest fires Swarms of locusts Insect plague
Extraterrestrial natural hazards Processes of meteorite movement in space	Meteorite impact

Table 6.2 The largest cities in natural hazard regions (ordered by number of inhabitants in 2010). (Data: Wendell Cox Consultancy 1999–2013)

City/metropolitan area	Inhabitants 2010 (in million)	Projected inhabitants 2030 (in million)	Exposed to the following hazards
Tokyo-Yokohama	35.2	36.0	Earthquake, cyclone
Jakarta	22.0	37.0	Earthquake, flood, landslide
Mumbai	21.3	31.4	Landslide, flood
Delhi	21.0	32.8	Winter storm, cyclone
Manila	20.8	34.1	Earthquake, flood
New York	20.6	22.7	Flood, typhoon
Sao Paolo	20.2	23.4	Earthquake, landslide, forest fire, flood
Mexico City	18.7	21.0	Cyclone, flood
Shanghai	18.4	24.9	Flood
Cairo-Giza	17.3	23.7	Earthquake
Osaka	17.0	17.1	Flood
Kolkata	15.5	22.8	Earthquake, cyclone, flood
Los Angeles	14.8	18.7	Landslide, flood
Beijing	14.0	19.1	Flood, heat and cold waves
Karachi	13.1	22.2	Earthquake, flood
Buenos Aires	13.0	14.1	Flood, earthquake
Rio de Janeiro	11.7	13.6	Flood, cyclone
Dhaka	10.1	18.0	Flood, cyclone
Lagos	9.5	17.2	Earthquake, volcanic eruption
Tehran	8.2	10.6	Earthquake

Many large cities are located in regions with significant natural hazards (Table 6.2). It can be seen that almost all of the world's twenty largest agglomerations are exposed to the two natural hazards of earthquakes and flooding. This means that there are permanent potential hazards for these urban ecosystems and their inhabitants.

Outbreaks of infectious diseases (epidemics, pandemics) have preoccupied people for thousands of years. Descriptions can already be found in very early records, such as in the Gilgamesh Epic or in the Bible. Sudden and massive outbreaks of life-threatening diseases with hundreds or thousands of deaths have paralyzed the everyday life of entire cities, to the point of failure of the social order. Only gradually did it become clear that humans are part of the complex environment and thus subject to its influences in many ways. In the fourth century B.C., Hippocrates, for example, was the first to relate disease and health to the environment. Especially urban areas are—in the past and today—susceptible to the spread of disease due to the concentration of people. Even if infectious diseases in industrialized countries have lost much of their horror of past centuries through appropriate drugs and vaccinations, they are still topical issues, because bacteria, viruses and parasites are constantly changing and often unpredictable (Kistemann et al. 1997). The trigger for the pandemic influenza (swine flu) 2009 was a previously unknown subtype of the influenza A/H1 N1 virus, which first appeared in Mexico and then spread worldwide within a few weeks. Urban areas were particularly affected. Historical and more recent examples can be found in map series such as Carl Friedrich Weiland 1832 (Overview of the progressive spread of cholera over Asia, Europe and Africa since its appearance in 1817), Johann Nicolaus Carl Rothenburg 1836 (The cholera epidemic in Hamburg) or Ernst Rodenwaldt 1961 (Global spread of smallpox 1939–1955). In all cases, cities are particularly affected, with urban environmental conditions and the (human) ecological situation being the decisive control variables. Very recently, the Sars-COV-2 virus outbreak led to the most spread pandemic—COVID-19—the globe ever faced. Millions of people at all continents have been heavily affected either being ill or dieing with COVID-19. Health systems found themselves close to fail and in particular dense cities faced long-term shut- and lockdowns including severe restrictions for all residents. Green spaces appeared to be key for mitigating the local pressure of the pandemic providing places for distanced outdoor activities and mental refreshment (Barton et al. 2020; Simon 2020). This finding strongly supports the role of green and open spaces in cities for mitigating resident's vulnerability and increasing cities' resilience.

These hazards are associated with technological or industrial accidents that cause major damage, including the collapse of infrastructure. The consequences can be very different, for example pollution from industrial plants, radioactive contamination, toxic waste, dam bursting, industrial accident, plane crash, pipeline rupture, explosions, fire, oil pollution, sabotage, chemical attacks, terrorist attacks.

Hurricane Katrina 2005

"Katrina" formed on August 23, 2005 as a moderate level 1 hurricane over the Atlantic Ocean, east of the Bahamas. Its path led via Florida into the Gulf of Mexico, where it developed its greatest force with wind speeds of up to 280 km per hour. On August 29, "Katrina" hit the US south coast in Louisiana and lost power. New Orleans was also preparing for flooding. What made the situation especially dangerous for the city was the high vulnerability of the city, since large parts of the city with its then 450,000 inhabitants were below sea level. New Orleans is surrounded by water on three sides—the Mississippi, the Gulf of Mexico and Lake Pontchartrain, which demarcates the city to the north. The city's dams were only designed to withstand flooding to a maximum of five and a half meters high. In the afternoon of August 29, a storm surge breached the dams to 150 m and flooded the center with water levels of up to 7.60 m. About 1500 inhabitants died. Even before Katrina's arrival, large parts of the city were under water. Due to the total loss of electricity, the pumps had stopped working. Their performance was also too weak to pump off the incoming water (Hartman and Squires 2006). On top of this came the constant loss of protective marshlands and swamp forests in the New Orleans area, which had been deprived of their livelihood by rising sea levels in the Gulf and, even more so, the lack of sediment from the Mississippi River. In recent decades, dykes, dredging and branch canals have increasingly altered the flow dynamics of North America's largest river from its headwaters to its estuary, so that it is no longer able to adequately store its reduced sediment loads in its delta. Also South American Nutrias escaped from fur farms caused severe damage to the marshy ecosystem by root feeding. The result is increased erosion of the silt, which in turn exposes new areas of coastal vegetation to the damaging influence of pure salt water. And finally, natural lowering movements of the unpaved new land—in the absence of sediment supply—also contribute to coastal erosion. In this way, this natural barrier of the city to the sea lost more than 4900 km^2 of surface area in the twentieth century (Childs 2005). The consequences of the flooding are still today increased concentrations of pollutants in the high tide sediments deposited in the city area and the standing waters such as Lake Pontchartrain.

The Elbe Flood 2002 and its Consequences for the Urban Ecosystem of Dresden

One of the biggest hydrological natural events and disasters of recent decades was the Elbe floods of 2002 and 2013, which affected several cities along the Elbe. Both events can be traced back to strong and long-lasting rainfalls in the southern Alps as well as in the Erzgebirge/Riesengebirge (Vb weather conditions). The consequences of these rainy and partly stationary lows, which “rain down” over limited areas, are often catastrophic for urban systems: severe flooding, mudslides and weeks of ground flooding. The Elbe flood of 2002 surpassed the flood of 1954, the strongest flood of the twentieth century, over the whole area and can therefore be considered a “once-in-a-century event". Cities and urban areas were particularly affected by the extreme floods, because people, material and ideal values are concentrated here. In the city of Dresden, the devastating damage was caused by the Weißeritz river in 2002 and later by the second, higher wave of the Elbe. The entire city center was flooded, including the main train station, the world-famous Semper Opera House, the Zwinger and the Saxon state parliament. Entire districts like Friedrichstadt were evacuated or completely flooded (districts Laubegast, Kleinzschachwitz, Zschieren). The traffic infrastructure was also badly affected. The railroad lines Leipzig-Dresden as well as Riesa-Chemnitz had to be closed, and thus especially the long-distance traffic. At the Elbe's highest point of 9.40 m, all of Dresden's Elbe bridges were also closed except for the A4 freeway bridge. According to the flow rates, the Elbe flood in 2002 was in fifth place of all registered floods in Saxony; therefore, purely statistically a return interval of 100–200 years is estimated today. The damage caused by such a natural catastrophe is enormous: for the Elbe region, it was estimated that more than 15 billion euros were spent on the flooding in 2002; in Dresden alone, the Semper Opera House recorded 27 million euros and the State Art Collections 20 million euros. Worse than the material damage were the 21 fatalities and 110 injured in Saxony alone, where in addition almost 26,000 residential buildings were damaged or destroyed. In addition, 11,961 companies and 108,198 employees were directly affected. The damage to the infrastructure also poses great challenges to the buffer capacity of an area, especially a city: During the Elbe flood of 2002, 740 damaged kilometers of roads, 450 damaged bridges, and 280 damaged social facilities were registered. Ten percent of hospitals in Saxony and even more schools were affected. In addition, 32 wastewater treatment plants on the Elbe River in the Saxon cities of Dresden-Kaditz, Pirna, Meissen and Riesa failed during the flood due to flooding or power failures, resulting in the discharge of untreated wastewater into the Elbe. However, the Elbe flood of 2002 was of great importance for flood research, as it resulted in the registration and designation of 300 additional flood-prone areas covering an area of 76,000 ha. Evaluations of aerial and satellite images as well as 2D modelling of the spread of flows in the area contributed to this. In the affected countries, new water laws and, for the first time, an EU Flood Framework Directive (Hochwasserrahmenrichtlinie, 2007) were enacted. For many large and smaller cities along the Elbe river, risk assessments for future floods have been carried out, which include not only absolute damages to buildings and household goods but also personal hazards and indirect damages (resettlement, mental consequences) in the consideration of the vulnerability of a region/city. Flood risk maps for cities such as Dresden have been fundamentally revised and water level systems have been improved. With the exception of a settlement in the Elbe floodplain (Röderau-Süd), all building structures were rebuilt with considerable financial support. Parts of the areas in Dresden, Grimma or Bitterfeld, which were rebuilt in 2002, were flooded again during the next major flood of the Elbe in 2013. Whether the cities along the Elbe are really more resilient to floods and whether extended structural uses of flood-prone areas should be pursued is questionable against this background (Fig. 6.5).

Fig. 6.5 Elbe flood 2002 in Pirna. (Photo © Haase)

Excursus

Earthquake The earthquake of April 18, 1906 in the San Francisco area is considered one of the worst natural disasters in the history of the United States. In San Francisco, the quake and the fires that followed it killed about 3000 people, according to official figures. The damage caused by the quake was estimated at that time at about 405 million dollars (in today's purchasing power 11 billion dollars). The economic impact is thus comparable to that of the hurricane Katrina catastrophe in 2005 (Kilpatrick and Dermisi 2007).

Volcanic Eruptions On November 13, 1985, a mudslide following the eruption of the Colombian volcano Nevado del Ruiz killed more than 25,000 inhabitants of the town of Armero, 70 km away.

The eruption of Tambora on Sumbawa (Indonesia) from April 10–15, 1815, caused 12,000 deaths, and another 50,000–80,000 people died as a result of the following earthquakes and tidal waves and the ash rain on Lombok. It is considered the largest volcanic eruption of the last 10,000 years (Oppenheimer 2003).

In 1669, Etna produced one of its most serious eruptions. In the process, the city of Catania was destroyed and about 20,000 people died (Schmincke 2000). Despite the extremely high natural risk, Catania is today one of the most growing regions of Sicily.

One of the most famous volcanic eruptions in the world is that of Vesuvius on August 24, 79 A.D. It ended with the destruction of the cities of Pompeii and Herculaneum, mainly by glowing clouds and pyroclastic flows (Schmincke 2000).

Vesuvius is considered a dangerous volcano. Nevertheless, settlement areas have grown up to the foot of the volcano.

Tsunami Tsunamis are caused by strong earthquakes under the ocean floor to about 90%. Tsunamis are among the most devastating natural disasters that can affect densely populated coastal areas and therefore often cities. Without protective coastal cliffs or coastal vegetation, waves as high as 3 m can penetrate the land several hundred meters deep. On December 26, 2004, a major tsunami in Southeast Asia killed at least 231,000 people. Several large cities like Galle in Sri Lanka and Banda Aceh in Indonesia were severely affected. The wave was triggered by one of the strongest earthquakes since records began (Koldau 2013).

Forest and Peat Fires in Russia 2010, Impact of SMOG on Moscow

On an area of up to 188,500 ha, there were an estimated 700 forest and peat fires in July and August 2010 between Karelia, Voronezh and the region southeast of Moscow. In Moscow alone, 10,900 more people died as a result of the heat and fires in July and August than in the same period last year. The fires resulted in high concentrations of carbon dioxide and carbon monoxide, which are hazardous to health. In the Russian capital Moscow, smoke spread so far in early August that residents were warned not to leave their homes. In some cases, the smoke only allowed a visibility range of up to 50 m and penetrated as far as the subway shafts. Foreign embassy personnel were partially evacuated, and governments (including the German Foreign Office) issued travel warnings to Russia. Air traffic was severely impaired at the three Moscow international airports, among others, due to poor visibility (Barriopedro et al. 2011).

Example Fukushima March 11, 2011

On March 11, 2011 at 14:46 h, the Tōhoku earthquake occurred under the seabed off the east coast of the main Japanese island Honshū. The epicenter was 163 km northeast of the Fukushima I nuclear power plant, so that the primary waves of the quake reached the power plant site after 23 s. The quake reached a magnitude of 9.0 and all six units switched to emergency cooling. From 15:35, tsunami waves with a height of approximately 13–15 m arrived at the power plant. Only a 5.70-m high protective wall existed for the seaward part of the site. Large amounts of radioactive material were released and contaminated air, soil, water and food in the land- and sea-side environment. About 100,000–150,000 inhabitants had to leave the area temporarily or permanently (Flüchter 2011). The example shows impressively how infrastructure and habitat are so burdened by (also natural) singular events that life in such an area is no longer guaranteed. Urban ecosystems located in coastal courtyards and exposed to seaquakes can be particularly affected.

6.4 Effects of Climate Change

Between 1901 and 2012, average global air temperatures at ground level increased by 0.89 °C. According to the scenarios of the Intergovernmental Panel on Climate Change (IPCC 2013), an increase of 1.1–3.1 °C for the mean representative concentration paths (RCP4.5 & RCP6.0) above pre-industrial levels is likely by the end of the twenty-first century. However, the climate is changing very differently from region to region. In Central Europe, for example, climate change will have a comparatively moderate impact, with Southern Europe and also the far north being much more affected, for example in terms of the predicted temperature increase (CEC 2007; EEA 2008). These differences must always be taken into account when discussing the possible effects of climate change on cities and urban nature below.

Not only do urban settlements contribute significantly to the greenhouse gas emissions (Chap. 1) that cause climate change, they will also be particularly affected by it. Disasters such as hurricanes Katrina and Sandy, which caused severe damage in New Orleans and New York, or the flooding of German cities by river floods in the summer of 2013, illustrate the risks to which cities are exposed due to natural hazards. The heat waves in the summer of 2003, which caused up to 70,000 additional deaths in Europe (Robine et al. 2008), also mainly affected cities.

In addition to the increasing risks posed by catastrophic natural events such as storm surges, river floods, hurricanes and heat waves (see above), the focus is also on the long-term changes in climatic conditions, such as temperature increases and changes in precipitation levels. In Central Europe, the number of so-called tropical nights, in which minimum temperatures do not fall below 20 °C and which are particularly stressful for humans, could approach the current conditions in the Mediterranean region (EEA 2008). In cities, these climatic changes will become more noticeable, because the dense building cover, soil sealing and correspondingly lower vegetation cover have already led to higher temperatures (heat island effect) and a faster and stronger surface runoff of rainwater (Chap. 6). Model calculations for London and the Manchester conurbation, for example, indicate that the temperature differences between urban and rural areas will increase (Wilby 2007; Gill et al. 2007). This will particularly affect densely built-up urban districts with poor green spaces, where socially disadvantaged population groups often live (Schwarz and Seppelt 2009; Lindley et al. 2006).

In Denmark, the intensity of heavy rainfall events with a 10-year return frequency has already increased by about 10% in the last 30 years (Madsen et al. 2009). According to model calculations, a further increase of 20% is possible by the end of the twenty-first century (DMI 2007). There will also be an increase in periods of drought, during which there may be bottlenecks in the drinking water supply and water shortages for urban greenery (EEA 2008; Gill et al. 2007).

Table 6.3 Possible effects of climate change in cities (global). (according to Wilbanks et al. 2007)

Climate change	Impact on cities
Change in average climatic conditions	
Temperature increase and intensification of the heat island effect	Increased energy demand for air-conditioning outweighs reduced heating energy demand Poorer air quality
Precipitation (increase or decrease)	Increased flood risk Greater risk of landslides Increased immigration from rural areas Endangering the food supply of cities
Sea level rise	Flooding of coastal areas Lower income from agriculture and tourism
Increase in extreme events	
Extreme precipitation events/tropical hurricane	Severe flooding Higher risk of landslides Impairment of the livelihood of the population and the economic processes in the city Damage to houses, infrastructure and business enterprises
Drought	Water shortage Higher food prices Impairment of electricity generation by hydropower Increased immigration from particularly affected rural areas
Heat waves/cold waves	Energy peaks for air-conditioning or room heating Health burdens on the population
Rapid climate change	Possible serious effects of a sudden rise in sea level Possible serious effects of a sudden sharp rise in air temperatures
Change in exposure	
Population movements	From affected rural areas
Biological changes	Spread of pathogens

In addition to the direct effects of climate change, however, consequential effects are also to be expected. For example, increased air temperatures can also lead to higher ozone concentrations in the air. For Los Angeles, it has been estimated that the urban heat island effect increases ozone concentrations by 10–15% (USEPA 2001). If the heat island effect intensifies, a further increase in air pollution can be expected.

In this context, urban vegetation, and especially tree populations, may also play a role. Not only do they filter air pollutants to a certain extent (Chap. 5), but they can also emit air pollutants, so-called *biogenic volatile organic compounds* (BVOCs) such as isoprenes and monoterpenes, which are involved in the formation of ozone. The level of these emissions in turn depends on air temperatures, intensity of solar radiation, but also on the water supply of the trees and, last but not least, the tree species (Steinbrecher et al. 2009). With increasing water stress, as is more likely to occur in climate change, emissions of volatile organic compounds also increase. There is little data available on the level of these emissions, but the results of a literature study suggest that trees in southern cities with hot and dry climates can contribute significantly to increasing the concentration of volatile organic compounds in the air, while in cities with temperate climate and good growing conditions, the absorption of ozone by urban trees tends to predominate (Calfapietra et al. 2013).

Earlier vegetation periods and higher temperatures may also possibly increase the pollen production of the vegetation, with negative consequences for allergy sufferers (Shea et al. 2008). Further consequences can be the spread of pathogens, for example. Climate change could, for example, promote the further spread of the mosquito species *Aedes aegypti*, which is the main carrier of dengue and yellow fever (Eisen et al. 2014).

It should not go unmentioned that climate change can also have positive consequences, for example if higher temperatures in cities at mid and high latitudes result in reduced heating energy requirements, a longer vegetation period, more warm summer nights in which one can spend pleasant time outdoors, and reduced winter mortality among the population. However, these welcome side effects of climate change are likely to be significantly outweighed by the negative effects shown in Table 6.3 (EEA 2008). Further negative impacts of climate change, such as damage to vegetation (especially road trees), more frequent and longer periods of drought or possible changes in urban flora and fauna, would have to be added to this table.

Urban vulnerability is a result of their varying exposure, sensitivity and adaptive capacity (Fig. 6.6). Thus, the effects of climate change are not only determined by how much natural hazards (e.g. river floods) increase in frequency and magnitude. The exposure of cities or city districts to these natural hazards is also crucial. Higher summer temperatures and heat waves will probably affect cities in southern Europe more severely than in the north (EEA 2008). Have settlements been built in the floodplains? Are there houses on slopes endangered by landslides? Are cities located on coasts affected by rising sea levels and higher storm surges? Worldwide, more than 600 million people live in coastal areas that are no more than 10 m above sea level (McGranahan et al. 2007). The proportion of these vulnerable population groups will continue to rise sharply, particularly in the rapidly growing cities of developing countries (Sect. 1: Case Study—Four examples of different urban development: Dar es Salaam).

There is little scientific evidence to date on the sensitivity of urban ecosystems to climate change (e.g. Wilbanks et al. 2007), so only some of the potential problems can be indicated here:

- A possible shift in vegetation zones due to climate change will also affect the habitats for urban flora and fauna, for example in the form of a change in species composition. It is likely that the more natural habitats will be affected above all (see Colding 2013).

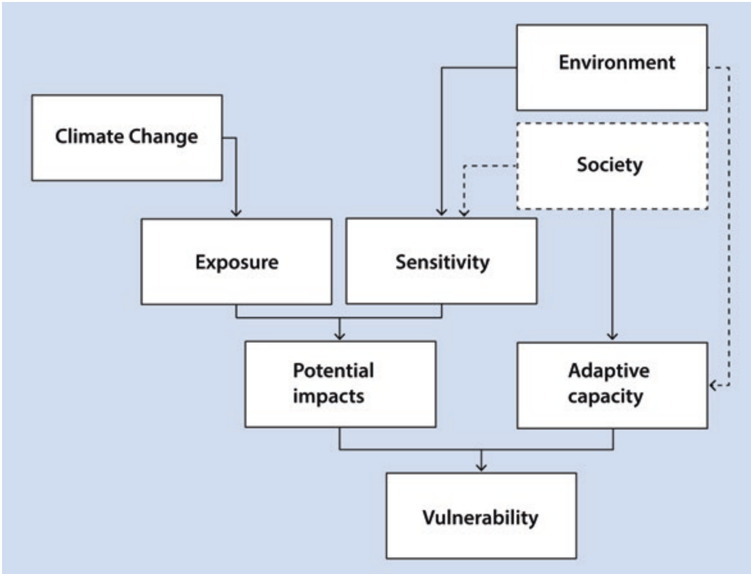

Fig. 6.6 Vulnerability as a result of climate change-related natural hazards, exposure and sensitivity of the city and its adaptive capacity. (BMZ 2014)

- However, changed climatic conditions may also have further effects on urban flora and fauna and their coexistence, for example if the time of budding and flowering or reproduction changes, the growth rate of the species is influenced in different ways and competitive conditions change (Wilbanks et al. 2007). Impacts can range from increased damage to trees and shrubs by late frosts, increased pest infestation to changes in the composition of vegetation, which in turn can affect ecosystem functions and services such as nutrient cycles or evaporation performance. Warmth-loving and drought-tolerant plant and animal species from southern regions may spread increasingly in cities at mid- and high latitudes and may even become invasive (Nobis et al. 2009; Sukopp and Wurzel 2003), while species requiring moisture will come under even greater pressure. Climate change may therefore have far-reaching impacts on urban biodiversity and its ecosystem services (Kendal et al. 2012), but these are difficult to assess so far. Despite these uncertainties, consideration must already be given to adapting urban nature to climate change in order to reduce its sensitivity to the potential impacts of climate change and thus safeguard its ecological performance (Chap. 5), for example to regulate the microclimate.

