Ecological Indicators xxx (2016) xxx–xxx

Contents lists available at ScienceDirect

Ecological Indicators

journal homepage: www.elsevier.com/locate/ecolind

Exploring local consequences of two land-use alternatives for the supply of urban ecosystem services in Stockholm year 2050

Jaan-Henrik Kain[a,*], Neele Larondelle[b,c], Dagmar Haase[b,d], Anna Kaczorowska[a]

[a] Chalmers University of Technology, Gothenburg, Sweden
[b] Humboldt University, Berlin, Germany
[c] Potsdam Institute for Climate Impact Research, Potsdam, Germany
[d] Helmholtz Center for Environmental Research (UFZ), Leipzig, Germany

ARTICLE INFO

Article history:
Received 5 September 2015
Received in revised form 15 February 2016
Accepted 29 February 2016
Available online xxx

Keywords:
Urban land use
Urban planning
Urban ecosystem services
Land-use options
Service Providing Elements
Synergies and trade-offs

ABSTRACT

Ecosystem services (ESs) are gaining ground in urban policy as a key to attaining sustainable cities. However, strategic and land-use planners need operational and accessible tools to better understand the consequences of policy and planning measures. Based on a study of the City of Stockholm and its surrounding region, we argue that spatially explicit land-use mapping is a good base for modeling and visualizing the supply of urban ESs provided by different patterns of Service Providing Units. By adding more detailed characteristics of land use through the concept of Service Providing Elements (SPEs), and by assessing synergies and trade-offs between these attributes, implications for the supply of ESs at different scale levels could be identified and discussed. Detailed land-use mapping and ES modeling were applied to two future land-use alternatives. The supply of eight urban ESs was found to vary significantly between the two alternatives depending on the ratios of different SPEs, even within identical land-use classes. One of the land-use alternatives had significantly higher potential for food and energy provision, much higher air cooling and air quality regulation capacity especially in densely built areas, showed less surface sealing, and provided better conditions for mental recreation. The exception was supply of physical recreation opportunities, where the other land-use option had an advantage. These differences became more accentuated when we zoomed in on two local urban areas. Based on these findings, our main conclusion is that, in order to provide planning and policy-making with an adequate knowledge base, it is necessary to move beyond land-use classes, as defined by European data sets like *Urban Atlas*, and toward tools capable of capturing more detailed aspects of land use and its relations to the supply of urban ESs. This should be made a priority, especially in early stages of planning and policy formation, and also used to support development of urban by-laws, procurement arrangements, neighborhood and building certification, etc. The approaches used in the study can serve as a valid starting point for further development of such tools and methods compatible with planners' ordinary working modes. However, to make such progress possible, the ecosystem service research community needs to step up to the challenge of delivering locally specific and useful data on how urban land-use links to ES supply, including synergies and trade-offs between different ESs.

1. Introduction

We are transgressing the resource and emission boundaries of our planet (Rockström et al., 2009). This is particularly true for cities, which are heavily dependent on, but still disconnected from, the natural areas of nearby or distant hinterlands (Elmqvist et al., 2013b). As the world becomes increasingly urbanized (UN DESA, 2014), it is getting more and more critical to reconnect cities to the biosphere (Elmqvist et al., 2013b). Urban green spaces (e.g., parks, gardens, forests, green roofs) and blue spaces (e.g., rivers, lakes, channels) can reduce urban externalities by providing vital environmental functions and delivering important social and health benefits (Chiesura, 2004). As a consequence, ecological restoration inside cities, in the form of greening and bringing water back to residential areas, becomes a key issue in tackling the disconnect and fragmentation of urban nature (Handel et al., 2013).

* Corresponding author at: Chalmers University of Technology, Department of Architecture, SE-412 96 Gothenburg, Sweden. Tel.: +49 46730387060.
E-mail address: kain@chalmers.se (J.-H. Kain).

http://dx.doi.org/10.1016/j.ecolind.2016.02.062
1470-160X/

There is a growing interest in the concept of ecosystem services (ESs) as a means to promote and operationalize vital ecological functions in cities (e.g., Elmqvist et al., 2013a; Gómez-Baggethun and Barton, 2013; Hansen and Pauleit, 2014; Niemelä, 2014). Largely agreeing on the definition of ESs as "the benefits that people obtain from ecosystems" (TEEB, 2008: 12), the Millennium Ecosystem Assessment (MA, 2003) and the Economics of Ecosystems and Biodiversity initiative (TEEB, 2008) have established the ES concept firmly within global and local policy debates (Lennon and Scott, 2014). TEEB has been the first initiative to develop a *Manual for Cities* (TEEB, 2011b).

In both policy and research, the ES concept is thus now seen as a potentially effective approach to assessing environmental values in urban decision-making (Lennon and Scott, 2014) and to raising awareness and helping to set priorities in urban planning (Gómez-Baggethun and Barton, 2013). Even so, due to lack of appropriate procedures, tools and data for local and neighborhood levels, it is difficult for urban planners and policymakers to assess the impact of alternative land uses and land-use composites on the supply of vital ESs (Ahern et al., 2014; Kaczorowska et al., 2015) as well as to balance the benefits of urban green and blue spaces against other urban development needs and construction pressures (Apitz, 2012). This becomes a serious difficulty because, increasingly, urban planning efforts need to address wider sets of urban complexities (Batty, 2014).

