Ecological Indicators 60 (2016) 879–883

Contents lists available at ScienceDirect

Ecological Indicators

journal homepage: www.elsevier.com/locate/ecolind

The studies of ecological environmental quality assessment in Anhui Province based on ecological footprint☆

Miao Cheng-lin[a,b,*], Sun Li-yan[a], Yang Li[c]

[a] School of Economics and Management, Anhui University of Science and Technology, Huainan, Anhui 232001, China
[b] National Institute of Technical Innovation and Resource-Based Cities Sustainable Development, Anhui University of Science and Technology, Huainan, Anhui 232001, China
[c] School of Humanities and Social Sciences, Anhui University of Science and Technology, Huainan, Anhui 232001, China

ARTICLE INFO

Article history:
Received 10 June 2015
Received in revised form 20 August 2015
Accepted 23 August 2015

Keywords:
Ecological environmental quality
Ecological footprint
Ecological deficit and surplus
Ecological environmental carrying capacity
Sustainable development

ABSTRACT

Under the dual pressures of the socio-economic development and the increase in population density, the ecological environmental quality issues in Anhui Province have become increasingly prominent, which seriously handicap the sustainable development of regional economy, and it is more important to evaluate ecological environmental quality. By using the data of ecological environment, society, economy and population in Anhui Province, this paper measures ecological footprint, ecological environmental carrying capacity and ecological deficit and surplus in Anhui Province based on ecological footprint. The results show that ecological environmental quality in Anhui Province is not in the best state of the coordinated development, and the relationship between the supply and the demand of per ecological footprint almost is not in balance.

1. Instruction

Currently, the development of the human society is confronted with two major themes, environment and development, to which increasingly high attention has been paid by various states' governments and the academic world. We must have a clear understanding of the effect of various activities on the environment and the effect of the modern environmental carrying capacity on the sustainable development of the human society (Cai and Yang, 2013; Bouchet et al., 2012). Therefore, properly coordinating the relationship between the ecological environment and economic development and carrying out economic construction based on the environmental protection and the increase of ecological environment carrying capacity are key core problems of the sustainable development of the social economy.

In recent years, the social economy of Anhui Province achieves rapid development and significant improvement (Hutton et al., 2015; Liu et al., 2012). However, the ecological environment of Anhui Province faces serious problems and deterioration. The gradual decline of the ecological environmental carrying capacity restrains the sustainable development of the social economy and influences the stability and development of Anhui Province to a great extent (Van Hoey et al., 2013; Drayson et al., 2015; Karimi et al., 2015). At present, Anhui Province is also establishing a strategic plan for building an ecological province and the ecological environmental quality is an essential part of construction of an ecological province. Thus, ignoring the ecological environmental issues and impeding the improvement of the ecological environmental quality of Anhui Province will shake the foundation of the social sustainable development of Anhui Province and necessarily influence construction of an ecological province.

The ecological footprint analysis method is a simple evaluation method for sustainable development based on biological physical quantity and closely associated with the sustainable development theory. The necessary data can be easily obtained and the operational method can be conveniently operated (Jia et al., 2004; Sun, 2008; Lei et al., 2012). Hence, in the context of the ambitious goal of ecological construction in Anhui Province and in combination with the theoretical knowledge of the system theory, the paper involves evaluation research on the ecological environmental quality of Anhui Province using the ecological footprint analysis

☆ Fund item: the National Natural Science Foundation of China (71503003, 71371014, 71272164); 2015 Annual Anhui Province Natural Science Foundation Youth Project of China (1508085QG147); 2015 Annual Anhui Province Soft Science Project of China (1502052055).

* Corresponding author at: School of Economics and Management, Anhui University of Science and Technology, Huainan City, Anhui Province 232001, China. Tel.: +86 13695610659.

E-mail addresses: chlmiao@163.com (C.-l. Miao), sliydy@163.com (L.-y. Sun), y321212@163.com (L. Yang).

http://dx.doi.org/10.1016/j.ecolind.2015.08.040
1470-160X/© 2015 Published by Elsevier Ltd.

approach. The paper also involves measuring of the ecological footprint, ecological environmental carrying capacity, and ecological deficit and surplus and analyzing and evaluating the measurement results based on the data regarding ecological environment, society, economy, and population in Anhui Province.

2. Computational formula for ecological environmental quality

The ecological footprint refers to various types of resources meeting the daily consumption of a certain human population and the area of ecologically productive land necessary for assimilating various types of associated domestic waste (She et al., 2011; Xu et al., 2001; Ferng, 2014). The ecological footprint analysis approach involves calculating the ecological footprint from the perspective of population consumption demand and calculating the ecological carrying capacity from the perspective of land supply based on quantification of a group of indexes regarding the area of ecologically productive land (Du and Qin, 2010; Wang et al., 2013). Both will be compared to evaluate the ecological environmental quality and ecological sustainable development of the research subjects (Butnariu, 2014; Hopton and White, 2012; Galli et al., 2012; Galli, 2015).

