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A Preliminary Assessment of Urban Ecosystem Services in Central European Urban areas. A Methodological Outline with Examples from Bochum (Germany) and Poznań (Poland)

Eine Methode zur Ersteinschätzung potentieller Ökosystemleistungen in mitteleuropäischen Metropolräumen, dargestellt am Beispiel von Bochum (Deutschland) and Posen (Poznań; Polen)

Summary

We propose a methodology for the rapid assessment of provisioning and regulating urban ecosystem services (UES) in Central European urban areas on a medium scale. The methodology is based on the Urban Atlas database that is free of charge for all major urbanized areas of the European Union. The proposed preliminary assessment of ecosystem services in urban areas contributes to detecting UES that are related to biologically active surfaces. Compared to other studies, our selection of UES including recreational service is still rather readily comprehensible since only a selection can reasonably be applied in practice from the extended catalogues of ES. Our approach supports identification of areas for enhancing ecosystem services. In the final analysis, urban planners and environmental agencies will decide which UES should be addressed elaborating more sophisticated methods.

In the context of applying the methodology to two selected central European metropolitan areas, Bochum (Germany) and Poznań (Poland), we discuss the potentials and restrictions of linking UES to the various categories of the database. Despite the overall larger area of open space and areas providing UES as well as for the provision of these areas per capita in Poznań, green urban areas are present in comparable distance from the residential areas in both cities. Green urban areas are more widely interspersed in Bochum than in Poznań. Connectivity of areas providing UES is higher in inner-city Poznań than in Bochum.

Keywords: urban ecosystem services, assessment, Central Europe, Bochum, Poznań

1 Standardized methods are needed for regional comparisons of urban ecosystem services

The significance of urban ecosystem services (UES) is well-acknowledged among scientists and is starting to be incorporated more and more into urban policymaking. According to Hubacek and Kronenberg (2013, 1–2), Cairns and Palmer (1995) were the first to suggest "that the concept of ecosystem services offered a perspective particularly useful for managing cities toward a sustainable development". Within the framework of urban restructuring on the metropolis and city scale, rapid assessment of UES is necessary in order to localize areas that call for intervention measures. Urban planners, decision makers, and the civil society need to know and to be able to decide where to protect areas with favorable green and blue infrastructure, where to mitigate adverse urban patterns posing stress or even causing ecological disservices (Dunn 2010, Lyttimäkki and Sipila 2009), and where to ameliorate areas with deteriorated environmental quality that might bear potentials providing enhanced ES.

Recently, the 4th MAES (Mapping and Assessment of Ecosystems and their Services) Working Paper provided examples of ecosystem classification and mapping of 10 European cities (Maes 2016). It was elaborated in the framework of target 2 action 5 of the EU Biodiversity Strategy to 2020. Besides reporting on common discussions among international scientists, this report was largely based on the standardized datasets that were provided by the Urban Atlas (EEA 2014). Especially for comparisons on regional, national and international scales, methodologies to assess ecosystem services are preferable that are not only based on standardized databases, but also on comparable assessment tools.

In this article, we propose a methodology for the rapid assessment of UES in Central European urban areas. The methodology is based on the Urban Atlas database that is freely available for all major urbanized areas of the European Union. Theoretical considerations justify our choice of the UES being addressed. In the context of applying the methodology to two selected central European metropolitan areas, Bochum (Germany) and Poznań (Poland), we discuss the potentials and restrictions of linking UES to the various categories of the database.

2 Scope, classification and selection of ecosystem services for urban landscapes

Ecosystem services are those benefits, amenities, or profits for people that are generated by the functioning of the ecosystems or come from the natural capital. Thus, ecosystem services are situated at the intersection of the realm of nature and the realm of people (Fig. 1). On the other hand, human activities – especially in cities – impose pressure on ecosystems that may reduce or eliminate ecosystem functions. We distinguish between potential and actual ecosystem services. If a benefit is not realized, it is unconscious; if it is not acknowledged or people are not aware of it, then it is a potential service (cf. Bastian et al. 2012). An investor who takes the vicinity of a nearby urban forest into his real estate calculation realizes the benefit or even profit from the ecosystem. As a consequence, demands on the natural capital and the ecosystem functions are formulated for expected benefits. Breuste et al. (2013) simply state: "Ecosystem services (ES) include all ecosystem functions and processes people and society benefit from in economic terms or related to their quality of life (cf. Costanza et al. 1997; de Groot et al. 2002)". If these ecosystem services are both requested and provided in urban areas and cities, we define them as urban ecosystem services (UES; according to Bolund and Hunhammar 1999; Breuste et al. 2013). For practical reasons, in the following sections of this paper, we treat urban ecosystem services as those generally perceived by the public without paying attention to differing perceptions of urban nature by social groups or individual actors.

