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Assessment and forecast of Beijing and Shanghai's urban ecosystem health

Yongfa Li [a,b,*], Dong Li [a]

[a] Economics and Management Institute, Southeast University, Nanjing 210096, Jiangsu, China
[b] Business Institute, Anhui University of Finance and Economics, Bengbu 233041, Anhui, China

HIGHLIGHTS

- The urban ecosystem health is measurable, predictable and worth studying.
- The reasonableness of selected indicators is of great importance.
- The coefficient to adjust the worst value is introduced innovatively.
- The process of assessment and prediction has been dissected in detail.

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ABSTRACT

In this paper, we first analyze the 5 most cited papers with the title containing "Urban ecosystem health" in Chinese academic journals, and 5 newer papers retrieved from the CSSCI (Chinese Social Sciences Citation Index). The results show that the number of indicators to be used together in more than three papers is 28, and then we select 27 of them to assess Beijing and Shanghai's urban ecosystem health from 2000 to 2011. Secondly, when we standardize the original data, the worst value adjustment coefficient is introduced innovatively. Thirdly, using the entropy method, the weights of concrete indicators of Beijing and Shanghai in the different adjustment coefficients are calculated respectively. Fourthly, based on the fuzzy matter-element method, using the Hamming approach degree, the two cities' ecosystem health index and the contribution value to overall health index from each component are calculated. Lastly, using gray prediction model, the evolutionary time response sequence function of Beijing and Shanghai's urban ecosystem health index is identified, and thus both cities' urban ecosystem health is predicted.

1. Introduction

Beijing is the capital of People's Republic of China, a city directly under the central government of China, China's political and cultural center, China's economic and financial decision-making and management center, and one of the largest cities in the world. Shanghai is a city directly under the central government of China, and a prosperous international metropolis. Shanghai is located in the Yangtze River estuary, adjacent to the East China Sea in the east, lying across the sea from the Japanese island of Kyushu, bordering on Hangzhou Bay in the south, and neighboring on Jiangsu and Zhejiang provinces in the west. Shanghai together with Jiangsu and Zhejiang provinces forms China's largest economic zone —Yangtze River Delta Economic Circle; and Shanghai is the core of the Circle. However, the continued urban development of Beijing and Shanghai is confronted with growing environmental pressures, such as the deterioration of water quality, air pollution, energy shortages, environmental degradation, and traffic congestion. The urban development of Beijing and Shanghai has switched to a quality-oriented growth phase from quantity-oriented one. It is absolutely essential for the two cities to decelerate the pace of development, adjust the economic structure and promote urban residents to enjoy a more ecological, green, low-carbon, livable, high-end city taste. In this context, it is meaningful to assess and predict the ecosystem health of the two cities.

This paper is structured as follows: (a) Literature review; (b) the design of the indicator system, selecting the highest rate of 5 articles for the title "Urban ecosystem health", and the recently published 5 articles in CSSCI (Chinese Social Sciences Citation Index), observing the common indicator used, the indicator system design and evaluating its rationality; (c) determining indicator weight in the entropy value

* Corresponding author at: Economics and Management Institute, Southeast University, Nanjing 210096, Jiangsu, China. Tel.: +86 13665526899.
E-mail addresses: liyongfa324@163.com (Y. Li), ldcf317@sina.com (D. Li).

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method; (d) the calculation of urban ecosystem health index, using gray correlation method the gray correlation analysis; (e) the prediction of health index trend, using the gray model *GM*(1,1); and (f) conclusion and discussion, summarizing the views and discussing the direction of efforts.

2. Literature review

An ecological system is healthy and free from distress if it is stable and sustainable; that is, if it is active and maintains its organization and autonomy over time and is resilient to stress (R. Costanza, 1992). Douglas (2012) thought that urban ecosystems could be described through the four scales: (a) Patches with the urban mosaic (neighborhoods and households); (b) built-up areas (municipal level); (c) urban region (peri-urban and urban); and (d) global. Therefore, urban ecosystem health is a research for the basic circumstances enabling an urban ecosystem to maintain full functionality and to remain unimpaired after suffering stress and difficulties. A healthy urban ecosystem is the basic requirement of a strong economy, healthy environment and harmonious sustainable development for human society.

Assessment of ecosystem health refers to natural ecological, economic and human health (Rapport et al., 1998). Especially, in recent years the ecosystem regeneration and urban ecosystem recovery ability have been faced with the ordeal of resource depletion and pollution causing people to worry about whether the urban ecosystem can support the dense population and provide sustainable services (Su et al., 2013). Costanza (2012) believes that the ideas of ecosystem health and sustainability are closely linked, and sustainability means that the system can maintain the structure (organization), function (vigor) and the ability to restore itself (resilience) in the face of external pressure at any time, while the lack of these signs indicate an ecosystem in crisis and distress. Therefore, ecosystem health is a multi-scale and comprehensive metric description of system vigor, organization and resilience. 20 years ago, Costanza (1992) had similar ideas that a healthy ecological system is stable and sustainable and can maintain long-term organizational structure and autonomous restoration after being threatened. Spiegel et al. (2001) used the DPSEEA analytical framework: *driving force–pressure–state–exposure–effects–action* to assess the efficiency and effect of a series of improvements to the quality of life and human health interventions in an inner city community. However, the concept of healthy urban ecosystems, as well as the concept of ecosystem health, have a lack of any generally accepted definition, although they do have some basic common characteristics: (a) the ecosystem possesses the ability service function to maintain production capacity; (b) being the system of integrity, which is one of the key factors of the urban ecosystem; (c) evaluation perspective needed; and (d) a rule governed by people that is one of the most important characteristics of the urban ecosystem. Therefore, urban ecosystem health is an integration of separate fields such as ecology, socioeconomic and human health (Su et al., 2010a).

