Land Use Policy 57 (2016) 405–417

Contents lists available at ScienceDirect

Land Use Policy

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

Regular research paper

Mapping ecosystem service capacity, flow and demand for landscape and urban planning: A case study in the Barcelona metropolitan region

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ARTICLE INFO

Article history:
Received 17 July 2015
Received in revised form 23 May 2016
Accepted 3 June 2016

Keywords:
Air purification
Ecosystem service mismatch
Outdoor recreation
Urban-rural gradient
Spatial modeling

ABSTRACT

Ecosystem services (ES) mapping is attracting growing interest from landscape and urban planning, but its operationalization in actual decision-making is still limited. A clear distinction between ES capacity, flow and demand can improve the usefulness of ES mapping as a decision-support tool by informing planners and policy-makers where ES are used unsustainably and where ES flow is failing to meet societal demand. This paper advances a framework for mapping and assessing the relationships between ES capacity, flow and demand with a focus on the identification of unsatisfied demand. The framework was tested in the Barcelona metropolitan region, Spain, considering two ES of critical relevance for the urban population: air purification and outdoor recreation. For both ES, spatial indicators of capacity, flow, demand and unsatisfied demand were developed using proxy- and process-based models. The results show a consistent spatial pattern of all these components along the urban-rural gradient for the two ES assessed. The flow of both ES mainly takes place in the periurban green areas whereas the highest capacity values are mostly found in the protected areas located on the outskirts of the metropolitan region. As expected, ES demand and particularly unsatisfied demand are mostly situated in the main urban core (i.e., Barcelona and adjacent cities). Our assessment also reveals that the current landscape planning instrument for the metropolitan region mostly protects areas with high capacity to provide ES, but might lead to declining ES flows in periurban areas due to future urban developments. We contend that the mapping of ES capacity, flow and demand can contribute to the successful integration of the ES approach in landscape and urban planning because it provides a comprehensive picture of the ES delivery process, considering both ecological and social underlying factors. However, we identify three main issues that should be better addressed in future research: (1) improvement of ES demand indicators using participatory methods; (2) integration of ecological thresholds into the analysis; and (3) use of a multi-scale approach that covers both the local and regional planning levels and cross-scale interactions between them.

1. Introduction

Ecosystem services (ES) mapping is gaining prominence in the environmental science and policy agendas (Egoh et al., 2012; Crossman et al., 2013; Malinga et al., 2015). For example, the

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http://dx.doi.org/10.1016/j.landusepol.2016.06.006
0264-8377/

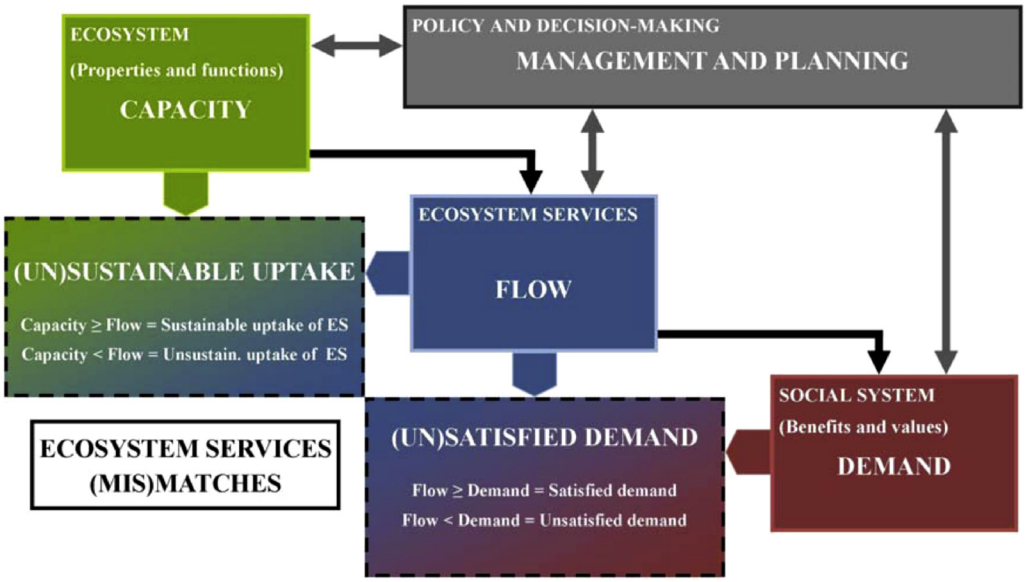

Fig. 1. Framework for assessing the relationships between ES capacity, flow and demand, i.e., if the uptake of ES is sustainable (capacity & flow) and if demand is being satisfied (flow & demand). Management and planning affect and are affected by ES capacity, flow and demand. Building on Haines-Young and Potschin (2010), Villamagna et al. (2013) and Geijzendorffer et al. (2015).