For calculating the ecological footprint, the area of the ecologically production land is divided into 6 types, i.e. cultivated land area, forestland area, grassland area, building land area, productive water area, energy land area, etc. The computational formula for ecological footprint is as follows:

$$EF = N \cdot ef = N \cdot \sum \gamma(a_i) = N \cdot \sum \gamma(c/p_i)$$

In the above formula, i is the type of the resources consumed by a certain human population; p_i is the average productivity for producing ith type of resources; c_i is the per capita quantity of the ith resources consumed; a_i is the ecologically productive area of land by converting the per capita consumption of the ith type of resources; γ is the equivalence factor. N is the total population of the research subjects; ef represents the per capita ecological footprint; EF presents the total footprint of the research subjects.

The computational formula for the ecological environmental capacity is as follows:

$$EC = N \cdot ec = N \cdot (1\text{–}12\%) \cdot \sum \gamma \cdot y \cdot a_i$$

In the formula above: i is the area of the biological productive land required; a_i is the per capita area of the productive land of the i is the biology; γ is the equivalence factor; y is the yield factor; N is the total population of the research subjects; ec represents the per capita ecological environmental capacity; EC presents the total ecological environmental capacity; the figure 12% represents the 12% land area deducted from the ecological supply for protection of the biological productivity. The Wil-liam method was used to determine the balance factor γ as shown in Table 1.

A positive result from the numerical value of the ecological footprint plus the numerical value of the ecological environmental capacity represents ecological deficit and a negative one represents ecological surplus. Ecological deficit and ecological surplus represent the level of sustainable development. The ecological deficit indicates that the status of the research subjects is unsustainable development and ecological surplus indicates that the status of the research subjects is sustainable development.

Table 1
Description of land types.

Land type	Main purpose	Balance factor
Cultivated land	Crops in the planting industry	2.8
Forest land	Improving forest products and wood	1.1
Grassland	Improving animal by-products	0.5
Building land	Land for human settlement	0.2
Productive water	Providing aquatic products	1.1
Energy land	Absorbing CO_2 released by humans	2.8

3. Data analysis and compilation

3.1. Collection of evaluation data

The evaluation of ecological environmental quality is a multi-object evaluation involving overall consideration of the regional economic situation and productive land necessary for production. The evaluation data required include:

(1) Geographical remote sensing imaging data: 2005 and 2010 TM images of Anhui Province.
(2) GIS essential data: ratio of 2005–2010 in Anhui Province is 1:100,000 for land use data; 1:250,000 for basic geographic data; 1:250,000 for contour data; 1:1,000,000 for landform data; 1:1,000,000 for land quality data; 1:1,000,000 for productive land data, etc.
(3) Economic statistical data: economic statistical data, total population data, etc. of Anhui Province and its prefecture-level cities in 2005 and 2010.
(4) Hydro meteorological data: water resource data of Anhui Province, precipitation data and meteorological station temperature data and main agricultural production areas of Anhui Province, etc.

3.2. Standardized processing of data

The collected data should be subject to standardized processing during evaluation of the production environment quality due to the fact that the collected evaluation data is huge complex and the units and measuring standards are inconsistent. The main methods include registration processing of the spatial data, rasterization processing of the vector data, spatialization processing of non-spatial data, interpolation processing of the meteorological data, etc.

(1) *Registration of spatial data*. The TM imaging data were subject to standard atmospheric radiation and scattering correction processing at the ground receiving station. The TM imaging data were subject to systematic geometric correction using the sensor attitude parameters, which eliminated the distorted data. For evaluation of the TM imaging data subject to the processing method met the accuracy requirements for evaluation.
(2) *Rasterization of vector data*. The collected GIS essential data, i.e. vector data, were converted into raster data after rasterization. 1:250,000 contour data were converted into slope and elevation vector data. The converted data and the GIS basic vector data such as 1:100,000 productive land data for production, 1:1,000,000 landform data, 1:1,000,000 irrigation water data, 1:1,000,000 productive land data, 1:1,000,000 land quality data, etc. were rasterized to 100 m × 100 m raster data with an error less than 1% during conversion.
(3) *Processing of non-spatial data*. The non-spatial would be processed to avoid any effect on the evaluation result arising from deviation of the data collected due to the fact that all prefecture-level cities of Anhui Province used inconsistent standards and statistical specifications for annual economic