Hancock (2000) thought urban ecosystems possess six dimensions: (a) Health status of the urban human population;(b) social well-being within the urban community;(c) quality of the constructed environment; (d) ambient environmental quality; (e) health of the biotic community; and (f) impact of the urban ecosystem on the wider natural ecosystems. In Hancock's opinion, the adequacy of urban ecosystem depended on whether it could support a livable, viable, and sustainable quality of human life or not.

3. The design of indicator system

Requirements for the selection and design of urban ecosystem health indicators: be capable of obtaining the appropriate data, be able to reflect the adequacy of the urban ecosystem through data analysis, monitor trends over time, provide early warning of the deterioration of urban ecosystem health, and diagnose the cause of an existing problem. We select the 5 most cited references with the title including “Urban ecosystem health” in Chinese academic journals and 5 relatively new pieces of literature from the CSSCI (Chinese Social Sciences Citation Index) retrieval and count up the indicators of urban ecosystem health in the literature, see Table 1 (We provide only the first author's name here, the complete information can be found in Ref.).

It should be acknowledged that the authors are really serious about the choice of each indicator to evaluate an urban ecosystem health. Table 1 shows that 108 indicators from 10 papers in common use were selected, indicators appearing in more than 3 papers in the literature total 28. Because the two cities' “industrial water recycling rate (4 times)” indicator data is not easy to obtain, we gave up this variable, and will use the 27 remaining indicators. These 27 indicators reflect the scholars' consensus in selection of the evaluating index of urban ecosystems (see Table 2).

The Five-Points Method and the Three-Points Method are two common ways to classify an urban ecosystem. Of the above-mentioned 10 papers, five adopt the Five-Points Method, two adopt the Three-Points Method and the rest adopt three other different classification methods. In Table 2 (Five-Points Method) the urban ecosystem is divided into five components: (a) Vigor, which means a city's vitality and metabolic ability, reflecting the productivity and energy consumption a region. We select two indicators, *X*1 (per capita GDP) and *X*2 (GDP growth), to represent the productivity of a region and the indicator *X*3 (energy consumption per 10,000 Yuan of GDP) to mirror the corresponding economic efficiency. (b) Structure, which means the diversity of configuration and the channels to the configuration in terms of the urban ecosystem, reflecting the economic, social and natural structure or relationship. We select another two indicators, *X*4 (tertiary industry accounted for the proportion of GDP) and *X*5 (proportion of expenditure on R&D to GDP), to represent the economic structure of a region; *X*6 (registered urban unemployment rate) and *X*7 (population density of urban area) to indicate the corresponding social structure; and *X*8 (forest coverage rate), *X*9 (green covered area as of completed area) and *X*10 (percentage of nature reserves in the region) to reflect the corresponding natural structure. (c) Resilience, which means the function of an urban ecosystem, that is about keeping the structure's usability and making a long term and sustainable development, reflecting a kind of systematic self-regulation. However, the self-regulation of urban ecosystem mainly depends on the humanity management activity. Therefore, 5 indicators, i.e. *X*11 (urban waste water treatment rate), *X*12 (attainment rate of the industrial waste water discharged), *X*13 (common industrial solid wastes comprehensively utilized), *X*14 (treatment rate of consumption wastes) and *X*15 (total investment in the treatment of environmental pollution as percent GDP) have to be adopted to represent the self-regulation of an urban ecosystem. (d) Service function, which mainly refers to the function of an urban ecosystem to provide the carrier of human production and life. We select 5 indicators, *X*16 (per capita urban residential area), *X*17 (per capita area of parks and green land), *X*18 (per capita area of paved roads in city), *X*19 (number of public transportation vehicles per 10,000 population in the city), and *X*20 (number of beds of hospitals and health centers per 10,000 population), to represent the physical carrier for human beings to exist and live in. (e) Population health, which is definitely the core issue of urban ecosystem health. As mankind is the subject in urban ecosystem, people's health of mind and body merits more attention. We select 6 indicators, *X*21 (natural growth rate of population), *X*22 (life expectancy), *X*23 (Engel's coefficient of urban households), *X*24 (per capita annual disposable income of urban households), *X*25 (proportion of days of air quality equal to or above grade II in the whole year), *X*26 (per capita daily consumption of tap water for residential use) and *X*27 (number of students enrollment of regular institutions of higher education per 10,000 population), to represent people's physical and mental health or the important