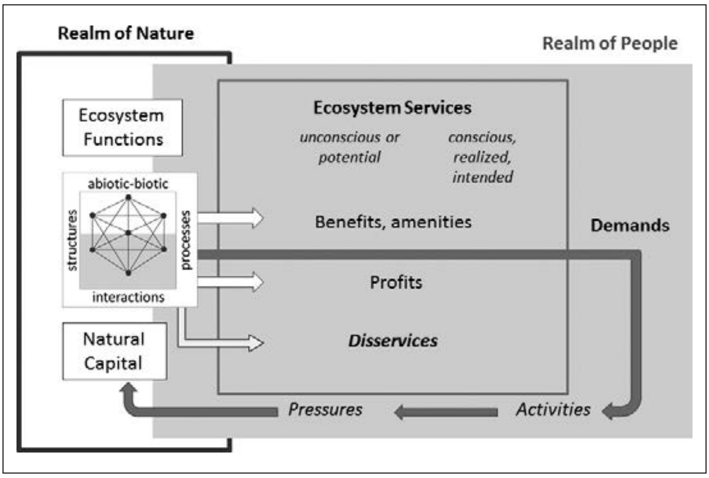

Fig. 1: Ecosystem services at the intersection of nature and people

Ecosystems and ecosystem services in urban areas can be viewed from different perspectives (Fig. 2); for instance from a biological or engineering science perspective and in a more integrative manner via urban ecology as an integrated field of environmental and engineering sciences. Spatial planners take the findings and analyses from these disciplines into urban design and political decision makers decide on the implementations of measures and the realization of projects that may have positive or negative effects. Planners and politicians act in the arena of conflicts between investors and many-voiced ideas expressed by members of the civil society.

In the literature, biological, social and economic perspectives are not often clearly distinguished and are more or less mixed. Integrative valuing of ES has been controversially discussed (Liu et al. 2010, Backhaus et al. 2008, Müller et al. 2010). Furthermore, the services chosen, analytical models, and indicators to quantify ecosystem services vary enormously in terms of perspective and spatial scale. This can clearly be seen when comparing Haase (2012) and Maes (2016).

TEEB (2010) listed 22 types of ecosystem services, irrespective of the character of the landscape. The Common International Classification of Ecosystem Services (CICES; Haines-Young and Potschin 2010) is a proposal to structure such services.

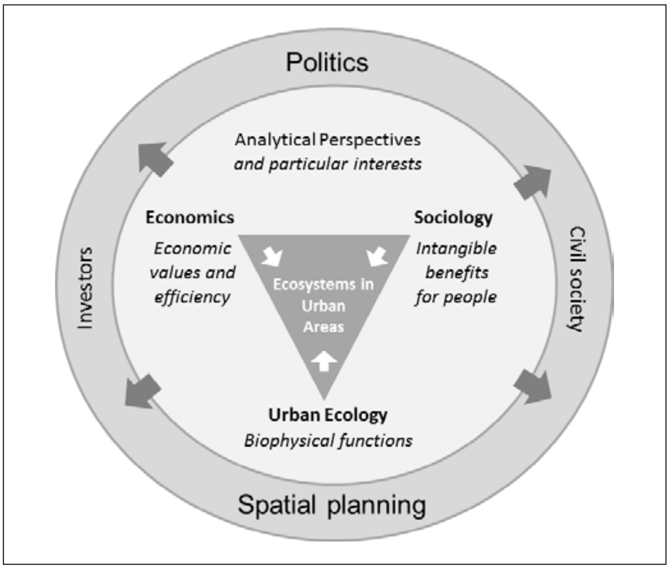

Fig. 2: Perspectives on ecosystem management in urban areas

It was designed by EEA (European Environmental Agency) for EU member states, but urban ecosystems have only recently been in the focus of this European initiative. Widely cited are BOLUND and HUNHAMMAR, (1999) who also related the concept of ES to urban areas. For Stockholm (Sweden), the authors distinguished six local and direct services generated by urban ecosystems: air filtration, micro climate regulation, noise reduction, rainwater drainage, sewage treatment, and recreational and cultural values. On a local scale, MCDONALD (2009) investigated temperature regulation by tree shade, water and pollutant filtration at a single soil plot, and timber production in a specific tree estate. On a regional scale, he considered recreation, climate regulation, and biodiversity.

BASTIAN et al. (2012) included an urban example to illustrate their concept of ecosystem properties, potentials and services (EPPS), namely climate regulation, carbon sequestration and recreation. HAASE et al. (2012) selected five ES of particular importance for urban ecosystems: (*1*) local climate regulation, (*2*) recreation potential, (*3*) biodiversity potential, (*4*) food supply and (*5*) above-ground carbon storage. GÓMEZ-BAGGETHUN and BARTON (2013) classified 11 important ecosystem services in urban areas and underlying ecosystem functions and components. BREUSTE et al. (2013) explicitly investigated UES for recreation, climate regulation, and biodiversity.

