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Evaluation of Ecological Carrying Capacity of Henan Province under the Sustainable Development

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Abstract Based on the overview of social economy of Henan Province, I probe into the concept and evaluation of ecological carrying capacity. By using the ecological footprint analysis and the data of various kinds of land supply of Henan Province from 2000 to 2008, the ecological carrying capacity of Henan Province is analyzed. It is unveiled that inharmonious population, natural resources and economic resources affect the efficiency of the sustainable development of ecological carrying capacity of Henan Province; the underdeveloped economy of Henan Province impacts the sustainable development of ecological carrying capacity of Henan Province and the overburdened population lead to the insufficiency of ecological carrying capacity. Around protecting the threshold of ecological system, the countermeasures are put forward, which cover forming the idea of ecological economy and circular economy and promoting the transformation of economy growth mode; taking the development road of using resources intensively and performing the strategy of sustainable utilization of resources; strictly control population growth and strengthening people's crisis awareness of resources and environment.

Key words Ecological carrying capacity; Ecological footprint analysis; threshold; Henan Province, China

Henan Province locates in central China, is a granary province with large population. It functions as a bridge between the east and the west in terms of economy and combines the resource advantages of the south and the north. Besides, it has convenient transportation and developed trade. All of these provide favorable terms for the economic and social development of Henan Province[1]. However, for quite a long time, with the rapid increase of population and the mushroom growth of economy, people' demands on resources increase accompanying by it and the problems such as population, resources, environment and the like, which have impact on ecological supply capacity, have become the most serious factors on restricting social economic development and people's physical and mental health. Therefore, it is necessary for researching the features, development momentum and rules of ecological carrying capacity of Henan Province, and supplying scientific and rational decisions on the healthy development of economy and society, and on the construction of ecological environment for the whole province.

1 The social economy profile of Henan province

Henan Province has an area of 167 000 km^2, ranking the 17th in China and accounting for 1.74% of the total area of the country. By the end of 2008, the total population has come to 99.18 million, second to none in China. The total acreage of farmland in Henan Province is 6.876 5 million hm^2, and the farmland acreage per capita is 0.07 hm^2, lower than two thirds of the average level of 0.11 hm^2 of the whole country. The regional output value comes to 513.766 billion yuan in the aggregate and the output value pre capita is 5 444 yuan. In addition, 71.7% of its population is farmers, so it is a granary province and a typical under developed region. In 2008, the GDP of Henan Province came to 1 840.778 billion yuan, ranking the fifth of China successively for 5 years, second only to Guangdong Province, Shandong Province, Jiangsu Province and Zhejiang Province. Besides, the GDP per capita in Henan Province ranked the 17th in China and become an emerging province with large amount of economic output[2]. In 2009, the grain yield in Henan Province has surpassed 50 billion yuan, which ranked first all over the country successively for 10 years. In 2009, the total financial revenue has achieved 192.16 billion yuan with the growth rate of 7.8%; the local general budgetary revenue has achieved 112.61billion with growth rate of 11.6% and the general budgetary expenditures have finished 290.26 billion yuan with the growth rate of 27.2%.

2 The concept and evaluation method of ecological carrying capacity

2.1 The concept of ecological carrying capacity "Carrying capacity" is a term comes from ecology in the early period. It refers to the maximum number of individual organism, who can survive in a certain environment conditions. The definition of ecological carrying capacity mainly comes from the concept, which saying that carrying capacity is the function of geographic area and organism. P. R. Ehrlich, an ecological economist, defined that ecological carrying capacity is the potency of maintain the number of certain organism without dwindling. Rough Garden supplemented that ecological carrying capacity uses the total number of organisms to measure the amount of the renew-

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able resources in a certain environment. In this paper, ecological carrying capacity is defined that in a certain region and restricted by resources, environment and natural ecological factors, the economic development, resource utilization, ecological conservation and other fields of social civilization can meet the maximum social economic development burden, including the total amount of population, economic scale and developmental speed, required by the management target of sustainable development.

2.2 The evaluation method of ecological carrying capacity As for the quantization of ecological carrying capacity, scholars at home and abroad put forward many visualized and easy-operating methods and models. They mainly include different methods of resources and demands, the model analysis method of sustainable environment carrying capacity, comprehensive evaluation method of ecological carrying capacity, system dynamics method, gray system method, fuzzy synthetic evaluation method and ecological footprint analysis and some other evaluation methods[3]. Based on the complexities of getting and abandoning the statistics of ecological carrying capacity, the ecological footprint analysis is chosen as the method for evaluating ecological carrying capacity.

