Ecological Indicators 55 (2015) 146–158

Contents lists available at ScienceDirect

Ecological Indicators

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

Mismatches between ecosystem services supply and demand in urban areas: A quantitative assessment in five European cities

Francesc Baró [a,*], Dagmar Haase [b,c], Erik Gómez-Baggethun [a,d], Niki Frantzeskaki [e]

[a] Institute of Environmental Science and Technology (ICTA), Universitat Autònoma de Barcelona (UAB), Edifici Z, Carrer de les Columnes, Campus de la UAB, 08193 Cerdanyola del Vallès, Barcelona, Spain
[b] Helmholtz Centre for Environmental Research (UFZ), Department of Computational Landscape Ecology, Permoser Straße 15, 04318 Leipzig, Germany
[c] Humboldt University of Berlin, Department of Geography, Lab for Landscape Ecology, Rudower Chaussee 16, 12489 Berlin, Germany
[d] Norwegian Institute for Nature Research (NINA), Gaustadalléen 21, 0349 Oslo, Norway
[e] Dutch Research Institute for Transitions (DRIFT), Erasmus University Rotterdam, Burgemeester Oudlaan 50, 3062PA Rotterdam, The Netherlands

ARTICLE INFO

Article history:
Received 16 April 2014
Received in revised form 3 March 2015
Accepted 12 March 2015

Keywords:
Air purification
Assessment
Global climate regulation
Green infrastructure
Human well-being
Urban temperature regulation

ABSTRACT

Assessing mismatches between ecosystem service (ES) supply and demand can provide relevant insights for enhancing human well-being in urban areas. This paper provides a novel methodological approach to assess regulating ES mismatches on the basis of environmental quality standards and policy goals. Environmental quality standards (EQS) indicate the relationship between environmental quality and human well-being. Thus, they can be used as a common minimum threshold value to determine whether the difference between ES supply and demand is problematic for human well-being. The methodological approach includes three main steps: (1) selection of EQS, (2) definition and quantification of ES supply and demand indicators, and (3) identification and assessment of ES mismatches on the basis of EQS considering certain additional criteria. While ES supply indicators estimate the flow of an ES actually used or delivered, ES demand indicators express the amount of regulation needed in relation to the standard. The approach is applied to a case study consisting of five European cities: Barcelona, Berlin, Stockholm, Rotterdam and Salzburg, considering three regulating ES which are relevant in urban areas: air purification, global climate regulation and urban temperature regulation. The results show that levels of ES supply and demand are highly heterogeneous across the five studied cities and across the EQS considered. The assessment shows that ES supply contributes very moderately in relation to the compliance with the EQS in most part of the identified mismatches. Therefore, this research suggests that regulating ES supplied by urban green infrastructure are expected to play only a minor or complementary role to other urban policies intended to abate air pollution and greenhouse gas emissions at the city scale. The approach has revealed to be appropriate for the regulating ES air purification and global climate regulation, for which well-established standards or targets are available at the city level. Yet, its applicability to the ES urban temperature regulation has proved more problematic due to scale and user dependent constraints.

1. Introduction

Green infrastructure (GI) has been defined as a "network of natural and semi-natural areas with other environmental features designed and managed to deliver a wide range of ecosystem services (ES). It incorporates green spaces (or blue if aquatic ecosystems are concerned) and other physical features in terrestrial (including coastal) and marine areas" (EC, 2013:3). In urban areas, GI elements may include parks, urban forests, allotments, street trees, green roofs, etc. (Landscape Institute, 2009). Relevant ES delivered by GI in cities include, for instance, air purification, urban temperature regulation, runoff mitigation, noise reduction and recreation (Bolund and Hunhammar, 1999; Gómez-Baggethun and Barton, 2013; Gómez-Baggethun et al., 2013).

An increasing body of literature highlights the contribution of GI and ES in enhancing environmental quality (e.g., air quality) in cities, hence fostering a better quality of life and well-being for the urban population (e.g., Nowak, 2006; Tzoulas et al., 2007; Escobedo et al., 2011; Pataki et al., 2011). Some studies even argue that urban policies based on the planning and management of GI can be comparable in terms of effectiveness or efficacy to other policies based on technological measures (e.g., Escobedo et al., 2008,

* Corresponding author. Tel.: +34 93 5868650.
E-mail address: francesc.baro@uab.cat (F. Baró).

http://dx.doi.org/10.1016/j.ecolind.2015.03.013
1470-160X/

2010). Yet, the assessment of the current (and potential) contribution of urban GI through ES supply as a means to meeting desired or required environmental quality conditions and goals at the city scale remains largely unexplored.

The main objective of the paper is hence the exploration of the possible contribution of ES supply to meet environmental quality standards and policy goals (hereafter referred as EQS) in urban areas. The underlying assumption derived from this objective is that EQS are to be met exclusively through ES supply. Conceptually, this hypothesis can be framed as the assessment of mismatches between ES supply and demand. This research argues that ES demand, defined here as the amount of service required or desired by society (Villamagna et al., 2013), can be expressed in relation to EQS because these provide a threshold value to determine whether the difference between ES supply and demand is problematic for human well-being. The assessment examines ES mismatches of three regulating ES which are relevant in urban areas (Gómez-Baggethun and Barton, 2013): air purification, urban temperature regulation and global climate regulation (through carbon sequestration). The methodological approach includes three main steps: (1) selection of EQS, (2) definition and quantification of ES supply and demand indicators, and (3) identification and assessment of ES mismatches on the basis of EQS considering certain additional criteria. While ES supply indicators estimate the flow or amount of an ES actually delivered (e.g., air pollutants removed by urban vegetation), ES demand indicators estimate the amount of inputs needing regulation (e.g., air pollutant concentrations) in relation to the corresponding EQS (e.g., air quality standards). The approach is applied to a case study consisting of five European cities: Barcelona, Berlin, Stockholm, Rotterdam and Salzburg. Based on the obtained results, the actual and potential contribution of urban GI to address mismatches between ES supply and demand at the city scale is discussed, as well as the advantages and limitations of using EQS to assess these mismatches.