- More frequent and longer-lasting drought events during the growing season can inhibit plant growth, even damage them, and thus limit their transpiration capacity. Brown lawns and dried-out green roofs lose their cooling effect and surface temperatures increase (Gill et al. 2013). Street trees already frequently suffer from water stress due to the limited root space (Bühler et al. 2006). An intensification of droughts will further restrict their growth and the associated ecosystem services. In the cities of developing countries, where the local supply of food to the population plays a major role, urban and peri-urban agriculture could be particularly affected. Drought resistance is also becoming a crucial criterion for the selection of tree species for paved areas and roads (Roloff et al. 2009; Gillner et al. 2013). Possibilities for irrigating roadside trees must also be included in climate adaptation considerations, for example by storing and using rainwater. Local rainwater management and climate regulation can thus be combined.

6.5 Urban Resilience—Dealing with Crises

6.5.1 What is Urban Resilience?

Adaptation to changing living conditions and, at the same time, further development and renewal denote progress in society and the evolution of life. The human striving for security and stability and the preservation of the created structures do not contradict this and also and especially apply to cities. The balance between change and stability stands for good urban development (Jakubowski 2013, p. 371). In spatial planning, the term resilience seems to suggest a long-term strategy that includes failure and could replace the concept of sustainable urban development based on adaptation and mitigation (Ersöz 2013). However, resilience can also be understood as the basis for a development geared towards sustainability and not just as a mere reaction to crises and as a new counter term to sustainability (Kegler 2013).

Definition
Resilience is the ability of a system to react to crises and disturbances and to strive for a dynamic balance of self-renewal and creative possibilities (self-regulation). In a transformation process, existing structures are transformed into resistant and forward-looking forms. In an urban-regional system, this is the basis for a development geared to sustainability, in which resilient structures are developed and strengthened in planning, self-design and natural processes (see also Vale and Campanella 2005; Walker et al. 2006; Newman et al. 2009; Kegler 2013).

From a resilience perspective, the macrosystem city and region can be divided into microsystems, e.g. urban structures, and subdivided into the relevant subsystems economy, environment, infrastructure, governance and social affairs (Jakubowski 2013). Urban resilience can thus be considered on different hierarchical levels and includes an ecosystemic view. When considering urban ecosystems, the focus must be on vulnerability, management, performance characteristics (ecosystem services, Chap. 5), security, stability and risks for city dwellers.

Newman et al (2009) argue why cities should be developed towards more resilience. The dependence of cities on the non-renewable resource oil and climate change are cited as main arguments. Newman et al. (2009) present four scenarios for urban development:

- Breakdown (*Collapse*),
- Suburbanization (*Ruralizing*),
- Dissection (*Segregation, Dividing*),
- Resilience (*Resilient City*).

The following features are implemented for the *Resilient City*: Use of renewable energy, CO_2, neutrality, green equipment (Photosynthetic City), eco-efficiency (use of ecological functions and cycles), embedding in the environment, sustainable transport. Urban resilience therefore has a lot to do with the realization of the eco-city objective (Chap. 7). A narrower focus of the consideration of urban resilience concerns the avoidance of catastrophic natural events and the handling of these events (*Disaster Risk Management* perspective) (UNISDR 2005).

The risks to which cities worldwide are exposed and their potential for resilience are not equally distributed. This is true not only between cities themselves, but also within cities, especially when they are large or very large.

Resilience Criteria of Urban Systems (Kegler 2013; see also Newman et al., 2009; Newman 2010; Evans 2011)

Autarky and Exchange

Independence of cities means self-determination and less dependence on external influences. However, cities in particular are based on regional, supraregional and global networking. Pure self-centeredness is not only impossible, but also counterproductive. Threats can easily be overlooked due to a lack of exchange. A well-functioning exchange of contacts and information is a prerequisite for responding resiliently to crises.

Redundancy and Diversity

Redundant system components and services in cities contribute to functional stability and to the safeguarding of resources in the event of a crisis, creating a competitive drive for continuous improvement. A variety of different system components as well as offers in different areas—business branches, news sources, networks, people with different skills, control options, urban ecosystems, etc.—enable flexible reaction, adaptation and further development.

Compactness and Decentralization
Urban compactness ensures efficient use of resources (e.g. short distances and energy consumption). However, this also increases the sensitivity and vulnerability of the system. Decentralization ensures that resources are optimally distributed and that supply is not jeopardized (e.g. supply of green spaces, climatic moderation).

Stability and Flexibility
Stability enables to act and plan in a calculated way, offers a long-term and foresighted supply, but does not include a necessary change. Perseverance is not an appropriate response to challenges. Flexibility means adaptation to changing conditions, adaptability of built and planned urban structures, flexible planning structures as well as orientation towards future-oriented measures.

Diversity and Stability
In ecology, diversity was recognized and discussed as a prerequisite for stability. This also applies in a modified form to other systems. Diverse structures are better suited to buffer unexpected impacts (stability) without destroying the system. This also supports the goal of diversity in ecological urban structures (building structures and open space) as a contribution to resilience in cities.

6.5.2 Growing Versus Shrinking Cities

New risks in a globalized world require new ideas and strategies for resilient cities, in the ecological, social and economic sense. Growth and shrinkage, mostly driven by population growth or decline (Haase et al. 2014), also harbor aspects of risk and force cities and urban systems to change and adapt. A resilient city is capable of moderating major changes—e.g. extreme events, social tensions, economic slumps, etc. -, dealing with them flexibly and "buffering" them in order to maintain basic functions of the city—especially in the areas of health, safety and quality of life of city dwellers (see above). This applies equally to both growing and shrinking cities: the former have to deal with the risks of increasing population, population density and, subsequently, significantly higher traffic volumes as well as particulate matter and noise emissions (Weber et al. 2014), the latter are more likely to deal with vacant buildings and large industrial and residential wastelands (Haase 2014).

Table 6.4 Risks and opportunities of growing and shrinking cities

	Growing city	Shrinking city
Population and area	Land consumption and soil sealing due to population growth (immigration) and housing construction	Fallow land as a result of population decline and deindustrialization
Water and energy supply	Scarcity of water resources and exploitation of surrounding reservoirs; growing cities become more dependent on energy imports	Underutilization of water supply and energy infrastructure and corresponding toxicity in the pipeline network due to lack of flow
City climate	Increasing population density can lead to the construction of green spaces and to higher thermal stress (heat stress) in the streets due to higher traffic volumes	Replacement of buildings by open spaces leads to an improvement of the local climate through better ventilation and the increase in climate-improving vegetation areas (Haase et al. 2014)
Traffic	Increased formation of traffic jams and corresponding concentrations of particulate matter, nitrogen and heavy metal emissions in the road area	Elimination of industrial traffic in the city center leads to inner-city relief
Urban nature including floodplains and forests	Endangerment due to construction measures (apartments, roads, businesses); ever decreasing chance of networking urban habitats; fragmentation	Increase of nature in the city on fallow land; active redesign of urban green spaces and creation of new habitats (Haase 2014; Haase et al. 2014)
Floors	Risk of very high soil sealing and increase in surface runoff; local flooding	Possibility of soil unsealing; danger of blowing polluted material from open brownfields

Table 6.4 provides an overview of the risks and opportunities of growing and shrinking cities in terms of their socio-ecological dimensions, which are at the same time an expression of the vulnerability (vulnerability), but also the buffer capacity (resilience) of such cities.

Growth and shrinkage, and thus also the risks and opportunities mentioned above, often occur simultaneously in cities, with varying degrees of dominance (Haase et al. 2014). Urban planning and *governance* approaches have the opportunity to increase the resilience of a city and thus reduce its vulnerability to external influences by identifying the risks and opportunities of growth and shrinkage, locating them spatially and coordinating appropriate countermeasures. In this way, effects of urban shrinkage—for example, the freeing up of space—can be used to improve the proportion of green space and increase the potential for recreation, thus counteracting the densification in growing urban districts with a more open, greener urban space that is accessible to all.

6.5.3 Resilience of Urban Structures in Dynamic Change

In terms of resilience, the urban structure (Chap. 2) is of particular importance. It defines the "building blocks" of the urban ecosystem as use-determined structural elements consisting of anthropogenic and natural components (e.g. buildings, greenery), but also their arrangement pattern (*urban pattern*). Both sides are equally responsible for stability and resilience of the urban structure. Thus, in the case of resilient urban structures, it is not only the components that matter, but also and above all the pattern that they form. This raises many questions, including how urban resilience can be achieved through adapted dynamic processes of change in urban patterns and what challenges are already foreseeable.

There is no doubt that existing urban structures must be rebuilt and thus adapted to increase resilience (Chap. 2; Henseke 2013; Henseke and Breuste 2014). For the new construction of urban structures, however, a high degree of flexibility and adaptability of building and open space structures to new, future challenges must be demanded from the outset. Flexible use as a prerequisite, monitoring and adaptation to new challenges must be part of the normality of urban change. Ecosystem services (Chap. 5) should not be reduced, but increased where possible. Environmental quality and quality of life should increase in this process and vulnerability to natural hazards should decrease.

It cannot be a solution to give preference to one particular type of urban structure and to repeat this again and again in the case of urban expansions (e.g. urban structure types with a lot of green space such as single and terraced housing) or to prefer the garden city model, for example. Instead, it is important to correctly assess the vulnerability of existing urban structures in relation to current and anticipated challenges and to initiate preparatory countermeasures for adaptation in good time (Henseke and Breuste 2014). Thus, for each type of urban structure in its specific location, a specific adaptation pattern will be necessary that also includes its surroundings. Despite the related specificity of urban spaces, however, some principles of urban ecology are generally applicable as long as they are associated with no or only minor risks:

- Promote natural process flows instead of technical solutions (e.g. rainwater infiltration),
- Use of climate moderation through photosynthesis of plants,
- Use of the evaporation capacity of vegetation and water surfaces as well as shading, especially by trees,
- Integration of diverse natural structures for recreation, nature contact and environmental education in residential areas and their neighborhoods,
- Use of water purification through natural processes,
- Natural flood protection, etc.

These aspects are currently discussed as *nature-based solutions*, promoted by the European Union (European Union 2015) and already applied. Promoting nature as an integral part of the urban living environment is a strategy that promotes resilience and can be implemented through targeted, locally adapted measures. Diversity can contribute to the stability of urban structural systems.

Current challenges requiring the increase of resilience of urban structures in a dynamic urban structural change of the twenty-first century (Chap. 1) (see also UN-Habitat 2009)

- Further increase in the concentration of the population in cities that are insufficiently prepared for it.
- Rapid and increasing urbanization, especially in Asia, combined with growing social and spatial inequalities.
- Unplanned and unregulated urban growth in many countries in Asia, Africa and Latin America.
- Dynamic expansion of cities far beyond the political city limits without control by city administrations; urban regions are formed by municipalities of different sizes, economic orientations and strengths, and different political positions.
- Limitation of development opportunities (especially of large cities) by individual ecological factors such as sufficient summer water supply in arid and semi-arid regions (e.g. Los Angeles, Sao Paulo).
- Continued dependence of cities on fossil fuels and individual car traffic.
- Demographic challenges, aging and population decline in developed countries, dominant, growing and often unemployed young population in developing countries.
- Shrinking cities in developed industrial countries.
- Climate change with summer heat, sea level rise, extreme events.
- Uncertain future growth and fundamental doubts about economic governance by the market.
- Reduced control possibilities through planning and city administration, decrease in financial expenditures for urban infrastructure despite dynamic city growth.
- Increasing democratization of decision-making processes and exercise of social and democratic rights by city citizens.
- Increasing diversity of needs, cultures, interests and participation of city residents.

This gives rise to questions on how urban resilience can be increased through urban structural development.

- Which urban structures increase resilience?
- Which urban structure patterns are particularly resilient?
- Which urban structures are indispensable, which are replaceable?

- Where do existing structures have to be rebuilt to increase resilience because of vulnerability?
- Can this conversion of existing structures be achieved by rebuilding existing structures or do new structures have to be added (e.g. by creating green spaces) or old ones removed (e.g. by reducing building density)?
- How can public spaces, green spaces and urban ecosystems contribute to the resilience of cities?

6.5.4 Compact City Versus Sprawling City

Should cities be designed to be compact and thus more resource-efficient, or more relaxed and green and thus better adapted to climate change? These (supposed) opposites are often cited as a dilemma of ecologically oriented urban development (Chap. 1), without considering that not all challenges can be met with each of the concepts. It is important to combine both concepts.

The basic principles of a "compact city", often referred to as a "European city" or "city of short distances", are urban–rural contrast (clear separation between the city and its surroundings), concentration of urban functions such as living, working and utilities, creation of dense building structures that form the central districts, as well as urban density and mix of uses. The model seems to have already been taken up in the New Charter of Athens. The reality, at least in many parts of Europe, is rather the spatial urban landscape, consisting of "city" and "in-between city" (*Zwischenstadt*) (Sieverts 1997, 2000; Sieverts et al. 2005). Density and compactness are not the same. The compact city also includes mixed development, mixed use, promotion of sustainable mobility, access to green spaces.

Based on the criticism of destructive modernist planning in U.S. cities after World War II (Jacobs 1961), the idea of the compact city emerged in the 1960s and 1970s as a multi-criteria, analytical, quasi-calculable decision-making process to solve the problem (Dantzig and Saaty 1973). The idea was applied early in the Netherlands as a practical urban development policy (e.g. Randstad with the so-called Green Heart) and later in Great Britain. Compact new residential districts with good public transport infrastructure connections and links to existing core cities were practical examples, especially in the Netherlands, of how to manage urban growth while preserving landscape and nature (VROM 2000). The concept of the compact city is still under discussion today as a problem-solving strategy for urban growth issues (VROM 2000; Boeijenga 2011). For Los Angeles, with 17.8 million inhabitants in the metropolitan region, it has been calculated that a further 10% area growth means a 5.7% increase in carbon dioxide emissions and 9.6% higher pollutant emissions per inhabitant and 4.1% and 2.9% lower added value of residential property as owner or landlord. Thus, space growth is associated with concrete restrictions and burdens that are calculable, which in turn reduces resilience (Barragan 2015).

Compact city

The compact city, often also called "city of short distances", is an urban planning and design concept. It usually includes residential quarters with high building and population density with mixed use, less car traffic and infrastructure per inhabitant. It includes efficient public transport, walking and cycling, energy efficiency in construction and low environmental impact. Social aspects such as social interaction and social security are also frequently cited (see also Chap. 1; Williams et al. 2000; Dempsey 2010).

Sprawling city

The sprawling city is characterized by its large spatial extent with a low density of inhabitants and building structures in wide areas (Chap. 1, *urban sprawl*, peri-urbanization). It grows through the establishment of uses and the erection of buildings, without any connection to built-up areas. Urban districts (residential, commercial) grow unstructured into the undeveloped space of the urban hinterland, often outside the administrative city limits. In addition to impairment of the landscape, other side effects include: inefficient use of resources, impairment of ecological functionality, biodiversity and ecosystem services (Chap. 5) (Newman et al. 2009; Jaeger et al. 2010; Breuste 2014a).

Expansion of the transport infrastructure, especially road construction, but also high real estate prices and the limited availability of land in the core area of the cities promote the process of suburbanization. This development is made possible and encouraged by the widespread availability of private motor vehicles. As a result of this process, functionally unconnected urban use structures are emerging in the mostly agricultural urban hinterland, which separate formerly ecologically connected areas (urban sprawl). Positive health and environmental effects as well as inefficient use of resources (especially energy) are discussed again and again, without concrete indicators and figures providing more precise proof (Jackson 1985; Ewing 1997; Bruegmann 2005; Bullard et al. 2000).

The sprawling city is only apparently the antithesis of the compact city. Both are extreme visions, some of which are already reality. Resilience, however, arises particularly when the advantages of the five resilience criteria (Box: Resilience Criteria of Urban Systems) can be taken into account in the urban structure.

There is no single strategy that takes everything equally into account, but there are promising approaches, such as "double inner development" (*doppelte Innenentwicklung*) or "city in a green network" (Figs. 6.7 and 6.8).

Fig. 6.7 Garden city Blasewitz in Dresden. (Photo © Breuste)

Fig. 6.8 Compact city center of Sao Paulo, Brazil. (Photo © Breuste)

As a spatial phenomenon, urban growth can affect both area and height. A compact, dense city—i.e. a city with large closed settlement complexes, with a high population and building density—also includes high-rise buildings. If density is a goal, the height of buildings must also be included in the discussion to save space. In Central Europe, for example, where there is much less pressure to grow than the global average, where there is a lack of high-rise buildings and some cities are shrinking (Chap. 4), this is not a generally shared vision. In many other countries with dynamic growth, the use of the third dimension not only for office towers but also as a residential option is already a reality (e.g. China, Japan, Thailand, Singapore, Chile, Brazil, Colombia, USA and many others). Less area is replaced by greater (building) height. The cost–benefit ratio, the availability of space and the price also play an important role. In many countries, the high-rise residential building combines efficient use of resources, minimized infrastructure, reasonable prices and generous green options. Approximately half of the living space built in Shanghai (148 of 294 km^2) is residential space with residential buildings over eight floors (Shanghai Municipal Statistics Bureau 2006). However, the ecological effects should be taken into account, but have received little attention so far (Figs. 6.9 and 6.10).

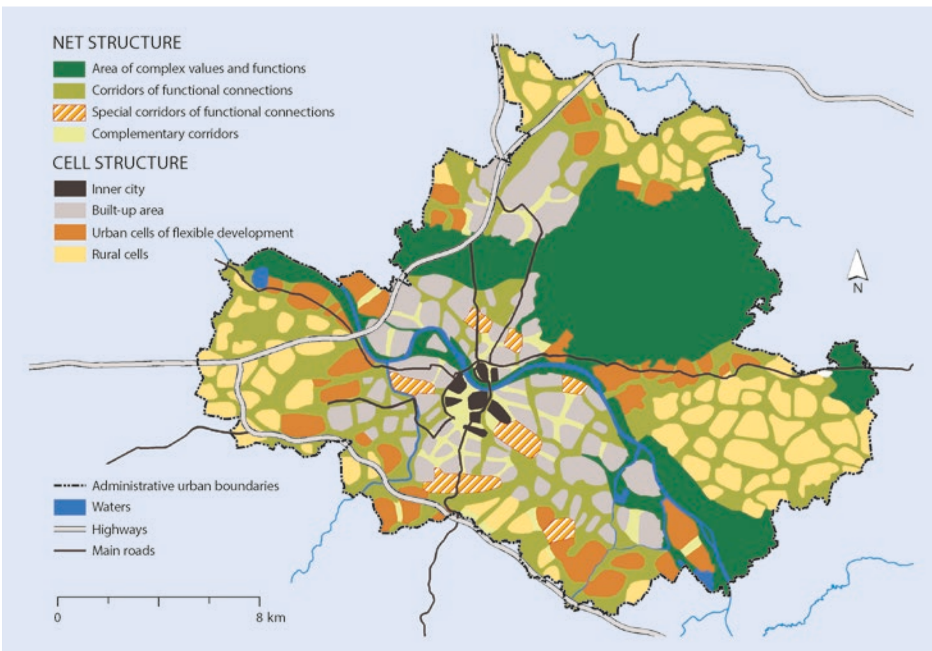

Fig. 6.9 Landscape plan Dresden. (Draft: J. Breuste, cartography: W. Gruber, source: REGKLAM 2015)

Fig. 6.10 Upper middle class residential area in Beijing. (Photo © Breuste)

Federal Agency for Nature Conservation (Bundesamt für Naturschutz; BfN) to Reduce Land Use

In a study, the Federal Agency for Nature Conservation emphasizes the necessity of reducing land use in Germany (Schweppe-Kraft et al. 2008). The counter-productive economic incentives based on the current distribution of tax revenues (e.g. trade tax and income tax) and the retroactive allocation of tax resources in the municipal fiscal equalization system should be eliminated or mitigated by new instruments. At the same time, planning instruments should be used to a greater extent to enable the best local solutions to problems adapted to the specific conditions in each case.

According to the Federal Agency for Nature Conservation, these include:

- The introduction of economic instruments should limit the designation of new outdoor settlement areas and make them economically less attractive. To this end, a new designation levy, tradable land designation quotas and a change in land tax can be applied. This could lead to a situation in which outdoor construction activity takes place only where it promises to be of great benefit to municipal development (see Breuste 2001a).
- By rewarding nature conservation-oriented services in the municipal financial equalization system, a positive incentive could be created to preserve unsealed areas and develop them further in the interests of preserving biodiversity.