2.2.1 Ecological footprint analysis. Ecological footprint analysis is a biophysics method used for measuring the degree of sustainable development, that is to say the quantitative index based on land area, raised by Canadian economist, Willian Rees in 1992. Ecological footprint analysis calculates the ecological footprint from the phase of demand and calculates ecological carrying capacity from the phase of supply, then through comparing the two aspects to evaluate the sustainable development situation of study object[4]. During the process of evaluating, different resources and energy use types are converted to six kinds of bio-productive land area, such as farmlands, grassland, forests, construction land, fossil energy land and waters (the six land types are assumed to be mutual exclusive in space). Taking the different ecological production of the six land types into consideration, the area calculated of each land type should multiply by an equivalence factor. That is to say, the area of the existing farmlands, pastures, forests, construction lands and sea multiply by the related equivalence factors, and then the ecological carrying capacity will be obtained. In order to conduct direct comparison, the differences between the local production and world average production represented by the production area of certain biology can be adjusted by "yield factor".

2.2.2 Calculation of ecological carrying capacity. According to the ecological footprint analysis, the formula used for calculating ecological carrying capacity is as follows:

$$EC = N \cdot ec = N \cdot \sum (r_j \cdot a_j \cdot y_j)\ (j = 1, 2, \ldots, 6) \qquad (1)$$

In the formula, EC refers to the ecological carrying capacity of the regional total population (hm^2); N is the number of people; ec is ecological carrying capacity per capital; r_j is balance factor; a_j is the real average area of the jth ecological production land; y_j is the yield factor.

During the process of calculating, due to the different production capabilities of the six types of ecological production lands, the results need adjusting, so as to collect the results and compare them with others. The balance factor is the balance area obtained by collecting the land areas with equivalent productivity after adjusting each kind of ecological production land. According to relevant data, the balance factors of fossil energy land, farmland, pasture, grassland, forest, construction land and maritime waters are 1.1, 2.8, 0.5, 1.1, 2.8 and 0.2 respectively (Rees&Wackemagel. 1994)[4].

3 Data source and processing method

According to the relevant statistics in *Henan Statistical Yearbook*, the data of various kinds of land supply from 2000 to 2008 can be obtained. Among the statistics, the forest area equals the sum of woodland area and garden area; the waters area is the sum of ocean continental shelf area of Henan Province and inland waters area; the construction land is the sum of residential area, enterprises and mining area, transportation land and water conservancy area. However, in fact, during the developmental process of a region, people would not reserve land just for absorbing CO_2 in particular, so in the calculation of ecological carrying capacity the fossil energy lands are excluded. In order to conduct comparison among regions, appropriate adjustment is required by using yield factors. The yield adjustment factor is the quotient obtained by dividing biological productivity of the local area per unit by global average biological productivity. If the yield adjustment factor is bigger than 1, then it indicates that the biological productivity or the capability of absorbing wastes of the local area per unit is higher than the world average level, or vice versa. The area after yield adjusting is called" yield adjustment area". In the paper, the yield factor is obtained from the comparison between productivity of various kinds of production space and the global average productivity, and the value of it equals the quotient of dividing the average productivity of various kinds of ecological productive lands in Henan Province by global average productivity.

4 Results and analysis

4.1 The calculation of ecological carrying capacity in Henan Province On the strength of the initial data and formula (1), the carrying capacity per capita of each land type in 2008 (Table 1) and the ecological carrying capacity of Henan Province from 2000 to 2008 (Table 2) can be obtained. And then based on the results calculated the dynamic structure figure of ecological carrying capacity per capita of Henan Province from 2000 to 2008 can be drawn (Fig. 1).

