ARTICLE IN PRESS

Ecosystem Services xxx (2017) xxx–xxx

Contents lists available at ScienceDirect

Ecosystem Services

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

Comparing costs and supply of supporting and regulating services provided by urban parks at different spatial scales

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ARTICLE INFO

Article history:
Received 22 February 2017
Received in revised form 29 June 2017
Accepted 10 July 2017
Available online xxxx

Keywords:
Urban parks
Emergy
Ecosystem services
Supporting services
Regulating services

ABSTRACT

Researchers all over the world have been involved for some time in valuing and measuring ecosystem services. However, methods to value both costs and supply and to match them on the same scale are still under discussion. This study assesses costs and supply of a subset of supporting and regulating ecosystem service in urban parks and discusses the role and the value of these services under an environmental/economic point of view using emergy synthesis. A total of 73 parks in the city of São Paulo, Brazil, are used as a case study. Results show that green areas in urban parks provide valuable services to the city's community through transformation processes of natural renewable inputs that would be otherwise wasted. The method can be applied in different locations and contexts to provide useful information to public managers and urban planners.

1. Introduction

The notion of urban park has been, for a long time, associated with aesthetics and recreational services. As the conditions and needs of the cities have changed, recreation now includes the provision of sport activities for all social classes, with the implementation of sport courts, jogging trails and fitness equipment in public green areas. Modern urban parks must, besides their leisure function, not only meet the demands for recreational activities, but also alleviate the negative effects of urban structures, compensating for built-up areas. Planning for an urban park is no more restricted to the perimeter of the park. The park borders are regularly crossed by individuals, by water flows into, out of, or underneath the park, and by the effects of the surrounding urban settlement and air quality conditions. In order to manage an urban park, urban planners must think about broader limits than the actual physical limits of the park, and this broader thinking must include the role and the value of ecosystem services (see Fig. 1).

Various authors relate green urban areas with aesthetics, noise reduction and habitat maintenance for wild animals (Chen and Jim, 2008; Xiao and McPherson, 2002; Nowak and Dwyer, 2000), recognizing the numerous social, environmental and economic services they provide (Buchel and Frantzeskaki, 2015; McPherson et al., 2005; Mellino and Ulgiati, 2013; Mellino et al., 2015). Benefits from the simple effect of a shadow to reduce heating of built and paved surfaces, to the reduction of heat islands that are intensified with cities growth are demonstrated empirically (Akbari et al., 2001; Rosenfeld et al., 1995). Xiao and McPherson (2002) and Xiao et al. (1998) emphasized the benefit provided by urban parks through reducing the volume of water runoff with consequent reduction of flood risk. In this context, concerns on preservation and implementation of urban parks are associated not only with leisure and aesthetics, but also with the supporting and regulating services they can provide to the whole city (Kaczorowska et al., 2016). Lin et al. (2011) associated urban green areas to double benefits of sequestration/storage of atmospheric carbon and high temperatures reduction in the vicinity of the park, concluding that: (1) the larger the amount of biomass in the park, the greater the energy savings and lower air pollution; (2) the implementation of several small green areas is more beneficial than the deployment of few units of larger green areas and (3) irregularly shaped green areas perform better than regularly shaped ones of the same size.

Methods for calculating the value of ecosystem services are attracting interest as instruments to express non-economic values of the environment into monetary terms (Claassen et al., 2008; Dobbs and Pretty, 2008; Pagiola, 2008; Wunder et al., 2008). The scientific discussion on methods to estimate those values is still ongoing. In several cases, the values of ecosystem services are derived by relying on economic-based instruments, such as the

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http://dx.doi.org/10.1016/j.ecoser.2017.07.003
2212-0416/

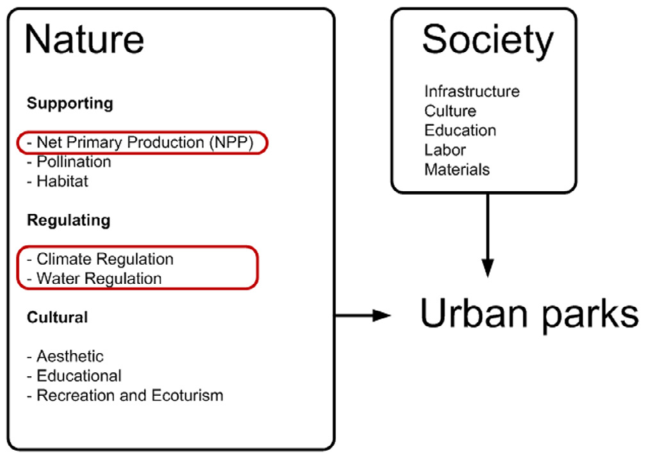

Fig. 1. Some of the main components integrated to urban parks from nature and society. The ecosystem services evaluated in this study are highlighted in red.

entry fees values to parks (Latinopoulos et al., 2016; Song et al., 2015), or the market value of the park as developable real estate (Sutton and Anderson, 2016).