These examples only indicate the broad spectrum of UES studies. Recently HAASE et al. (2014) analyzed 217 papers. Methodologically, they range from research-based analyses with special focus on the urban heat island and the capacity of vegetated areas to reduce surface and air temperatures (LI et al. 2011) to complex biophysical models and GIS-based abbreviated valuation schemes. In this paper, we focus on Urban Ecology and set up a hierarchy of ES that is applicable in urban landscapes. There are other services connected to ecosystems that can be analyzed by specific methods of the mentioned disciplines such as sociology and economy (Jim and Chen 2003, Chen & Chang 2015, Rusche 2012). Among them, the recreational value of green urban spaces as well as open spaces is prominent. Therefore, we consider it in our analysis. Hence, we exclude aspects of green governance (e. g., Costanza and Liu 2014, Ernstson et al. 2010), politics, and environmental planning in favor of a natural science approach.

3 Mapping urban ecosystem services

"Depending on the focus of a study (i. e., which services have the main attention) and the respective scale level (the spatial extent and resolution), it is likely that different quantification and mapping methods are needed" (Müller et al. 2010, 4). Seppelt et al. (2012) suggested a five-step blueprint for ecosystem service assessments of which we address a – c in this section, whereas recommendation and results are presented following the results from our study areas:

a. Purpose and design
b. Scope of problemscape and concept
c. Analysis, assessment
d. Recommendation and results
e. Monitoring

3.1 Purpose and design

In terms of purpose, Burkhard et al. (2012) suggested mapping landscapes' capacities to supply ecosystem services, a rather sophisticated theoretically sound approach that is preferably applicable in rural areas. For urban areas in which the processes are predominantly governed by human interventions, adaptations are not yet available. Müller et al. (2010, 6) underpinned that in order "to provide information for actual management trade-offs, it is important to represent all potential significant services within the respective assessment study." In most cases, especially in preparatory planning processes, when several ecosystem services have to be determined at the same and for the same area, it is not feasible to model the underlying ecosystem functions in great detail (cf. Müller et al. 2010). Therefore, abbreviated and preliminary assessment methods are needed.

3.2 Scope of problemscape and concept

In general, regarding an urban landscape from an ecological perspective means either treating a city as one ecosystem or as a pattern of scattered natural, semi-natural or technical ecosystems (cf. Rebele 1994, Bolund and Hunhammar 1999). The former investigates the complexity of matter and energy fluxes including all anthropogenic and technically supported flows and energy transformations (Duvigneaud and de Smet 1977); the latter is restricted to green spaces and water bodies hosting biocoenoses. Bolund and Hunhammar (1999, 2) classified urban nature into street trees, lawns, parks, urban forests, cultivated land, wetlands, lakes, sea, and streams and thus exclude other spatial units that make up an urban area.

In this paper, we adopt an intermediary understanding of urban areas as being composed of spatial units that show a gradient from semi-natural to technical systems. In accordance with MAES (2016, 24), we have to acknowledge that "urban areas represent mainly human habitats but they usually include significant areas for synanthropic species, which are associated with urban habitats. This class includes urban, industrial, commercial, and transport areas, urban green areas, mines, dumping and construction sites." With Kowarik (1988) we define 11 classes of hemerobic state according to the degree of disturbance of the vegetation from undisturbed natural (ahemerobic) to metahemerobic areas where vascular plants are absent. If we understand ecosystem functions in a broader sense as biophysical processes that take place in a quasi-natural manner, i. e., according to the laws of natural sciences, we have to look for ecosystem functions in all types of ecosystems. Only then we are able to fully make use of the concept of ES.

We adopted version 4.3 of the CICES-system (Haines-Young & Potschin 2010). In applying it, we focused on ES that are highly related to urban landscapes. Modifications were introduced in terms of joining some services into one class (Tab. 1). Services exclusively connected to isolated natural elements that are not part of ecosystems, such as animal breeding in stables and religious connotations to ecosystems were not evaluated. We considered surface water for drinking since in some of Europe's urban areas, surface water is used to provide that service after treatment und purification. Thus, the selection is applicable on the local level and adapted to a European cultural background. The effect of urban green spaces on the global climate system via carbon dioxide fixation is negligible on the local scale, but has to be addressed on larger scales. One could even argue against the significance of material and food supply from urban ecosystems in provisioning urban populations.

Tab. 1: Classes of Provisioning and Regulating Services (according to CICES-system, version 4.3; Haines-Young & Potschin 2010) selected for a preliminary assessment in urban landscapes

Provisioning services	Regulating services
Cultivated crops, Reared animals and their outputs	Filtration/sequestration/storage/ accumulation by ecosystems
Wild plants, algae and their outputs	Hydrological cycle and water flow maintenance
Wild animals and their outputs	Pollination and seed dispersal
Surface water for drinking	Ventilation and transpiration
Fibers and other materials from plants, algae and animals for direct use or processing	Global climate regulation by reduction of greenhouse gas concentrations
Materials from plants, algae and animals for agricultural use	Micro and regional climate regulation
Surface water for non-drinking purposes	
Plant-based resources	

Yet, "if conventional chains of food supply collapse during crises, market substitutes can become very expensive and allotments can make non negligible contributions to meet basic nutritional requirements" is the argument of Gómez-Baggethun & Barton (2013) referring to Barthel et al. (2013). If not on a local scale, at least on a regional scale, this service should be included in assessment and evaluation. Mediation of smell/noise/visual impacts can be services of green infrastructure and built constructions to reduce noise, e. g., psycho-acoustic effects. Assessment of these functions requires site specific small scale information and is not covered in our scheme. The same is true for other services included in CICES, such as buffering and attenuation of mass flows; storage of sediment by rivers, lakes and sea is excluded. We assigned recreational value to urban green areas and open spaces that are close to presumably populated urban areas as the only cultural service we took into account.

