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Developing a sustainability indicator set for measuring green infrastructure performance

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Abstract

An urban ecosystem is a dynamic system. Therefore, regular monitoring through the use of measurable indicators will enable an assessment of performance and effectiveness. This paper presents a conceptual framework to facilitate the development of an inclusive model for the sustainability assessment of green infrastructure. The framework focuses on key interactions between human health, ecosystem services and ecosystem health. This study reviews existing models for assessing green infrastructure performance and evaluates these models via a range of selection criteria proposed by the authors based on literature review and interviews with stakeholders. This enables derivation of a novel conceptual framework that identifies and brings together the criteria and key indicators. This integrated framework may then be applied to develop a composite indicator-based assessment model to measure and monitor performance of green infrastructure projects and support future studies.

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Keywords: sustainable development; green infrastructure; urban ecosystem; sustainability indicators; conceptual framework

1. Introduction

Urbanization is a dominant demographic trend and an important component of global land transformation. It is predicted by the United Nations that cities will be saturated from the forecast population growth expected over the

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next four decades (U.N., 2012). This will impose a tremendous ecological burden both locally and globally. The rate of urbanization is directly correlated with increased production and consumption of goods, services and infrastructure. This leads to greater land consumption, landscape fragmentation, biodiversity loss, the creation of urban heat islands, increasing greenhouse gas emissions and the destruction of sensitive ecosystems. The outcomes are a decrease in human health and well-being among other negative impacts on society, which interact with and are exacerbated by climate change (Tzoulas et al., 2007).

As a remedy to some of these negative consequences of urbanization, the installation of green infrastructure as opposed to grey infrastructure is identified as an alternative nature-based and cost-effective solution for improving the sustainability of the urban development. Grey or technical infrastructure refers to the facilities that support social and economic production such as roads, sewerage treatment, water treatment systems, and electricity supply networks (Van de pol, 2010, pp 17). Green infrastructure is described as an integrated network of natural and semi-natural areas and features which deliver a variety of benefits to humans (Naumann et al., 2011). Green infrastructure has become increasingly valued in a wide variety of settings from water purification to climate change adaptation and mitigation. Green infrastructure potentially has lower capital, maintenance and operational costs, has fewer negative impacts on the environment and it significantly reduces carbon emissions compared to grey infrastructure (Benedict & McMahon, 2006; Lafortezza et al., 2013). Where grey infrastructure tends to be designed to perform only single functions, green infrastructure networks serve multiple functions and provide a wide range of engineering, environmental and human services, known as 'ecosystem services' (Ely & Pitman, 2014). Ecosystem services are defined as *'the benefits people obtain from ecosystems'* (MEA, 2005). In this context, integrated networks of green spaces at city scale, or green infrastructure, are seen increasingly as fundamental to the delivery of ecosystem services for human and environmental health.

The ability to assess and regulate the sustainability performance of the built and natural environments, based on measurable criteria at a variety of temporal and spatial scales is critical for sustainable urban development. A range of models that assess the performance of specific aspects and elements specially related to green infrastructure have been developed in response. However, there is no consensus on a model that is comprehensive and integrative across all types and aspects of green infrastructure and ecosystem services.

The purpose of this study is to critically examine the existing frameworks for urban sustainability indicators and to compare the existing green infrastructure conceptual models. This will lead to an outcome that proposes a new framework to facilitate the process of selecting green infrastructure performance indicators to best reflect the comprehensive and integrated function of green infrastructure.

2. Existing frameworks for assessing urban sustainability

Since the concept of sustainable development first became a major concern, a number of methods, frameworks and tools have been developed to assess the state of, or changes to, urban areas in relation to sustainability performance. The method mainly used to assess sustainability is indicator-based assessment, which has been applied to many scientific fields from socio-economic science to environmental sciences. Comprehensive lists of urban sustainability indicators have been developed by international and regional organizations, such as the European Foundation (1998), the European Commission on Science, Research and Development (2000), the UN Habitat (2004), the European Commission on Energy Environment and Sustainable Development (2004), the United Nations (2007) and the World Bank (2008).

In addition a number of composite sustainability indices have been developed more recently such as the Environmental Sustainability Index (ESI), the Environmental Performance Index (EPI), the Environmental Vulnerability Index (EVI), the Rio to Johannesburg Dashboard of Sustainability and the Wellbeing of Nations and National Footprint Accounts (Ecological Footprint and Bio-capacity) (SEDAC, 2007).

The development and selection of urban sustainability indicators is a complex process. The most common frameworks for selecting indicators is the Causal Network (CN) method. The CN framework is a combination of a series of causal loops and feedback loops, such as the pressure–state–response (PSR) framework and its transformations: the driving force–state–response (DSR) and the driving force–pressure–state–impact–response