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Analysing scale, quality and diversity of green infrastructure and the provision of Urban Ecosystem Services: A case from Mexico City

Rafael Calderón-Contreras[a,*], Laura Elisa Quiroz-Rosas[b]

[a] Universidad Autónoma Metropolitana, Unidad Iztapalapa, Departamento de Sociología, Mexico
[b] Universidad Autónoma Metropolitana, Unidad Cuajimalpa, Departamento de Ciencias Sociales, Mexico

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ABSTRACT

Fostering urban resilience requires a social-ecological systems approach that considers the ecological and social feedbacks of cities. In this paper we argue that Urban Ecosystem Services (UES) could increase urban resilience; and that resilient UES depends directly on the quantity, quality and diversity of the green infrastructure that produces them. The case of the western boundaries of Mexico City is used to map and assess these issues. We classified the different settings of green infrastructure as Service Providing Units (SPUs) and identified their provision of UES through remote sensing techniques; the Normalized Difference Vegetation Index (NDVI) combined with fieldwork verification in two scales of analysis, the local and regional. The results reveal that the vast majority of green infrastructure has low quality, hindering the provision of the UES required for building Mexico City´s resilience. At the regional scale, the growing pressures of urban development and the consequent reduction of SPUs threatens the delivery of provisioning ecosystem services while at the local scale, the low quality of SPUs threatens the provision of regulating ecosystem services. We argue that addressing these challenges could improve the design and implementation of environmental decision-making and urban policy towards more resilient urban social-ecological systems.

1. Introduction

Cities are social-ecological systems characterized by complex networks of interacting components, making resilience in cities a difficult-to-achieve goal. However, in the context of global environmental change characterized by an unprecedented and rapid urbanization, the concept of urban resilience is being widely applied to urban planning and decision-making (Schewenius et al., 2014; McPhearson et al., 2014; Chelleri et al., 2015; Kremer et al., 2015; Meerow et al., 2016a; Bennett, 2016). Accounting for an estimated 71% of the global energy-related carbon emissions, urban areas have passed from 10% in 1990 to more than 50% in 2010 (International Panel on Climate Change, IPCC, 2014). According to Meerow et al. (2016a, 2016b:39): “Urban resilience refers to the ability of an urban system and all its constituent socio-ecological and socio-technical networks across temporal and spatial scales to maintain or rapidly return to desired functions in the face of a disturbance, to adapt to change, and to quickly transform systems that limit current or future adaptive capacity”.

Some approaches to achieve resilience in cities are based on the assumption that urban resilience can be built through securing the local provision of Urban Ecosystem Services (UES) (Schewenius et al., 2014; McPhearson et al., 2014). Moreover, parallel to the efforts of creating a more resilient city, recent research highlights the importance of dealing with the resilience of UES themselves (McPhearson et al., 2014, 2015). Urban planning deals vaguely with the issues of building resilience *through* and building resilience of UES, especially due to the fact that mainstream urban design and planning do not take into consideration the intricate nature and dynamics of cities. The use of the resilience approach when dealing with urban planning and design offers the possibility to regard cities as complex social-ecological systems, in which wellbeing and health of urban residents are closely tied to human-nature relations.

According to McPhearson et al., 2014:504: “Ecosystem services refer to those ecosystem functions that are used, enjoyed, or consumed by humans, which can range from material goods (such as water, raw materials, and medicinal plants) to various non-market services (such as climate regulation, water purification, carbon sequestration, and flood control)”. This definition of Ecosystem Services is especially important for understanding the complex interactions and feedbacks between the social and ecological components of cities. Improving the resilience of urban social-ecological systems requires a better under-

* Corresponding author.
E-mail addresses: rcalderoncontreras@yahoo.com (R. Calderón-Contreras), lauquiroz@gmail.com (L.E. Quiroz-Rosas).

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standing of the way in which UES are delivered to urban dwellers; the way they are modified, and the different characteristics that allow or limit their ability to achieve urban resilience and better sustainability practices (Peters et al., 2004; Kremer et al., 2015).

Urban resilience is, therefore, linked to the provision of UES in two ways: "First, resilience can be fostered by incorporating the concept of ecosystem services in urban planning, design and management of urban social–ecological systems. Second, cities need to safeguard resilient supply of ecosystem services in the long-term to ensure urban human well-being" (McPhearson et al., 2015:152). Consequently, in order to secure urban resilience in the long run, there is a need for a better understanding of the importance of specific places that produce UES. In other words, while the literature around both the importance of urban green infrastructure, and ecosystem services is vast, often these issues are analysed separately (Andersson et al., 2014). Hence, there is still a limited understanding of the role green infrastructure plays to produce UES (Haase et al., 2014). Some of the most commonly referred links between green infrastructure and UES are related to the provision of cultural services, e.g. recreation, health and aesthetic value (Schewenius et al., 2014; Sandifer et al., 2015; Camps-Calvet et al., 2016); provisioning services such as food production and urban agriculture (Summit, 2010; Tornaghi, 2014; Dieleman, 2016), biodiversity conservation in cities (Tidball and Stedman, 2013; Kotzee and Reyers, 2016) and regulating ecosystem services such as temperature control (Pulighe et al., 2016; Kong et al., 2016), forest regulating services (Manes et al., 2016) and water availability for cities (Grizzetti et al., 2016).

