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Mapping the diversity of regulating ecosystem services in European cities

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ABSTRACT

This paper presents the first analysis of the diversity of regulating ecosystem services (ESS)—key variables for global environmental sustainability and change in an urban era—across a globally important part of the urban world, urban Europe. We map the first pan-European pattern of regulating ecosystem services in urban core areas and their associated hinterlands and discuss data against the background of each city's land-use development history and planning culture. Upon selecting more than 300 cities, we used the Urban Atlas database and a straightforward calculation method to map three regulating ecosystem services. The main results of this study show (a) a heterogeneous distribution of regulating ecosystem services across European cities, (b) considerable provisioning differences between core cities and the hinterland, (c) a grouping of European regions according to their potential for urban ecosystem service provisioning and (d) an ecosystem services supply ranking for European cities. Considerable differences in urban ecosystem services were found among northern countries, such as Sweden and Finland, which are rich in supplying ecosystem services compared to the UK and Belgium, which, similar to Spanish and Greek cities, are characteristically low in ecosystem services provision. Our results provide the first overall picture of regulating services in urban EU-Europe and serve to inform decisions on the key aspects of future European policy and strategies involving urban nature, green spaces and health.

1. Introduction

Worldwide, ecosystems' capacity is under increasing pressure, which is especially important in urban regions (Elmqvist et al., 2013). Due to urbanization and urban sprawl, cities often suffer from poor provision of ecosystem services (ESS), which is directly linked to the quality of life of the urban population (Boone et al., 2014). Soil sealing and land consumption are severely increasing in European urban areas (Scalenghe and Marsan, 2009); in addition, air pollution and water contamination from traffic, industrial production and habitat extinction are challenging urban areas (Kronenberg et al., 2013).

Often, urban land consumption is accompanied by a reduction of green spaces (e.g., parks, forests and allotment gardens) and blue spaces (e.g., lakes, rivers and wetlands) (Nuissl et al., 2009), which in turn alters the city's ability to sustain functioning ecosystems and, consequently, to provide ESS. At the same time, humanity faces increasing urbanization. The worldwide share of people living in cities (currently >50%) will increase to 75% in the near future and is predicted to reach approximately 90% by the end of the 21st century (UN, 2012). The global urban land area is expected to grow at a faster rate through 2030 as 60% of urban spaces have not yet been built (Elmqvist et al., 2013; Seto et al., 2011). Meanwhile, as urban land-use and the built fabric increase, reducing the amount of space for urban nature and ecosystems, there are more people who depend on precisely those urban environments and ecosystems to provide drinking water, clean air, food and green spaces for recreation. To maintain suitable conditions for human health and welfare in cities, additional knowledge about the function of and demand for green and blue spaces and the respective ESS provisions is needed. Although the pressure on urban ecosystems is disproportionately high, the value that nature offers urban citizens should not be ignored (TEEB, 2011).

Urban green spaces, such as parks, trees or wetlands, reduce local air pollutants by absorption (Bolund and Hunhammar, 1999), mitigate heat waves through evaporation and tree cover

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(Bowler et al., 2010) and help to regulate extreme weather events (Costanza et al., 2012), an issue of particular importance given the recent damages from extreme floods in Central Europe in 2013 and storms Sandy or Katrina in the US. Furthermore, the ability of ecosystems to provide humans with local food, fresh water and raw materials is increasingly being acknowledged (Satterthwaite, 2007; Kremer and DeLiberty, 2011). Urban green and blue areas provide urban citizens with spaces for recreation and aesthetic appreciation and, therefore, help to maintain human physical and psychological health (Chiesura, 2004). Ecosystems also serve educational purposes by connecting urban dwellers to nearby nature and, in the best case, enhancing public knowledge about the environment. Contact with nature is of particular importance in cities where people are increasingly concentrated. Altogether "...cities depend on a healthy natural environment that continuously provides a range of benefits" (TEEB, 2011: 1), an environment within city borders as well as beyond (Bolund and Hunhammar, 1999). Climate regulation services play a vital role in providing and maintaining human welfare and health in cities. These services help to create a favourable place to live by reducing urban heat stress, producing cool air and mitigating climate change effects.