- Mandatory audits (such as fiscal impact analyses) should make it clear to municipalities, in addition to the ecological effects, to what extent economic benefits can actually be expected from the designation of new building land.
- The planning and nature conservation instruments should be further developed in such a way that existing inner development potential in the settlement cores is increasingly used for construction in accordance with ecological goals. The aim is a "double interior development" that maintains and improves the ecological quality of inner-city residential areas and thus makes them more attractive as residential locations.

Such a strategy is not only necessary in terms of environmental and nature conservation policy, it also makes economic sense (Schweppe-Kraft et al. 2008).

Mission Statement "Double Inner Development"

In a statement issued in 2006, the German Council for Landscape Management assumes that urban qualities include not only a rich offering of culture, communication, leisure activities, shopping facilities and good infrastructure, but above all an attractive residential environment, a good supply of designed and near-natural open spaces, low-pollution air and unpolluted soil and water. To this end, it developed a future urban planning model of dual interior development. Urban open spaces and their ecological quality will receive special attention. To this end, quality objectives and orientation values for the dimensioning of three types of urban open spaces are developed:

- immediate living environment,
- residential area-related living environment,
- open spaces close to settlements.

This is a recognition that urban development is not only about structural aspects and infrastructure, but also about the "second side of urban development", the associated open space. This must be planned and realized not only in terms of sufficient quantity, measured against target criteria, but also in terms of quality and location to fulfill its function. Open space quality thus acquires the significance of a development potential for cities (DLR 2006). To this end, the German Institute of Urban Affairs (Deutsche Institut für Urbanistik, DifU) has been commissioned by the Federal Agency for Nature Conservation (BfN) (2013–2015) to conduct a research project on strategies, concepts and criteria in the area of conflict between urban development, open space planning and nature conservation in order to develop criteria for evaluating individual urban areas (types) (urban ecosystems) and their functions and to determine which concrete instruments can be used to safeguard or further develop these functions (Difu 2013).

Dresden—the Compact City in the Ecological Network

The compact city in an ecological network"—the landscape plan of the state capital Dresden is based on this model. City greenery is understood as infrastructure, open spaces are guiding structures for urban development. Nevertheless, the city is "compact". A compact city is more resilient to the challenges posed by scarce resources, an ageing society and climate change. Compact cities can operate water supply and public transport more economically, need less energy and produce fewer emissions, if only because inner-city distances are shorter and the private car is used less often (REGKLAM 2015; Wende et al. 2014; Fig. 6.9).

The necessary adaptation to climate change requires more green spaces to mitigate summer heat and to allow precipitation water to seep away, especially during heavy rainfall, instead of draining it into the often overburdened sewerage system. How does this harmonize with compact dense development? With the landscape plan, the Dresden Environmental Office has developed a proposal for 2012 on how to combine these seemingly contradictory goals. The solution: Compact settlement areas are embedded in a network of interconnected green spaces, which also continue into the built-up areas, providing a variety of ecological services for people as well as many different functions in the environment.

In order to implement the Dresden landscape plan, areas must be specifically unsealed and greened. Which green structure fits best where? Can green areas with little maintenance and much spontaneous development find a place? So far, the city of Dresden has succeeded in doing so primarily in outdoor areas where, for example, former military or agricultural facilities have been converted into green spaces. This is more difficult in residential areas.

The 400 municipal streams form an almost comprehensive network. Step by step it is planned to develop it together with green spaces into an ecological network. In this way, three goals can be achieved with one measure: the protection of the aquatic ecology, the preservation of retention areas during flooding and the moderation of the urban climate. Especially in Dresden's current growth phase, it is important to keep areas in the middle of the city free of development, not first for aesthetic reasons, but because they provide important ecosystem services. Where a use is abandoned, the city can try to lease or buy the land in order to integrate it into the ecological network. Dresden will continue to grow in this task (REGKLAM 2015; Wende et al. 2014).

6.5.5 Is Resilience Dependent on the Size of the City?

It is often assumed that cities above a certain size are particularly efficient, but they also face a variety of potentially increasing problems and are not very resilient (Krämer et al. 2011; Kraas et al. 2014). At first glance, small or medium-sized cities appear to be better organized. Limiting growth in size, even independently of the city structure, is therefore often a goal (Moscow and Beijing, among others). However, it has hardly been achieved to date, and is still unlikely to be achieved. Is there an optimal city size for reasons of resilience? For many other reasons, attempts are repeatedly made to determine this optimal city size (generally, e.g. Getz 1979 or specifically, measured by the number of inhabitants, from the decision-making behavior of households, Schöler 2009). As early as 1979, Getz came to the conclusion: "… our understanding of the relationship between city size and human welfare is too primitive to justify active policies to promote a particular pattern of city sizes …". (Getz 1979, p. 210). This limited knowledge about complex relationships of urban resilience allows us to distance ourselves from the idea that smaller or larger cities are more resilient, or that an optimal city size could also optimize resilience. Instead, a network of cities based on the division of labor (1. Resilience criterion) and the structure of cities from different perspectives (2.–5. Resilience criterion) have the effect that crises can be met more robustly. This enables both smaller and larger cities to develop and improve resilience. Megacities, too, can develop resilient structures and become more resilient to crises. The following two examples of improving resilience with the means of green space planning and urban structure development are presented. The greening of cities can certainly not be the only reason for urban resilience. However, it can very well be an essential factor in this. Both large and small cities have demonstrated this successfully. They are thus not only developing their own visitor-friendly attractiveness and thus the tourism sector, but are also becoming increasingly attractive as business locations and places to live for those working there. Salzburg in Europe and Shanghai in Asia are good examples of this.

Dynamic Megacity Shanghai

The megacity Shanghai in China has an area of 6341 km^2 and a resident population of about 24 million. Thus, Shanghai has about seven times as many inhabitants and area as Berlin. In Shanghai, 6000 km^2 of urban area are under urbanization pressure! One of the most urgent problems is to deal with the high building density and urban growth in order to create a resilient urban structure. Urban planners in Shanghai were already asking themselves this question in the 1980s. They opted for compact building structures combined with green spaces. Until then, Shanghai had one of the lowest green space proportions of all Chinese cities. In 1978, this made up only 8.2% of the total urban area. The proportion of green spaces per inhabitant was 0.69 m^2, the proportion of public green spaces per inhabitant was 0.35 m^2.

In 2003, the city planners decided on an ambitious Greening Master Plan with the following elements:

- Development of two green rings, the inner one around the city center, the outer one around the outer city districts. The green rings consist of reforestation areas, tree nurseries and recreation parks and are thus intended to fulfill both ecological and economic functions.
- Eight large connected green islands (*greenlands*) around the city to positively influence the city climate.
- Green corridors along main roads into the city, railroad lines and waterways
- Accessible green spaces for everyone with the aim of creating green spaces in all residential areas at a maximum distance of 500 m.
- The goals of the Greening Master Plan are: Protection of biodiversity, climate improvement, protection of wetlands, water catchment areas.

The efforts to give the city a completely new structure are enormous and successful in many areas. A high building density is to be maintained during the city expansion, but it should be accompanied by a stabilizing green structure. This green infrastructure will be the framework of the new city. The share of green spaces in the city's total area will increase to 38.4% in 2013. Both public green spaces and green spaces in development areas and the infrastructure accompanying them have seen a rapid increase. In 2013, street greenery and reforestation areas outside the city had the largest share of all urban green spaces with approximately 68%. The urban policy with the motto “Wherever there is a road, there is greening” was successful in view of the rapid expansion of the road network without creating really usable green spaces that provide ecosystem services. Since 2003, extensive investments have been made in the development of roadside greenery. In 2013, 9.9 million trees were registered as roadside greenery (Shanghai Municipal Statistics Bureau 2014). Public parking areas did not increase after 2005. They are missing in the current statistics (Table 6.5).

The proportion of public green spaces per inhabitant has been rising steadily since the 1980s. In 2013, there were 86.8 m^2 of green spaces (124,295 ha) per (registered) resident of the city, of which 12.0 m^2 of public green spaces. As recently as 1998, there were only 2.96 m^2, which corresponds to a quadrupling in 15 years.

In 2004, Shanghai received the status of “National Garden City". This title is awarded by the Chinese Ministry of Construction to those cities whose “Urban Green Coverage Rate” is at least 35% and whose share of public green spaces per inhabitant is at least 6.5 m^2 (Leung 2005; Shanghai Municipal Government 2007; Shanghai Municipal Statistics Bureau 2014).

Table 6.5 Green development Shanghai (Shanghai Municipal Statistics Bureau 2006, 2014e), data in ha

Year	City green space	Public green space	Parks	Street green and new forest	Green portion in %
1990	3570	983	712		12,4
2000	12.601	4812	1153		22,2
2005	28.856	12.038	1521	1284	37,0
2010	120.148	16.053	?	83.340	38,2
2013	124.295	17.142	?	84.152	38,4

Salzburg—Declaration of the City Council in 1985 Defines the Extensive Green Stock Until Today

Few cities in the world have as much high-quality open space as Salzburg. Here, only one kilometer from the historical center, there is still a lot of productive agriculture. This undoubtedly makes Salzburg a special cityscape!

The administrative city of Salzburg proudly points out that 58% of its territory is green space (agriculture, forestry, parks, etc.). 16% of the total city area (27.5% of the green space) is protected by law (LSG, NSG, protected landscape element). This means that protected areas in Salzburg are about half the size of the total building area. 50% of all apartments in Salzburg (more than 20,000 units) are located in single- and two-family houses, which occupy far more than half of the residential construction area. This is where Salzburg's additional, hidden (private) green space in the form of gardens and trees is to be found. However, the lush greenery does not have the same qualities of use and ecological functions everywhere, nor is it equally distributed.

In 1985, the City of Salzburg's magistrate for the first time adopted a declaration of "Protected Greenland" (Greenland Declaration). Since then, Salzburg has pursued a clear policy of protecting and preserving green space within its borders and has integrated this into urban development planning. In 1998, the "Greenand Declaration" was concretized and expanded in text and space. In 2007 it was integrated as part of the Spatial Development Concept (REK 2007) of the City of Salzburg.

The declaration area covers about 3700 ha, i.e. about 57% of the approximately 6570 ha of the city of Salzburg.

The four objectives of the grassland declaration are:

1. Protection of still existing larger contiguous open spaces and landscapes,
2. Securing the continued existence of agriculture by keeping land free,
3. Preservation of local recreation areas and inner-city open spaces worthy of protection,
4. Prevention of the growing together of the city and neighboring communities with regard to building development.

Objective 1 is to be explained with species and biotope protection. Objective 2 is to preserve the agricultural landscape character of the city. However, agriculture close to the city, short distances between producer and consumer or qualitative aspects (reduced use of fertilizers and pesticides) are not intended. Objective 3 is also oriented towards the landscape character, but also towards the quality of the recreational landscape in the city. Objective 4 is not ecologically justified and does not correspond to the already existing reality. With the protection of green and open spaces in Salzburg, urban development has been shifted to the outskirts of the neighboring municipalities and has indirectly promoted suburbanization there.

This is an expression of the endeavor to permanently maintain a status quo of the existing open space and building situation, at least in the political city of Salzburg, and thus the cityscape that is perceived as ideal. However, it is not based on prior analysis and evaluation of the ecological and other functions of green spaces, which, regardless of their differentiated significance and performance, are to be preserved only in the existing urban fabric. It remains to be assumed that it is less their functions than the "image of the beautiful city" that is to be preserved. A side effect is that within Salzburg's political borders, building land will thus become scarcer. This leads to an increase in the price of real estate in Salzburg, to a densification of existing development, to a diversion of developers with their construction projects into the neighboring municipalities of the urban landscape of the conurbation, which have not adopted such a regulation and are pursuing their own policies only a few kilometers away, and ultimately to a migration of less solvent tenants and real estate buyers to the outskirts of the city, the outer ring of Salzburg's urban landscape (REK 2007; Breuste 2014b; Fig. 6.11).

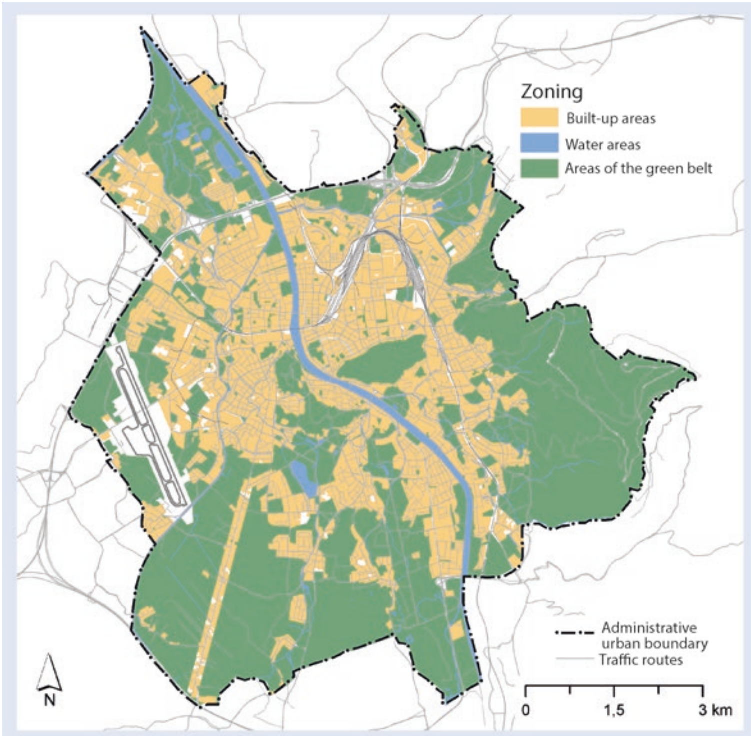

Fig. 6.11 Green structure of Salzburg. (Design: J. Breuste, cartography: W. Gruber, source: REK 2007)

6.5.6 Adaptation to Climate Change

Climate change will affect buildings and infrastructure, urban functions and services and especially the inhabitants of cities (Rosenzweig et al. 2011; UN-Habitat 2011). Strategies and measures for climate protection, i.e. for reducing greenhouse gas emissions, must therefore be supplemented by climate adaptation in order to prepare cities for climate change. Assuming that climate change cannot be reversed in the coming decades due to the continuing high emission of greenhouse gases and their long residence time in the atmosphere, but is likely to intensify, climate change adaptation should be given high priority in urban development. However, climate protection and adaptation should not be considered separately, in order to avoid that climate protection measures increase urban vulnerability and, conversely, that adaptation to climate change counteracts climate protection goals.

Section 6.4 has already described the possible impacts of climate change on cities. They are caused by the exposure of urban areas (e.g. coastal areas or large rivers), the sensitivity of urban land use and infrastructure to natural hazards such as heat waves or floods, and the often low adaptive capacity (see Components of vulnerability, Sect. 6.4).

The latter is particularly low in cities of developing countries, due to the poverty of the population and weak urban administration, which is hardly able to respond adequately to the consequences of natural disasters such as floods and has little influence on urban development.

While strategies and measures for climate protection are now being developed and implemented by numerous cities, comprehensive approaches to climate change adaptation are still rare. An ongoing evaluation of climate adaptation strategies in 58 major German cities (Zölch, unpublished, as of April 2015) showed that only about one-third of the cities are pursuing climate change adaptation goals and measures, either as a stand-alone adaptation strategy or as part of a climate protection strategy. The still low level of attention paid to climate change adaptation to date certainly has to do with the fact that major climate change impacts can only be expected in the medium to long term and are therefore pushed into the background by problems that need to be solved in the short term. However, strategies and measures for climate change adaptation also face two challenges that are difficult to overcome in principle. First, adaptation measures practically always relate to specific areas, such as rivers and their floodplains. This means that many interests must inevitably be taken into account in adaptation, such as different use claims and landowners or societal concerns such as nature conservation, recreation, etc. Adaptation therefore always requires cross-sectional approaches, which are much more difficult to develop and implement than sectoral approaches, for example to reduce the energy demand of the urban building stock.

A second major challenge is the uncertainty of the projected impacts of climate change. Predictions are not possible, but only scenarios that span a wide corridor of possible climate changes and the associated natural hazards. But what should a city like Copenhagen adapt to if the climate at the end of the twenty-first century could resemble today's moderate Atlantic climate of Bordeaux or the hot summers of Tirana in Albania (see Hallegatte et al. 2007)? In view of these uncertainties, it seems tempting to wait and see how things will actually develop. As the report by British economist Sir Nicholas Stern (Stern-Report, *Stern Review on the Economics of Climate Change*; Stern 2007) based on economic calculations has already illustrated, doing nothing does, however, entail considerable risks because it passes on to future generations the very high costs of much higher damage and the need for more drastic adaptation measures. It therefore makes more sense to initiate systematic approaches to climate change adaptation already today in order to gradually adapt to climate change. These general considerations also apply to cities.

Adaptation to climate change can be achieved through autonomous measures by individuals or organizations. One example is the purchase of air-conditioning systems by homeowners to avoid heat loads caused by increasing heat. It is probably understandable that this is a very problematic measure from an energy point of view. If implemented by many homeowners, it would greatly increase energy demand and thus also run counter to climate protection. Planned adaptation, which leads to effective and holistic solutions, is therefore particularly important. There are other reasons for early and planned adaptation (according to: Burton 1996; Willows and Connell 2003):

- Climate change may come more quickly, and it has more dramatic effects than previously assumed. It is therefore important to reduce risks early on.
- Immediate measures protect against climate extremes and lead to further improvements in the environment, such as increasing the quality of recreation through the creation of green spaces.
- The benefits of climate change can be exploited, for example when warmer summers improve the quality of outdoor recreation. However, this advantage can only be exploited if there are also open spaces that make it possible to stay outdoors for longer.
- The adoption of strategies for climate change adaptation increases political sensitivity because it becomes an integral part of the discourse.
- Principles for planning under great uncertainty and for promoting resilient behavior of the urban system were already introduced in Chapter 1 (Table 1.2) and in this chapter. According to the concept of vulnerability, as introduced in Sect. 6.4, climate change adaptation is about
- the reduction of exposure to natural hazards, for example by keeping floodplains free of development,
- reducing sensitivity to natural hazards caused by climate change, and
- the increase of the adaptive capacity.

Increasing adaptive capacity is again a complex field of action. On the one hand, it involves securing and strengthening the adaptability of the physical environment, and on the other hand, society, from the individual citizen to the municipal administration and policymakers, must be enabled to adapt successfully. Under the heading “Ten Essentials for Making Cities Resilient”, the above-mentioned United Nations strategy paper UNISDR, prepared by the Office for Disaster Risk Reduction, emphasizes the special importance of well-functioning organizations and their coordination as a prerequisite for disaster reduction and strengthening urban resilience (UNISDR 2012). Participation of civic organizations is considered particularly important. Functioning land use planning and the protection of ecosystems are also mentioned.

The importance of ecosystems for climate change adaptation is increasingly emphasized and promoted under the term *ecosystem-based adaptation*, especially in the context of developing countries (Naumann et al. 2011; Doswald et al. 2014). But what contribution can urban nature actually make to adaptation to climate change? One could answer spontaneously: a very large one! After all, a major cause of urban vulnerability is the change in natural processes caused by settlement development. Dense development and a high proportion of water-impermeable, sealed surfaces (Chap. 2, Fig. 2.9) generate increased and faster runoff of rainwater after heavy rainfall events, and they cause the heat island effect, i.e. higher temperatures in the city compared to the surrounding countryside (Chap. 3 and 5). The retention capacity of floods is often limited, for example, by the canalization of running waters and the development of floodplain areas. Measures that promote natural processes in cities should therefore also increase their adaptive capacity. The renaturation of the Isar in Munich, for example, is an example of an adaptation measure that has increased flood safety while at the same time creating new habitats for flora and fauna and significantly improving the recreational quality of open spaces along the Isar (Chap. 4 Case Study—Renaturation of the Isar in Munich 2000–2011).

In Chap. 5, the ecosystem services of urban nature have already been discussed in detail. However, the description of these services does not yet answer the question of the extent to which urban nature will be able to reduce or even compensate for the increasing impacts of climate change in the future. So far there are only a few studies that try to give an answer. However, results of a study for the Manchester (England) conurbation indicate that securing and increasing the share of urban nature can make a significant contribution to climate change adaptation (Case Study—Contribution of urban nature to climate change adaptation: the example of Manchester). In addition to the ecosystem services presented in the Manchester case study that directly mitigate the impacts of climate change, urban nature also plays a role in climate protection. Trees, for example, can store carbon (Nowak 2002; Strohbach and Haase 2012), as well as significantly reduce the heating and cooling energy requirements of buildings through evaporation and by shading the sun (e.g. Huang et al. 1992).

Ecologically oriented planning has a key role to play in strategically developing green space systems that realize the potential of urban nature to adapt to climate change as much as possible, while at the same time fulfilling other ecological and social functions. They are also increasingly referred to as “green infrastructures”. The term “green infrastructures” is used to indicate that they are just as indispensable to the functioning of the city as technical and social infrastructures, and should be thought of and planned together with them—for equally adaptable, green and climate-friendly, compact cities (Sect. 1.2.3). This refers to networked systems of green spaces that provide diverse ecosystem services (Pauleit et al. 2011; Hansen and Pauleit 2014). They are not only limited to public green spaces, but can and even must include all types of urban nature, from semi-natural forests, moors and water bodies, agricultural areas, landscaped green spaces such as parks, gardens and avenues to urban wastelands. Technical greenery such as roof and façade greening or trough-rigolene systems are also part of green infrastructures.