4.2 The ecological carrying capacity analysis of Henan Province

4.2.1 From the perspective of ecological supply. It can be seen from Table 1, that the ecological products and services provided by farmlands, construction lands and woodland account for 56%, 37% and 5% of the whole system respectively, which take the overwhelming majority of the whole ecological system and are the major components of ecological carrying capacity. So the importance of farmland and woodland in ecologi-

cal system can be seen. In the ecological carrying capacity, farmlands take the largest responsibilities. The ecological supply of farmland accounts for 56%, while that of water grassland and fossil energy land only account for 1%, 1% and 0, so the biological resources and energy should be made up for by trade adjustment. Hence, in order to maintain regional development, we need to import the lacked resources from other regions to balance ecological demand and replenish the ecological gap, which will cause pressure to the external regions.

Table 1 The ecological carrying capacity per capita of the six kinds of lands of Henan Province in 2008

Land types	Real area per capita//hm^2	Yield factor	Equivalence factor	Ecological carrying capacity per capita//hm^2	Proportion of ecological carrying capacity per capita //%
Farmland	0.072 6	1.46	2.8	0.296 8	56
Grassland	0.038 0	0.15	0.5	0.002 9	1
Waters	0.025 1	1	0.2	0.005 1	1
Forest	0.027 2	0.91	1.1	0.027 3	5
Fossil energy land	0	0	1.1	0	0
Construction land	0.047 1	1.46	2.8	0.192 1	37
Total	0.21			0.524 2	100

Table 2 The ecological carrying capacity per capita of Henan Province from 2000 to 2008

Year	Ecological carrying capacity per capita hm^2	Year	Ecological carrying capacity per capita hm^2
2000	0.535 6	2005	0.482 8
2001	0.535 0	2006	0.491 1
2002	0.521 1	2007	0.493 8
2003	0.493 4	2008	0.524 2
2004	0.493 8		

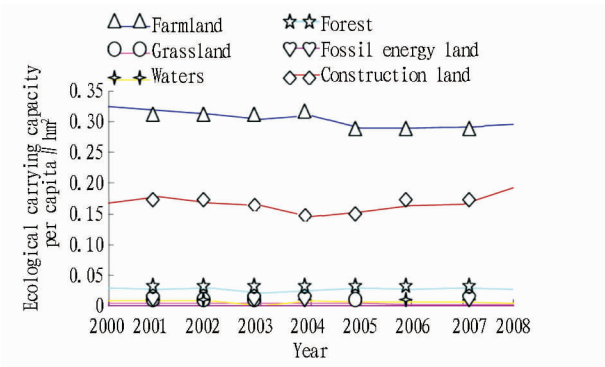

Fig.1 The dynamic structure figure of ecological carrying capacity in Henan Province from 2000 to 2008

4.2.2 From the perspective of dynamic structure of ecological carrying capacity. It can be seen from Table 2 and Table 1 that the supply of ecological carrying capacity in Henan Province is asymmetric. In various kinds of lands, the supply capacity of farmland is falling and that of construction land is increasing slightly. Among the six kinds of lands, farmlands, grasslands and construction lands have fairly larger ecological gap, among which the ecological supply of fossil energy land is 0, and only the construction lands stay in ecological surplus state.

4.2.3 From the perspective of statistics. Under the current population and consumption level of Henan Province, the economic activity has surpassed the ecological carrying capacity extent of natural system. Therefore, with the development of economic and social development of Henan Province, on one hand, the notably enhancement of consumption capability and consumption level will directly lead to the increase of ecological demand; on the other hand, if the population growth could not be controlled effectively, the resources per capita would dwindle. The results will be that the natural ecological system can not satisfy the continuously increasing demands of people, the ecological balance will be broken and ecological deficits will continue to exist.

4.3 The problems of ecological carrying capacity of Henan Province

4.3.1 The imbalance among population, natural resources and economic resources inflicts bad impact on the implementation efficiency of sustainable development of ecological carrying capacity in Henan Province. The mounting population is likely to cause excessive and reckless lopping and serious water loss and soil erosion; the surge of non-production land; occupying and using land illegally and the serious phenomenon of land waste. Statistics show that, in recent years, the area of water loss and soil erosion in Henan Province has come to 61 200 hm^2. Land use in Henan Province bears great burden and the land fertility faces apparent slide. Relevant data shows that the multiple-cropping indices of farmlands in Henan Province have increased from 150% at the beginning of the liberation to over 170% in 2008, and the farmlands with less than 1% of organic account for more than 50% of the total farmland. The relevant land resources carrying capacity of Henan Province increased in step with its relevant economy carrying capacity in 1994 and its contribution to comprehensive ecological carrying capacity showed the stable but slight uptrend, after 1994, with the speeding up of economic development, the elevation of land resources carrying capacity was far less than the elevation of economic carrying capacity, and its contribution rate to comprehensive ecological carrying capacity also decreased progressively, which deceased from 0.602 in 1994 to 0.492 in 1996, and then to 0.483 in 2008. The figures show that in recent years, the swift growth of relevant economic carrying capacity is based on the relevant decrease of natural resources carrying capacity and the increase of GDP is realized at the cost of natural resources inventory decrease and the quality deterioration. All of the above mentioned problems show the conflicts between population, natural resources and economic resources in Henan Province and theses problems still remain unsolved.

