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Ecosystem health pattern analysis of urban clusters based on emergy synthesis: Results and implication for management

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HIGHLIGHTS

- The use of integrated emergy synthesis and set pair analysis model was standardized.
- The integrated model was applied on the scale of an urban cluster.
- Health patterns of different urban clusters were compared.
- Policy suggestions were provided based on the health pattern analysis.

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ABSTRACT

The evaluation of ecosystem health in urban clusters will help establish effective management that promotes sustainable regional development. To standardize the application of emergy synthesis and set pair analysis (EM–SPA) in ecosystem health assessment, a procedure for using EM–SPA models was established in this paper by combining the ability of emergy synthesis to reflect health status from a biophysical perspective with the ability of set pair analysis to describe extensive relationships among different variables. Based on the EM–SPA model, the relative health levels of selected urban clusters and their related ecosystem health patterns were characterized. The health states of three typical Chinese urban clusters – Jing-Jin-Tang, Yangtze River Delta, and Pearl River Delta – were investigated using the model. The results showed that the health status of the Pearl River Delta was relatively good; the health for the Yangtze River Delta was poor. As for the specific health characteristics, the Pearl River Delta and Yangtze River Delta urban clusters were relatively strong in Vigor, Resilience, and Urban ecosystem service function maintenance, while the Jing-Jin-Tang was relatively strong in organizational structure and environmental impact. Guidelines for managing these different urban clusters were put forward based on the analysis of the results of this study.

1. Introduction

Cities play an important role in regional, national, and even international development (Huang, 1998). Clearly, the health of urban ecosystems can influence economic prosperity and social progress at regional and larger scales; therefore, urban ecosystem health should be a priority for both researchers and managers. However, a holistic understanding and diagnosis of urban ecosystem health has not been emphasized and the emergent and accumulated environmental impacts in recent years now jeopardize economic development and the continued provisioning of ecosystem services within the urban support area. Our goal is to apply integrated approaches for the assessment of urban ecosystem health to better understand and improve the structure and function of urban ecosystems.

First used by the World Health Organization (WHO) (Hancock and Duhl, 1988), urban ecosystem health assessments have been developed to focus on health concepts, indicators, standards, and models. This approach has been applied to independent urban ecosystems (Chen et al., 2010; Liu et al., 2011; Spiegel et al., 2001; Zhang et al., 2008), urban ecosystem regions (Liu et al., 2009; Su et al., 2009b), and different urban ecosystems in the same urban cluster (Bi and Guo, 2007; Jin and Zheng, 2010; Su et al., 2011b). A review of the development of these assessments over the past 23 years shows that two main problems remain. First, the concepts and methodology still lack a full integration of social, economic, environmental, and ecological factors with human welfare. Second, methods need to be established to define the health

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standards of urban ecosystems since there is not an absolute and well-acknowledged urban ecosystem health standard (Su et al., 2010).

To address the first point above, a systemic analysis framework and method is being developed to integrate multiple factors of urban ecosystem health, elucidating the features of urban ecosystems. For example, conceptual models of PSR (pressure–state–response), DPSIR, and DPSEEA (driving force–pressure–state–exposure–effects–action) were applied by Zeng et al. (2005), Zou and Wu (2011), and Spiegel et al. (2001), respectively, to organize the urban ecosystem health indicators. Emergy synthesis has also been introduced to establish health indicators and describe ecosystem health levels from the perspective of the biophysical features of urban ecosystems (Liu et al., 2009; Su et al., 2009b) considering the importance of energy and material flows for urban ecosystems and the merit of emergy as an embodied energetic equivalent and sustainability indicator for complex ecological economic systems (Brown and Ulgiati, 2011; Campbell and Garmestani, 2012; Lei et al., 2012; Odum, 1983; Ulgiati and Brown, 2009). Moreover, emergy synthesis has been successfully applied to characterize urban development from the scale of urban clusters (Bi and Guo, 2007; Cai et al., 2009) to mega-cities (Huang et al., 2007; Lan and Odum, 1994; Ulgiati et al., 2011; Zhang et al., 2011), as well as mid-sized cities (Geng et al., 2010; Lu et al., 2003; Whitfield, 1994). Emergy synthesis is regarded as an effective tool for urban ecosystem health assessment because it links multiple factors in urban ecosystems, unifying them by a common unit.

