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Research article

A framework for assessing urban greenery's effects and valuing its ecosystem services

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ABSTRACT

Ongoing urban exploitation is increasing pressure to transform urban green spaces, while there is increasing awareness that greenery provides a range of important benefits to city residents. In efforts to help resolve associated problems we have developed a framework for integrated assessments of ecosystem service (ES) benefits and values provided by urban greenery, based on the ecosystem service cascade model. The aim is to provide a method for assessing the contribution to, and valuing, multiple ES provided by urban greenery that can be readily applied in routine planning processes. The framework is unique as it recognizes that an urban greenery comprises several components and functions that can contribute to multiple ecosystem services in one or more ways via different functional traits (e.g. foliage characteristics) for which readily measured indicators have been identified. The framework consists of five steps including compilation of an inventory of indicator; application of effectivity factors to rate indicators' effectiveness; estimation of effects; estimation of benefits for each ES; estimation of the total ES value of the ecosystem. The framework was applied to assess ecosystem services provided by trees, shrubs, herbs, birds, and bees, in green areas spanning an urban gradient in Gothenburg, Sweden. Estimates of perceived values of ecosystem services were obtained from interviews with the public and workshop activities with civil servants. The framework is systematic and transparent at all stages and appears to have potential utility in the existing spatial planning processes.

1. Introduction

Urbanization has become one of the most extensive and permanent land-use changes globally, causing increasing pressure to transform green spaces in or near cities (UN, 2014; World Bank, 2015). However, urban greenery provides a range of social and environmental services that benefit city residents and visitors (Kabisch et al., 2015). The potential synergies and conflicts arising from the benefits of urban green areas and demand for their exploitation pose challenges for sustainable urban development and initiatives to maintain or improve human well-being. A concept that has received increasing attention and can help efforts to address these challenges is ecosystem services (ES) (Haase et al., 2014; Kabisch et al., 2015; Luederitz et al., 2015). The ES concept

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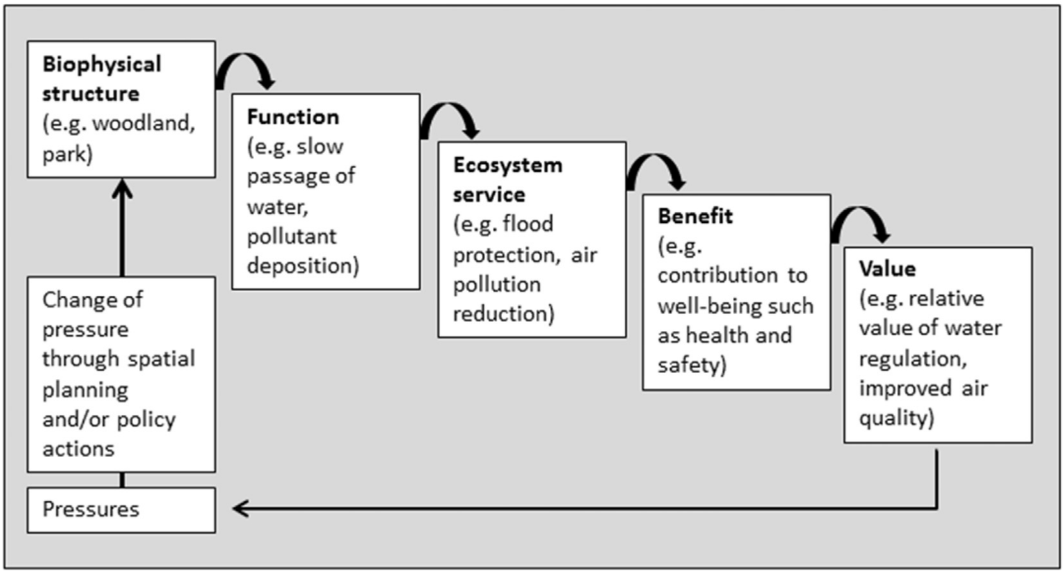