3.3 Assessment method

Selecting the indicators is a crucial step. The indicators must be adapted to the type of ecosystem, the prescription at hand to classify the UES. Assessing UES is always an interpretative procedure. UES can only be mapped indirectly through land cover, land use and other interpretation of landscape elements. Depending on the scale, mapping base data can be more or less detailed (Costanza & Liu 2014). Gomez & Barton (2013) differentiated economic valuation of ecosystem services in urban planning according to different scales. The authors explicitly mentioned valuation methods, but did not address the mapping procedure. Here, not only the scale matters, but also the problem of spatial heterogeneity (Pickett et al. 2001) has to be taken into account. Haase et al. (2012) based indicators on the land use type and assigned values such as indexed surface emissivity to express the local climate regulation, or indexed habitat potential for bird species, and food supply. They used look-up tables and regression models to rate the degree of ES performance. We regard the proportion of sealed and unsealed surfaces, the type of vegetation coverage as well as of surface water bodies as crucial indicators. Surface sealing causes overland flow and direct runoff with the consequence that the covered soil loses its function as a percolation medium, as a buffer in the hydrological cycle, and as an absorbing medium for harmful substances. In major parts of urban areas, rainwater infiltration is restricted to small areas with rather complex geometries. These geometries are attached to the land use, and this is the reason why land use is taken as the basis to identify urban ecological units in most studies. To be precise, land cover type is more appropriate than land use as land cover relates to the physical properties and land use designates a specific function of an area (Breuste et al. 2013), e. g., a shopping mall, a workshop, or an administration building. Nonetheless, land use often substitutes for land cover due to the non-availability of the latter.

Urban ecosystems services are connected to phenomena of various spatial scales that vary from isolated flowerbeds over trees and gardens to urban forests (cf. McDonald 2009). And indeed, urban landscapes exhibit intricate patterns of spatial units with different biophysical properties. In order to classify general land

Tab. 2: Linking land use classes with provisioning and regulating ecosystem services in urban areas

Ecosystem services selected from CICES v.4.3 → / ↓ Land use classes after Urban Atlas	Provisioning services						
	Cultivated crops, Reared animals and their outputs	Wild plants, algae and their outputs	Wild animals and their outputs	Surface water for drinking	Fibres and other materials from plants, algae and animals for direct use or processing	Materials from plants, algae and animals for agricultural use	Surface water for non-drinking purposes
Continuous Urban Fabric (S.L. > 80%)	N	N	N	N	N	N	N
Discontinuous Dense Urban Fabric (S.L. : 50% - 80%)	I	N	N	N	N	N	N
Discontinuous Medium Density Urban F. (S.L. : 30% - 50%)	I	N	N	N	I	N	N
Discontinuous Low Density Urban F. (S.L. : 10% - 30%)	I	N	N	N	I	I	N
Discontinuous Very Low Density Urban F. (S.L. < 10%)	S	N	N	N	I	I	N
Isolated Structures	N	N	N	N	N	N	N
Industrial, commercial, public, military and private units	N	N	N	N	I	I	N
Construction sites	N	N	N	N	N	N	N
Fast transit roads and associated land	N	N	N	N	N	N	N
Other roads and associated land	N	N	N	N	N	N	N
Railways and associated land	N	N	N	N	N	N	N
Airports	N	N	N	N	N	N	N
Land without current use	N	N	N	N	N	N	N
Sports and leisure facilities	N	N	N	N	N	N	N
Green urban areas	N	N	N	N	N	N	N
Agricultural + Semi-natural areas + Wetlands	P	S	P	N	P	P	N
Forests	N	P	P	N	P	N	N
Water bodies	N	I	P	P	S	N	P
Mineral extraction and dump sites	N	N	N	N	N	N	N

LEGEND: The potential level of ES supply: P – Priority; S – Significant; I – Insignificant, N – Non-relevant