To address the second point, methods are being developed to resolve the existing problems in urban ecosystem health assessment. To account for the intrinsic relativity of ecosystem health (Campbell et al., 2004), set pair analysis is a helpful method to link multiple factors and understand their interactive relationships (Zhao, 1989). Based on set pair analysis, an optimal reference set can be derived by integrating the best values of multiple macroscopic health indicators, rather than subjectively setting the health standard. Therefore, the approach is internal and data-driven rather than imposed as an arbitrary user-defined classification.

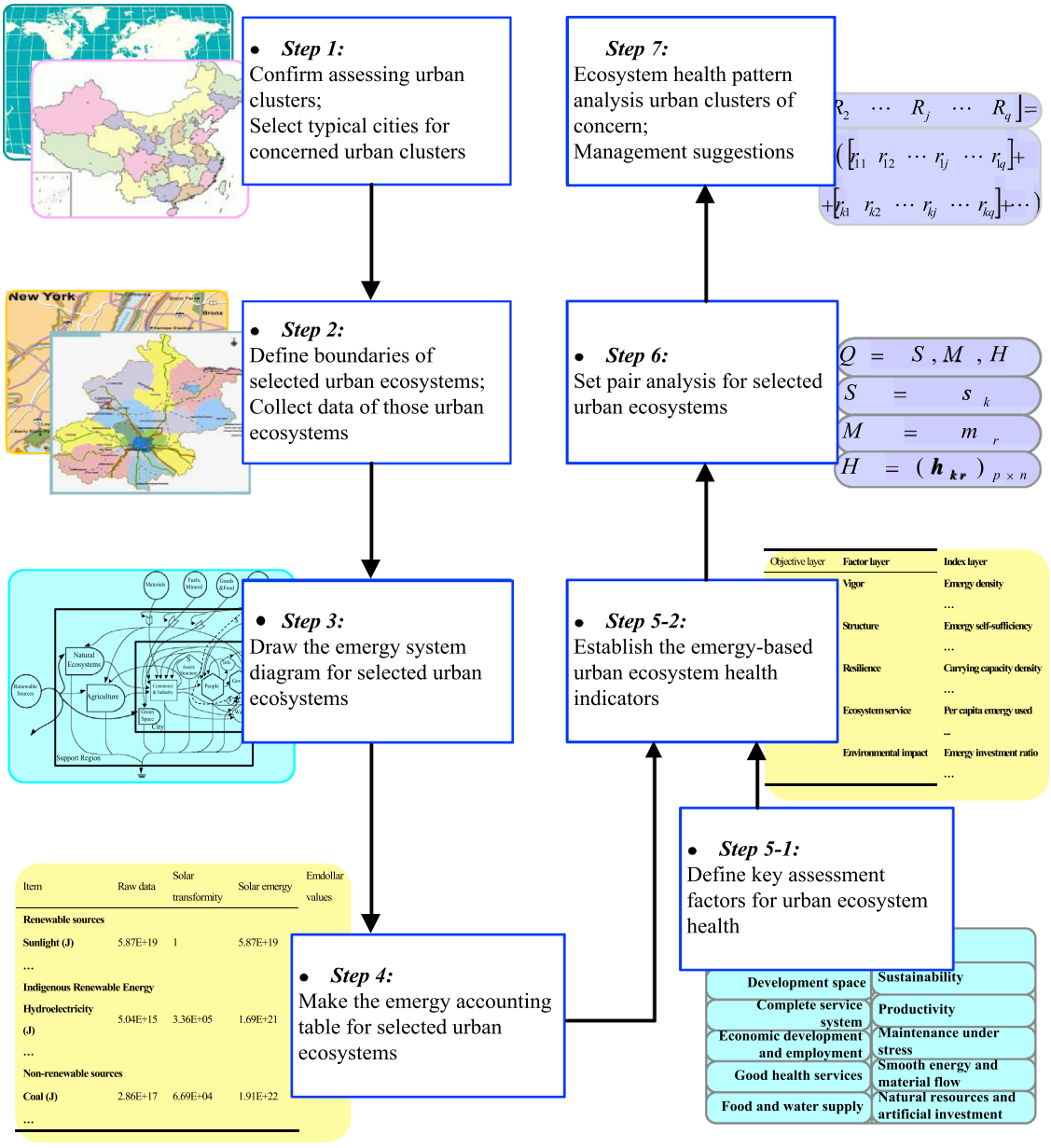

Fig. 1. The basic procedure to assess ecosystem health of urban clusters.