European Union (EU) Biodiversity Strategy to 2020 called Member States to assess and map ES in their national territory as a supporting action to maintain and enhance ecosystems (EC, 2011). ES mapping can inform a variety of decision-making contexts (Gómez-Baggethun and Barton, 2013), including: awareness raising and communication (e.g., Hauck et al., 2013); ecosystem accounting (e.g., Schröter et al., 2014); landscape and conservation planning (e.g., Palomo et al., 2014); and instrument design (e.g., Locatelli et al., 2014), among others.

In order to make ES maps operational for landscape and urban planning, recent ES literature calls for a clearer distinction between the three main components of the ES delivery process, namely ES capacity, flow and demand (Bastian et al., 2013; Villamagna et al., 2013; Burkhard et al., 2014; Schröter et al., 2014). Most spatially explicit ES assessments have focused on studying ES capacity, i.e., the ecosystems' potential to deliver ES (see Martínez-Harms and Balvanera, 2012 for a review). In contrast, despite increased interests and efforts to assess and map ES flow and demand (e.g., García-Nieto et al., 2013; Palomo et al., 2013; Schröter et al., 2014), the conceptualization of both components is still subject to different approaches (Villamagna et al., 2013; Wolff et al., 2015). According to Wolff et al. (2015), ES demand can be framed either as the direct use/consumption of an ES or as the desired/required level of the ES by society. However, the conceptual framework developed by Villamagna et al. (2013) argues that only the latter approach should be considered ES demand, whereas the actual use of the ES constitutes its flow.

At the operational level, the spatially explicit distinction and assessment of ES capacity, flow and demand can enhance the integration of ES in planning, management and decision-making because it can inform planners and policy-makers about the localization of potential ES mismatches, either in terms of *unsustainable uptake* of ES or in terms of *unsatisfied demand* for ES (Geijzendorffer et al., 2015). This information can be used to design plans or policy regulations oriented to: (1) redirect ES flows from overused areas (Schröter et al., 2014), and (2) improve access to ES benefits by identifying areas where ES flows fail to meet societal demand (Kabisch and Haase, 2014).

The aim of this paper is to advance an operational framework for assessing and mapping ES capacity, flow and demand to inform landscape and urban planning. First, we build on previous conceptual frameworks to distinguish between ES capacity, flow and demand, as well as their relationships in terms of (un)sustainable uptake and (un)satisfied demand. Second, we use proxy-based and process-based models within the ESTIMAP tool (Zulian et al., 2014) to develop, test and discuss suitable spatial indicators for the three components with a focus on the identification and mapping of unsatisfied demand. Third, we assess the spatial patterns observed from the application of these indicators in a case study and discuss their implications for planning and policy.

The framework was tested in the Barcelona metropolitan region, Spain. Assessing and mapping ES capacity, flow and demand can be particularly relevant in urban landscapes, where urbanization impinges upon ecosystem's capacity to deliver sustained ES flows and where the high concentration of human population and assets usually entails high demands for ES (Kroll et al., 2012; Burkhard et al., 2012; Haase et al., 2014). We focused on air purification and outdoor recreation, two ES of key importance for improving health and well-being in urban areas since they contribute to air pollution abatement and to the provision of opportunities for relaxation and physical activity (Bolund and Hunhammar, 1999; Gómez-Baggethun et al., 2013).

2. Methods and materials

2.1. Conceptual distinction between ecosystem service capacity, flow, and demand

The distinction between ES capacity, flow and demand ultimately builds on the conceptual framework for ES assessment known as the "ES cascade model", which illustrates the links between ecosystems and human preferences along a chain of ecosystem properties, functions, services, benefits and values (Haines-Young and Potschin, 2010; Fig. 1). Despite the varying understanding, terminology and application of the capacity, flow and demand concepts in the ES literature (see Villamagna et al., 2013; Wolff et al., 2015), in this paper we mostly follow the framework developed by Villamagna et al. (2013) because it provides a flexible, yet consistent approach for decision-making. Therefore, we define ES capacity as "the ecosystem's potential to deliver