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Urban self-sufficiency through optimised ecosystem service demand. A utopian perspective from European cities

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ABSTRACT

Most cities are not self-sufficient in terms of supply and demand of urban ecosystem services (UES) which creates important social, economic and environmental problems at different scales. Cities have enormous potential to reduce pressures on the environment while enhancing wellbeing for their inhabitants by acting both on the UES supply and demand sides. In this study we focus on the demand side by exploring the feasibility of self-sufficient cities under an environmentally radical, utopian scenario that implies the optimisation of UES demand by individuals, *i.e.* the minimum possible consumption of provisioning UES, a reduced need for regulating UES and the adequate fulfilment of cultural UES demand for a reasonable human wellbeing. Definitions of optimal demand are provided for a set of essential UES by 2050: food supply, freshwater supply, urban cooling, air purification, carbon sequestration, flood prevention, physical recreation and mental recreation. Operational UES demand indicators are identified for these UES. Based on these, we show the current average ecosystem service demand values in European cities, the current most exigent demand values and propose optimised future demand values. These utopian values intend to serve as benchmarks towards optimised UES demand that will make cities more self-sufficient.

1. Introduction

1.1. Background

Ecosystem services (ES) and sustainability are closely linked concepts (Tallis, Kareiva, Marvier, & Chang, 2008). Both are aimed at sustaining natural capital while at the same time providing social and economic benefits to human populations. The ES approach can be viewed as an influential line of argumentation within the wider sustainability science debate that strives to stress societal dependence on natural ecosystems expressed on biophysical or monetary terms in contexts where both

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development and conservation are important imperatives (Lele, Springate-Baginski, Lakerveld, Deb, & Dash, 2013) and where traditional narratives for conservation have failed to sufficiently influence policy and decision-making (Braat & de Groot, 2012; Gómez-Baggethun, de Groot, Lomas, & Montes, 2010). The dependence of humans on nature becomes even more notorious in the case of heavily-altered systems such as urban systems. The emphasis on valuing the natural or semi-natural remnants in cities has an extraordinarily powerful educational and political value (Lele et al., 2013). The new use of old terms like 'service' or capital' has shifted the negative tone of economic development being bad for wildlife (a classic argument in many sustainability studies) to a positive one of conservation being good for humans. Moreover, Lele et al. (Lele et al., 2013) argue that the ES approach takes a 'strong sustainability' (Daly & Cobb, 1989) stance by recognising essential life-supporting services (natural capital) that cannot be replaced by man-made capital. By 'the benefits people obtain from ecosystems' (MA. Millennium Ecosystem Assessment., 2003), the ES concept implicitly includes the three dimensions of sustainable development and makes the 'sustainability' concept operational by framing these dimensions less abstractly for more tailored urban policy debates.

Mounting urbanisation linked to growing populations and increasing resource consumption *per capita* makes cities the main source of a number of global environmental impacts (Grimm et al., 2008; VVAA, 2009) and turns urban areas into focal points for sustainability and the provision of ecosystem services (ES) (Borgström, Elmqvist, Angelstam, & Alfsen-Norodom, 2006; Kroll, Müller, Haase, & Fohrer, 2012). In Europe, nearly 80% of the population lives in urban areas and this percentage is forecasted to increase in the forthcoming decades (EEA. European Environment Agency, 2010). In this context, UES are seen as effective and efficient ways of dealing with some social and environmental problems of cities, such as air pollution (Bolund & Hunhammar, 1999). Urban ecosystems are 'green and blue' spaces located in areas where infrastructure and buildings cover a large proportion of the land surface, or where people live at high densities (Pickett et al., 2001).