Moreover, UES constitute a source of resilience in the case of catastrophic events. They provide the means for city inhabitants to face non-catastrophic and continuous disturbances of a social, economic, ecological and even psychological nature (McPhearson et al., 2015; Carpenter et al., 2001). Hence, resilience building through UES is not constrained to events that might be considered catastrophes; resilience encompasses persistence, recovery, adaptation and transformation of urban social-ecological systems (Walker et al., 2004; Holling, 2001, 1973; Tidball and Stedman, 2013; Folke et al., 2005). However, urban planning and urban climate change policy has only vaguely engaged with the notion of urban resilience. Mainstream urban environmental and climate change policy and planning often use terms such as sustainability, adaptation, coping and resilience interchangeably, without regarding the complex dynamics of cities as social-ecological systems, implied by the latter term (Calderón-Contreras, 2013; Redman, 2014; Calderón-Contreras, 2016; Meerow et al., 2016b). Building urban resilience implies placing special attention on areas of urban spaces experiencing pressures related to urban encroachment, development and ecological issues that make cities more sensitive to the expected effects of climate change (Andersson et al., 2015; Kremer et al., 2015).

Two issues arise in this respect: first, there is a current tension between city expansion and conservation, which shifts urban areas towards an unsustainable future where UES are not regarded as critical for ensuring urban wellbeing (Andersson et al., 2014; Kaczorowska et al., 2015). Second, cities need to reconnect their inhabitants to their surrounding life-supporting systems, turning into their main stewards (Andersson et al., 2014). We argue that green infrastructure in cities can contribute to these issues by decreasing the overall urban footprint, locally providing ecosystem services needed by urban populations, and decreasing their reliance on externally produced services. This article seeks to illustrate with the case of the western boundaries of Mexico City, the extent to which the provision of UES through green infrastructure depends on their quality, quantity and diversity. Furthermore, we offer an illustration on how different scales may influence the identification of different UES. We highlight the potential of this analysis to better understand and integrate the importance of green infrastructure in plans and programmes to foster urban resilience.

This study focuses on diversity, quantity and quality of green infrastructure and its potential to effectively deliver UES at different scales, allowing in turn increasing the overall resilience of the urban social-ecological system. Measuring their quantity and assessing their quality and diversity may provide insights as to how the potential of the provision of UES may increase urban resilience to both catastrophic, or 'fast' events, as well as to the long-term effects or 'slow variables' of global environmental change.

2. Methods

2.1. The study site

Mexico city and its metropolitan area represent a quintessential example of a complex social-ecological system. Located in a central valley of Mexico (Fig. 1), the metropolitan area has more than 24 million inhabitants, making it Mexico`s most densely populated area (Berdegué et al. 2015). The environmental and social implications that such population density implies is combined with the fact that the metropolitan area has over 40,000 industries, as well as more than 5.5 million cars that contribute to the physical condition of the valley, by frequently causing air temperature inversions, and trapping pollutants near the surface that result in chronic health and environmental effects (Calderón-Garcidueñas et al., 2015; Caro-Borrero et al., 2015). Mexico City encompasses the core of the metropolitan area, with a population of more than 8.5 million people, and is divided according into two land uses: Urban and conservation. The former represents the built environment, while the latter represents an area designated by law as Mexico City`s Conservation Lands, representing the 58% of the total area of Mexico City (Pérez-Campuzano et al., 2016). The conservation area is the source of 70% of the water consumed in Mexico city, while providing recreational and landscape amenities (*Ibid*:131). Furthermore, given that the main land uses are agriculture and forest, the conservation zone is regarded as an important source of UES.

Although the conservation area has specific restrictions regarding environmental protection and urban development, the area has been facing intense pressure from irregular settlements and the construction of urban infrastructure allowed by official construction licences. These pressures are specially intense at the west boundary of Mexico City, where the conservation area meets the surroundings of Mexico City, which is characterized as a mainly rural area that has faced the strongest urban development (Vázquez and Rocha, 2009) and the area that has been projected to grow in terms of urban infrastructure and population (Aguilar, 2002; Suárez and Delgado, 2007). Under this consideration, this study aims at emphasizing the importance of this area for incorporating a social-ecological systems approach for future decision-making and urban planning.

2.2. Green infrastructure as ecosystem service providing units

We define green infrastructure as the vegetated areas within and surrounding an urban setting that deliver UES. When it comes to the provision of ecosystem services, ecological research often takes into consideration the ecosystem and environmental conditions that eventually deliver ecosystem services. These conditions are found in specific settings that include agricultural fields, forests, community parks, street trees, vegetated open spaces such as ridges median strips, and other urban green infrastructure. These settings are referred as ecosystem Service Providing Units (SPU) (Wurster and Artmann, 2014; McPhearson et al., 2014, 2015; Kremer et al., 2015; Kati and Jari, 2016). SPUs can only be effectively analysed when they provide specific ecosystem services for humans (Andersson et al., 2015). On this respect, we apply the definition of SPUs as the physical unit whose generation of specific UES is determined by the scale of service production. Analysing the scale at which different SPUs are situated, allows a deeper exploration of the production of specific UES.