In order to develop green infrastructures specifically for climate adaptation, scientific findings, such as urban climatology, on the relationship between the size and distribution of green spaces and their climatic effects should be taken into account (Bowler et al. 2010; Horbert 2000). This also applies to the design and maintenance of individual open spaces, such as parks or street spaces. Trees are particularly suitable for reducing heat stress during the day due to shading and evaporation of water in open spaces. However, they require space, both for the crown and the root space. In urban street spaces that are intensively used above and below ground, however, it is already extremely difficult to provide the tree population with the conditions for vital growth.

If the results presented in the case study on Manchester indicate the potential for climate adaptation through urban nature, a subsequent study will show how difficult it will be to achieve ambitious goals such as increasing the proportion of woodland in densely built-up areas by 10%. According to Hall et al (2012), the proportion of trees in four dense forms of housing in Manchester, currently ranging from 1.6–14.8%, could be increased by a maximum of 2.8–5.3%.

Such figures are, of course, based on various assumptions about the suitability and availability of land for tree planting. In order to plant significantly more trees, however, comprehensive and, as far as we understand it today, radical measures would be necessary, such as extensive traffic calming combined with a reduction in the space required for stationary traffic. But who would voluntarily give up their car to make room for a road tree? Other greening measures, such as backyard, roof or façade greening, are also very difficult to implement on a large scale in existing buildings. This simple example may indicate how difficult it will be to develop and implement comprehensive climate adaptation strategies using green infrastructure. But precisely because the difficulties are so great and progress will only be made in small steps, it is all the more important to start adapting now! The question of the desirable relationship between building density and adequate greening of the city must be discussed and answered again and again (see Fig. 1.10, Sect. 6.5.3).

The contribution of Urban Nature to Climate Change Adaptation: The Example of Manchester

In the Greater Manchester conurbation, about 2.5 million people live in an area of about 1300 km^2. With the help of model calculations, scenarios were used to investigate the adaptation capacity of urban nature to climate change.

For the modelling, a structural type mapping was carried out (Chap. 3), which provided detailed information on the land use structure and the distribution of green spaces and water bodies in the city. Information on the area proportions of buildings, paved surfaces and the various forms of greenery (trees and shrubs, meadows and lawns, etc.), as well as climate data and climate change scenarios were the basis for the spatial modeling of surface temperatures (Fig. 6.12). A regional soil map served as a further basis to also simulate the surface rainwater runoff after a heavy rainfall event (Gill et al. 2007).

Surface temperatures in the city centers of this polycentric urban region and other densely built-up areas are approximately 10 °C higher than in well greened residential areas and green spaces. Further global warming will further increase the differences. While an increase in surface temperatures of 4.3 °C has been determined for city centers in the most extreme climate scenario, they increase by only 3.1 °C in the loosely built up residential areas.

A particularly interesting result of the study is that an increase in the proportion of vegetation-covered surfaces in the city centers from the current level of just under 20% by a further 10% could approximately compensate for the temperature increases caused by climate change (scenario 1). In this scenario, surface temperatures would increase by an average of only 0.6 °C. If, on the other hand, the

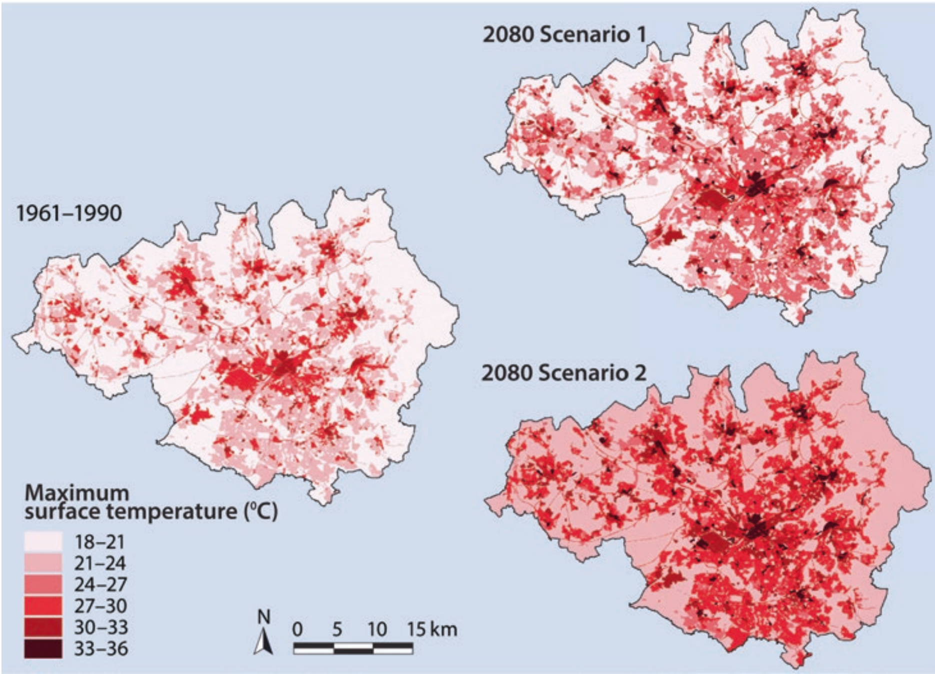

Fig. 6.12 Effects of climate change on surface temperatures in the Greater Manchester conurbation. (Gill et al. 2007, modified)

proportion of green areas were to be halved by a further increase in sealed surfaces, this would result in an increase in surface temperatures of 8.6 °C (scenario 2).

These model results are not intended to claim that increasing the proportion of green spaces in cities could compensate for or even reverse climate change, but they do provide a clear indication of the importance of green spaces for urban adaptation strategies.

Precipitation levels during heavy rainfall events will increase from 18 to 28 mm within 24 h according to the extreme scenario in Manchester. Under status-quo

Planning Association for the Frankfurt/Rhine-Main Conurbation Creates Urban-Regional Cooperation in Planning

On April 1, 2001, a Hessian state law established the Planning Association for the Frankfurt/Rhine-Main (approx. 1.6 million inhabitants, 900 km^2). The basis was a law on conurbations passed in 2000 (BallrG, "Law to strengthen municipal cooperation and planning in the Rhine-Main region" (Gesetz zur Stärkung der kommunalen Zusammenarbeit und Planung in der Region Rhein-Main)).

A council of the region, consisting of mayors and district councillors, is responsible for the strategic control of intra-regional cooperation. In addition, the law provides for "voluntary" special-purpose associations to be set up by the municipalities concerned. These take over from the Umlandverband Frankfurt (UVF; Frankfurt Regional Association), which has been responsible since 1975 for supra-municipally important planning, sponsorship and implementation tasks in the city region.

Like the Regional Land Use Plan (RegFNP), the Landscape Plan is drawn up by the regional association for the entire area of the Frankfurt/Rhine-Main conurbation. It provides a comprehensive overview of ecological contents and structures (plants and animals, soil, water, climate and air) and derives from it the requirements and measures of nature conservation and landscape management and the compensation of interventions on a regional scale (Regionalverband FrankfurtRheinMain 2015).

conditions, this will increase the share of superficial rainwater runoff from 56 to 82%, which will lead to a considerable additional load on the sewer system. An increase in the proportion of vegetation-covered areas by 10% can additionally retain 4–5% of this rainwater in the city centers. Increasing the proportion of green areas alone will therefore not solve the problem. Further concepts for local rainwater management are required, for example for the retention and infiltration of rainwater in trough-trench systems. However, it is also important to protect soils that are particularly susceptible to infiltration from further surface sealing. However, urban nature can only provide the indicated adaptation services if it also remains functional in the face of climate change, for example by using drought-resistant lawns and tree species in the street space.

6.5.7 City and Surrounding Area as a Resilient Region

"Cities melt into the landscape. Today we can speak above all of the inhospitality of the surrounding countryside. At the same time, there are signs of a dualization between the core city and the surrounding area. The poor and foreigners are concentrated in the core cities. The surrounding communities are increasingly becoming areas of middle class and single-family housing. Concepts from the 1960s and 1970s cannot be used to solve the new problems. Even further concentration on interior development, as in the 1980s, will not provide a solution" (BmBau 1993, p. 8).

This statement by a commission called "Future City 1993" can be understood as a direct call for integrative developments of the city and its surroundings as an urban region. Without this task having been solved in Germany to date, there are already promising examples of this (Case Study—Planning Association for the Frankfurt/Rhine-Main). The aim is to develop dynamic urban regions that are economically and structurally diverse, build on an economic and natural infrastructure that provides them with resilience and enable dynamic development without destroying the natural services of the urban and surrounding ecosystems. More and more functions and uses originally concentrated in core cities are shifting to a wider landscape environment in an urban region. This is associated with ecological impacts (Breuste 2001b, Chap. 1, 3 and 7).

The urban region is represented as a mosaic of the "landscape inventories" of the agro-forestry cultural landscape and that of the urban core landscape, in which a process of competition for use determines the structure. This process is sought to be moderated by spatial planning. Typical situations in suburban space are present:

- Decline of areas that are not regularly maintained,
- Area-effective pollutant emissions and noise propagation ("noise") in wide strips along the dense road network,
- Landscape fragmentation and destruction of habitat potential (e.g. by fragmentation of habitats, erection of barriers to dispersion or decoupling of complex habitats by removal of individual habitat parts),
- Loss of the small-scale nature of the cultural landscape and structural diversity through increasing sealing and increasing the intensity of care, removal of small structures such as walls, verges, village ponds, village green, small water bodies, etc.,
- Loss of regenerative properties of the ecosystems through modern intensive agriculture and frequency of change of use on an area (*biotope turnover*)
- Reduction of the agricultural production potential of the soil through building development,
- Reduction of the groundwater recharge potential by surface sealing and increase of the discharge peaks (with floods) of the receiving waters,
- Anthropogenic design of the entire water network and its banks up to the sewerage system and laying into the underground,
- Change in the recreational value of the landscape for many types of open space recreation (e.g. hiking, walking, cycling, etc.) due to the loss of landscape coherence due to barriers that are being extended in the course of infrastructure development,
- Loss of nature worthy of protection and complete, identity-destroying changes to the landscape (Breuste 1997, 2014a, p. 115; Spehl 1998; Villa et al. 2002).

The offers of ecosystem services in an urban region can in a special way come from the suburban area and, if their preservation, development and use are taken into account, can contribute to a stringent and resilient urban region.

Fig. 6.13 Cape Town. (Photo © Breuste)

Draft City of Cape Town Bioregional Plan

South Africa's second largest city, Cape Town (3.7 million inh.) has set itself an ambitious goal. It wants to put the biodiversity of its city and surrounding area at the center of its planning (Figs. 6.13 and 6.14).

"The vision of the City's adopted Local Biodiversity Strategy and Action plan (LBSAP) is to be a City that leads by example in the protection and enhancement of biodiversity. A City within which biodiversity plays an important role, where the right of present and future generations to healthy, complete and vibrant biodiversity is entrenched, and to be a City that actively protects its biological wealth and prioritises long term responsibility over short-term gains" (CCTM 2013, p. 3).

Cape Town has developed a "Bioregional Plan" for this purpose in 2013. It continues the earlier efforts of 2006 and 2009 (Biodiversity Network, BioNet), is part of the steering overall plan "Cape Town Spatial Development Framework" (CTSDF) and covers the entire metropolitan region of 2460 km^2. In view of the many social and economic problems, it is a great challenge for Cape Town to protect the biodiversity, which is under high pressure of use in the Cape Region—a global biodiversity hotspot. The "Bioregional Plan" provides a basis for nature conservation in this dynamically developing urban region. Not only do many protected areas contribute to the biodiversity, above all the Table Mountain National Park in the middle of the city, but also a large number of previously unprotected areas with diverse flora and fauna. The "Bioregional Plan" does not only have a conservative character that blocks all developments, but it also wants to contribute to sustainable development. All areas (terrestrial and aquatic) that are valuable for biodiversity and ecosystem functions are recorded as *Critical Biodiversity Areas*

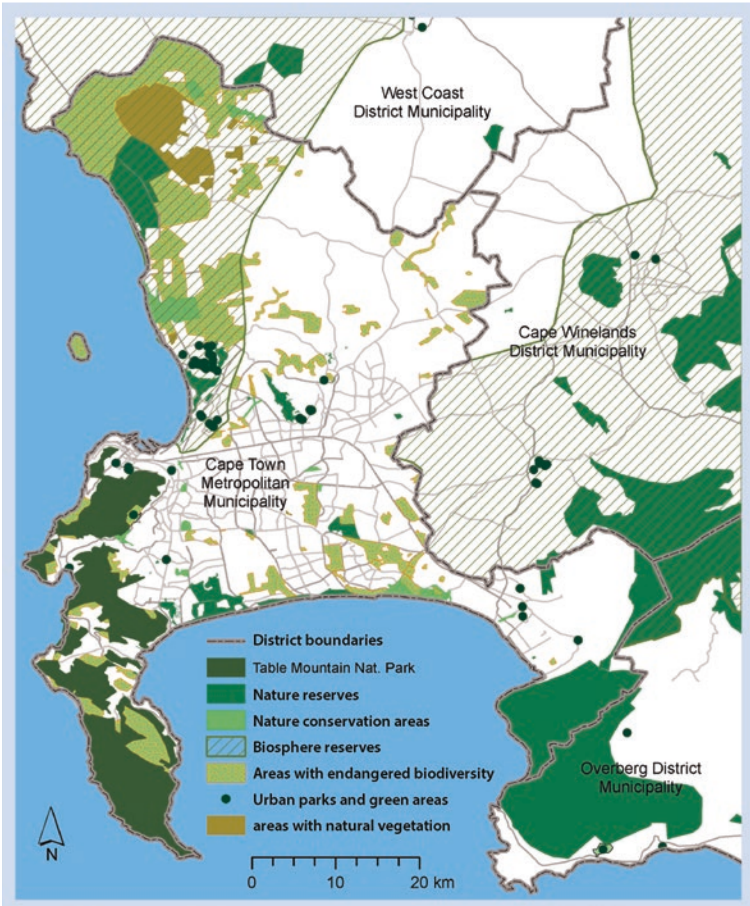

Fig. 6.14 Cape Town Bioregion. (Design: J. Breuste, cartography: W. Gruber, source: CCTM 2013)

(CBAs) and *Critical Ecological Support Areas* (CESAs). The *National Spatial Biodiversity Assessment* of 2004 is thus implemented locally as a national task. The focus of the plan is to determine the ecological properties of these different ecosystems, which form an ecological infrastructure in a network (*Biodiversity Network*) and exhibit ecological performance characteristics as a whole. The aim is to achieve a sustainable urban development that builds on the services of nature to develop a resilient urban region (Fig. 6.14).

The implementation of the “Bioregional Plan” is reviewed every 5 years on the basis of biodiversity targets and indicators (CCTM 2013).

Questions

1. What does flood risk mean for an urban system?
2. To what extent can internal and external influences influence the ecological sensitivity of urban ecosystems?
3. Under which circumstances can natural events in urban areas lead to natural disasters?
4. What are possible effects of urban shrinkage on urban climate?
5. what do you understand by "double inner development"?
6. name resilience criteria of urban systems!

Answer 1

Conceptually, the risk R of a city, a district, but also of an individual city dweller is understood as the probability P with which a certain damage D occurs or will occur.

Answer 2

Urban ecosystems are open systems in terms of their energy, material and water balance. This means that they are dependent on the input of a variety of substances, water and energy. If some of these factors are limited, the functionality of urban systems may be severely restricted. On the other hand, urban systems have cycles. If these are disturbed internally, the functionality of the urban systems may also be impaired.

Answer 3

Natural events become natural catastrophes when human lives are lost or when the affected society is dependent on outside help. Many urban areas are located in such a way that they are exposed to hazards, e.g. many coastal cities are endangered by the effects of earthquakes and subsequently tsunamis.

Answer 4

The demolition and "freeing up" of previously built-up areas leads to an improvement in the local climate, better ventilation and an increase in vegetation in the urban area.

Answer 5

This concept of the German Council for Landscape Management 2006 recognizes that urban development is not only about structural aspects and infrastructure, but also about the "second side of urban development", the associated open space. This second side of urban development, the open space, must be aligned with target criteria that relate to sufficient quantity, quality and location to fulfill its function. Open space quality thus acquires the significance of a development potential for cities.

Answer 6

- Autarky and exchange,
- Redundancy and diversity,
- Compactness and decentralization,
- Stability and flexibility,
- Diversity and stability.

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7

What Does the Eco-City of Tomorrow Look like and What Are the Paths Leading to It?

Jürgen Breuste

Abstract

This chapter takes up the great vision of the ecological city of the future and describes its roots, approaches and implementation. The first section defines and describes ideal cities as models. It is shown that the modernism as initiator of functional and efficient urban development took up existing approaches and developed them further. The model of the so-called sustainable city of the twenty-first century, whose interpretation is diverse, includes ecological components and requires binding assessment and design criteria, was based on this. In the second section, the criteria that form the concept of eco-cities are explained in more detail. It should become clear that, depending on the perspective and in relation to natural processes ("ecological" criteria), a large number of criteria or only a few can be used. The third section presents the eco-city model using examples in new building projects "top down", and in district projects and in actions for more open space and nature "bottom up". In this way, the eco-city model takes on real form, can be assessed from various perspectives, and must therefore be redefined in each individual project. It is shown that the grand vision of the eco-city is often certainly ambitious and must be redefined in each individual project, but that it can also be pursued in small steps. In this way, a constructive approach to the topic is created, which turns the vision into a practically manageable project.

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7.1 From vision to mission statement - urban development in the twentieth century

7.1.1 The principle of the ideal city

The ideal city was a vision of architects and urban planners from various angles in the course of historical urban development (Lang 1952). The aim was to create the best possible city, the one with the highest degree of perfection, the "ideal city". This is based on the idea that with the help of the human imagination, the highly complex structure of the city could be designed in a predictable and conscious way, at least in its physical and technical elements, in all details. Little consideration was given to its location, the natural and other conditions on site or existing cities. The ideal city should be created anew by an intellectual elite with insight into the universal laws. Whether it was to remain a prototype against which others were to measure themselves, or whether many "ideal cities" of the same structure were to form a network, remained mostly open. Thomas Morus's state had 54 almost identical cities spread over the island of Utopia (Morus 2009, first published in 1516). He took up Plato's idea that any deviation from an ideal model can be disadvantageous (Platon 1989, first published 380 BC). This idea of multiplication of the ideal blueprint is also found later.

Ideal cities were often planned and in some cases built during phases of historical upheaval or a paradigm shift in social ideas. The utopias present themselves as alternatives to the existing situation, from which one consciously turns away and which is criticized. Scientific progress and efficient transformation of society characterize the alternative model. The "chaotic nature" should be dominated by the "rationality of man". Diversity of opinion and tolerance, essential characteristics of democracy, are not found in the social conceptions underlying the utopian-ideal city concepts (Eaton 2003).

The ideal city must be seen in its social context. It should, although itself only an expression of society, often solve social problems—an utopian task.

Three important guiding principles have determined the 20th century as an ideal city. Two of them were developed from modernity as answers to the crisis of the real city. They could not be more opposite: The Garden City (Ebenezer Howard), which emerged as a counter-image to the industrial metropolis; the Functional City/Ville Radieuse (Le Corbusier), which formed the model of the metropolis of mechanized modernity; and the Sustainable City (sustainability as a model of local development), which emerged from the environmental and resource crisis in the second half of the twentieth century. The image of the ideal city exists in many sub-models with more or less great complexity (e.g. Compact City, Smart City, Green City, ElCity, Healthy City, Eco-City, etc.)

7.1.2 Ideal Cities as Models of Modernity in the Twentieth Century

The idea of solving social problems by means of new cities combining the advantages of rural and urbanlife was developed at the end of the nineteenth century in the most developed industrial society, in England. Its proponent, Ebenezer Howard (Howard 1898, 1902) was convinced that if industrial cities became either increasingly exploitative or health-destroying, they would provoke violent class conflict. His solution was the ideal city as the city of the future - the garden city—which, as a physical reorganization with a more civilized level of social development and linked to the cooperative system, would avoid this development (Eaton 2003). The garden as a symbol for better, more hygienic living conditions with "light, air and sun" stood for a new turning to nature that touched all parts of society. The "natural" became the ideal, and their criticism of industrialisation, materialisation and urbanisation became a "life reform", which propagated a "nature-oriented way of life" (life reform movement). The life reform movement and the garden city come together, for example, in the garden city of Dresden-Hellerau (1909) (Fig. 7.1). Howard's garden cities were concentric designs of single-family and terraced house structures whose concentric residential rings were separated by park rings. The relatively small cities (32,000–58,000 inh.) were only equipped with commerce and were intended as a counterpart to the large industrial city. Lechtworth was built in 1903 and in the 1920s the much larger Welwyn Garden City near London.

The fact that the garden city became the first and certainly the most successful model of urban modernism is probably less due to these two examples than to the extensive transformation of the idea into large-scale realities. These were, on the one hand, the cooperative housing construction in Central Europe after the First World War to eliminate the great housing shortage. On the other hand, the model of the garden city is behind the even more successful planned suburban and later suburban single and

Fig. 7.1 First German Garden City Dresden-Hellerau. (Photo © Breuste 2012)

terraced housing estates worldwide. The fact that the house and garden became affordable for everyone became a social concept and the driving force behind the rampant, extensive urbanisation of the twentieth century (Fig. 7.2).

The garden city as example forced the garden city movement, reached the European continent at the beginning of the twentieth century and was a successful model especially in Germany. In 1902, the German Garden City Society (Deutsche Gartenstadt-Gesellschaft; DGG) was founded in Berlin, a life and social reform organisation whose aim was to establish garden cities.

