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Evaluation of sustainable land management in urban area: A case study of Shanghai, China

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A R T I C L E I N F O

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A B S T R A C T

With the accelerating urbanization process, there is an increasing shortage of land resource. It leads to an increasingly serious conflicts between built-up areas and other types of land use. This will further hinder city sustainable development. To address the issue, this paper takes urban land management sustainability as the study object and puts forward an evaluation method on sustainable land management (SLM) in urban area. First, four aspects of sustainable land management are proposed, namely economic progress, social stability, urban improvement and ecological balance. Second, a system with fourteen indicators is built according to the aspects. Third, using the indicators, the sub-performance and the overall efficiency of SLM are evaluated with the technique for order preference by similarity to ideal solution (TOPSIS) based on entropy weight. After that, the proposed method is applied to a case study of Shanghai, China. The results show the time series changing of SLM performance from 2000 to 2011 and reveal an unbalanced development path among the four aspects of SLM. Accordingly, policy recommendations are proposed to improve the sustainable land management efficiency. Therefore, it demonstrates that the proposed evaluation method can be used to reveal to what extend the urban land use is reasonable and sustainable and provides guidance on government urban land planning and policy making. Consequently, it helps to improve the land use efficiency and ease the land use conflict.

1. Introduction

The expansion of industry and transport systems ushered in an unprecedented process of urbanization (Thinh et al., 2002). Recently, 400,000 km^2 of the earth's surface is covered by built-up areas in cities and it is estimated to be 700,000 km^2 in 2030. With the acceleration of urbanization that has occurred during the past century, the increasing demand for built-up areas has led to increasingly serious conflicts between various types of land use and biodiversity hotspots with built-up land in rapid urbanizing areas (Li et al., 2014a, 2014b; Seto et al., 2012). With the continuous city sprawling, land use faces large challenges (Li et al., 2014). Sustainable land management is a good way to reduce those conflicts and guarantee for regional sustainable development (Long et al., 2007; Luo et al., 2010).

Sustainable land management (SLM) is firstly proposed in the proceedings International Workshop on Sustainable Land Use System 1990 and many researchers have done a lot of work on it (Haberl et al., 2004; Ling et al., 2013; Smith et al., 2000). Later on, the FESLM: An international framework for evaluating sustainable land management established comprehensive indicators of SLM considering resource availability, environmental impact, economic viability, biodiversity and social justice (FAO, 1993). It defines SLM as the adoption of land use systems enabling land users to maximize the economic and social benefits from the land while maintaining or enhancing the ecological support functions of the land resources. Evaluation of urban SLM is a way to analyze to what extent the land use is reasonable and sustainable. Therefore, it provides guidance for the government in urban land management and policy making.

Sustainability is a comprehensive issue including various dimensions thus characterized by a high degree of conflict. Evaluation of SLM gives a way to consider the sustainable related dimensions and provides a basis for land planning towards sustainability. Recently, most of the studies are about rural area and their definition on SLM mainly concerns agro-ecosystem (Bouma, 2002; Gutzler et al., 2014; Treesilvattanakul et al., 2014). Human-ecological function, accessibility, biocoenosis, geomorphy and productivity are considered in sub-urban area (Gameda and Dumanski, 1995; Kawy and Darwish, 2014; Wolf and Meyer, 2010). Undeniably, as a natural source on earth providing a flow of natural capital (Petrosillo et al., 2013), the most notable characteristics of land is its ecological and environmental

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functions. However, in urban areas, except for the ecological aspect, land reveals other obvious functions. It has enormous impact on city development, economic progress and social stability. Cities are complex socio-economic-natural ecosystems dominated by human activities, which define land use patterns (Li et al., 2014a, 2014b; Wang et al., 2011). Thus, land use in urban areas should be characterized by its physical, ecological, social, and economic attributes.

There are researches concentrating on evaluating one aspect of SLZhao et al. (2014) considered ecological risk degree by resource intensity and ecological vulnerability. Yuan and Dong (2014) asessed the SLM from perspective of low carbon and divided the indicators based on carbon emission and carbon sink. Xiong et al. (2013) analyzed the sustainable use of arable land based on niche theory. As to the integrated evaluation on SLM, social and economic are connected (Wiggering et al., 2006). The economic (Li et al., 2014a, 2014b) and urban compactness (Thinh et al., 2002) are also considered together. Su et al. (2014) considered the social and economic impacts of vegetated landscape pattern change. Thinh et al. (2002) managed sustainable development of a compact city considering the degree of sealing and price of land. There are also researches with indicators covering a wide variety of land uses across the three dimensions of sustainability: social, economic and environmental (Fleskens et al., 2014; Mander and Uuemaa, 2010; Paracchini et al., 2011).