Provisioning and regulating UES are closely linked to cities' metabolism (Table 2) which is characterised by three main drivers: (1) the consumption of great quantities of resources such as land, food, water, energy, building materials and others (provisioning UES) as inputs; (2) the production of huge quantities of waste (solid, liquid, toxic, air pollutants, heat and noise; regulating UES) as outputs resulting from the previous processes (Kennedy, Cuddihi, & Engel-Yan, 2007; Newman, 1999) and (3) the delivery of comparably small quantities of most ES (provisioning, regulating, cultural and supporting) providing significant wellbeing for urban inhabitants (Baró, Haase, Gómez-Baggethun, & Frantzeskaki, 2015; Burkhard, Kroll, Nedkov, & Müller, 2012). In consequence, cities are typically dependent on external fluxes of energy and materials and their ecological footprints and dependencies extend not only to their hinterlands but also condition land uses (EEA. European Environment Agency, 2010) and ES (Eigenbrod et al., 2011) much further away. It is argued that the metabolism of cities needs to be decoupled from the use of finite resources as part of a transition to a green, sustainable economy (Swilling, Robinson, Marvin, & Hodson, 2013). The most radical proponents of such decoupling argue for virtually self-sufficient cities or 'low-impact cities' when it comes to energy, water and materials supply (Agudelo-Vera, Mels, Keesman, & Rijnaarts, 2012; Trainer, 2012). Such self-sufficiency is however in stark contradiction with mainstream views of urban development based on increasing exchange of resources and services in globalised networks (Moulaert, Martinelli, González, & Swyngedouw, 2007; Taylor et al., 2011).

Exploring the potential of UES self-sufficiency is of interest to better understanding the metabolistic dynamics that may lead to environmentally sustainable cities. Linking the purported benefits of UES to actual UES demand 'figures' can also shed light on the use of the ES approach when applied to urban sustainability and make it more useful in urban policy development. One way of accomplishing this is by developing innovative scenarios that portray ES demand optimisation and ES supply maximisation using common measurement units and indicators (Paetzold, Warren, & Maltby, 2010). Most current indicators on biodiversity and ecosystems were developed for purposes other than showing the range of benefits they provide to people. That is why developing indicators from an ES perspective remains fundamental (Braat & de Groot, 2012). Different studies have made the 'ES' concept operational by linking it to land uses (Bastian, Haase, & Grunewald, 2012; Burkhard et al., 2012; Eigenbrod et al., 2011; Haase, Schwarz, Strohbach, Kroll, & Seppelt, 2012; Kroll et al., 2012; Nedkov & Burkhard, 2012; Nuissl, Haase, Lanzendorf, & Wittmer, 2009). Whereas 'ES supply' quantification is closely linked to specific land uses (Martínez-Harms & Balvanera, 2012), the demand for ES can be assessed without necessarily considering where ES are actually provided (Burkhard et al., 2012). A number of papers have addressed the ES 'balance' or 'budget' from the supply–demand perspective in urban and peri-urban settings (Baró et al., 2015; Burkhard et al., 2012; Kroll et al., 2012), but emphasis has mainly been on changes to the supply side (Eigenbrod et al., 2011; Haase et al., 2012). This might be a consequence of the focus by the Convention on Biological Diversity to enhance ES supply worldwide (CBD., 2010.). The detailed study of the other necessary side of urban self-sufficiency, the optimisation of ES demand, has somehow been neglected (Burkhard et al., 2012), despite consumption being recognised as essential for determining environmental impact since long (Holdren & Ehrlich, 1974; OECD. Organization for Economic Co-operation and Development, 2013; Spangenberg & Lorek, 2002). Eliciting, quantifying and managing ES demand drivers become thus fundamental for attaining sustainable ES use (Paetzold et al., 2010). When assessed, UES demand has generally been identified with the current use of the UES (Burkhard et al., 2012; Kroll et al., 2012), despite the fact that there may exist an excess or deficit of UES demand leading to environmental, social and economic problems in urban areas. For example, more food is typically demanded by urban populations than the amount that can be provided by urban ecosystems (excess of demand). Conversely, insufficient demand of urban green or blue areas for leisure, social interactions and inspiration increases stress and mental disorders (Groenewegen, van den Berg, de Vries, & Verheij, 2006). UES demand has been implicitly considered as stationary (Baró et al., 2015) or as evolving due to population shifts (Burkhard et al., 2012; Haase et al., 2012; Kroll et al., 2012). However, shifts in