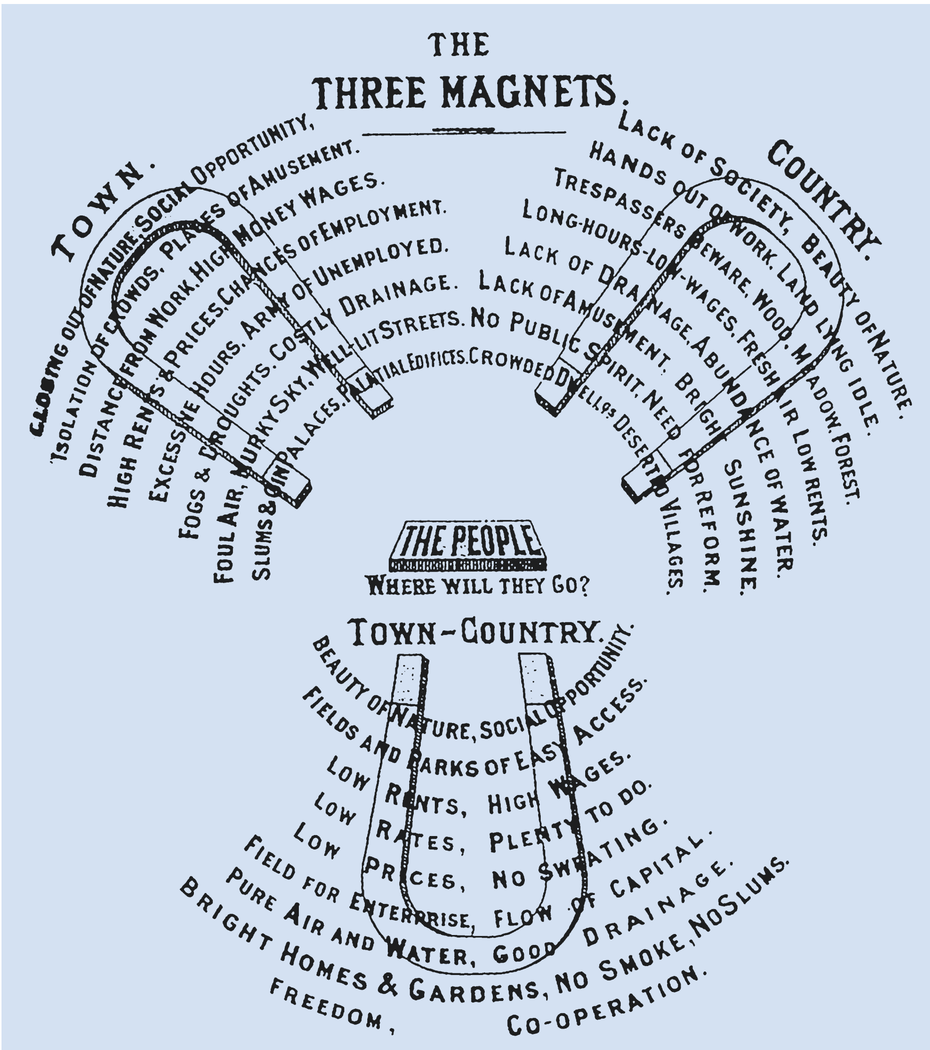

Fig. 7.2 The third "magnet"—Town-Country is for Howard the solution of the town problems. The garden city combines all the positive aspects of city and countryside. (Howard 1898)

Theodor Fritsch had already published his book "The City of the Future" in Leipzig in 1896. He preferred a technically dominated and socially hierarchical society, with the large, significantly growing cities at its centre. Fritsch developed his city of the future in two variations. In the first draft, like Howard, he conceived of a new city, and in the second draft, he conceived of an urban expansion, which contains the historically grown city only as a peripheral district (Fig. 7.3). Both designs take up the radial-concentric urban model, but reduce it to a semicircle, which is supplemented by a forest and park landscape and interspersed with green spaces. Nature in different forms is an essential component of Fritsch's city of the future, a new pioneering idea at the turn of the twentieth century.

Modernism in the first half of the twentieth century developed a second model of the city of the future: the functional city as an expression of a collective, functional society, the city of modernity.

Classical modernism in architecture is oriented towards a clear rationalism, a subordination of form to function, minimalism and collective solutions. The standardization of life was intended to enable maximum efficiency in standardized cities. Modern building materials (reinforced concrete, steel skeleton, glass, etc.) allow the detachment from traditional building and urban structures. The dissolution of urban structures such as

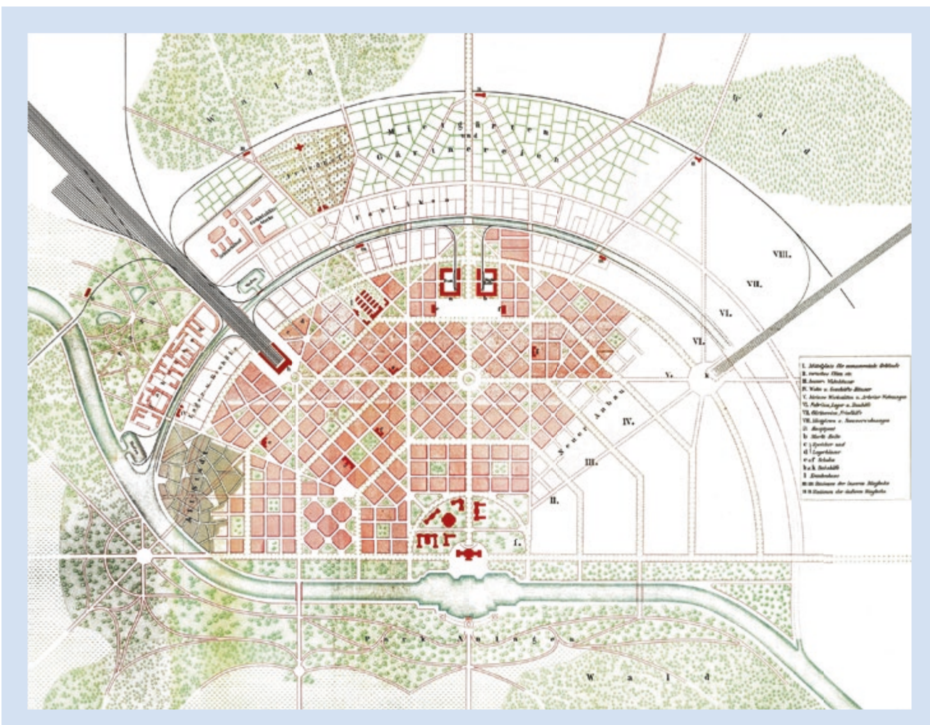

Fig. 7.3 Draft II by Fritsch (1896)—a city integrating the old town

building blocks and streets, as well as the separation of functions (e.g. living and working) are characteristic of this. The communally used house with standardized apartments and infrastructure facilities (*Unité d' habitation*) is the basic ideal of these ideal urban and social concepts (Le Corbusier 1935).

With his works, the Swiss architect Le Corbusier (1887–1965) symbolizes the ideal city of modernity. He developed two far-reaching plans for it: the "Ville contemporaine pour trous millions d'habitants" (Le Coubusier 1922; Fig. 7.4) and the "Ville radieuse" (1930, Le Corbusier 1935) (later also a band city). In contrast to the representatives of the garden city movement, the architects of the modern age were enthusiastic about big cities as well as technology and industry, and shaped them with large housing estates with multi-storey apartment blocks and needs-based infrastructure in many parts of the world—from the USA, Brazil, Europe, the Soviet Union to Australia. But also whole new ideal cities, such as the Brazilian capital Brasilia (responsible architects were Oscar Niemeyer and Lúcio Costa, 1956–1960), stand for this.

At the Fourth International Congress of Modern Architecture (*Congrès Internationaux d'Architecture Moderne*, CIAM) in 1933, a charter of 95 theses on modern urban planning was adopted (published in 1943), the core of which, the separation of the key functions of urban planning (living, working, recreation, education, transport), acquired programmatic significance and became famous and implemented as Athens Charter.

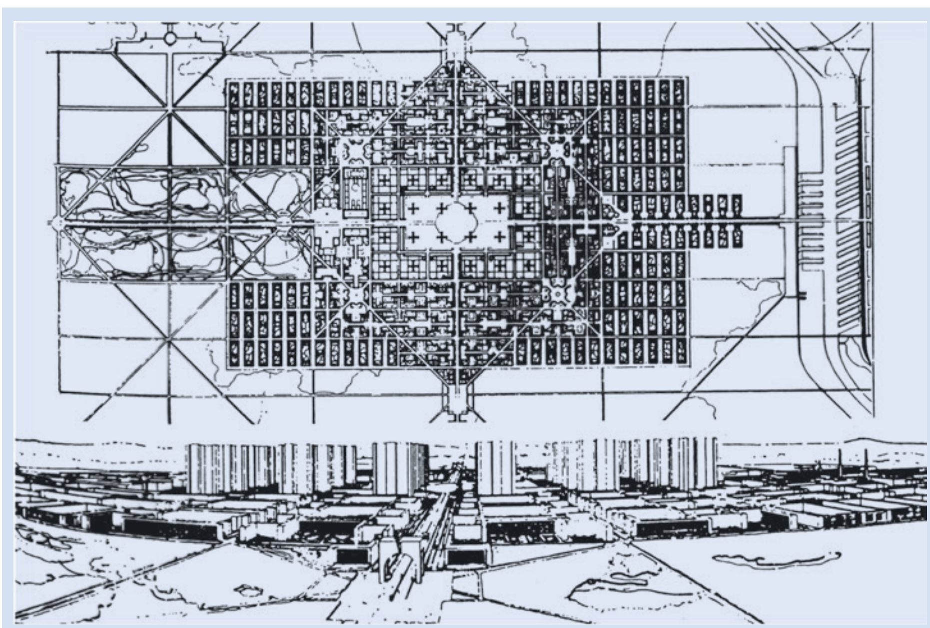

Fig. 7.4 A contemporary city for 3 million inhabitants, general view (Le Corbusier 1922)

The Happy City ("Cité radieuse")—The Unité d'Habitation by Le Corbusier

A total of five of the so-called Unités d'habitation (housing units) were built, the first in Marseille from 1947 to 1952. The 18-storey reinforced concrete structure, which is 138-m long, 25-m wide and 56-m high, is supported by a ground floor made of pylons. The 337 apartments, made up of 23 basic types of different sizes, are each two-storey, occupying the whole floor on one floor, half of the floor on the other, and are accessed by a continuous corridor. The row of buildings is aligned in a north–south direction, so that both sides receive sufficient sunlight. On the seventh and eighth floors, there are shops, a small hotel for visitors and a laundry. On the last floor, there is a primary school and a gymnasium. On the walk-on roof, there is a kindergarten, paddling pool for children, play areas, open-air theatre and sports hall for common use. The building is nothing less than an attempt to create a new "living system", a "living machine" and a basic element of the new cities (see also Haberlik 2001; Eaton 2003; Office de Tourisme et des Congrés Marseille 2013; Fig. 7.5).

The Functional City of Moderne

The eleven International Congresses of Modern Architecture (*Congrès Internationaux d'Architecture Moderne*, CIAM) held between 1928 and 1959 were a think tank on a wide range of topics relating to modern architecture and urban planning. In the urbanistic models of the CIAM, urban planning is not understood

Fig. 7.5 Unité d'Habitation, Marseille, Le Corbusier. (Photo © Breuste 2007)

as a further development of historical cities, but as a comprehensive, rationalistically planned new design.

Cities are subdivided into functional areas to be unbundled: housing, work, recreation and transport.

The founding declaration from CIAM I (1928) states

- Building is an elementary activity of man.
- Architecture should express the spirit of an epoch.
- The transformation of the social and economic structure requires a corresponding transformation of the architecture.
- Architecture has an economic and sociological task in the service of man.

At the fourth CIAM in 1933, the Charter on the "Functional City" was adopted (Charter of Athens). It was of great importance for urban planning in the twentieth century.

Under the leadership of Le Corbusier, the Charter of Athens (*La charte d' Athènes*) aimed at disentangling urban functions and creating liveable living and working environments in the future. The charter was published in 1943 in 95 theses and is based on an analysis of 33 cities.

The following findings were made (Le Corbusier 1943; Conrads 1981; Keul 1995, reproduction of the contents of the theses):

- The current cities do not satisfy the urgent biological and psychological needs of their inhabitants (thesis 71).
- Ruthless private interests as an expression of growing economic forces lead to an imbalance in the cities in view of the ever weaker and more powerless administrative control and social solidarity (thesis 73).
- The keys to urban development lie in the four functions: Living, working, recreation, movement (traffic) (thesis 77).
- Each of the four key functions is assigned to quarters, meaningfully located in the city as a whole and structured by internal planning (thesis 78).
- A rational network of large superordinate traffic arteries for car traffic connects the newly structured urban districts (thesis 81).
- Man must be the measure of urban architecture (thesis 87).
- The basic component of urban planning is a residential cell (a flat) and its insertion into a group that forms a housing unit of appropriate size (thesis 88).
- Private interest must be subordinated to the community interest in urban development (thesis 95).

After the publication of the Charter of Athens in German language (1962), the principles became the ideological dogma for urban planning in Germany. The

Fig. 7.6 Brasilia's, capital of Brazil, loosened up centre, urban design of modernism realized from 1956 to 1960 (Costa, Niemeyer). (Photo © Breuste 1998)

urban planning models of the 1950s (the divided and loosened up city) and 1960s (the car-friendly city/areal renovation) are largely derived from the Charter of Athens (Fig. 7.6). It was not until the mid-1980s that a turning away from the ideals of the charter began in view of the negative consequences of the separation of functions.

7.1.3 Sustainable urban development as a model for the twenty-first century

After the collapse of the Second World War, the belief in any form of ideology and also in the principle of authority in general was shaken. The rebellion against the political authorities of the 1960s was an expression of this. Alternative ways of life and communities were tested. The necessary rapid reconstruction of cities in Europe had promoted the "international style", mass production and prefabrication, also in urban planning. Monotonous tenement block quarters created "urban nowhere" (Eyck 1999) (Aldo van Eyck 1918–1999). Modernity had become academic, individuality and diversity were demanded. The many different models of the 1960s and 1980s reflect this.

The "ecologically oriented urban development" (e.g. Hoffjann 1994 and many others) became a model in the course of the growing environmental awareness and broad acceptance of environmental protection since the 1970s, which formed the basis of the eco-city and sustainable city models.

Around 1975, the American architect Charles Jencks (born 1939) (Jencks 1988) used the term "postmodern" for the first time to describe new tendencies in architecture.

Fig. 7.7 The grand style in postmodernism—Antigone district, architect Ricardo Bofill, 1979 (“every public space is a theatre”). (Photo © Breuste 2007)

Postmodernism rejected the modernist division of the city into functional zones and demanded a New Charter of Athens. Historical references and traditional forms again moved into urban planning (Eaton 2003) (Fig. 7.7).

The sustainable city or sustainability as a model of local development became the postmodernist model of the last quarter of the twentieth century, which is still relevant today. It exists in concepts, approaches and exemplary realities, but not in a large model project, the model city. The starting point for the concern for sustainable development in harmony with the environment were the publications of the *Club of Rome*, especially “The Limits to Growth” (Meadows et al. 1972), and in 1987, the “Brundtland Report of the World Commission on Environment and Development” (WCED and Hauff 1987). The finite nature of available resources and the vulnerability of ecological systems as a basis for life were for the first time recognized worldwide and fixed in the term “environment”. At the same time, the term “ecology”, originally used to designate a science, was normatively transformed into everyday language, in politics and planning, but with the new meaning of “ecological” in the sense of “environmentally sound”. An ecological urban development, e.g., no longer meant a scientific urban development based on ecology, but an environmentally sound urban development.

Chapter 3 of the Brundtland Report (1987) introduces the term *sustainable development*, the concept of “future-proof” or “sustainable development”, which henceforth has been a guiding principle of postmodern urban development worldwide.

The new principle of sustainability is much broader than “environmentally sound” or “ecological” modes of action, but includes them. Sustainable urban development is now no longer just about the human–environment debate in the city, but also about social justice, *governance* (forms of control for steering and regulating structures and intentions), economic resilience and many other issues. Three main components - ecology (understood normatively as the structural and functional fabric of nature, not as science), economy and society—form its sub-areas.

Sustainability cannot therefore stand for "ecology" or "human–environmental relationships" in the city. *Sustainable City* (Speer and Partner 2009) as a model applied to cities should therefore not be identical with "ecological city" or shorter "eco-city", since "eco-" is not a synonym for *sustainable.*

Endlicher (2012) also shows that the "urban-ecological" system has a share in both the socio-economic and the ecological system and that the characteristics of the urban ecosystem result from the interaction of both "systems". However, urban ecology does not examine population or economic development in cities, although these undoubtedly have a considerable influence on the urban ecosystem (Fig. 7.8, Chapter 1).

Sustainability as a model of urban development thus has, in contrast to the two earlier models of urban development of the twentieth century, a wide range of approaches and serves as orientation for achieving an ideal goal without a concrete, regulatory model. Ultimately, it is the selection of accesses and areas that are to fill out the mission statement that matters. These are not necessarily set, but are selected by actors, planners or scientists, sometimes in communicative processes.

What could make a sustainable city could only be defined if the challenges of the future were known. Assumptions and forecasts must be made here.

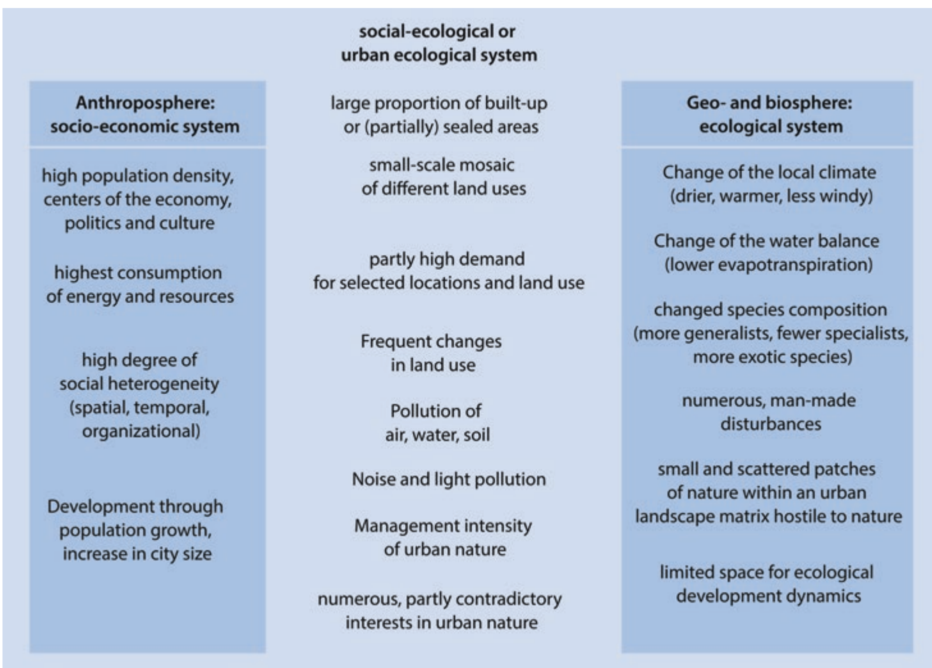

Fig. 7.8 A selection of socio-economic and ecological characteristics of the urban system and social–ecological or urban–ecological interactions (Endlicher 2012, p. 176, after Borgström 2011)

Fields of action for sustainable urban development are:

- economical soil management,
- precautionary environmental protection,
- mobility management compatible with the city,
- socially responsible housing,
- location-securing business development.

In 1994, European cities launched a European Cities and Towns Initiative on the road to sustainability. This led to the Aalborg Charter as a joint resolution of some 2500 local and regional administrations in 39 countries and the commitment of the 80 European cities and towns that signed up to it to a future-proof, sustainable policy. This was the starting point for the European *Sustainable Cities and Towns Campaign*.

In the Lisbon Action Plan of 1996, the Local Agenda 21 path was taken further with now 250 local authorities in Europe. The adopted document *From Charter to Action* stresses that action should now follow. The *European Sustainable Cities & Towns Campaign*, which initiated the *Aalborg Process* of self-regulatory actions, has since held further conferences in Hanover 2000, Aalborg 2004 (Aalborg+10), Seville 2007, Dunkirk 2010 and Geneva 2013. In Aalborg in 2004, the *Aalborg Commitments*, a list of fifty quality objectives on ten themes for European sustainable urban development, were adopted. At the 7th Conference in Geneva 2013, the *European Sustainable Cities Platform* (www.sustainablecities.eu) was established as an information hub to support actions for European municipalities, organisations and interested parties. It is an initiative of *Local Governments for Sustainability* (ICLEI) based in Freiburg, Germany and the City of Aalborg (ESCTC 2013).

The New Charter of Athens 2003. Vision for cities of the twenty-first century

In 1998, the European Council of Urban Planners (ECTP), founded in 1985 and representing 25,000 European planners united in associations, adopted in Athens a New Charter of Athens, which was to be reviewed and developed every four years and which was to provide the orientation for urban planning in Europe in the twenty-first century.

The trends and challenges of modern urban development are examined and reactions to them are described. The core of the presentation is the draft of the vision “Networked City”. The networked city comprises a multitude of interactions at different levels and on different scales. It includes concrete and visible links to the built environment as well as links between a variety of urban functions, infrastructure networks and information and communication technologies. Social, economic and ecological networking and the design of a spatial system are dealt with (ECTP/SRL 2003).