2. Materials and methods

2.1. Conceptual framework

Recently developed conceptual frameworks in the ES literature call for a distinction between ES *capacity*, *flow* and *demand* as the main components of the ES delivery process (Villamagna et al., 2013; Burkhard et al., 2014; Schröter et al., 2012, 2014; Guerra et al., 2014). Capacity is defined as the ES potential (i.e., hypothetical maximum yield) and flow as the actual supply or use of ES experienced by people. ES demand, however, has been approached differently depending on the authors. Burkhard et al. (2014:5) define demand for ES as the "services currently consumed or used in a particular area over a given time period, not considering where ES actually are provided". Alternatively, ES demand has been described as "the amount of a service required or desired by society" (Villamagna et al., 2013:115) or "the expression of the individual agents' preferences for specific attributes of the service" (Schröter et al., 2014:541). In this paper, ES supply is conceptualized as ES flows (Hein et al., 2006) and ES demand as the required level of ES delivery by society (Villamagna et al., 2013). ES mismatches occur when the demand for ES is not totally met by the supply within a defined spatial and time scale. Thus, ES mismatches express the existence of an unsatisfied or remaining demand (Geijzendorffer et al., 2015).

According to the framework developed by Villamagna et al. (2013), the supply of regulating ES contribute to the maintenance of environmental quality within socially acceptable ranges only until a certain level of ecological pressure (e.g., air pollution). Beyond this level, ES supply cannot sustain a good environmental quality and ES demand should be considered as not totally met. Under this approach, estimating regulating ES demand requires hence information about two main elements: (1) desired conditions (i.e., good environmental quality); and (2) inputs needing regulation (i.e., ecological pressures). In line with Paetzold et al. (2010), this paper considers that EQS can be used as a threshold of desired conditions in relation to the demand for regulating ES. In general terms, EQS rely on scientific evidence and/or expert knowledge concerning the relationship between environmental quality and human well-being with the underlying aim to secure or enhance the latter (e.g., EEA, 2013a). Thus, the methodological approach considered here assumes that EQS can provide a common minimum threshold value to assess regulating ES mismatches across different contexts (in this case study, different European cities). For example, World Health Organization (WHO) air quality guidelines (WHO, 2005) can be used to provide a minimum threshold to assess the mismatch between supply and demand of the ES air purification. A city where air pollution levels exceed WHO reference values reflects a mismatch in which air purification demand exceeds the current local supply. Yet, this situation does not necessarily imply that the EQS is to be achieved solely by ES supply.

2.2. Selection of environmental quality standards

Based on a non-exhaustive examination of European-context regulatory frameworks, relevant EQS were identified for the three ES assessed in this study (Table 1). EQS for ES air purification were derived from the European Union (EU) air quality Directive (EU, 2008) and WHO air quality guidelines (WHO, 2005). Reference values for ground-level concentrations of air pollutants are generally more stringent in the WHO standards, but only the EU standards are legally binding for the case study cities, hence the inclusion of both standards in the assessment was considered pertinent. The focus was limited to the following air pollutants: (1) particulate matter with a diameter of 10 μm or less (PM_{10}); (2) nitrogen dioxide (NO_2); and (3) tropospheric ozone (O_3), considered three of the most problematic air pollutants in terms of exposure to concentrations above the EU and WHO reference levels in Europe for its urban population (EEA, 2013a).

The ES global climate regulation is generally assumed to be demanded at global scale (Burkhard et al., 2012), yet city specific GHG emission reduction and offset targets can be considered as a desired condition at lower scales. Following the EU 20-20-20 targets (EC, 2008), many municipal authorities have signed up to the 'Covenant of Mayors' initiative,[1] voluntarily committing themselves to reduce their GHG emissions by at least 20% until 2020 (see Table 1 for specific reduction targets of the case study cities).

No explicit EQS were found in relation to urban temperature regulation at the European regulatory level, probably because human health vulnerability to temperature extremes depends on a complex interaction between different factors such as age, health status, socio-economic circumstances (e.g., housing) and regional adaptation (Kovats and Hajat, 2008; Fischer and Schär, 2010). However, general critical temperature thresholds for health impacts in Europe have been estimated based on the spatial and temporal variance in excess mortality during recent heatwaves[2] episodes (Fischer and Schär, 2010). According to this research, the consecutive occurrence of days with maximum temperature above 35 °C ('hot days') and nights with minimum temperature above 20 °C ('tropical nights') has been found to explain the correlation with excess mortality. These values match well with specific

[1] See www.covenantofmayors.eu.

[2] Fischer and Schär (2010) define a heatwave "to be a spell of at least six consecutive days with maximum temperatures exceeding the local 90th percentile of the control period (1961–1990)".