In conclusion, there are a few studies focusing on urban area. A city represents a large and permanent settlement with a dense non-agricultural population and well-developed industries (Li et al., 2014a, 2014b). Unlike in rural areas, the urban land is mostly occupied by highly intensive build-up areas and with less cultivated areas. It highlights the different land usage and development pathway in urban area. Moreover, in China, there is a clear distinguish between the collective land and state land (Wehner et al., 2014). The urban land belongs to the state and can be reserved and sold by the local government, thus endows the urban land with directly economic benefit. It also brings with more conflict between the economic and other aspects. The urban land use impacts on the economic, social, urban and ecological development.

As to the researches on urban land managemnt, most researches only focus on limited aspects of SLM and are not sufficient to reflect the overall performance and the conflicts among different aspects. The paper intends to propose an evaluation method on SLM in urban area considering different aspects of sustainable urban land use. To this end, the paper takes urban land management sustainability as the study object and evaluates the SLM performance in urban area based on Chinese context where the urban land is state owned. An indicator system is built considering economic, social, urban and ecological aspects. Based on that, the sub-performances and the overall land management efficiency are evaluated by the technique for order preference by similarity to ideal solution (TOPSIS). The proposed approach is applied to the case study of Shanghai, China. The results show the time series changing of SLM performance, thus reveal the effects of land management strategy in different phases. The synthetic assessment on SLM proposed in this paper is helpful for the government to make sustainable use of urban land.

2. Materials and methods

2.1. Study area

Shanghai is located in the east of Yangtze River (Fig. 1). As one of the municipalities of China, Shanghai is the important center of economy, transportation, science and technology. The excellent geographical location and natural conditions provide a plenty of land resource. However, in recent years, with the high pace of reform and rapid development in industry, almost all land resources on continent are occupied. Agricultural land is gradually atrophic, the quality of the arable land is in decrease, and the built-up land is gradually increasing. By 2015, the total land area in Shanghai had been 634050 ha with the population of 24.26 million and the GDP of 2496.5 billion RMB. However, the arable land per capita was only 0.013 ha, which made Shanghai the city with the least area of arable land in China. As Shanghai is experiencing a significant change in land use structure and serious resource shortage, it is urgent to evaluate the land use sustainability to help plan a sustainable city based on SLM. Moreover, as the first city established urban land administration in China, considering its rapid economic development and land resource, Shanghai is in an upper-middle level of overall development in China. Thus, the evaluation on SLM in Shanghai can provide lessons and suggestions to other cities in China.

2.2. Methods

In this section, we introduce the proposed evaluation method that integrates TOPSIS with entropy weight =. Besides, we describe the ecological footprint and ecological carrying capacity. Then the choices of indicators are explained, and followed by the data sources of the case study.

2.2.1. TOPSIS based on entropy weight

TOPSIS is a rational and comprehensible method for multi-objective analysis (Deng et al., 2000). It emphasizes that the best performance should not only have the shortest distance from the positive ideal solution, but also have the longest distance from the negative ideal solution. The closer the result is to the positive ideal solution and the further to the negative ideal solution, the better performance it will be. The steps of TOPSIS are as follows (Opricovic and Tzeng, 2004):

(1) Calculate the normalized decision matrix. The normalized value $R = (r_{ij})_{m \times n}$ is calculated as:

For benefit indicators, which increase with the incremental of the performance, rij is:

$$r_{ij} = \frac{x_{ij} - a_i}{b_i - a_i}$$

$$a_i = min|x_{ij}|$$

$$b_i = max|x_{ij}|$$

For cost indicators, which decrease with the incremental of the performance, r_{ij} is:

$$r_{ij} = \frac{b_i - x_{ij}}{b_i - a_i}$$

i = 1, 2, 3……m, $j = 1, 2, 3……n$, m is the number of indicator and n is year

x_{ij} is the value of i indicator in year j, a_i is the minimum x_{ij} for indicator i over the n years, b_i is the maximum x_{ij} for indicator i over the n years.

(2) Calculate the weighted normalized decision matrix. The weight is calculated by entropy weight, which is an objective weighting method based on the data itself, through the analysis and explanation of the implicit information. It enhances the difference between indicators. The weights are calculated according to the data variation degree (Liu, 2007).

$$w_i = \frac{1 - e_i}{m - \sum_{i=1}^{m} e_i}$$

$$e_i = -k\sum_{j=1}^{n} P_{ij} lnP_{ij}$$

$$P_{ij} = \frac{r_{ij}}{\sum_{i=1}^{m} r_{ij}}$$

w_i is the weight for indicator i and $0 \le w_i \le 1$; $\sum_{i=1}^{m} w_i = 1$