Ecosystem Services 23 (2017) 82–93

Contents lists available at ScienceDirect

Ecosystem Services

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

# Assessing mismatches in ecosystem services proficiency across the urban fabric of Porto (Portugal): The influence of structural and socioeconomic variables

Marisa S. Graça[a,b,*], João F. Gonçalves[a,b], Paulo J.M. Alves[a], David J. Nowak[c], Robert Hoehn[c], Alexis Ellis[d], Paulo Farinha-Marques[a,b], Mario Cunha[b,e]

[a] Research Center in Biodiversity and Genetic Resources (CIBIO/InBIO) – University of Porto, Campus Agrário de Vairão, Rua Padre Armando Quintas, nº 7, 4485-661 Vairão, Portugal
[b] Faculty of Sciences of the University of Porto, Rua do Campo Alegre, s/n, 4169-007 Porto, Portugal
[c] Northern Research Station, USDA Forest Service, 5 Moon Library, SUNY-ESF, Syracuse, 13210 NY, USA
[d] The Davey Institute, The Davey Tree Expert Company, 1500 N. Mantua Street, P.O. Box 5193, Kent, OH 44240, USA
[e] Geo-Space Sciences Research Centre (CICGE), University of Porto, Departamento de Matemática, Rua do Campo Alegre nº 687, 4169-007 Porto, Portugal

ARTICLE INFO

*Keywords:*
Urban ecosystem services
Regulating ecosystem services
Urban planning
Urban vegetation
Socioeconomic inequity

ABSTRACT

Knowledge regarding Ecosystem Services (ES) delivery and the socio-ecological factors that influence their proficiency is essential to allow cities to adopt policies that lead to resource-efficient planning and greater resilience. As one of the matrix elements of urban ecological structure, vegetation may play a major role in promoting ES proficiency through planting design. This research addresses the heterogeneity of ES delivered by the urban vegetation of Porto, a Portuguese city. A methodology is proposed to investigate associations between socioeconomic indicators and structural variables of the urban forest, and also which structural variables of the urban forest, if any, differ along a socioeconomic gradient. Our results reveal that before setting planning and management goals, it is crucial to understand local patterns of ES and their relationships with socioeconomic patterns, which can be affected by variables such as building age. This should be followed by the identification of structural variables of the urban forest that better explain the differences, in order to target these through planning and management goals. The conceptual framework adopted in this research can guide adaptation of our methodology to other cities, providing insights for planning and management suitable to site-specific conditions and directly usable by stakeholders.

## 1. Introduction

According to UN estimates, it is expected that the world population living in cities will exceed 66% in 2050 (United Nations, 2014). The complex and intense interaction of ecological and socioeconomic systems shaping cities has highlighted the need to foster an inter-disciplinary approach to urban issues integrating Natural and Social Sciences (Alberti et al., 2003). Recent research has also stressed the role of urban ecosystems in providing vital services to city dwellers, and the need to embody ecosystem services in urban planning practice (Ahern et al., 2014; Colding, 2011). Ecosystem services (ES) has come to light as one of the most widespread concepts of Ecology in recent years, and refers to the benefits human populations derive from ecosystems (MEA, 2005). Research on ES and the socio-ecological factors that influence their proficiency is essential to allow cities to adopt policies that lead to resource-efficient strategies (Andersson et al., 2007) and greater resilience, which supports ecological, economic and social sustainability (Berkes et al., 2003; McPhearson et al., 2015). Some benefits generated by ecosystems need to be delivered locally to be enjoyed by city inhabitants, such as clean air, runoff regulation, microclimate regulation, erosion control, storm protection and recreation. Urban green areas provide a wide range of these local ecosystem services and thus become very important to sustain human wellbeing in cities (Bolund and Hunhammar, 1999). However, many obstacles prevent ES from being widely operational in urban planning practice. Studies and assessments of urban ES many times lack operability for professionals and planners because they are not developed at a scale relevant for planning and policy decisions (Hölzinger

* Corresponding author at: Research Center in Biodiversity and Genetic Resources (CIBIO/InBIO) – University of Porto, Campus Agrário de Vairão, Rua Padre Armando Quintas, nº 7, 4485-661 Vairão, Portugal.
*E-mail address:* graca.marisa@fc.up.pt (M.S. Graça).

http://dx.doi.org/10.1016/j.ecoser.2016.11.015
Received 7 July 2016; Received in revised form 8 November 2016; Accepted 22 November 2016
Available online 05 December 2016
2212-0416/ 

et al., 2014) or do not address the transfer of knowledge and methods in an accessible way to stakeholders, thus providing limited clues for planning and management (Haase et al., 2014). In addition, key concepts remain controversial (Fisher et al., 2009; Hermann et al., 2011), and the lack of consistent methodologies for quantifying, visualizing and valuing ES poses challenges (Seppelt et al., 2011).