4.3.2 The underdeveloped economy affects the sustainable development of ecological carrying capacity in Henan Province. The economic resources carrying capacity in Henan Province presents the continuous and progressive uptrend, the statistics show that in 1990, the GDP in Henan Province was 93.465 billion yuan, in 2008, the figure rose to 513.766 billion yuan, ranking the fifth in China, 4.5 times against that in 1990. Calculating according to comparable price, the annualized growth rate is 19.7%. In 2008, the GDP per capita attained 5 444 yuan, 4 times more than 1 090.6 yuan in 1990. Calculating according to comparable price, the annualized growth rate is 16.9%. However, comparing with the eastern developed regions, its contribution rate to ecological carrying capacity is relatively insufficient, and there is still huge potential needs developing.

4.3.3 The overburdened population leads to the insufficient ecological carrying capacity in Henan Province. From the above statistics, it can be seen that as a underdeveloped province in central China, the ecological supply is insufficient in Henan Province and the population continues to stay in an overburdened and seriously overburdened state. That is to say, a large population is still the key problem which affects the economic and social development and the essential factor which chokes the sustainable development of ecological carrying capacity of Henan Province. Problems and conflicts arising from the coordinating development of population, economy, society, resources and environment and from the sustainable development has close relations with the overburdened population.

5 Countermeasures and suggestions

Ecological carrying capacity is the threshold of the ecological system, functions for maintaining and modulating ecological system[5]. Surpass the threshold, ecological system would lose the ordinary ability to maintain natural environment system, the natural environment system would be damaged and the ecological system would be degraded to lower level. Therefore, in order to solve the problems of ecological capacity in Henan Province, the countermeasures should be put forward by circling ecological system threshold protection.

5.1 Establishing the idea of ecological economy and recycling economy development and promoting the transformation of economic growth

5.1.1 Taking industrial eologization road. We should optimize industrial structure, take new industrial road, persist in using informatization to propel industrialization and promote the transformation of industrial development from processing to research and innovation base. The ecological industry, ecological agriculture and ecological tourism should be vigorously developed, so as to enhance the proportion of the tertiary industry and promote the all-around upgrade of industrial structure. The economic growth should be boosted by optimizing environment, such as restricting and abandoning the industries with high input, high energy consuming, high pollution and low output. The environmental protection industry and resources recycling industries should be vigorously developed. In addition, the new technologies and new industries of energy saving and environment protection should be promoted, especially, using the modern technology or the energy saving and pollution reducing technology to reconstruct the traditional industries and reduce the reliance on resources and damages on environment during the process of industrial development.

5.1.2 Rationally adjusting the industrial layout. The government should integrate the existing industrial layout by the request of ecological function region, regional environmental capacity and the conditions of resources. The government should deepen the industrial developmental space through the balanced, different and ecological adjustment, and then realize the consistency of industrial layout and ecological environment protection. Besides, the government should boost the industrial clustering across the region on strengthens of varied natural conditions, highlight the distinctive features of industrial development and arrange the industrial development reasonably. To be specific, relative to the places, such as Zhengzhou, Luoyang, Jiaozuo and Xinxiang, whose economic resource carrying capacity contribute more to comprehensive ecological carrying capacity, should display the advantages in terms of capital, management and technology and give priority to developing technology intensive industries, capital intensive industries and environment friendly industries. Thus, the pressure caused by overburdened population to comprehensive ecological carrying capacity would be reduced as a whole and sustainable development would be realized. As for the southeastern Henan Province, whose natural resources carrying capacity has high contribution rate to comprehensive carrying capacity, should fully display its water resources, labor forces, fertile soil and other advantages for developing ecological agriculture and take actions that suit the local circumstances to develop distinctive agriculture, labor economy, recycling economy, tertiary industry, so as to shift surplus rural labors and to promote the development of local economy.

