A three-dimensional evaluation model for regional carrying capacity of ecological environment to social economic development: Model development and a case study in China

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ABSTRACT

A three-dimensional evaluation model was established to evaluate the carrying capacity of regional ecological environment to social economic development, based on the study on the relationship between environmental quality, ecological quality and social economy. It includes socio-economic subsystem, ecological subsystem and environment subsystem. X axis represents the level of ecological quality index; Y axis represents the level of environment quality index; Z-axis represents the level of socio-economic development index. The three-dimensional cube model divides into eight blocks of "I, II, III, IV, V, VI, VII, VIII", which represent different social and economic development levels and the integrated status of ecological environmental quality. It covers 25 indicators of social economic development, ecological quality, and environmental quality. Entropy weighting method was adopted to determine the weight of each index. Ecological quality index, environmental quality index and socio-economic development index were divided into three grades; the subsystem index of grade II is taken as the inflection points X_{ip}, Y_{ip} and Z_{ip} respectively. 11 prefecture-level cities in Jiangxi province in China were used as a study on carrying capacity evaluation for regional ecological environment to social economic development by the three-dimensional evaluation model. The comprehensive evaluation index and indexes of each subsystem were calculated. The actual ecological environmental quality and socio-economic values of the study area were compared with the corresponding indexes.

The study shows that the environment subsystem has a great influence on the comprehensive model. The comprehensive evaluation index of 11 prefecture-level cities in Jiangxi province has exceeded the medium value (grade II). Jiujiang, Ganzhou, Yichun and Shangrao in Jiangxi province are in the model block VIII , other cities in Jiangxi province are in the model block V . It shows that all cities of Jiangxi province are still at the intermediate level of carrying capacity and are in the development stage of economic and environmental coordination. The three-dimensional model effectively reflects the actual situation of regional ecological environment, provides a way for other regional carrying capacity evaluation. It is feasible and scientific, and the results are more intuitive, spatial, and visual. The model provides a reference for the macro-management and decision making of ecological environment in the government sector.

1. Introduction

The sustainable development of ecological environment and social economy has always been the focus of attention in the world (Garry et al., 2016; Li et al., 2017; Broman et al., 2017; Jia et al., 2017; He et al., 2016). The coordinated development of ecological environment and social economy was the common responsibility and pursuit of the international community. China, as the largest developing country in the world, has created the "miracle of China" at an average annual rate of 9.8% over 30 years of reform and opening up, but at the same time,

"high investment, high pollution and high emissions" model has also led to a series of environmental problems. Environment pollution and ecological destroy gradually evolved into constraints of China's economic and social sustainable development of the outstanding obstacles.

At present, the economic growth continues at the same time the environment is worsening, the ecological damage is becoming more and more serious. Comprehensive evaluation of the environmental economy has been widespread concern in academia (Boggia et al., 2014; Siva et al., 2016). Scholars have studied from the perspective of coordinated development on social economy and ecological environment, ecological

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security warning, economic growth and environmental pollution, ecological economy (Yuan et al., 2017; Wang et al., 2014). But on the whole, there were few studies on qualify the relationship between social economic development with ecological quality and environmental quality at home and abroad, and lacked of macroeconomic research on the development stage and path of regional environmental economy. Some developed countries mainly focus on the study of micro-scale, such as atmospheric environment (Yang et al., 2016), water environment (Yu et al., 2015) and other aspects of pollution characteristics, pollution on biological and human health (Liu et al., 2017; Xu et al., 2017) and macro-scale focuses on pollution emissions and economic growth, cross-border pollution and regional environmental quality (Twerefou et al., 2017; Almeida et al., 2017; Özokcu et al., 2017) and so on.

Single study cannot guide the overall regional environmental governance; other issues had increasingly arisen in the process of solving some problems (Boggia et al., 2014; Miao et al., 2016). At present, there are several methods used in regional environmental assessment, such as ecological footprint (Miao et al., 2016), coordination degree, matter element analysis (Deng et al., 2015) and ecological health risk analysis. Although these methods have their own advantages, but they cannot fully objective evaluate the region's comprehensive socio-economic development level, the development stage and the main contradictions.