Fig. 1. The cascade model framework for ecosystem valuation modified from TEEB (2010) and Potschin and Haines-Young (2011).**.

embraces all the interlinked aspects of ecological structures with functions that are advantageous to humans (services), and thus contribute to human well-being (benefits) (MEA, 2005; Potschin and Haines-Young, 2011; TEEB, 2010). The ES cascade model may also be helpful. This captures the view that a “production chain” links biophysical structures and processes to the benefits and values of the services a considered system provides (Fig. 1). For example, an ecosystem such as urban woodland may have the capacity (function) of slowing the passage of surface water, thereby reducing flooding in cities (service), which provides benefits to humans. The value of these benefits (and, thus, preceding links in the chain) depends on time- and place-related factors that can be summarised as supply and demand. The cascade model also includes feedback loops, based on assumptions that services' values will impact the ecosystem, e.g. high demand for provisional services will result in high pressure on them. However, the pressure imposed on ecosystems can be modified through policy actions (Potschin and Haines-Young, 2011).

The aims of ES valuation are to unravel the complexities of socio-ecological relationships, recognize how human decisions impact perceived values of services, and express them in units that allow incorporation in planning and decision-making (Mooney et al., 2005; TEEB, 2010). Various methods can be used to estimate the value of ES, all of which have limitations because of the difficulties in quantifying most ES. Their values can be determined in monetary terms, such as current market prices, e.g. market prices for biofuel and timber, or estimates of costs that would be incurred if the services had to be created by artificial means (TEEB, 2010). This direct approach cannot be applied to various other ES (such as well-being and aesthetic appreciation) that do not have any market prices, but their monetary values can be estimated using proxies, e.g. travel costs, or hedonic pricing methods (TEEB, 2010; Goulder and Kennedy, 2011). Alternatively, non-monetary choice preference methods can be used to estimate most non-market ES values. These methods include perception ranking analysis and attitude rating, which are regarded as useful for probing perceived values and preferences regarding possible planning options (e.g. García-Llorente et al., 2008; TEEB, 2010).

In addition, multi-criteria methods for assessing ES based on Corine (Coordination of information on the environment) Land Cover (CLC) have been recently developed. They have been applied, for example, to estimate a region's contribution to provisioning services as well as climate regulation, air quality, water regulation, recreational facilities, aesthetic appeal and biodiversity, based on stakeholder-based weighting to reflect the relative importance of the investigated ES (Koschke et al., 2012). CLC data have also been applied to estimate gradients of cooling potential, carbon sequestration and available recreational area in four European cities (Larondelle and Haase, 2013).

Few studies have covered all the sequential steps related to urban ES, including links between ecological structures, their functions, performance and values to humans (Luederitz et al., 2015). However, during the last decade various models have been developed to quantify and value urban ES. One example is the i-Tree urban forest management tool[2] (developed from the UFORE model, Nowak et al., 2008) for assessing integrated benefits of services provided by urban trees (such as removal of atmospheric carbon dioxide and storm-water reduction), valuing the services in monetary terms. The results have been applied for several purposes, such as assessing and visualizing the benefits of trees and the impact of land use changes (e.g. Nowak et al., 2014a; Hilde and Paterson, 2014).

Despite the availability of models such as the i-Tree model, further development of appropriate methods for integrated quantification of benefits and valuation, including additional potential services and urban biophysical structure components other than trees, is still required (Haase et al., 2014; Luederitz et al., 2015). Further, both CLC- and i-Tree-based analyses require detailed modelling, which may hinder their use in local urban management. To address the requirement for methods that can be more readily applied, we present a method to integrate regulating ES (pollination, local climate regulation, air pollution control, noise reduction, storm water management) and cultural ES, allowing inclusion of additional ES not considered here. The method is a systematic process involving description of urban green structure components (trees, bushes, herbs, bees, birds) contributing to ES through functional trait indicators and a sequence of subsequent steps

[2] www.itreetools.org.