5.2 Taking the developmental path of using the resources intensively and implementing the strategies for sustainable use of resources

5.2.1 Strategies for the sustainable use of land resources. The strategies for the sustainable use of land resources cover effectively protecting farmlands and enhancing the ecological benefit and economic benefit of land resources. The government should strengthen the implementation of the basic farmland protection regulations and strictly control the occupation of basic farmlands by various kinds of constructions. Furthermore, the government should implement the compensation system according to the law and improve the land use efficiency. In addition, the government should operate various kinds of agricultural lands intensively and open " three high " agriculture concerning high yield, high efficiency and high input; fully make use of the market to allocate land resources; guide investment subjects to positively participant in the farmland resource protection work and farmland supplementation work through researching market operation system.

5.2.2 Strategies for sustainable use of water resources and energy resources. The strategies for the sustainable use of water resources include constructing the water saving system of social development, exploiting water resources and ensuring the sustainable development of water resources. The govern-

ment should allocate the water for production, daily life and ecology reasonably and guide the reasonable use of water resources; propaganda the importance of water-saving and cultivate citizens' consciousness of water-saving and improve the use efficiency of water resources; display the regulatory role played by water prices, publicize water-saving technology, accelerate the technical reform of high water-consuming industries and construct water-saving society. In addition, the strategies for the sustainable use of energy resources include constructing ecological energy structure, enforcing industrial energy-saving and publicizing life energy-saving. Hence, the government should enact the strategies of energy safety, energy cleanness, and energy saving, adjust energy structure and establish ecological energy structure, so as to ensure the sustainable use of energy; restrict the energy saving level of pillar industries and enforce the management of energy-saving; promote the use of new energy-saving technologies and materials and promote energy-saving in the fields of construction.

5.3 Strictly controlling the total sum of population growth and enforcing the crisis awareness of resources and environment of the entire population in China

5.3.1 Regulating and controlling the scale and structure of population. In order to lighten the population burden of the society and to fit the population growth to the growth of production means and livelihood means, the population growth must be controlled, and the population growth and the reproduction speed of population should go hand in hand with the speed of labor productive forces to satisfy the social economic development demands. The government should improve the population quality, optimize population structure, cultivate human resources and add the stocking of human capital. Besides, much efforts should be made on deepening the implementation of the nationwide people' science and quality project, including farmers' science and quality project, urban and town labors' science and quality project, cadres and civil servants' science and quality project, science education and training and some other quality-building projects, so as to improve the labors' science and culture quality from all-around aspects and realize the complementation and flow of human resources to provide intellectual support for the economic and social development.

5.3.2 Cultivating ecological culture and ecological behavior norms. Henan Province is experiencing rapid economic growth. Without strong resources support for the high-consuming and high population way of economic growth, the losses caused by energy conflicts will reduce, only by enhancing the environment protection awareness of workers and enterprises. Therefore, the government should vigorously promote ecological civilization; lift environment awareness to ecological awareness, development awareness and ethnic awareness; bring ecological civilization into the whole process of national education and the process of ideological civilization construction; enforce people' consciousness, initialness and creativity of environmental protection and strengthen the sense of vocation and the sense of duty in ecological construction. In addition, the government should carry out green strategy to develop clean production and reduce the population in the production process; develop green industry and reduce the damage to ecological environment during the consumption process.

6 Conclusions

Ecological carrying capacity is more than the ecological science problems, but closely related to humanity social sciences concerning the whole social development. In the current stage, the precise results of ecological carrying capacity can not be obtained. Affected by the human social and cultural factors, the value of ecological carrying capacity is determined to be a approximate value. The quantitative estimation must apply the method of combining subjective and objective factors. As for the social cultural factors, the subjective methods should be applied and as for the natural environment factors, the mathematics measurement methods are applied, and then the calculation method for calculating ecological carrying capacity can be established. The most notable features of using ecological footprint analysis to research the ecological carrying capacity problems in Henan Province are concise and easy to operate comparing with traditional evaluation of sustainable development. Furthermore, ecological footprint analysis builds direct relations with supply and quantitative resources, so it is effective in evaluating the effects of human activities on ecological environment.

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