There are methods in which value is given by observing ecosystem services' users/consumers preferences (Wunder and Albán, 2008; Asquith et al., 2008; Buchel and Frantzeskaki, 2015). Millward and Sabir (2011) investigated the value of services provided by the trees in a public park in Canada, estimating the monetary value of benefits related to energy savings, CO_2 sequestration, and increased property value. Their work showed that the money spent for planting and maintaining trees is justified by the benefits they brought to the city. McPherson et al. (2005) studied the relationships between urban forests and the local population considering benefits and costs. The benefits were accounted for by different methods: (i) benefits derived from climate regulation were evaluated by computer simulations and compared to the expenditure on electricity and natural gas; (ii) carbon dioxide sequestration was associated to the amount of biomass; flood risk reduction was compared to expenditures on flood control. These authors reported that for each dollar invested in the maintenance and deployment of urban forests, the benefits return approximately between $ 1.37 and $ 3.09 a year.

A different option for evaluating ecosystem services is the emergy synthesis (Odum, 1996). Emergy synthesis offers a complement (or a substitute) to market-based and monetary evaluations. It allows calculating biophysical values, also linking them with monetary flows. For these reasons, emergy synthesis is increasingly used for evaluating ecosystem services.

In this vein, most of the research focused on large scale territorial systems (Coscieme et al., 2014), including environmental, cultural and economic subsystems (Higgins, 2003), biomes (Campbell and Brown, 2012; Campbell and Tilley, 2014a; Coscieme et al., 2011) and natural reserves (Liu et al., 2009; Tilley and Swank, 2003; Pulselli et al., 2011). The ecological and economic benefits of an urban wetland park in China were evaluated by Duan et al. (2011) using emergy indices. Mariano et al. (2015) proposed emergy as a management tool for urban parks. A stimulating debate on the value of natural capital and ecosystem services suggests that emergy synthesis is the most dependable scientific measure to assess the provision of ecosystem services, since it is capable of assessing both the quantity and quality of contributions, providing a foundation for managing the economy/environment interface (Ulgiati et al., 2011). Due to its very own nature, emergy is suitable to assess the role and value of supporting (i.e. services that are the basis for further services and are not often considered as final services or direct benefits) and regulating services (i.e. benefits obtained from the regulation of ecosystem processes) (MA, 2005).

Starting from that, this paper presents an emergy-based evaluation of the supply and indirect use of net primary production (NPP) and of a subset of regulating services directly connected with NPP in urban parks, and aims to:

- Evaluate how these ecosystem services are provided and used in urban parks at different spatial scales,
- Evaluate the environmental costs, as well as the costs sustained by the municipality, maintaining the supply of these ecosystem services in urban parks at different spatial scales,
- Contribute to the effective implementation of new parks based on the costs and supply of ecosystem services.

The city of São Paulo, Brazil is used as a case study. This approach is applicable in other geographical contexts, providing useful information for public managers.

2. Methods

2.1. System description

The total green area of the municipality of São Paulo is approximately 40 times larger than the green area of the 73 urban parks studied (SVMA, 2012), since it includes permanent protected areas, areas under State protection, and the afforestation of streets and avenues. Fig. 2 shows the distribution of the parks studied within the metropolitan area.

Table 1 shows the total area, the built area and the cost per square meter of the 73 parks assessed. A detailed cost report for each park was provided by the municipality and includes equipment, workers and auxiliary materials used for maintenance and use of each park.

2.2. Emergy synthesis

Emergy tracks the cumulative quantity of solar equivalent joules necessary to create a product or service through the network of energy transformations (Odum et al., 2000). It can be used to represent the work done by nature and humans to provide a service calculated in terms of equivalent solar energy processed and expressed in solar emergy Joules (seJ) (Odum, 1996; Pulselli et al., 2011; Coscieme et al., 2013). The factor that enables to express different forms of energy and materials in terms of solar equivalent is the Unit Emergy Value (UEV) that represents the quantity of solar energy directly or indirectly required to produce 1 unit (i.e. 1 J or 1 g) of a product, a different form of energy, or a service (Brown and Ulgiati, 2004).

Ecosystem services emerge from the interactions between Natural, Human, and Social capital (Costanza et al., 2014). The main advantage of using emergy for ecosystem services evaluation is that it is able to account for the different inputs to the final contribution coming from these different forms of Capital on a common unit.

To perform the emergy accounting, an energy diagram is used (Fig. 3) indicating the flows that make up the system investigated. The diagram also shows the interactions of the internal processes taking place in the urban park and the ecosystem service flows. For this reason, emergy is particularly suitable to understand the nexus between supporting services (such as NPP), and regulating services.

From the energy diagram, tables containing the emergy of renewable resources (R), local non-renewable resources (N) and