Local Agenda 21 for sustainability development

"Sustainable development represents a positive socio-economic change that strengthens the environmental and social systems on which societies and their subgroups depend. The aim of sustainable community development is to improve the local quality of life in all its social, cultural and material aspects without compromising the life chances of future generations or of people in other cities and communities around the world" (Ecolog 2013).

The Rio Conference in 1992 formulated an action programme for sustainable development in the twenty-first century. Its municipal implementation is Local Agenda 21 (BMU 1992).

Agenda 21 comprises 359 pages, divided into 40 chapters and four sections:

1. Social and economic dimensions,
2. Conservation and management of resources for development,
3. Strengthening the role of key groups,
4. Possibilities of implementation.

Chapter 28 ("Initiatives by local authorities in support of Agenda 21") emphasises that many of the global problems can best be solved at the local level ("Think globally—act locally!"), thus directly calling on local authorities to act, although international organisations and national governments are primarily addressed. Each municipality of the 178 signatory countries was called upon to develop its own (local) Agenda 21. At the World Summit on Sustainable Development in Johannesburg (2002), the representatives of the local authorities assessed only mediocre successes of "Local Agenda 21" after ten years and wanted to concentrate their efforts over the next ten years more on implementing the "Agenda 21" goals through *local action 21 campaigns.*

Aims of Sustainable Urbanisation—UN-Habitat 2009

UN-Habitat (2009) sets *goals of sustainable* urbanization

The *environmentally sustainable urbanization* requires

- Reduction of climate-damaging gas emissions and serious prevention and adaptation strategies to climate change,
- Minimising urban growth and developing compact cities accessible by public transport,
- Non-renewable resources are used in a sensitive and conservative manner,
- Renewable resources should not be exhausted,

- Per capita use of energy and waste is reduced,
- Waste is recycled or landfilled without causing environmental damage,
- Ecological footprint of cities is reduced

Further criteria of "economic sustainability of cities" and "social aspects of urbanisation" are dealt with in detail. It becomes clear that sustainable urban development is not a topic that is restricted to human–environmental relations (UN-Habitat 2009).

The Aalborg Commitments

1. Governance: Commitment to more direct democratic participation in decision-making processes.
2. Urban management for sustainability: Commitment to implement effective management processes, from formulation to implementation and evaluation.
3. Community natural assets: Obligation to take full responsibility for the protection and conservation of natural common goods.
4. Responsible consumption and lifestyle: Commitment to support prudent use of resources and sustainable consumption and production.
5. Urban planning and development: Commitment to play a strategic role in urban planning and development with regard to environmental, social, economic, health and cultural issues.
6. Improved mobility, less traffic: Attention to the interrelationships between transport, health and the environment and a commitment to promote sustainable mobility alternatives.
7. Local health promotion measures: Obligation to protect and promote the health and well-being of citizens.
8. Dynamic, sustainable local economy: Commitment to develop and ensure a dynamic local economy that creates jobs without harming the environment.
9. Social justice: Obligation to ensure an inclusive and supportive community.
10. From local to global: Commitment to local action for the benefit of global peace, global justice and global sustainable development.

7.2 Eco-Cities—Cities in Harmony with Nature

7.2.1 Eco-Cities—Sustainable Cities

The term *ecocity* or *eco-city* was first used in the 1970s and 1980s (in Russia e.g. Brudny et al. 1981, in the USA e.g. Register 1987). It was created long before the term *urban* *sustainability* was widely used. The much broader term *Sustainable City* (see also) (Speer and Partner 2009) is not a synonym for eco-city. Both contain normative concepts of future urban development. The ecological city is about the relationship between city, people and nature, i.e. the ecological aspect of sustainability. Economy and society are not equal subjects of investigation here (see sustainability triangle). The eco-city is thus a sectoral aspect of the sustainable city. The eco-city designation allows concrete references. The fact that the internet encyclopaedia Wikipedia announced in January 2013 that it would integrate the page on the term sustainable city into that on eco-city shows that there is still a lack of conceptual clarity here. This would correspond either to a completely different view of sustainability or to the synonymous use of the terms (Ecocities 2013).

▶ **Definition**

Register (1987, p. 3) states

"An ecocity is an ecologically healthy city. No such city exists. There are bits and pieces of the ecocity scattered about in present-day cities and sprinkled through history, but the concept- and hopefully, the reality- is just beginning to germinate."

Register understood *sustainable city* to mean a city that "coexists peacefully with nature" (Register 1987, p. 5, own translation).

Low consumption of resources (land, energy) is the focus from the very beginning, supplemented by the use of renewable energy, reuse of waste products, renaturation (especially water bodies), *urban gardening* and tree planting. The whole has been integrated into modern urban development with much higher priority, building on a "concept of nature". This always meant the goods provided by nature (resources, services, Chapters 4 and 5), nature as an ethical object, aesthetic natural beauty and learning from and with nature. Terms and approaches such as "Ecopolis" (Brudny and Kawtaradse 1984; Downton 2009; Wang et al. 2011), "Ecocity" (Register and Peaks 1970; Register 1987, 2001, 2006,2012; Tjallingii 1995; Roseland 1997; Archibugi 1997; Graedel 1999; Breuste and Riepel 2007, 2008; Harvey 2010; Breuste 2011; Joss 2011; Yang 2012; Su et al. 2012), "Green Cities" (Gordon 1990), "ecologically ideal city", "ecologically oriented urban development" (MURL 1993; Hoffjann 1994; Wittig et al. 1995, 2008; Betker 2002; Speer and Partner 2009), "Biophilic City" (Beatley 2010), "Green Urbanism" (Lehmann 2010) and "ElCity" (Lipp 2010) stand for this. It is scientists, but also architects and planners who are working on the concept behind the eco-city vision (Table 7.1).

A summarizing and historical perspective on eco-urban development is formulated by Joss (2011). He sees the sources in the environmental movement of the 1970s and the sustainability debate of the 1990s.

But it is only since about the 1990th that the discussion about eco-cities and the implementation of the concepts has become global. It does not primarily take place for large-scale projects (e.g. in China), although these receive the most international attention.

Table 7.1 Ecocity and related terms with different contents (after Joss 2011)

Designation	Declaration
Eco City	Term used for a number of Austrian, German and Swiss cities which in the 1990s declared their intention to introduce guidelines for environmentally friendly urban development and sustainable development, often as part of Agenda 21
Sustainable City	Synonym for “Eco City". The UN Sustainable Cities Programme has been promoting this concept since the early 1990s
Smart city	Emphasises the importance of high-tech development, smart grids, IT networks and similar productivity in energy and services supply
Slim City	A World Economic Forum knowledge transfer initiative to encourage cities to improve the performance of specific sectors such as energy, transport, construction
Compact city	Counter-concept to the (sub)urbanisation that takes up space. Guiding principles a high population density and the reduction of private motor vehicle mobility
Zero Energy City/ Zero Net Energy City	Complete in-house production of energy consumption This is achieved through a combination of measures to reduce consumption and the use of renewable energy sources
Low Carbon City	“Carbon” is used as a synonym for all greenhouse gases. The main focus is on reducing these emissions in the areas of energy, transport, infrastructure and buildings
Carbon neutral city	A city that offsets carbon/greenhouse gas emissions so that its net emissions are zero
Zero Carbon City	A city that produces no greenhouse gases and works exclusively with renewable energies
Solar City	Replacement of fossil energy sources with exclusively solar energy
Transition Town	The transition town initiative has its origins in Great Britain and Ireland. Activities in this field typically take place at grassroots level and are not embedded in politics. The aim is to strengthen the social and environmental resilience of the local population with regard to the effects of climate change and the replacement of fossil fuels. This is seen as a necessary “transition
“Eco-municipality”	The “Eco-Municipality” label identifies municipalities that have adopted ecological and social sustainability values into local politics. The movement is strongly associated with Sweden, where it originated in the 1980s, but is also becoming increasingly important in the USA

Definition

Ecocity Builders (2020) describe an eco-city as

- a healthy city, based on self-sustaining regulating, resilient structures and functions of natural ecosystems and living beings,
- a spatial unit that includes its inhabitants and their ecological influences,

- a substructure of ecosystems to which it belongs—river basins, bioregions and ultimately the Earth,
- a subsystem of the regional, national and global economic system.

  An eco-city provides healthy abundance to its inhabitants without consuming more (renewable) resources than it produces, without producing more waste than it can assimilate, and without being toxic to itself or neighboring ecosystems. The reference to ecosystems is clear, and it is also clear that the eco-city itself represents such an ecosystem or a sum of them. The long suppressed relationship of the city to the (animate and inanimate) nature of its space and the nature it has created is central to the eco-city concept. This nature provides indispensable services (ecosystem services, Chapter 5), which, as they have no market value, have usually been undervalued. But it is precisely this relationship that is at the heart of the concept.

Definition

The ever-evolving concept of the eco-city attempts to concretise a practical, not initially illusory vision of the interaction between man and nature in the urban habitat of man. The model that emerges is not an existing city, as Register wrote as late as 1987, but is realized in "bits and pieces" (Ecocity Builders 2020), which are already emerging everywhere as successful examples.

Principles of the Ecocity Concept

Contents of the Ecocity concept

Downton (2009) lists ten principles, which in some points also go beyond dealing with nature and approach the general concept of sustainability:

1. Renaturalization,
2. Integration into the bioregion,
3. Balanced development,
4. Compact settlement construction,
5. Optimized energy use,
6. Support for the economy,
7. Health and safety,
8. Support of the social community,
9. Promotion of social justice and equality,
10. Enriched by history and culture.

Ecological urban development

Wittig et al. 1995 named 6 core principles based on ecological criteria for ecological urban development:

- Healthy living in relation to nature,
- Reduction of energy consumption,
- Avoidance or cyclization of material flows,
- Protection of all living spheres (air, soil, water),
- Preservation and promotion of nature and urban open spaces, and
- Small-scale structuring and extensive differentiation.

The topic of health and quality of life in the city is rarely addressed centrally (Lötsch 1994). Among Downton's ten key issues, "health" is ranked 7th (Downton 2009).

Downton's (2009) ten principles allowed it to also call its eco-city a sustainable city. In contrast to Register (1987), it is no longer primarily about "balance with nature", but also about culture, social affairs, health, safety and economy. The actually clear references of the eco-city to nature are extended to general sustainability under the same name eco-city. This explains why both contents are often understood synonymously - eco-city = sustainable city.

Wittig et al (1995) developed guidelines for an "ecologically ideal city" that does not harm but rather promotes the physical and mental health of people, that does not burden or destroy its surroundings, and that promotes the development of all types of nature in the city (Table 7.2).

Ecocity Builders

Founded in 1992, *Ecocity Builders* is an organization that aims to support cities in their efforts to develop their socio-ecological systems in a sustainable and healthy way.

It develops and promotes applications of policy approaches, blueprints and educational building blocks that pursue the goal of improving the human-environment system in cities. The aim is to find and apply new solutions to problems on the way to the eco-city. The initiative started in Berkely, California, around eco-pioneer Richard Register and a group of innovative ecologists and architects. Richard Register started a non-profit organisation in 1975, which was merged into *Ecocity Builders in* 1992.

Ecocity Builders supports the development of the eco-city from initial projects (*pieces of ecocity*) by linking global challenges with local activities (see also Local Agenda 21).

In 1990, Register organised the 1st International Ecocity Conference with over 800 participants from thirteen countries. The growing inter- and transdisciplinary public interest in the theme of eco-cities led to further conferences, ten in all: 1990 Berkeley (USA), 1992 Adelaide (Australia), 1996 Dakar/Yoff (Senegal), 2000 Curitiba (Brazil), 2002 Shenzhen (China), 2006 Bangalore (India), 2008 San Francisco (USA), 2009 Istanbul (Turkey), 2011 Montreal (Canada), and 2013 Nantes (France), 2015 Abu Dhabi (VAE), 2017 Melbourne (Australia), and 2019 Vancouver (Canada) (Ecocities 2020).

Table 7.2 Guidelines for planning an ecologically ideal city (Wittig et al. 1995)

Planning principles	Concrete measures
1. Reduction of energy use	Rational use of energy in urban land use planning Increasing the degree of utilisation and the energy demand Avoidance of any unnecessary use of energy Preference of public transport over private transport Extension of cycle and footpaths Shifting the economic network to rail Decentralisation and mixed use to avoid car traffic Short distances of the products to the consumer
2. Avoidance or cyclisation of material flows	Reduction of packaging material Preference for regional products Energy saving Replacement of fossil by renewable energy Use of reusable and durable construction and packaging materials Decentralised composting of organic waste Development of a comprehensive water management system (rainwater, cooling and service water circuits, promotion of groundwater recharge)
3. Principle of protection of all life spheres (air, soil, surface waters and groundwater)	Monitoring of pollutant concentration by means of area-wide measuring networks Preventive measures (separate sewerage, avoidance of the release of toxic and harmful substances such as fine dust) Remediation measures (soil decontamination, improvement of air and water quality)
4. Conservation and promotion of nature and urban open spaces	Creation of priority areas for environmental and nature conservation Promotion of the development of spontaneous nature also in the city centre Networking of open spaces Preserving the diversity of typical elements of the urban landscape and differences in location Elimination of all avoidable interventions in nature and landscape
5. Principle of small-scale structuring and rich differentiation	Conservation and promotion of a species-rich nature Individual and unmistakable design of individual city districts Preservation of the structures that have developed in the historical context Promotion of residents' identification with their district to increase their sense of responsibility (participatory processes)

7.2.2 Eco-city criteria

The most frequently mentioned design areas of the sustainable city are resource consumption, mobility, housing, work, economy, social/cultural issues, participation. Indicators are shown for these to determine the status achieved, e.g. land consumption or private energy consumption for the resource consumption dimension.

A similar approach can be taken for eco-cities as special approaches to sustainable urban development.

Here, however, the areas are still somewhat blurred and not uniformly defined. Lötsch (1994) mentions as criteria: Energy, transport, waste, resource consumption, water, building ecology and housing health, urban landscape and green planning, dealing with children and the elderly, agricultural and open spaces.

The view to the outside world, the "*ecological footprint*" of cities, can provide a framework for evaluation.

Indicators can be defined as measurement parameters for the dimensional ranges to be defined for an eco-city, Tübingen determines 25 of them (Universitätsstadt Tübingen 2006):

1. Accessibility for everyone,
2. Public space for everyday life,
3. Balance with nature,
4. Integration of green zones,
5. Bioclimatic comfort,
6. Minimized land consumption,
7. City of pedestrians, cyclists and public transport,
8. Waste avoidance and recycling,
9. Closed water circuits,
10. Balanced mix of uses,
11. Short distances,
12. New relationship between concentration and dencentralization,
13. Network of quarters,
14. City as a power plant for renewable energies,
15. Health, safety and comfort,
16. Sustainable lifestyle,
17. Qualified density,
18. Human scale and urbanity,
19. Strong local economy,
20. City built and run by citizens,
21. Concentration at suitable locations,
22. City integrated into the surrounding region,
23. Minimized energy consumption,
24. Integration into global communication networks,
25. Cultural identity and social mix.

Breuste and Riepel (2007) developed an *Ecological Criteria Catalogue* for eco-cities with reference to Krusche et al. (1982), Kennedy and Kennedy (1997) and Sperling (1999). Design principles are assigned to the criteria. In a further step, indicators for measuring the status achieved can be determined. Some indicators are to be evaluated qualitatively or only ordinally scaled.

Open space, energy, transport, water, waste, building materials, environmental quality in buildings, localisation, land use and soil are defined as criteria of the eco-city. Especially the last three criteria are rarely or, like the criterion soil, mostly not included in eco-city projects.

EcoDistricts

The Portland Sustainability Institute (since 2013 EcoDistricts) is a non-profit organization that initiates innovative projects for more green in neighborhoods and districts. EcoDistricts are supposed to be sources of ideas for ecological development that can be applied all over the world. Cooperation with companies, sustainable development experts and municipalities is used for these activities. The focus is on strategies for energy supply, water management and district greening (e.g. the "We Build Green Cities" campaign).

EcoDistricts aims to develop eco-cities by transforming their constituent parts, the neighbourhoods, and has attracted worldwide attention. Providing tools, research, educational initiatives, organizing annual EcoDistrict Summits and advocacy are part of the organization's spectrum. The abstract theme of eco-cities thus suddenly becomes tangible and translates into concrete action in neighbourhoods. This also appeals to many proactive co-creators in the cities' NGOs. EcoDistricts are a successful initiative to make the eco-city concept manageable, e.g. through "Green Neighbourhoods". In 2013, the EcoDistricts Summit was held in Boston to exchange experiences. In 2014, this will be in Washington (EcoDistricts 2013; Portland 2011; Portland Sustainability Institute 2012).

The localisation of an eco-city project in new development is already a first essential criterion that has a significant influence on other criteria, e.g. transport, conservation of nature, energy use, etc., but has hardly been taken into account so far. Concepts for both sustainable cities and eco-cities have so far hardly dealt with the spatial dimension of their investigations and target systems. They start from a politically determined spatial dimension, the urban area. This is certainly an important approach with regard to options for action. However, with regard to ecological (and also other) contexts, it is completely unsuitable. What is at issue is a processual structure of urban building blocks in a cultural-landscape context, an urban–rural system and its qualities as an eco-city beyond political dimensions.

Sustainable Seattle

In 1991, Seattle began the process of sustainable urban development with a group of volunteers. Sustainable Seattle became one of the first model cities to define urban sustainability and related development by example, and to do so from within existing cities. Sustainable Seattle was the world's first Sustainable Community Organization in the USA. Today there are over fifty of them in Washington State alone. Of 170 sustainability projects in the USA in 2013, ninety referred to Sustainable Seattle as a reference project and model.

Systemic thinking, cooperation, commitment and an urban-regional perspective (beyond the political urban boundaries) characterised the project from the very beginning. Forty sustainability indicators, which could also be developed, understood, supported and monitored locally by the population, were determined and successfully applied. This led to broad popular support for Sustainable Seattle and made Seattle an example and model for many other cities. Seattle is considered a world leader in the development of an indicator concept for urban sustainability based on the values of the local population. The indicator development process is at the heart of this concept and is the key to its success. It starts from a simple perspective: What kind of city do its inhabitants want in the future? What is important to them? At present, the fourth improved development of this process has already taken place.

In 1996, the Sustainable Seattle Indicators were awarded the "*Excellence in Indicators Best Performance*" prize by the United Nations Centre for Human Settlements (Sustainable Seattle 2013; Stevens 2013) (Fig. 7.9, Table 7.3).

Fig. 7.9 Seattle. (Photo © Breuste 1997)

Table 7.3 Categories of sustainability objectives in the Sustainable Seattle concept (Sustainable Seattle 2013)

Natural range of action	Built-up area	Social sphere of action	Social area
Sufficient and clean water	Liveable residential areas and communities	Equal/equivalent health care	Aged citizens
A pollution-free environment for all	Thriving/flourishing economy	Food security and equality	Healthy living opportunities
Conservation of regional biodiversity	Responsible use of land	Social and income justice	Strong attachment to homeland/sense of place and place
Protection of unspoiled nature	Sustainable transport	Affordable, sophisticated living space for all	Happy, secure and satisfied citizens
Responsibility for ecological services	Clean production	Sustainable industries	Co-determination in decision-making processes, responsibility and management
	Climate protection	Responsible use of resources	High-quality education, lifelong learning opportunities
	Green buildings/ buildings		

A hierarchy of the spatial dimensions (from detail to the overall system) of the eco-city: buildings/open space—district - city and urban surroundings can be assumed in a meaningful way (Fig. 7.10).

Eco-cities of the future are first and foremost our existing cities, which have set themselves the goal of ecological and sustainable development and are taking action accordingly. They do this in small steps, e.g. in small individual projects concerning buildings and/or open spaces, in the ecological design of an entire district or the entire city.

To redesign an entire existing city ecologically is a special challenge. Seattle e.g. has accepted it.

A further spatial categorisation concerns the type of eco-city development.

1. New construction: Construction of a new independent eco-city, not connected to existing cities.
2. Eco-district—new construction: Construction of a new district to complement the city.
3. Eco-district conversion: Conversion of an existing district into an eco-district.
4. Eco-initiative: Local in a specific urban area.
5. Eco-labelling: Designation for various sustainability initiatives by local authorities that take place throughout the city (not necessarily associated with building aspects) (see also Joss et al. 2011).

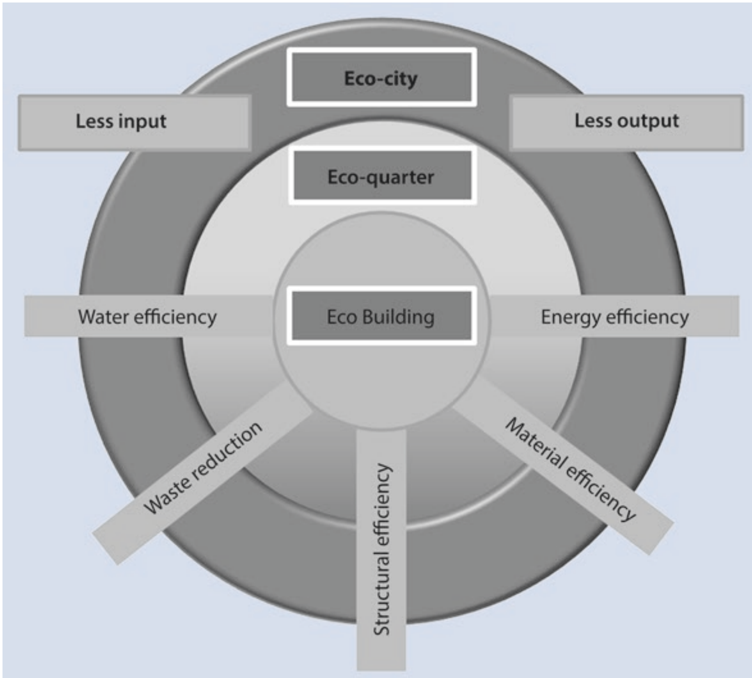

Fig. 7.10 Spatial dimensions of the eco-city. (Design Breuste, drawing: Wurster, Artmann 2010)

Categories 1 and 2 refer to new construction projects in which existing buildings are usually not taken into account, but nature and landscape amenities are certainly included.