			Regulating services								**Overall ecosystem services**		
Plant-based resources	*Sum of significant provisioning services*	*Sum of priority provisioning services*	Filtration/sequestration/storage/ accumulation by ecosystems	Hydrological cycle and water flow maintenance	Pollination and seed dispersal	Ventilation and transpiration	Global climate regulation by reduction of greenhouse gas concentrations	Micro and regional climate regulation	*Sum of significant regulating services*	*Sum of priority regulating services*	*Sum of significant services*	*Sum if priority services*	**Overall weighted prominence of provisioning and regulation services; Sum (Weight for significant services: 0,5; weight of priority services: 1,0)**
N	*0*	*0*	N	N	I	N	N	N	*0*	*0*	*0*	*0*	**0**
N	*0*	*0*	I	I	I	I	N	N	*0*	*0*	*0*	*0*	**0**
I	*0*	*0*	I	S	I	I	I	S	*2*	*0*	*2*	*0*	**1**
I	*0*	*0*	I	S	I	S	I	S	*3*	*0*	*3*	*0*	**1,5**
I	*1*	*0*	S	P	I	S	I	P	*2*	*2*	*3*	*2*	**3,0**
N	*0*	*0*	N	N	N	N	N	N	*0*	*0*	*0*	*0*	**0**
N	*0*	*0*	I	N	I	N	N	N	*0*	*0*	*0*	*0*	**0**
N	*0*	*0*	N	I	N	I	N	N	*0*	*0*	*0*	*0*	**0**
N	*0*	*0*	N	N	N	N	N	N	*0*	*0*	*0*	*0*	**0**
N	*0*	*0*	N	N	N	N	N	N	*0*	*0*	*0*	*0*	**0**
N	*0*	*0*	I	N	I	N	N	N	*0*	*0*	*0*	*0*	**0**
N	*0*	*0*	I	S	N	S	N	N	*2*	*0*	*2*	*0*	**1**
N	*0*	*0*	I	I	S	S	I	N	*2*	*0*	*2*	*2*	**3**
N	*0*	*0*	S	S	S	S	I	I	*4*	*0*	*4*	*4*	**6**
I	*0*	*0*	P	P	S	P	S	S	*3*	*3*	*3*	*3*	**4,5**
P	*1*	*5*	P	P	P	S	S	S	*3*	*3*	*4*	*8*	**10**
P	*0*	*4*	P	P	P	P	P	P	*0*	*6*	*0*	*10*	**10**
N	*1*	*3*	P	P	N	P	S	P	*1*	*4*	*2*	*7*	**8**
N	*0*	*0*	N	S	N	N	N	I	*1*	*0*	*0*	*0*	**0**

use types, Breuste et al. (2013) defined subtypes of residential estates that take different percentages of sealed surfaces into account (cf. Pauleit & Breuste 2011). This refers to earlier approaches (Breuste et al. 2001) to categorize the complexity of the urban fabric by mapping Urban Structural Types. The resulting spatial units provide a basis for assessment and evaluation of UES: *They are characterized by comparable eco-environmental properties (features) and are defined according to the actual land use and are further differentiated by attributes that describe the environmental conditions. Thus, Urban Structural Types enable subdividing hybrid urban landscape mosaics into physiognomically homogeneous units. Mostly, they have an internal characteristic configuration, specific pattern of built-up areas and open space. Each Structural Type exhibits a characteristic percentage of sealed surface and vegetation structure* (text in italics: translated and modified according to Breuste et al. 2001). Urban Structural Types reflect categories of spatial heterogeneity characterized by specific functions and processes that are interpreted in terms of ecosystem services.

The Urban Atlas (European Environment Agency (EEA 2014) provides European-wide comparable land use data for urban areas with more than 100,000 inhabitants. Land use data contain useful descriptions of land cover. Data sets are downloadable as vector data in ESRI shapefile format. Data was derived mainly from Earth Observation data backed by other reference data, such as COTS navigation data and topographic maps at a scale of 1: 50 000 or larger (EEA 2014). The corresponding mapping guide requires that interpreted areas should have a minimum extension of 100 m to ensure accuracy and continuity of polygons. The minimum mapping unit for Class 1 polygons is generally 0.25 ha; for agricultural land, forests and water bodies it is 1.0 ha. Hence, the spatial scope required for applying our scheme is for homogeneous spatial units exceeding 50 m x 50 m, equivalent to 0.25 ha, equivalent to the spatial resolution of Landsat TM, corresponding to 5 mm x 5 mm on maps at the scale 1 : 10,000 (Meirich 2008).

Table 2 links land use types according to the Urban Atlas (EEA 2014) with selected UES (Tab. 1). UES, scale and spatial resolution match and allow for a preliminary assessment. We tentatively valued the level of UES potential in four categories: P – Priority; S – Significant; I – Insignificant, N – Non-relevant. This rating has to be seen as the authors' expert estimation. We then counted the number of priority or significant potential UES assigned to each land use unit, both for provisioning and for regulating services. Lastly, we cumulated all priority and significant services. To summarize in a highly debatable overall figure for each land cover type, we calculated the UES Significance according to the following formula and classified according to Table 3.

$$\text{UES } Significance = \sum_{s=1}^{n} \cdot ws + \sum_{pr=1}^{n} \cdot wp$$

with weight of significant services $ws = 0.5$

weight of priority services $wp = 1.0$.

Tab. 3 Classification of areas with provisioning and regulating ecosystem services

	UES Significance
1st class UES	> 7.5
2nd class UES	≤ 7.5; > 3.0
3rd class UES	≤ 3.0; > 0,5
no significance	≤ 0.5

In order to assess the provision of recreational services, urban green areas and open spaces (> 2 ha) were considered. No distinction was made for land use classes between significant or priority service. The proportion of areas covered by continuous and discontinuous dense urban fabric within 300 m and 1000 m of green urban areas and within 300 m and 1000 m of open spaces was determined separately. Distance to green spaces is one of the most frequently used indicators to map physical usage of green space for recreational purposes (Coles and Bussey 2000). A distance of between 300–400 m was recognized as a distance beyond which frequency of visits in green spaces decreases (Grahn & Stigsdotter 2003; Nielsen & Hansen 2007). Open space was understood in a broad sense comprising the land use classes agricultural, semi-natural areas, wetlands, forests, green urban areas, discontinuous very low density urban fabric (S.L. < 10 %) and water bodies.