To support urban planners and policy-makers in incorporating and implementing the concept of ESS in urban land-use management and planning, a straightforward and transferable calculation method is needed that is both comprehensive and easy to implement. To date, very few quantification studies have focused on large urban areas that include both the urban core and hinterland or the valuation of a number of cities simultaneously. However, methods for quantifying single or multiple urban ESS within specific cities have been described by Burkhard et al. (2012), Bastian et al. (2012), Su and Fath (2012), Pellissier et al. (2012), Strohbach et al. (2012), Larondelle and Haase (2013) and many others. Currently, international and national teams of scientists working in the area of urban ESS conceptualize knowledge systems about ESS provisioning at the national level (TEEB for Germany and the UK National Ecosystem Assessment). Moreover, comprehensive reviews on ESS research at the global scale have been published (Seppelt et al., 2011; Hernández-Morcillo et al., 2013). Nevertheless, research beyond the case-study scale for cities and their hinterlands is still extremely rare, although this research would present a more detailed picture of the distribution and performance of ESS in urban areas.

To bridge this gap, we present a study on regulating ESS across a wide range of European cities to deliver a more complete picture at the continental scale—and thus of global relevance as well—of how European urban dwellers might benefit from the surrounding and nearby ecosystems. The study focuses on ecosystem regulating services, which belong to the most important urban ecosystem services, in European cities and seeks to better differentiate between the ESS that originate from core cities and hinterland areas (Westerink et al., 2013). The hinterland is defined as the region around an urban core where at least 15% of the employed residents commute to work into this urban core (OECD, 2013). In sum, the hinterland and the urban core city represent the functional urban region (OECD, 2013) or the larger urban area (European Commission, 2004).

Cities are more than their administrative boundaries as they are ecologically, economically and socially connected to their hinterland (Haase, 2014), and urban dwellers often use the green and blue spaces in their surroundings. Cities are connected to their hinterland through flows of people (commuting and transport), materials (food and water), energy and other goods. Research hypothesizes that cities depend on their hinterlands for ESS provisioning, but "there is also a presence of natural ecosystems within the city limits" (Bolund and Hunhammar, 1999: 294) that affects the surrounding areas in return. Generally, European cities are supposedly not self-sufficient in providing sufficient ESS within their administrative boundaries. Therefore, Jansson and Nohrstedt (2001) suggest that one should not only be concerned with the ecology 'in' cities, but should focus on the ecology 'of' cities, meaning 'of cities within their environment'. Due to all of the different connections and dependencies that exist between cities and their hinterlands, these areas need to be treated as a single unit (Breuste et al., 2013) when investigating the urban ESS. Understanding how cities are connected to their hinterlands via the provision of ESS is necessary to support urban and regional planning towards a more sustainable and integrated policy. Thus, the following four research hypotheses guide our research:

1. Provisioning ESS differ largely across European cities. There are significant differences in the provision of ESS among large European regions.
2. The reasons for these differences are diverse and do not simply reflect major drivers, such as population dynamics or city area growth.
3. Past urban land-use development, urban form and urban planning culture significantly influence both the patterns and total supply of ESS in cities and urban regions.
4. Compact cities, even though a positive normative in planning, are not necessarily optimal for the provision of ESS.

To respond to these hypotheses, a large Europe-wide (EU27) dataset is used for quantification and for empirical evidence for two reasons: due to its long urban history and large urban form and planning culture diversity, Europe is of more than continental representativeness for an urban systems analysis. Additionally, many existing empirical studies on specific European cities in selected countries help to calibrate, validate and interpret the results of this study.

In general, Europe has a long history of urban and city development (Batty, 2008; Haase, 2014). Presently, there is considerable variation among European cities in terms of urban land-use development and compactness (Schwarz, 2010), urban population dynamics (Kabisch and Haase, 2011), urban economic performance and success (Mykhnenko and Turok, 2008) and the city's environmental situation (Breuste et al., 2013). The case of Europe clearly illustrates a variety of city sizes, densities, developments, planning cultures and resulting structures (Andersson and Bodin, 2009; Ernstson et al., 2010; Jansson and Nohrstedt, 2001; Lakes and Kim, 2012; Kabisch et al., 2012; Soares et al., 2011; Pouyat et al., 2002).

The worldwide picture shows Europe with similar urban form and growth patterns as those of most of the cities in the developed, early industrialized world (Elmqvist et al., 2013). In terms of built-up and population density, European cities are midrange worldwide (mean 67 persons/ha (p/ha)), lower than in developing countries (mean 136 p/ha) and denser than cities in land-rich countries (mean 23 p/ha), such as the U.S.A., Canada and Australia (Angel et al., 2011). Angel et al. (2011) state that certain urban phenomena, such as the decline in both population and built area density, can be found in different parts of the world, such as Europe (for example, Paris and London), the U.S.A. (for example, New York City and Pittsburgh), Latin America (for example, Guatemala City and Buenos Aires) and Asia (for example, Tianjin and Manila). Thus, a study using a sample of European cities may, to some extent, be representative for other—but not for all—urban development patterns across the world, definitely excluding the dynamics in emerging megacities in the Global South.