Categories 3, 4 and 5 refer to conversion activities of existing urban structures, ranging from district (3) to local activities.

Since eco-city activities are often communicated to the public at an early stage, it is necessary to distinguish whether they are a) in a planning phase, b) under construction or c) in completion. When assessing projects, it is also important to know whether they are based a) on technical innovations, b) on integrative, sustainable planning or c) on citizen involvement (Joss et al. 2011).

In 2009, Joss was able to participate in a worldwide evaluation of eco-city projects in 2010, which included 79 eco-city initiatives in the sense of the above-mentioned categories 1–4 and documented them. Category 5 was not included for understandable reasons, as it is often used for city marketing purposes only and consequently a very large number of "city eco-labels" are in inflationary circulation. Unfortunately, there is still no certification of eco-city activities, so that the use of the terms in public does not include the contents to which they are attributed. China e.g. awards eco-city labels after cities apply for them at ministerial level using self-selected statistical categories.

In 2011, Joss et al. have already registered 174 eco-city initiatives in categories 1–4 worldwide. This is an increase of more than a third in only two years and shows the high

Table 7.4 Eco-city development by continents (Joss et al. 2011)

	Asia and Australia	Europe	Middle East and Africa	North, Central and South America	Total number
I New construction projects	15	2	4	6	27
II Urban expansion	17	45	4	6	72
III Eco-district redevelopment	37	23	2	13	75
Total	69	70	10	25	174

dynamics that eco-city development currently has worldwide. Official registration (e.g. by the UN) is not yet taking place (Table 7.4).

As Table 7.4 shows, eco-city development is a worldwide phenomenon and by no means limited to Western societies. The most frequent eco-city activities worldwide take place in China. Fifteen new construction projects and seventeen urban expansions alone are registered here. In addition, there is a large number of urban redevelopment projects (Joss et al. 2011). This underscores China's global importance as an initiator and experimental field for eco-city development (Table 7.5). The most active urban development is already located in Asia, but also that of eco-city development. The least eco-city activities take place in Africa.

The majority of initiatives are based on technological innovation (105), 63 on innovative planning. Only 6 come about through civic involvement.

7.2.3 The Real Eco-City—Examples

Urban new construction projects, urban expansions, urban redevelopment projects and many small individual projects (“bits and pieces”) are the activities currently observable in eco-urban development. While the former projects are mainly carried out exclusively from “above”, i.e. through central decision-making, planning and organisation, in democratic societies, the participation of urban citizens and their will to shape the city begins to be taken into account as early as in the process of urban redevelopment and especially in many individual projects. Representative examples from all three areas will be presented here.

7.2.3.1 The Grand Design, Initiatives “top down”

Planning and building new cities are only necessary where the existing network of cities is no longer sufficient due to rapidly advancing urbanisation or where the ambition of an authority dictates this. The latter has happened several times in the twentieth century with the political decision to build a new capital city in less urbanized regions (e.g. Canberra, Australia, 1927, Arch. W.B. Griffin, Rio de Janeiro, Brazil, 1960, Arch.

Table 7.5 Examples of eco-city projects in China (own incomplete survey)

Project	Foreign partner	Status
Beijing Mentougou Eco Valley	Finland (Eero Paloheimo Eco City Ltd., Eriksson Arch. irekts)	Contract signed in May 2010; construction planning phase, 28 km^2,50,000 inh
Beijing Changxing International Eco-City	England (Arup)	60 km^2, Construction planning phase
Caofeidian International Eco-City	Sweden (Sweco)	Start of construction in September 2008; Start of construction in March 2010 with 10 major projects, investment volume: 11.6 billion RMB
Shanghai Chongming Dongtan Eco-City	England (Arup)	Contract signed in January 2008; Start of construction in 2008; No further construction progress at present; the project is considered a failure
Western Eco-City Suzhou	Germany/China (SBA)	Start of construction February 2010
Wanzhuang Eco-City, Langfang	Singapore (SCP)	Start of construction June 2008
Wuxi National Low-Carbon Eco-City Demonstration Zone, Wuxi Sino-Swedish Low-Carbon Eco-City	Sweden (Tengbom)	Start of construction July 2010
Tianjin Sino-Singapore International Eco-City (www.eco-city.gov.cn; www.tianjineco-city.com)	Singapore (Keppel)	Start of construction 2008, planned total investment 17.0 billion RMB, 350,000 inh., finished 2020
Zhangjiagang Sino-Danmark Ecological Science & Technology Park	Denmark	Construction planning phase
Hubei Xianning Eco-City	Germany (Siemens)	Contract signed in October 2009; currently in the construction planning phase

O. Niemeyer, L. Costa, Chandigarh, States of Punjab and Haryana, 1952, Arch. Le Corbusier, India, Abuja, Nigeria, 1991, Arch. K. Tange). The planned cities are great designs of ambitious projects. Only in recent decades have new planned city projects with ecological aspects been combined into eco-city projects, primarily in China.

Such new eco-cities are rather the exception, only 15% of all current eco-city activities concern new eco-cities (Joss et al. 2011). The majority of current eco-city projects are either under construction (69) or in planning (60). Only 45 have already been completed.

Every eco-city is an individual grand design. A few examples will be given here.

Ecopolis—Pushchino, Russia's Eco-City Vision

In 1963, the science city Pushchino (20,000 inh., 120 away from Moscow, six research institutes of the Academy of Sciences are located here, no industry) was founded. Fifteen years later (1978), the city was to become the first Russian “ecopolis” according to a program of the Moscow State University. 22 Moscow university institutes participated in the project.

In 1985, an “Ecopolis laboratory” was set up. The Ecopolis programme (1978–1996) included analyses of flora/fauna, soils, geology, design and planning, and covered social aspects, the impact of water and automobile traffic on ecosystems, pesticides, domestic animals, the inhabitants’ relation to nature (e.g. approx. 17,000 l of forest berries and 250 t of mushrooms are collected annually and 39 t of fish are caught), tourism and nature conservation (Ignatieva 1987, 2000; Brudny et al. 1981).

Particularly noteworthy is the involvement of schools and children who were able to combine theoretical and practical learning and the work of volunteers. Green and nature are design principles. The city has extensive agricultural and forest areas. Five nature reserves are located on the city territory.

After 1991, the ambitious project was not developed much further for economic reasons and because it was out of political focus. An Ecopolis 2000 conference in Moscow drew a rather sober balance of little progress.

Vision of Eco City Development for Pushchino Russia 1984

“Imagine a small town. The solar and thermal energy generated on its territory is used to grow technical or nutritious plants. The product of biomass per unit area of the city can even be larger than in the natural plant community. Additional (low-effective) heat and new biotechnological principles can also contribute to this: immobilised ferments and chloroplasts. For example, the outer part of the houses of the Ecopolis represents a photosynthetic surface (immobilised chloroplasts). The chimney of the thermal power plant serves as a vertical scaffolding and heat source for orangeries. From the outside, the chimney reminds of a glazed tower. Brooks flow through the city, life surges beside them: butterflies flutter, birds fly ... Monotonous lawns have been replaced by honey-bearing meadow grasses. In the city, the hay harvest is in full swing. In the vicinity of the city, eco-technology and the population, together with the ecological service, have ensured the preservation of the forests with their mushrooms and berries, game and birds. People do not harm the forest soil because they only enter the forest with appropriate large shoes—"summer ski boards" (Brudny and Kawtaradse 1984, p. 217).”

Masdar City, Emirate of Abu Dhabi, Ambition of an Emir

Masdar City proudly calls itself the “first eco-city in the world”. The new city is being built on an area of around 6 km^2 in the Emirate of Abu Dhabi. It is still doubtful whether the 17.5 billion € megaproject will become a complete reality. The first buildings have already been completed. However, the date for the inauguration had to be postponed from 2016 to 2030 due to financing problems.

Around 50,000 people are expected to live in the new city and around 1500 companies with expertise in renewable technology and clean tech. The Masdar Institute of Science and Technology also aims to settle there. Up to 90% of the required energy is to be generated by solar technology. Numerous wind turbines, the (re)production of energy from waste and residual materials and other technologies are planned. In the city itself, photovoltaic systems will convert solar energy directly into electrical energy. 300 million m^2 of roof surfaces are to provide an energy output of 240 MW. For further energy generation, a thermal solar power plant with a capacity of 100 to 125 MW will be built on an area of over 2.5 km^2. A traffic concept consisting of three levels is based on the Personal Rapid Transit system, underground, track-bound, electrically operated cabins, one level higher pedestrians and cyclists.

In the initial phase, a water consumption of 180 l per person and day is to be achieved in the city, which is significantly below the national average of around 550 l per person and day. In the further course of the project, water consumption is to be reduced by a further 40%. A solar-powered seawater desalination plant will be built to supply the city with water.

Wastewater is to be recycled at 100% and used for irrigation of the city greenery. This will save around 60% of the average water consumption required for this purpose.

In order to minimise transport, vegetables, fruit and cereals are to be produced in specially developed greenhouses on farms in the city.

A large number of open spaces will be available for recreation. The important parks are not formal squares, but form a green infrastructure in the city.

Controllable umbrellas and sails are intended to protect against solar radiation. Wind towers and a narrow alleyway development based on traditions additionally contribute to the temperature regulation of the desert city.

The basic waste strategy should be to minimize waste and recycle waste (reuse, composting and energy recovery) (2DAYDUBAI.COM 2010; Lohmann 2010).

7.2.3.2 The Urban Eco District

Solar City Linz, Austria's contribution to eco-city development

In 1990, the need for new housing in Linz led to the planning of a new district Linz-Pichling for the Upper Austrian capital for 3000 inhabitants in 1300 flats on 35 ha of land, primarily in multi-storey housing, which was realised in 2001. The goal of environmentally friendly energy production and the reduction of climate-damaging emissions was combined with other ecological and eco-technical aspects and realised in an exemplary supra-regional model project. The name “Solar City” was chosen in accordance with the energy goal. The project was completed in 2005 (Treberspurg 2008; Fig. 7.11).

The use of solar energy and district heating played a central role in the construction of the Solar City. The energetic optimization concerns:

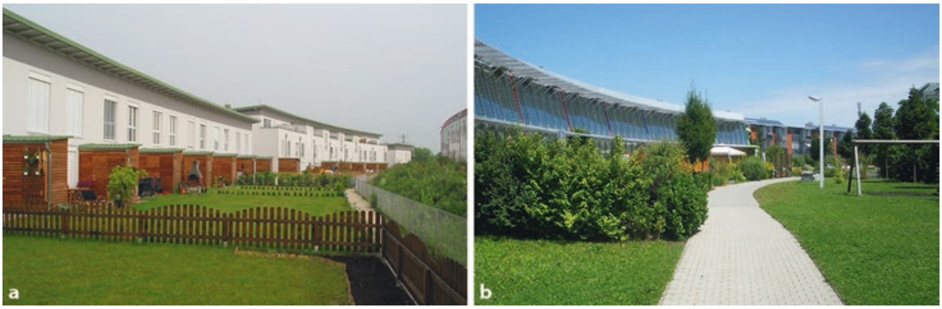

Fig. 7.11 Solar City Linz-Pichling. (Photo © Breuste 2010, 2007)

- Individual use: Quality of daylight, view, sunbathing areas integrated into the building.
- Technical use: Through physical or biological energy production and environmental relief (photovoltaics, solar thermal—geothermal energy, biomass, hot water preparation).
- Social use: Sun exposure of outdoor areas, improvement of outdoor comfort and plant growth.
- Deep, east–west-oriented building structure with large-format window areas.
- South-facing houses with winter gardens up to six metres high as solar facades.
- Passive houses in different construction methods.

A trough-trench system for decentralised rainwater infiltration and an alternative wastewater concept with constructed wetland was also implemented.

The district was created according to the "concept of short distances". Every part of the settlement can be reached on foot from the centre in less than 400-m distance. The connection to the city is provided by a new tram line. All housing estates are integrated into a networked open space concept with a variety of green spaces. Recreational facilities, sports and bathing areas as well as forest areas are directly adjacent and within walking distance. Private car parking spaces are not located directly next to the houses, thus creating open space (Breuste and Riepel 2007, 2008).

Eco-District Tübingen-Derendingen

The EU project Ecocity (2002–2005) in the 5th Research Framework Programme "Cities of Tomorrow" promotes the development of concepts for sustainable urban development with a focus on settlement area development and transport concepts. Thirty project partners from nine European countries took part. The aim was to ensure the most sustainable mobility possible through new urban structures. New urban districts were planned in seven different European countries: Tampere (Finland), Bad Ischl (Austria), Trnava (Slovakia), Györ (Hungary), Umbertide (Italy) and Tübingen-Derendingen (Germany).

Planning principles were:

- Decentralized concentration with
- A balanced proportion of different types of use in a
- Compact structure, which allows short distances

The main objectives of the eco-district project are shown in Fig. 7.12.

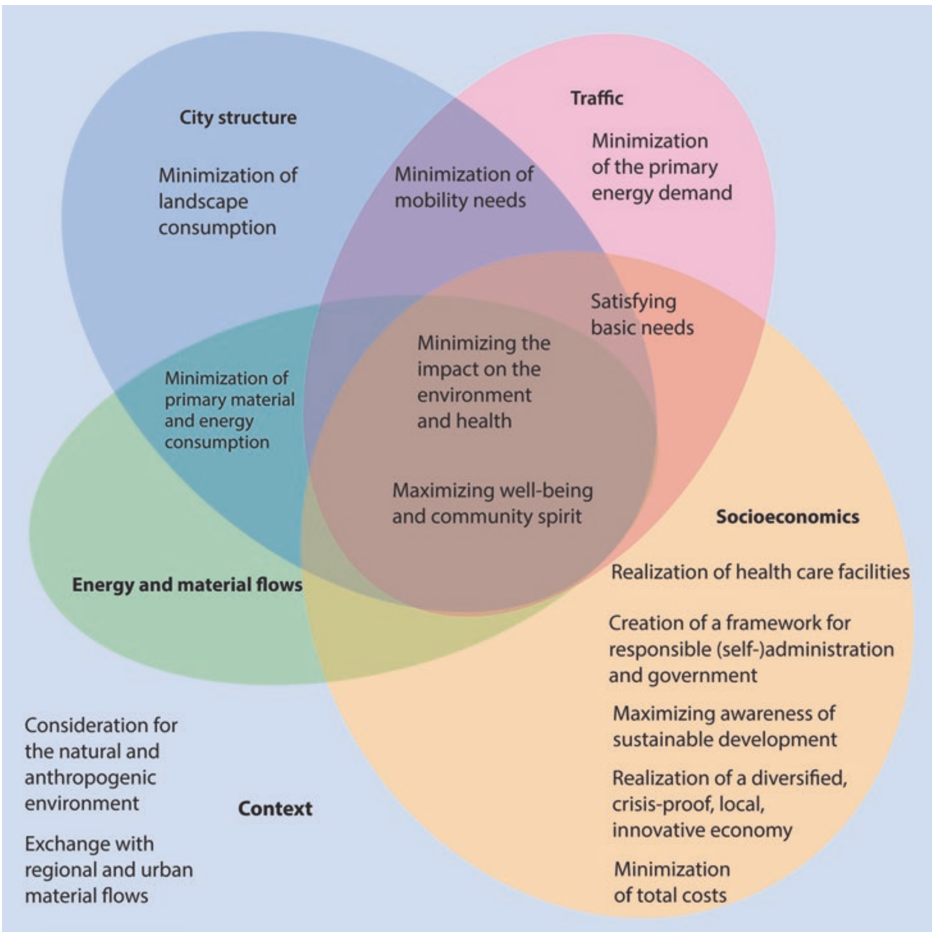

Fig. 7.12 Main objectives of the Tübingen-Derendingen eco-district project (Universitätsstadt Tübingen 2006)

The project was realized on 24,2-ha area on an industrial wasteland and on an agricultural area (“green meadow”) in the urban densification area on the outskirts of the city of Tübingen (82.000 inh.). 3300 new residents, about half of the predicted urban growth until 2010, were settled in the project. The following principles of sustainable urban development were integrated:

- Priority for inner development over outer development in the case of urban development in peripheral locations, concentration on locations with good potential for development by public transport to prevent car-oriented suburbanisation
- Organisation of the city as a network of urban neighbourhoods, balance between concentration and decentralisation in supply and disposal systems at neighbourhood level and at urban and regional level.
- Public space with a high quality of stay for social encounters and with as little disturbance and danger as possible from car traffic.
- Attractive urban design on a human scale.
- Minimization of land consumption through a compact urban structure.
- A wide range of high-quality, compressed and compact building typologies.
- Mixed structures for housing, commerce, culture, science, education and social functions, mixed use on the smallest possible scale.
- Integration of retail locations for local supply, best possible accessibility of all facilities for all inhabitants.
- Reconstruction of “landscape in the city” as a nature compound system.
- Creation of a sufficient supply of attractive open spaces.
- Development of new fields of activity for urban agriculture and integration of urban permaculture to form an urban agriculture.
- Viewing the city as a bioclimatic system.
- Development of neighbourhood geometry to promote small and regional climatic air exchange.

Open space and its quality are the backbone of district development. An essential element of the open space concept is the integration of the Mühlbach and an accompanying green space as a landscape element that opens up all sub-areas. A new urban fringe, which contains traditional open space elements such as orchard meadows or allotment gardens as well as ecological infrastructure for water purification and infiltration and thus prevents further growth of the settlement structure in the future, was realized.

Through an ecological water concept, the infiltration could be increased from 25 to 49%.

Hongqiao Low Carbon Business District, Shanghai

China's largest *Low-Carbon Business Center is* being built at Hongqiao Airport in Shanghai. In 2008, *SBA design* (www.sba-int.com), a planning office based in Munich, Shanghai and Stuttgart, won the urban design competition for the area. The *Low-Carbon Business Center* (1,4 km^2) is defined by sustainability goals in the fields of urban development, traffic planning, building technology and energy production. The goals set were defined in the form of planning standards and guidelines and implemented together with energy and infrastructure planners, specialists for building technology, traffic planners, landscape architects and the Shanghai Municipal Planning Office.

Together with the University of Duisburg-Essen, an innovative planning tool for the application of measures to reduce CO_2 emissions and their effectiveness control was developed within the framework of a research project. Due to the convenient location on the outskirts of Shanghai and connected to the expanded Hongqiao Airport, the concept provides for a high density of the planned building plots, while at the same time creating sufficiently dimensioned and clearly defined open spaces. Since 2010, the plots have been sold with strict requirements for sustainable construction and the architectural concepts for the individual blocks have been evaluated. Effective monitoring contributes to the control of the set goals (SBA design 2013; Fig. 7.13).

Fig. 7.13 Hongqiao Low Carbon Business District. (© SBA design, 2013)

Vision of the Fraunhofer Morgenstadt City Insights—Germany's Future Initiative

The high-tech fantasy "Morgenstadt" as a narrative. An excerpt:

"For almost 30 years now, the emissions clock at Morgenstadt town hall has been showing the amount of carbon dioxide emissions that each inhabitant is statistically responsible for each year. On its homepage, the city has been tracing its ecological footprint in detail for more than a generation. The clock has long since reached the kilogram scale and is hardly noticed by the younger inhabitants of Morgenstadt, so carbon dioxide-neutral living has become so natural to them. For their parents and grandparents, the watch has remained a visible witness to the commitment with which the city administration has made Morgenstadt a driving force for climate protection since the beginning of the century. They have single-mindedly exploited the existing scope for municipal energy policy. In the "solar champions league" for example, it soon climbed to first place in the big city category. It was the first to present an ecological rent index, which gave landlords additional incentives for the energy-efficient renovation of their houses. Tighter building standards were prescribed early on in new development areas and the local heating supply with combined heat and power and solar energy was systematically extended to large parts of the city (BBF 2010, p. 1)" (see also Fraunhofer 2013).

7.2.3.3 *Bits and Pieces*—The Small Steps Towards more Nature in the City—Initiatives "Bottom Up"

Many small steps lead, so to speak, "bottom up " on the way to the eco-city, bring immediate advantages and improvements and help to consolidate the eco-city orientation. These steps are not spectacular and do not make it into the national news. Often they are not recorded, balanced and evaluated. Taken together, however, they often make up more than some major initiatives. Their costs are often manageable. Participation "from below" strengthens the sense of community and brings forward things that really move citizens. It has been shown that civic involvement, the feeling of taking responsibility for the development of the city, grows through responsibility in one's own neighbourhood. Some important initiatives for eco-cities have emerged from this commitment in recent years and have received national or international attention. A few of them will be given below as examples.

The topics are as varied as the eco-city itself. The topic "more nature in the city" has therefore been chosen as an example, without underestimating other themes such as energy efficiency, mobility, climate adaptation, etc. The diversity of information on these topics is usually already broad.

The topic of "more nature in the city", on the other hand, is often treated only marginally and is often given less attention because of the lower level of technical innovation (compared to energy, mobility, climate, etc.).