4 Study areas Bochum (Germany) and Poznań (Poland)

The valuation schema was applied to Bochum (Germany) and Poznań (Poland). Bochum is part of the Ruhr metropolitan area covering an area of 146 km². 365,000 inhabitants thus cause a population density of 2504 people/km². Bochum extends from south to north, from the Ruhr valley to the Emscher valley. Whereas the Ruhr valley was incised by about 100 m into the Variscan Mountains during the entire Pleistocene, the undulating relief and sediments north of the divide are a result of glacial and periglacial processes during the two youngest glacial periods. Periglacial cover beds in the south and loess deposits in most of the city's surface together with a temperate and humid climate throughout the year are the reason for favorable agricultural conditions that were especially important in the pre-industrial period. The development of coal and steel industries during the 19th and 20th century caused land use changes from rural to an urbanized landscape with areas for manufacturing, coal mines, steel industries and residential areas. The structural change that started in 1958 brought about another transformation with impact on the land cover. Two thirds of the area is used for settlement and traffic, 20 % is agricultural land, and about 6 % of the area is still covered by forests.

Poznań, the capital of Greater Poland region, is situated in Western Poland on the Greater Poland Lowland along the Warta River that crosses the city on an S-N axis. 545,000 inhabitants live on 262 km² (population density is 2,080 people/km²). The topography is characterized by mostly flat terrain with loamy and sandy morainic deposits from the last glacial period as soil parent material. A vast land surface within city's administrative borders is dedicated to agriculture with mosaic patterns and large semi-natural areas (27 %). Forests cover 15 % of city area, urban green space comprises 8 % of the land and surface water takes 3 %. An additional 4.5 % of city area is used for sport and leisure. Urban fabric with transportation areas and land without current use comprise 42.5 %.

5 The spatial patterns of ecosystem services in Bochum and Poznań

The maps (Fig. 3) visualize the potential UES in Poznań and Bochum. They are shown at the same scale to facilitate comparisons. The most striking difference is the coarse structured blocky pattern in Poznań, both for the inner city and the peripheral areas. This is supported by the differences in mean patch size of all categories of open space and areas providing UES (Tab. 4). Bochum exhibits finer grained patterns in which a core-periphery-gradient is less distinct. The former settlement cores of today's administrative area of Bochum can only be detected with prior knowledge. These are areas with no UES (urban fabric > 50 %). Today's Bochum's administrative area was subject to continued urban sprawl in the 19th and 20th century amalgamating clusters of coal mines, industrial and residential areas. The most prominent features of Poznań's green infrastructure are the green wedges, which split up the urban fabric. The southern and northern wedges are formed by the Warta Valley, which is linked with the western and eastern green wedges as tracks of ancient subglacial channels. The historical city itself is surrounded by a more or less contiguous ring of urban green. The so-called regional green belt of the Ruhr area forms the backbone of the green infrastructure extending north to south at the western and eastern margins and two additional ones in the left and right half of the map. In the south, along the Ruhr River and Lake Kemnade another fairly extensive band is an area with varied UES. The size of the individual patches with considerable value for the provision of UES as well as the proportion of the total open and green space is smaller than in Poznań. The biggest difference is related to the 1st class area for UES where Poznań overtops Bochum. A remarkable feature is Poznań's richness of water bodies close to the inner city (Warta River and two artificial lakes, Lake Maltańskie 2 km and Lake Rusałka 4 km, as well as two natural lakes, Strzeszyńskie and Kierskie about 9 km away from the city), whereas in Bochum, the linear distance between Lake Kemnade and the inner city is about 7 km and access via streets is even farther (10 km).

The difference is even greater when viewed against the background of the landscape patterns surrounding the administrative areas of both cities. Bochum is part of a polycentric conurbation of the Ruhr metropolis, whereas Poznań is surrounded by mostly rural areas. However, perhaps most important for nature-based recreation is the vicinity to urban green and open space within walking distance to the residential areas. In this respect, Poznań and Bochum resemble each other. Despite the overall larger area of open space and areas providing UES as well as for the provision of these areas per capita in Poznań, green urban areas are present in comparable distance from the residential areas in both cities (Fig. 4). Green urban areas are more widely interspersed in Bochum than in Poznań.

