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Mapping ecosystem services in New York City: Applying a social–ecological approach in urban vacant land

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ABSTRACT

As urbanization expands city planners and policymakers need to consider how ecological resources can be strategically developed and managed sustainably to meet the needs of urban populations. The ecosystem services (ES) approach provides a useful framework for assessing the status quo, setting goals, identifying benchmarks and prioritizing approaches to improving ecological functioning for urban sustainability and resilience. However, new tools are required for comprehensively evaluating urban ES for ecosystem management and to understand how local and regional trends and plans may affect ES provisioning. We develop an ES assessment methodology that can be used to assess multiple ES of urban green space and integrate them with social conditions in urban neighborhoods. Our approach considers social–ecological conditions and their spatial patterns across the urban landscape. Our analysis focuses on vacant land in New York City. Results suggest that a combined social–ecological approach to ES assessment yields new tools for monitoring and stacking ES. We find that clusters of vacant lots in areas with overlapping low ecological value (e.g. low concentration of green space) and high social need for ES (e.g. high population density) are primarily concentrated in three areas of the city – East Harlem, South Bronx and Central Brooklyn.

1. Introduction

The world is increasingly urban, interconnected and changing (Seto et al., 2011). Over the last few decades there has been increasing recognition that human population expansion and development, especially in cities, is reshaping the ecology of the entire planet (Alberti et al., 2003; Folke et al., 2003; Rockström et al., 2009a, 2009b). Urban regions create significant disproportionate direct and indirect environmental impacts at the local, regional and global scale that affect local and global sustainability (Grimm et al., 2008, 2000; Seto et al., 2012). Given global urbanization trends compounded by the effects of climate change and other global environmental pressures (IPCC, 2011; Rockström et al., 2009a, 2009b), a critical dynamic that must be understood for increasing urban sustainability and resilience is the social–ecological relationships between humans and the urban ecosystems in which the majority of people live (Folke, 2006; Pickett and Grove, 2009).

Local and regional urban ecosystems provide important functions that benefit urban residents including habitat for biodiversity, primary productivity, stormwater retention, air pollution removal and heat mitigation (Bolund and Hunhammar, 1999). The ecosystem services (ES) approach provides a useful framework for assessing the status quo, setting goals, and identifying benchmarks that facilitate long-term monitoring and prioritizing approaches to enhance ecological functions in ways that serve urban communities (Daily et al., 2009; Niemelä et al., 2010; Sukhdev et al., 2010). In particular, spatially-explicit tools are needed for decision-makers to consider how social–ecological characteristics constrain site suitability for restoring or improving the production of crucial ES (Chan et al., 2006; De Groot et al., 2010a, 2010b; Seto et al., 2012). Here, we develop an ES assessment methodology, which considers social–ecological conditions and relationships between multiple ES, as well as spatial patterns of these conditions and relationships across the urban landscape. We present a social–ecological analysis that focuses on New York City (NYC) vacant lots, understudied areas of the city, which by virtue of being underdeveloped, hold potential as spaces for transformation to improve ES and meet social need for ES (Kremer et al., in press). Goals of this study were to: (1) develop a conceptual framework for mapping the spatial patterns of multiple ES of vacant land and social need for ES in NYC; (2) offer an empirical example of how this framework can be applied in the urban context using simple indicators and available data; (3) exemplify a spatially explicit ES

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stacking methodology for evaluating the combined ES of a given lot or patch; (4) investigate how landcover and other environmental characteristics relate to the quantity and quality of different ES provisioning across the urban landscape at the city scale; and (5) identify patterns and clusters of vacant lots exhibiting similar social–ecological characteristics (i.e. areas of high social need and low ecological values).

2. Urban social–ecological systems

Urban areas are made up of complex combinations of heterogeneous social–ecological patches (Cadenasso et al., 2007). In coupled social–ecological systems such as urban areas, mutual dependence exists between social communities and ecological processes with interactions and feedbacks affecting each other over time (Folke, 2006; Holling, 2001; Peterson, 2000). The Human Ecosystem Framework (Machlis et al., 1997; Pickett et al., 2001) provides a useful theoretical context to integrate natural and institutional resources, social structure, ecological processes, and spatial patterns across the urban landscape. The spatial heterogeneity of urban systems has been well noted (Jacobs, 1961; Pickett et al., 2007); however, interactions among various drivers of heterogeneity in urban systems are not well understood (Pickett et al., 2008). Despite the analytical challenges to working in heterogeneous urban systems, relationships between social and vegetation characteristics in urban areas have been identified. For instance, lifestyle behavior, housing age, family size, marriage rates and other demographic characteristics of neighborhood residents have been linked to vegetation cover and biodiversity in urban areas (Grove et al., 2006). Additionally, the ways in which social and ecological systems are linked have been examined in a number of communities that depend on natural resources for economic productivity (Agrawal, 2001; Haase et al., 2012, Larondelle and Hasse, 2012; Olsson et al., 2004).