In the course of urbanisation worldwide, nature in all its forms is being pushed back ever further by urban growth. There is no doubt that contact with nature is essential for a healthy life in cities (Chapter 5).

Nature can exist or be developed in cities in very different forms. Some of them, for which citizens are increasingly involved and form initiatives, will be briefly presented here as examples:

Urban Gardening

The allotment garden is already an integral part of greenery in many cities (Chapters 4 and 6). To deal with nature in an independent and creative way is an experience that can rarely be made in cities (and often outside them). This keeps the (small) garden idea and the idea of gardening in general attractive for generations and makes it more and more part of the modern, active green culture of our cities. Gardening is becoming attractive not only in more traditional forms, but increasingly also in new forms of *community gardening* or *urban gardening*, even *guerilla gardening* on occupied land for age groups well before retirement age. Müller (2011) confidently calls this "the return of gardens to the city" (Fig. 7.14).

The mostly small-scale, horticultural and agricultural use of urban areas, environmentally friendly food production and a conscious consumption of home-grown vegetables and fruit are in the foreground. This *urban gardening* is a special form of urban agriculture (Müller 2011; Fig. 7.15).

Fig. 7.14 Postcard as an advertisement for garden use in the younger population (BDG 2012)

Fig. 7.15 Urban Guerrilla Gardening on a publicly accessible brownfield site in the centre of Łodz (Poland). (Photo © Breuste 2011)

Allotment gardens in Beijing—Sanyuan Agriculture Gardens

In Beijing, a city of twenty million inhabitants, small gardens have been created since 2010 for city dwellers who feel increasingly alienated from nature. There are already about one hundred such facilities. In the north-western district of Haidian, such a facility was created in 2008 and is still growing. It already has more than 1000 spaces between 60 and 80 m^2 that are rented to interested parties. This has little to do with German allotment gardens (Chapter 4), as the areas are very small and not designed for recreation in the countryside. They are used exclusively to produce vegetables, but even this is not primarily to save costs or to produce food ecologically. The reason why many Beijingers lease and use land in such facilities is primarily because they are active in gardening in the "open countryside" of the city and gain a zest for life from it.

The *Beijing SanYuan Strong Agricultural Technology Co. Ltd.* leases the areas (approx. 190 € per year) and rents out gardening tools, provides a water connection and even maintains the small gardens with its own staff when necessary (approx. 30% of the areas), if the tenants cannot come every week due to lack of time. In VIP gardens (80 m^2, several areas can also be rented together) plastic seats with table and sun protection are also available.

The predominantly older users come by public transport or by car and accept up to 1.5 h for the journey. This shows how important self-managed gardens can be in cities, not only in Europe (Fig. 7.16).

Fig. 7.16 Sanyuan Agriculture Gardens Beijing. (Photo © Breuste 2014)

The High Line Park in New York—more freedom and open space for people in the city

The High Line is a former light rail system operated between 1934 and 1980 on an elevated track on the West Side of Manhattan (New York). The light rail line remained unused for almost twenty years until it was to be demolished in 1999. Residents founded a civic organization against it, the *Friends of the High Line*. It was about preserving the historical structure as part of New York's industrial heritage, but also about making something new out of it, something that the people in this part of New York City needed most: open space and urban greenery. In 1999, work began on turning the High Line into a public park, which runs through a total of nineteen building blocks from 34th Street to 13th Street, a length comparable to that of Central Park. The High Line is thus 2.44-km long.

The High Line is owned by the City of New York, but its management and funding has been transferred to the *Friends of the High Line* in an agreement between the *Friends of the High Line* and the *Parks and Recreation Department* of the New York City Government. More than 90% of the annual budget is raised through donations from *Friends of the High Line* members. *Friends of the High Line* organizes tours, workshops and festivals, addresses all sections of the population, brings modern art to public spaces and promotes new forms of garden design. All this together makes up the special feature of the “linear” park above the streets in a densely built-up area with little open space.

The park was opened in 2009 according to a design by *James Corner Field Operations*, *Diller Scofidio* and *Renfro and Piet Oudolf* in a first part, and in 2011 in the second part. With more than four million visitors a year, the park is a huge success as a tourist attraction on the High Line. The largest user group currently does not come from the surrounding residential area. This indicates a high degree of supra-regional open space attractiveness, but also a lack of comparably attractive offers in other densely developed New York city districts. The needs of the city's population for more open space are clear, however. The project would not have come about if residents had not committed themselves to it (FHL 2013; Fig. 7.17).

The Tempelhof Park—an example for the city of tomorrow

To develop a park landscape with more than two hundred hectares in the middle of a densely built-up city is a unique opportunity in Europe (SSB 2010).

In 2008, flight operations at the inner-city airport Berlin-Tempelhof were finally discontinued. Tenants' alliances called for protests to prevent development plans for subsequent use. It was feared that the space would be taken away from the public, privatised, commercialised and gentrified. This expresses the great need for public open spaces in an inner-city district in Berlin.

Currently, the former airfield site with its open grassy areas and asphalt runways is a recreational area as Tempelhof Park and covers 250 hectares of the site of the former airport. It is thus Berlin's largest city park and is open from sunrise to sunset. The park was officially opened on 8 May 2010. On the first weekend, it was visited by about 250,000 urban dwellers. Only four months later, more than 1 million visitors were counted (SSB 2010; Fig. 7.18).

The official plans for the Tempelhof Park are drawn up by the Berlin Senate. An international landscape planning competition was held in 2010 with 78 planning teams from Germany and abroad. The development of the Tempelhof park landscape is a task that can only be accomplished with the help of the population. Right from the start, citizens were involved in the planning process through participation procedures. The citizens

Fig. 7.17 High Line Park in New York. (Photo © Zepp 2011)

Fig. 7.18 Tempelhofer Feld Park. (Photo © Breuste 2011)

organised themselves for this purpose and brought in their justified interests for green open space and against further development intentions. Key points of the dialogue were surveys, discussions and visitor monitoring. It will be important to include the wishes and needs of the residents of the surrounding neighbourhoods and visitors to the park in future developments (Table 7.6).

There are private initiatives that want to realize their plans alternatively on the site. Since 2011, the citizens' initiative "100% Tempelhofer Feld" has been pursuing the goal of preventing the development of the site and permanently maintaining the Tempelhofer Feld as an inner-city open space with special recreational functions in its present form.

It was planned to hold the IGA 2017 there until 2012. Bathing lake, green landscape with lake and climbing rocks, new building of the state library, residential and commercial properties were brought to the public as concepts (Roskamm 2010).

On 26 May 2014, the Senate Administration confirmed that no construction projects will take place on the site—long a bone of contention—and that the area as a whole will be preserved as a park for the population.

The inner meadow areas of the airfield site are particularly worth protecting from a nature conservation point of view as a habitat for ground-breeding birds. Rare smooth oatmeal meadows and sandy dry grasslands are among the most valuable habitats. 368 species of wild plants can be found in the park (e.g. common thrift or sandflower). Grassland and dry grassland habitats are important habitats for bird species that are highly endangered beyond the region (e.g. endangered ground-nesting birds such as the wheatear, meadow pipit, fallow pipit, corn bunting and skylark).

Table 7.6 Most frequently expressed expectations of residents and visitors regarding the development of the Tempelhofer Feld in Berlin, in percent (Argus GmbH 2009)

Wishes of the respondents	Citizen survey in the catchment area	Visitor survey
Large trees	92	83
Benches for relaxation and meetings	91	85
Smaller protected areas for recreation	90	87
WC facilities	89	90
Small water elements	87	77
Large lawns for lying and playing	85	84
Areas with flowering shrubs	78	71
Specific areas for nature conservation	75	82
Refreshments offers	75	70
Moving terrain with hills and depressions	70	65
Meeting places, communication areas also for picnics	69	75
Flowerbeds	68	57
Play areas for different age groups	65	72
Possibility of nature observation	62	70
Areas for leisure sports	62	66
Natural designed areas with lawns for sunbathing	60	56

The concept of the city of Berlin envisages a landscape “that focuses on the luxury of space and the freedom of the open sky and preserves the large meadows. In addition, the park will provide opportunities and free space for the development of a new urban feeling. A living space will be created that reflects a new understanding of nature and the self-conception of the people in the city” (SSB 2010).

The mission statement for the Tempelhofer Park brings together the economic, ecological and social tasks of sustainable urban development. To this end, six themes were formulated: knowledge and learning, clean future technology, sport, wellness and health, integration of the neighbourhoods, dialogue between the religions and a stage for the new. The diverse social and religious neighbourhoods could also find a place of dialogue on the Tempelhofer Feld (Kabisch and Haase 2013).

Forest city Halle-Silberhöhe—Forest as an opportunity for revitalising urban districts

The large housing estate Silberhöhe, in the south of the city Halle/Saale, was built between 1979 and 1989. On an area of 213 ha, living space for approximately 39,000 people was built (Stadt Halle 2011). With approximately 185 inhabitants per hectare, Silberhöhe was the most densely developed district of Halle in 1992. The design of the open spaces, green areas, playgrounds and recreational areas was given less importance during the construction of the district (Breuste and Wiesinger 2013).

From 1990 onwards, there was a massive decline in the number of inhabitants due to emigration. While the district had about 40,000 inhabitants in 1989, according to available housing market forecasts, only about 10,000 people will live there in 2015. In 2011, the figure was still 13,000. 7,200 of the 15,000 apartments were demolished by 2010 due to vacancies. In 2004, the integrated urban development concept with the guiding principle "Forest City Silberhöhe" was drawn up and adopted as a development perspective (Stadt Halle 2007). The new planning approach within the urban development concept for the Silberhöhe district (Geiss et al. 2002) defines an "orderly retreat" with the development goal of a "Forest City Silberhöhe". This approach includes above all the preservation of essential elements of the building structure and the planned development of large open spaces after building demolition. "Restructuring areas" were defined to achieve these overriding objectives. The restructuring areas are areas on which existing residential buildings were demolished and open space development potentials for future subsequent use have been determined (Stadt Halle 2007; Breuste and Wiesinger 2013).

From an urban development perspective, there is still a good social infrastructure and transport connections. Especially the open spaces and the proximity to the Saale-Elster-Auen landscape are seen as an increasingly important quality feature for the district.

The very large gain in open space and the afforestation measures on the same should increase the quality of living, improve the competitiveness and the economic value of living space (Stadt Halle 2007; Vollroth et al. 2012). Almost 50% of the residential area is now green. Of the 213-ha residential areas, only 70 ha are newly acquired forest areas. Whereas in 1992, every inhabitant had access to approximately 17 m^2 public green space, by 2014, this will be approximately 100 m^2, i.e. almost six times more green space. The maintenance of these enormous green spaces for a few inhabitants is impossible for the city of Halle for financial reasons alone. New concepts therefore had to be sought (Figs. 7.19 and 7.20).

For the time being, the formulated model "Forest City" is more a vision of the future than a reality. It identifies forest as the dominant green space structure of the future, especially on renaturation areas. In this way, it wants to assign a new function in the upgrading of the district to the unintentionally created open spaces and also to "forest" existing green spaces more strongly (Stadt Halle 2007).

The model of the "Forest City" implies a qualitative and quantitative improvement of the originally rather open lawn spaces between the buildings. The concept ranges from a park-like urban forest in the central green corridor to near-natural reforestation and succession areas (Stadt Halle 2007). A total of 8265 trees have been planted so far (Vollroth et al. 2012).

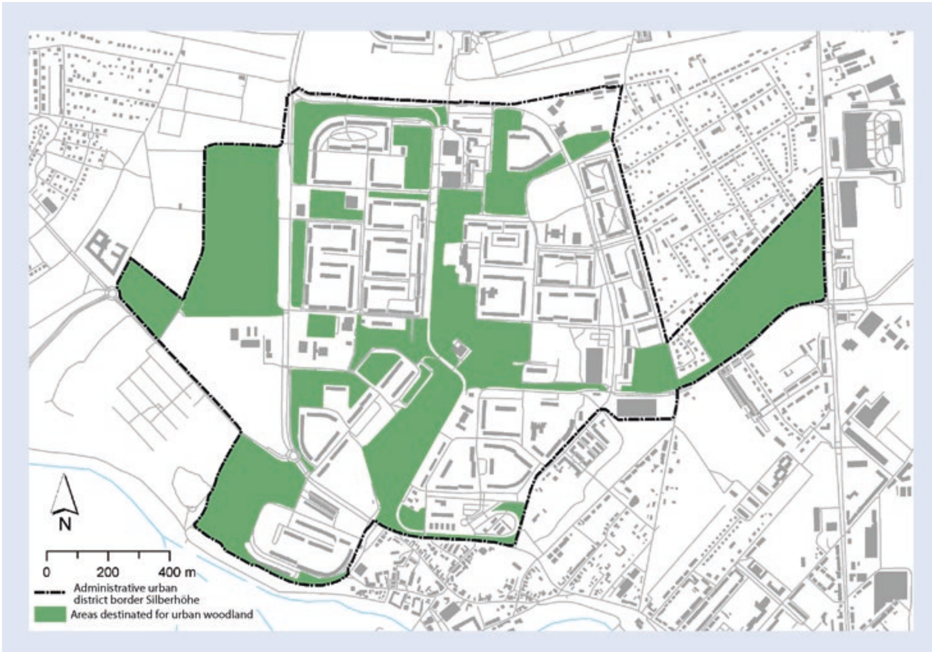

Fig. 7.19 The open space potential of the forested urban dirstrict Halle-Silberhöhe, Germany, until 2025. (draft: J. Breuste, cartography: W. Gruber, source: Vollroth et al. 2012)

Fig. 7.20 Urban (park) forest in the Silberhöhe district in Halle/S, Germany. (Photo © Breuste 2006)

At present, there are.

- 23-ha wooded areas with a forest-like tree density of 203 trees/ha,
- 23-ha with park-like tree density of 76 trees/ha,
- 24-ha short rotation plantations (poplars).

Vollroth et al. (2012) describe this as Alternative A, as a "regenerative forest park", and develop two further scenarios from this, the forest and park development, which are to be aimed at as targets.

Which forest do the citizens want now? What will be better, what will be less accepted and used? And why? The involvement of the local residents in the forest design process is still completely outstanding (Breuste and Wiesinger 2013)!

Biodiversity in the City—Riccarton Bush Christchurch, New Zealand

Biodiversity in the city is widely discussed scientifically (e.g. NatureParif 2012). Its benefits are repeatedly seen in connection with ecosystem services (Chapter 5). Werner and Zahner (2009) have compiled a comprehensive bibliography on this subject.

Probably nowhere else is the link between urban biodiversity and a regional and national consciousness as strong as in New Zealand. Being *native* means preserving identity. This also and not least concerns the native flora and fauna. Unlike in many other countries, their preservation is a direct concern of the people and leads to broad-based initiatives and civil movements (Meurk and Hall 2006; Stewart et al. 2004; Ignatieva et al. 2008).

Christchurch is the largest city in New Zealand's South Island with 348,000 inhabitants (2006). From 1850 onwards, the planned settlement of colonists began here. In 1856, the settlement was granted city rights. The settlement took place in extensive swampy lowland forest areas, alluvial deposits of rivers, which were easy to settle and mainly consisted of stone disc forests (*Podocarpaceae*). The stone disk plants are a plant family of the conifers (*Coniferales*), which has its distribution mainly in tropical and subtropical mountain forests and in coastal lowlands of the southern hemisphere. Riccarton Bush (Pūtaringamotu) is the last remaining remnant of the originally widespread swamp stone disc forests of the region. As early as 1914, the value of the forest area, which had been preserved in parts until then (approx. 7 ha), was recognised and the land, which belonged to the City of Christchurch, was farmed by a trust (Riccarton Bush Trust), which has since then received annual public funding to help preserve the forest (Chilton 1924). Riccarton Bush has since been a protected forest in the heart of the City of Christchurch.

Character tree of the forest is Kahikatea (White Pine, *Dacrycarpus dacrydioides*). The trees, which are over 600 years old and some of which are 60-m tall, are the last specimens of the forest, which was created about 3000 years ago. Other indigenous tree species such as Totara (*Podocarpus totara*), Kowhai (*Sophora microphylla*) and Hinau (*Elaeocarpus dentatus*) form the lower tree layer.

The forest area is now surrounded by a protective fence to keep out mainly small predatory mammals—Australian Brushtail Possum (*Trichosurus vulpecula*), marsupials of the order Diprotodontia (introduced from Australia around 1900), but also hedgehogs (introduced from 1890) and rats (introduced from 1850)—and to protect the rare native ground-breeding bird population. In 2009, the first attempt to reintroduce the Great spotted Kiwi/Roroa (*Apteryx haastii*), a kiwi species native only to New Zealand's South Island, began. Since 2008, another regional tree species Wētā (*Hemideina femorata*) has been reintroduced (Fig. 7.21).

Riccarton Bush is probably the oldest protected area in New Zealand. The people of Christchurch use the area and the protected forest as a recreation area and are very aware of the outstanding importance of their small stone disc forest.

Fig. 7.21 Riccarton Bush Predator Proof Fence, protective fence around the forest, especially against possums (marsupials of the order Diprotodontia from Australia, erected in 2000). (Photo © Breuste 2006)

7.3 Conclusions

It is apparent that the city of the future is generally, in all its sub-areas, a very comprehensive concept (sustainable city), but the eco-city can only cover a part of it. First and foremost, the eco-city is about a city that is in balance with nature and that benefits from nature and its processes and structures without destroying them (Cities in Balance with Nature). This does not cover all aspects of a city of the future (e.g. transport, social city, energy use). Even in the areas of nature and city, focal points are often selected in the effort to develop a concept. These can be green spaces and their combination, water bodies, greening of buildings, as well as the protection and preservation of "valuable" or rare natural resources. Existing nature is often given too little consideration, but often newly developed. To see eco-cities merely as a technological field of experimentation (e.g. CO_2 emission reduction, low-energy houses, transport technology, rainwater technologists, etc.) is too limited an approach. Technical solutions often dominate social concerns. Cities are first and foremost people's living space, and enabling them to enjoy better living conditions in it, while taking nature and its processes into account, can be a viable approach. People should and must be involved in shaping this. There is thus much to be said for eco-urban development "from below". Eco-towns can be built on criteria whose degree of fulfilment must be assessed. Many eco-cities limit themselves to a few criteria, and focus on their fulfilment in an optimised way (e.g. energy, CO_2 neutrality, etc.). An international certification of eco-cities could help to improve the assessment and separate real eco-city successes from projects that merely advertise with the eco-label.

Eco-cities look different in different cultural and natural areas. The eco-city does not exist. Depending on the social, cultural and natural problems, different priorities will have to be set for eco-cities. Climate regulation will play a greater role in hot deserts (e.g. Masdar City) than in the temperate climate zone. But even there, the challenge will be to consciously adapt cities to the climate changes of the future in terms of design.

Most eco-cities are not built from scratch, but must be developed in their functionality from the existing building stock and open spaces. These are the most important efforts worldwide. They are documented in many innovative individual projects by architects and planners, but also in the demands of city dwellers (e.g. for more green space close to their homes or garden areas), in the realisation of which they themselves participate. In this way, the eco-city is created "from below" and on a small scale.

China is the most dynamic region for eco-city development, because urbanization here is progressing fastest with modernization funds. Here, ecological principles could be applied from the outset and international role models could be created. However, vision, technical feasibility, economic considerations and propaganda do not always lead to optimal results and often do not create role models, despite huge investments and far-reaching decisions.

The relationship of eco-cities to their surroundings is usually hardly taken into account. Eco-cities cannot be eco-islands, where conditions are completely different from those in their surroundings. Eco-cities are also not "finished" after a programme

Fig. 7.22 A contribution to the eco-city from below: "special" greening. Haarlem (Netherlands). (Photo © Breuste 1992)

has been implemented or built, but continue to develop. This includes growth and functional change. Above all, however, they are in a pulsating relationship with their urban surroundings and form an urban region with them. The eco-city must therefore be conceived locally, designed globally to conserve resources and implemented regionally.

The big visions and the small steps together will make it possible to make further progress on the way to the eco-city (Fig. 7.22).

Questions

1. Which three important guiding principles for future cities were developed in the twentieth century?
2. What are the characteristic components of the garden city idea?
3. What did the Athens Charter (1933) contain?
4. What does the New Charter of Athens (2003) want to change in relation to the Charter of Athens?
5. What is meant by Solar Cities?
6. What are "low-carbon city" projects about?

Answer 1

The Garden City (Ebenezer Howard), which emerged as a counter-image to the industrial metropolis, the Functional City/Ville Radieuse (Le Corbusier), which formed the model of the metropolis of mechanized modernity, and the Sustainable City (sustainability as a model of local development).

Answer 2

The physical reorganization should be combined with a more civilized level of social development, the cooperative system. The garden as a symbol for better, more hygienic living conditions with "light, air and sun" stood for a new turning to nature, which was to reflect the city with green elements.

Answer 3

Charter of Athens: Insufficient biological and psychological satisfaction of the needs of city dwellers, imbalance in cities due to ruthless private interests and weak control, spatial division of functions of: Living, working, recreation, movement (traffic), superior traffic arteries for car traffic, the human being as a measure of urban architecture, the dwelling as a basic urban construction unit ("living row"), subordination of private interests in urban development to the interests of the community.

Answer 4

Elimination of the spatial separation of living, working, recreation, movement (traffic).

Answer 5

Replacement of fossil energy sources with exclusively solar energy.

Answer 6

"Carbon" is used as a synonym for all greenhouse gases. The main focus is on reducing these emissions in the areas of energy, transport, infrastructure and buildings.

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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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