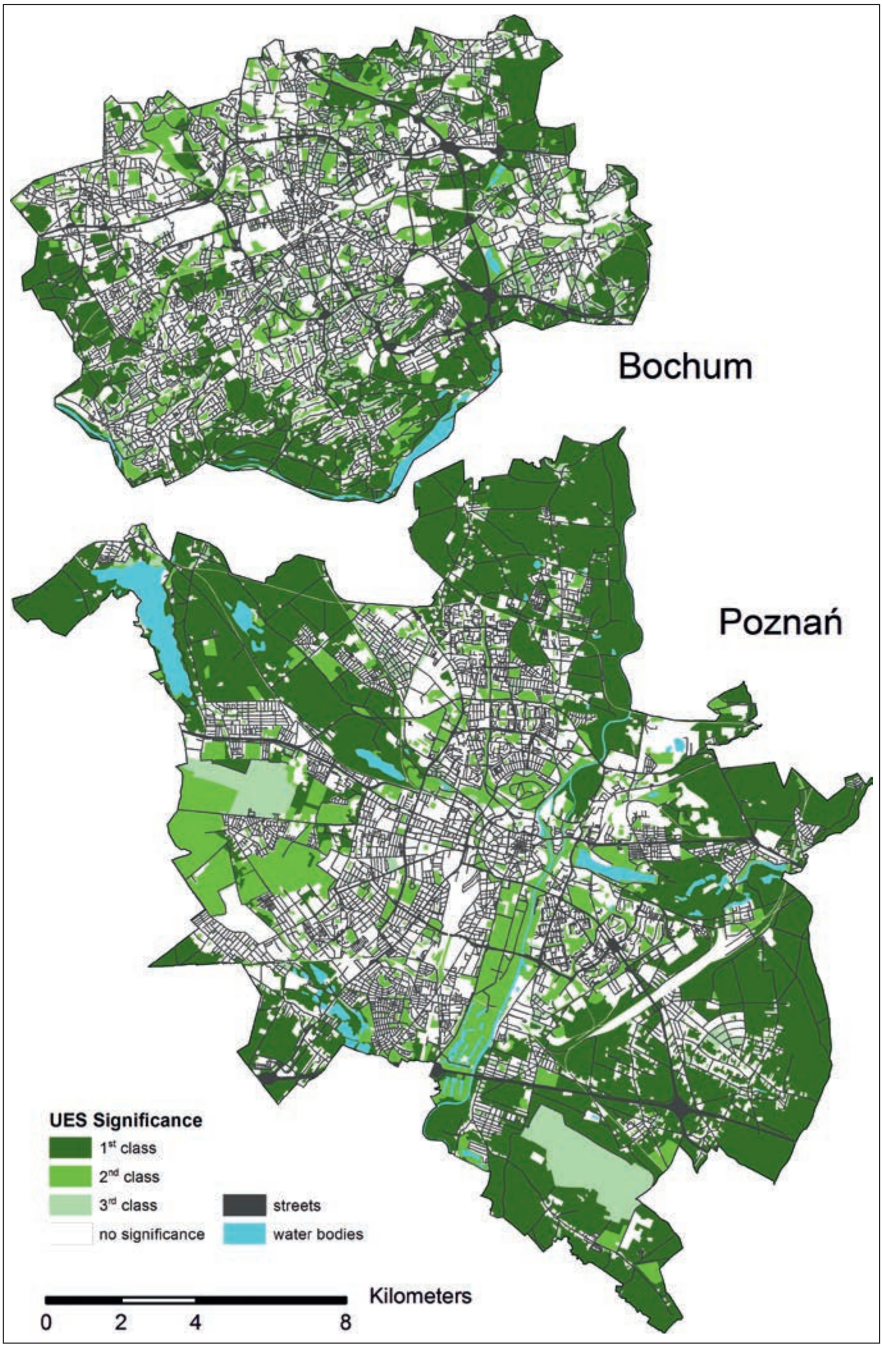

Fig. 3: Preliminary assessment of overall provisioning and regulating ecosystem services in Bochum and Poznań.

Connectivity of areas providing UES is higher in inner-city Poznań than in Bochum. This is due to the natural setting and the conversion of Poznań's fortification into a green ring at the turn of the 19th and 20th century. The Warta River and its tributaries exhibit a cross-like configuration with a junction next to the city center.

Tab. 4: Statistics of open space and areas providing UES in Poznań and Bochum (S.L. sealed surface)

	Poznań	Bochum	Poznań	Bochum	Poznań	Bochum
	in % of total area	in % of total area	area/ capita providing UES [ha]	area/ capita provid-ing UES [ha]	mean patch size [ha] (count)	mean patch size [ha] (count)
Open space • Agricultural + Semi-natural areas + Wetlands; • Forests; • Green urban areas; • Discontinuous Very Low Density Urban Fabric (S.L. < 10 %); • Water bodies	53.0	34.1	254.3	135.9	11.9 (1165)	6.0 (823)
1st class UES • Agricultural + Semi-natural areas + Wetlands; • Forests; • Water bodies	45.1	26.9	216.7	107.2	16.3 (725)	7.6 (515)
2nd class UES • Discontinuous Very Low Density Urban Fabric (S.L. < 10 %); • Green urban areas; • Sports and leisure facilities	12.3	12.0	59.0	47.6	5.1 (643)	3.0 (576)
3rd class UES • Discontinuous Medium Density Urban Fabric (S.L.: 30 % – 50 %); • Land without current use; • Airports	5.3	7.5	25.6	29.7	4.4 (317)	2.1 (526*)
Sum of areas providing UES (1st class – 3rd class)	62.8	46.4	301.4	184.5	8.6 (1685)	4.2 (1617)