Urban ecosystems differ from other ecosystems because they are intensely dominated by human beings, being characterized by high fragmentation and heterogeneity levels. They raise additional questions to researchers and are still poorly understood compared with other types of ecosystems (Gomez-Baggethun and Barton, 2013). Services such as air filtration, thermal regulation, contribution to the perception of the urban environment, sense of place or social cohesion are difficult to assess, and knowledge about the local ES delivery is frequently scarce or not suitable for planners. This knowledge should inform the setting of goals before urban interventions, but usually it cannot be generated within the traditional timeframe of project planning due to time and resource constraints. Because of such difficulties, the structural or functional aspects that sustain urban ES are usually not taken into account in an objective way in the planning and design process, particularly regarding green spaces. Recent investigations suggest a relationship between type and management of green areas and ES provided (Andersson et al., 2007), and that variation in the abundance and layout of vegetation in different types of urban green spaces originates differences in ES delivered (Hayek et al., 2010). There is also evidence of relationships between plant functional diversity and ecosystem processes (Díaz and Cabido, 2001). However, properties like functional redundancy of species are not traditionally taken into account in professional practice regarding planning, design and management of urban green spaces. In addition, biodiversity in green spaces may affect the provision of many services that affect the health and wellbeing of city dwellers, but it is many times seen as having little impact in the urban context, and providing few direct and essential benefits for human beings (Ahern, 2013). Even promoting biodiversity *per se* raises questions about how this can be accomplished, because emerging evidence is revealing that, for example, species richness alone probably does not drive ecosystem function (Cadotte et al., 2011).

Delivery of ES is also greatly determined by socioeconomic factors and reflects urban patterns. Examples include dissimilarities of provision of urban green spaces by demographic variables like immigrant status and age (Kabisch and Haase, 2014), relationships between public urban forest structure and socioeconomic strata (Escobedo et al., 2006), increased exposure towards urban flooding according to indices of social segregation (Romero et al., 2012), spatial variation in urban plant diversity across low to high-income areas (Hope et al., 2003), inequity in the spatial distribution of public right-of-way street trees (Landry and Chakraborty, 2009) and the impact of lifestyle behavior and housing characteristics in species composition and configuration (Grove et al., 2006). However, to our knowledge these findings have seldom been translated into objective guidelines that can help to inform planning and design practice.

All these considerations could mean that it is not enough to include green areas in urban settings, without addressing their specific characteristics and ability to sustain the well-being of city's inhabitants. Urban green areas can be designed to contribute for the provision of specific ES such as microclimate regulation (Jenerette et al., 2011), mental wellbeing (Kuo, 2001), physical and psychological health (Lachowycz and Jones, 2013), water quality control and storm protection (Windhager et al., 2010), just to name a few.

As one of the matrix elements of urban ecological structure, vegetation may play a major role in promoting ES proficiency through planting design. Although a few examples have explicitly applied the ES approach to urban planting design (Hayek et al., 2010; Hunter, 2011) or to urban forestry (Morani et al., 2011), these are very recent and still emerging. To our knowledge, very few studies address how composition and configuration of urban vegetation might enhance ES proficiency, though this need has been identified (James et al., 2009). It is also important to better understand the relationships between ES and socioeconomic factors, because these can impact urban ecosystems. Acknowledging these topics can provide useful insights to urban planning, planting design and management.

This paper addresses the heterogeneity of urban ES proficiency, and aims to:

- test a conceptual framework relating socioeconomic urban patterns and the shaping of the urban forest structure;
- present a methodology to investigate associations between socioeconomic indicators and structural variables of the urban forest;
- investigate which structural variables of the urban forest, if any, differ along a socioeconomic gradient, to objectively set planning and management goals and contribute to the effective implementation of the ES approach in urban issues.

The city of Porto (located in mainland NW Portugal) is used as a case study, but the methodology can be adapted to other geographical locations and contexts to provide information easily usable by stakeholders and practitioners with responsibilities regarding urban planning and management.

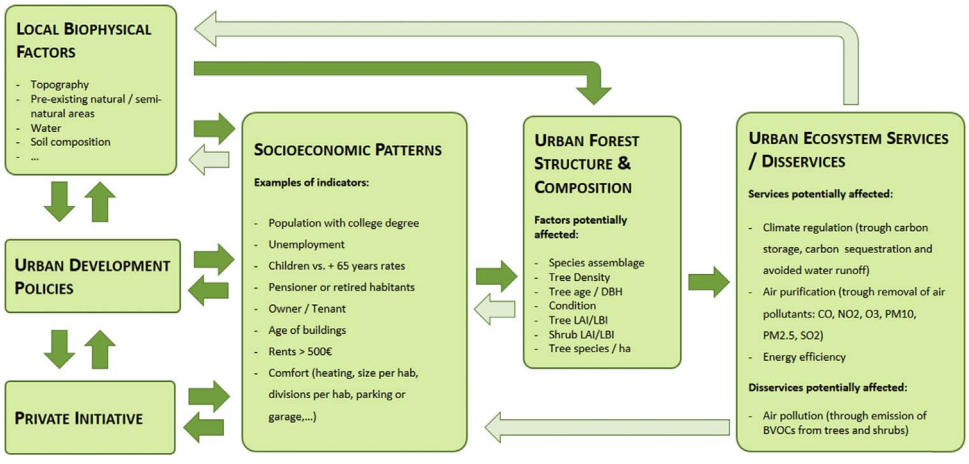


**Fig. 1.** Conceptual framework underlying the impact of socioeconomic patterns in shaping differently the urban forest structure across the urban fabric, thus affecting spatially ecosystem services proficiency. Dark green arrows highlight relationships predominantly direct, and light green stresses connections assumed to be more indirect among components of the framework. (For interpretation of the references to color in this figure legend, the reader is referred to the web version of this article.)