It is urgent to develop clear information evaluation models to simulate the relationship between ecological environment and social economic development for management and decision-making basis. Three-dimensional model has been gradually applied to the evaluation field, such as the city's environmental quality (Fan et al., 2015), eco-city planning (Ren et al., 2016), and the natural capital utilization (Fang, 2015). Few coupled model has been studied, such as Niccolucci et al. (2009, 2011) proposed the concept of "three-dimensional ecological footprint" for natural capital accounting. Application of three-dimensional model on simulation the relationship between ecological environment and social economic development, especially on carrying capacity of regional ecological environment to social economic development was less reported. Therefore, a three-dimensional evaluation model for the carrying capacity of regional ecological environment to social economic development has been established to evaluate the comprehensive level of regional integrated system. It can clarify the main contradiction between social development stage and sustainable development, and can provide management and decision-making basis to achieve economic and environmental coordination, sustainable development.

The three-dimensional evaluation model including social economic subsystem, ecological subsystem and environmental subsystem has been built, based on the relationship between social economic development, ecological quality and environmental quality. It covers 25 indicators of social economic development, ecological quality, and environmental quality. The three-dimensional cube model is divided into eight blocks, it representative eight states of low ecology-low quality-low economic development level and so on. Three functions of the model were put forward: comprehensive evaluation of social development, trend analysis and development stage division. 11 prefecture-level cities in Jiangxi province in China have been used to create a three-dimensional evaluation model for example.

2. A three-dimensional model to simulate socioeconomic and ecological-environmental system

2.1. The general methodology

By simulating the process of natural changes and development of environmental quality, ecological quality and social economy, a three-dimensional evaluation model was established to evaluate the carrying capacity of regional ecological environment to social economic development. The general methodology is showing in Fig. 1.

2.2. Overall framework of the three-dimensional model

A three-dimensional evaluation model for the carrying capacity of regional ecological environment to social economic development was established based on the study of the relationship between environmental quality, ecological quality and social economy. It includes socio-economic subsystem, ecological subsystem and environment subsystem. X axis represents the level of ecological quality index; Y axis represents the level of environment quality index; Z axis represents the level of socio-economic development index, as shown in Fig. 2.

2.3. Meaning of the three-dimensional model for carrying capacity evaluation

The three-dimensional evaluation model for carrying capacity evaluation includes two meanings:

I. Relative meaning: The value of ecological quality index, environmental quality index and socioeconomic development level of the study area were compared with the evaluation index value to confirm the position and status of the research area. It is mainly used to compare the environmental economic level among the regions, and can provide the scientific basis for improving the strategic decision of all-round development of regional environmental economy.

II. Absolute meaning: Ecological quality index, environmental quality index and socio-economic development index were set up three grades. The subsystem index of grade II is taken as the inflection points X_{ip}, Y_{ip} and Z_{ip} respectively. The trend of the evaluation indexes of each subsystem was analyzed.

2.4. The division of the state block of the three-dimensional model

In Fig. 2, OX (YA) in the X axis, the ecological quality increases gradually with the increase of X value, that is, OX_{ip} is low ecology, $X_{ip}X$ is high ecology. OY (XA) in the Y-axis, the higher the Y value, the higher the environmental quality, that is, OY_{ip} is low environmental quality, $Y_{ip}Y$ is high environmental quality. OZ (AD) in the Z axis, the higher the Z value, the higher the socio-economic development level, that is, OZ_{ip} represents the low socio-economic development level, $Z_{ip}Z$ represents high socio-economic development level. The model is divided into 8 blocks of "I, II, III, IV, V, VI, VII, VIII", which respectively represent 8 different comprehensive status of ecological quality, socioeconomic and environmental quality in the study area (Table 1).

2.5. Index comparative analysis on regional socio-economic and ecological-environmental system

For a single study area, the relationship between ecological environmental quality and social economic development can be clearly defined. Points in diagonal OD are the same, it represent the same value of each subsystem. The other indices of socioeconomic and ecological-environment in the model are biased, it represents different environmental problems.

3. Comprehensive evaluation index system for carrying capacity of regional ecological environment to social economic development

The choice of evaluation index is divided into three steps:

Firstly, we constructed a frame of three-dimensional model for the carrying capacity of regional ecological environment to social economic development; the indexes which related to socio-economic, ecological and environmental studies were extracted;
Secondly, the indexes were classified and selected according to the evaluation model. According to the constructed three-dimensional