*without airport

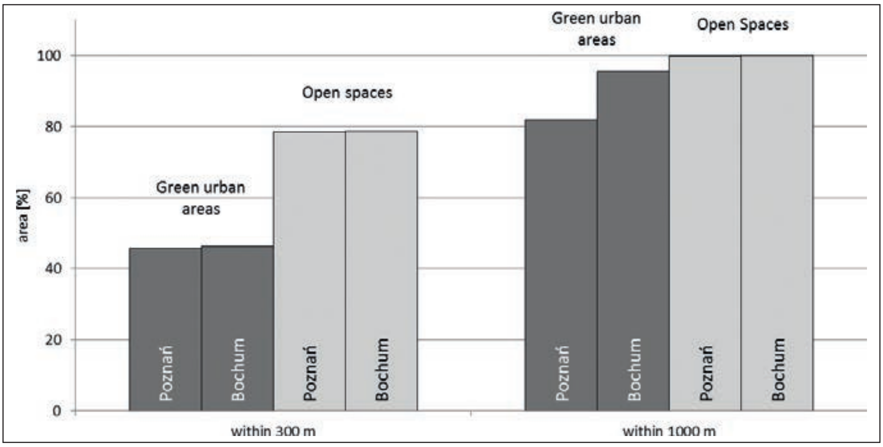

Fig. 4: Proportion of areas covered by continuous and discontinuous dense urban fabric in reach of green urban areas and of open spaces within 300 or 1000 m in Poznań and Bochum.

6 Discussion. Potentials and limitations of the preliminary assessment method

A clear understanding and methodology of UES is of prime significance for adequate planning of urban green infrastructure (Austin 2014). In this paper, we underlined that improving ES in urban areas should not be limited to open green spaces or water bodies. On the other hand, caring for green urban infrastructure refers to more than ornamental greening of houses and streets. We propose rethinking potential ecosystem services for the total urban area.

One could argue that green urban spaces according to the Urban Atlas database should be redefined to include more diverse forested areas or other types of green urban space. Unfortunately the Urban Atlas does not distinguish between agricultural land, semi-natural areas and wetlands. This is a definite shortcoming for ecosystem service assessment and evaluation. However, it can be overcome by using additional sources of land use or land cover information based on which wetlands and semi-natural areas can be extracted for ES analysis.

The illustrated method complements the analogue matrix suggested by Burkhard et al. (2012) that was designed for a regional scale. The special land use types and intricate spatial patterns of land use and land cover in urban areas called for a modified approach. A definite advantage of the preliminary assessment scheme is the linkage between UES and urban structural units that are available for all European metropolitan areas at the same level of detection. Thus, comparisons and preliminary evaluations of the UES performances are facilitated. This is clearly shown when comparing the potential UES for Bochum and Poznań. Poznań has more and larger areas that provide UES than Bochum, whereas Bochum is equal in terms of the provision of green urban spaces. Bochum's inner-city green infrastructure lacks connectivity when compared to that of Poznań. The stronger connectivity of green urban spaces in Poznań is related to its natural heritage; its value has generally been respected in urban planning. Bochum's comparable level of green urban area provisioning is on the one hand due to left-over areas from the industrial era and on the other hand is due to the successful restoration of former coal mines and industrial sites.

Considering urban structural units on city scales allows for an overview. Neither single trees nor plant containers and linear elements such as tree rows, alleys and front yards are taken into account. Thus, detailed elements undoubtedly providing ES are neglected. In densely sealed urban areas, further potential ES may come from green walls that were not discussed in this paper. The approach has several other restrictions and deficits, which call for follow-up detailed analyses: In hilly or mountainous areas, the assessment scheme is not applicable for regulating services connected to surface or near-surface water runoff. Underground structures (bedrock, sediments, and soils) and groundwater are not considered. Water cycle interactions (flow directions, flow accumulation) are not addressed. Areas subject to flooding need to be assessed by in-depth studies. Neighborhood effects, spatial patterns of cold air producing units, flow patterns and ventilation corridors remain subject to further studies. Pollination and seed dispersal in parks and on arable land varies with species composition and management. Decomposition of contaminants and related fixing processes largely depend on the physico-chemical properties of the surfaces materials that remain unknown.

Compared to other studies, our selection of UES including recreational service is still rather readily comprehensible since only a selection can reasonably be applied in practice from the extended catalogues of ES. In the final analysis, urban planners and environmental agencies will decide which ES should be addressed in a certain context. Compared to the rather aggregated definition of UES in Haase et al. (2012), our table optionally allows room for more specific services. Our approach supports identification of areas for enhancing ecosystem services. The proposed preliminary assessment of provisioning and regulating ecosystem services in urban areas on a medium scale contributes to detecting UES that are related to biologically active surfaces. It helps to raise awareness for policy makers who decide which ecosystem services should be selected for detailed analyses in which areas.

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