Connections, relationships, and feedbacks among social and ecological components of urban systems are critical to assess, and can theoretically be teased apart to explain observed social–ecological system dynamics (Pickett et al., 2004). A significant feature of the Human Ecosystem Framework is that it points to the interactions among social and ecological components of urban systems and suggests the need to assess social–ecological interactions in a spatially explicit way (Gottdiener and Hutchison, 2000). Our inability to tightly control and independently manipulate variables in real-world coupled social–ecological systems limits understanding of relationships in these systems (Walker et al., 2006). However, by combining the insights gained through theory development with those derived from analysis of case studies, we can improve our understanding of how social–ecological systems function, and extract generalities about the fundamental processes that structure the interactions of human societies embedded in ecological systems (Walker et al., 2006). We utilize a case study in NYC to investigate the spatially explicit relationship between social need for ES and the ecological value of vacant lots as determined by the current production of ES, in order to provide a real-world application of the conceptual framework we develop for mapping social–ecological conditions of urban spaces in the context of ES. While our study does not hypothesize which specific dynamics link social communities to ecological processes in NYC neighborhoods, it does identify patterns in the configuration of ES and socio-economic indicators of need for ES across the NYC urban landscape.

2.1. Urban ecosystem services

The concept of ES involves the concurrent analysis of the biophysical and ecological foundation of ecosystems and the ways human beings use, benefit from, and value these ecosystems (De Groot et al., 2010a, 2010b). Thus, addressing ES inherently requires a social–ecological perspective (Folke, 2006) and multi-disciplinary tools for analysis (Seto et al., 2012). Since the Millennium Ecosystem Assessment (MA, 2005), ES have been widely conceptualized as connecting natural resources, human society and the economy (TEEB, 2011). For example, urban forests and other green spaces in cities provide a wide variety of important ES (Akbari, 2002; Grove et al., 2005; McPhearson et al., 2010; McPhearson, 2011; Nowak et al., 2002; Troy et al., 2007). In the MA framework, stocks of natural resources and a host of regulating cycles and support mechanisms underlie the social and economic capacity to support human development and well-being (Müller et al. 2011) As the human population expands, consumption of natural resources moves closer to planetary boundaries of regeneration rates (Rockström et al., 2009a, 2009b) and the ability of the natural environment to support human development and well-being is eroded. In a world operating near or beyond these boundaries, there is growing need for the assessment, evaluation, and monitoring of the capacity of the natural environment to provide services and support human well-being (MA, 2005).

Ecosystem services can be quantified either as the biophysical units of the service provided or the societal value of the service (most often monetary value) (Müller et al. 2011); the choice of assessment method is often informed by the research goals as well as data availability and this study is focused on both social indicators of social need for ES and biophysical indicators of ES production. Equitable distribution of resources and social-cultural need for ES are rarely evaluated. Few studies suggest a connection between socio-economic status and the availability of urban green spaces and the ecosystem services they provide (for a short review see Pham et al., 2012). Developing methods that are able to account for these multiple perspectives is one of the pervasive challenges in making social–ecological approaches to urban sustainability and resilience operational.

2.2. Stacking ecosystem services

Concurrent assessment of multiple ES, often referred to as “stacking” has been a contentious approach in the development of ecosystem valuation methods (Cooley and Olander, 2012). Nonetheless, the importance of considering multiple ES for the purpose of decision making in the context of green infrastructure planning and resource conservation management has been increasingly acknowledged (Buckland et al., 2005; Müller et al. 2011; Hepcan and Ozkan 2011; Koniak et al., 2010; Tallis and Polasky, 2009; Weber et al., 2006). Research has only recently begun to provide tools and methods for ES stacking. Buckland et al. (2005) offered a composite indicator analysis for monitoring change in biodiversity and more recently Naidoo et al. (2008) stacked four ES based on their biophysical units and spatial distribution, then correlated average ES provisions with a measure of biodiversity. They suggest that this methodology is effective in identifying areas of enhanced opportunity or need for ES. It is also important to understand tradeoffs and synergies between different ES. For example, it has been demonstrated that optimizing for one service does not necessarily result in improvement in the other (Haase et al., 2012; Nelson et al., 2008).

In NYC, the effects of climate change including sea level rise, changing heat and precipitation patterns, and storm frequency and intensity are predicted to place increased pressure on local urban ecosystems to provide critical urban ES (New York City Panel on Climate Change, 2009). Only by simultaneously assessing multiple services provided by urban ecosystems, how they change over time, and the factors that strengthen or limit their performance,