Strengthening the position of urban ESs in urban planning and governance therefore still involves a number of challenges. First, more advanced and robust knowledge about ecological concerns needs to be brought into urban planning and governance (Breuste et al., 2013b; Hilde and Paterson, 2014; Lennon and Scott, 2014; Wilkinson, 2011). Second, different types of land use deliver distinct bundles of ESs (Larondelle and Haase, 2012; Raudsepp-Hearne et al., 2010), but the effects of changes in complex land-use patterns on the supply and demand of ESs have not been researched sufficiently (Burkhard et al., 2014; Gómez-Baggethun and Barton, 2013). Moreover, there is a particular lack of knowledge regarding the effects of more fine-grained changes in land use in, e.g., neighborhoods and gardens (Alberti, 2005; Goddard et al., 2009; Turner and Galletti, 2015). Third, in situations of increasing competition for urban land, there are risks of encroachment (Hofstad, 2012), overuse (Arnberger, 2012) and inequalities in access to urban green and blue spaces (Kabisch and Haase, 2014) as well as overall shortages of such spaces (Breuste et al., 2013b). A more integrated appreciation of the multifunctionality of urban green and blue spaces is required to counteract further segregation, denaturing and subsequent impoverishment of urban environments, including identifying and addressing potential synergies and trade-offs between different ESs (Hansen and Pauleit, 2014; Lennon and Scott, 2014). Finally, both quantitative and qualitative approaches are required, especially when quantitative data are lacking (Busch et al., 2012), if we are to better understand how these functions and services relate to the supply and demand of other urban ESs across different types of built-up areas and waste land (Haase et al., 2014; Hamin and Gurran, 2009). This is necessary in enabling us to identify and discuss synergies and trade-offs between environmental, social, health and economic development goals (Haase et al., 2012; Seppelt et al., 2013).

Digital planning support systems can help us to address these challenges (Pelzer et al., 2014). Mapping using Geographical Information Systems (GIS) facilitates input of substantive knowledge into planning processes (Te Brömmelstroet and Schrijnen, 2010), e.g., for data linked to ecological systems (Queiroz et al., 2015). Land-use maps can incorporate both quantitative and qualitative knowledge (Walz et al., 2007) and capture how land-use dynamics and trends influence future ecosystem functions and the supply of ESs (Hou et al., 2013; Larondelle and Haase, 2012). Describing, quantifying, mapping and comparing different urban land-use options at local and neighborhood levels can thus help us effectively explore the nexus between changes in land cover and the supply of urban ESs in support of urban planning and policymaking (Haase et al., 2014).

In the present paper, we discuss how to bring various types of knowledge about urban ESs into urban land-use planning and governance to project a more sustainable, pristine urban future, based on a mapping of land-use alternatives. We seek to contribute to addressing the challenges outlined above by responding to the following two questions:

1. How can we use spatially explicit land-use mapping to generate advanced and robust knowledge about the detailed supply of urban ESs and bring this knowledge into urban planning and governance?
2. What implications do different types of land-use/cover changes have for the supply of and trade-offs between urban ESs?

Efforts to better understand the more detailed aspects of ES supply are already under way, e.g., by conceptualizing the range of relations between ES supply and spatiotemporal factors pertaining to different Service Providing Units (SPU, see Andersson et al., 2015; Luck et al., 2009). The SPU concept was developed within ecology, and views ecological functions as being affected by various social, technological, environmental, ecological and cultural contextual factors (Andersson et al., 2015). However, urban planning and architecture tend to be moving increasingly beyond the distinction between built artifacts and living nature (du Plessis, 2012). We, therefore, see an opportunity to further advance the potential of the ES concept in the urban setting by integrating ecological, sociotechnical and cultural preconditions and dynamics, in this way linking our understanding of the urban ES supply more firmly to urban spatial conditions. We do so here by tentatively introducing Service Providing Elements (SPEs) as a more fine-grained land-use layer alongside established land-use classes (LUCs) employed in land-use planning, as well as by identifying relevant indicators of ES supply, including assessment of synergies and trade-offs across ESs (Section 2). We also present results on the application of such an approach (Section 3) and discuss how changes in fine-grained land use affect the supply of urban ESs (Section 4). Finally, we make recommendations for land-use planning and governance and outline needs for future research in the field of detailed land-use mapping and urban ES modeling (Section 5).

2. Methods

2.1. A mixed-methods approach to modeling urban ESs based on fine-grained land-use data

In the present paper, we map land-use changes and model supply of urban ESs by integrating two complementary points of departure:

(a) urban land use and the potential supply of ESs from this land use, and
(b) individual ESs, exploring how these display a variety of synergies and trade-offs when combined into bundles of urban ESs.

The backbone of the study was a comparison of the potential ES supply from two alternative land-use options in the year 2050. The applied research process builds on a sequence of methods exploring how fine-grained land use links to supply of ESs. The following components were used to investigate the alternative