CALCULATION OF RESOURCES CARRYING CAPACITY BASED ON ECOLOGICAL FOOTPRINT IN BEIJING MOUNTAINOUS AREA

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Abstract: The issue uses ecological footprint method to research 7 target counties of Beijing and gains the per capita ecological deficit after 12 percent areas deduction for biological diversification. We found that target region has a magnified trend of ecological deficit and then, we try to offer some proposals about how to develop the mountainous counties.

Keywords: Beijing mountainous county, ecological footprint, resources carrying capacity, ecological deficit

1. INTRODUCTION

According to 'the eleventh five-year plan' of Beijing and 'The overall urban planning of Beijing (2004-2020)', Beijing mountainous areas are classified as Ecological Conservation Regions. The progress of mountainous areas is favor for constructing a comprehensive construction well-off society，expanding the domestic market, and humanizing the development of urban and county.

Mountainous areas are the ecological conservation regions, protected field of wellspring, civic leisure place and ecological protective screen for maintaining benign environment of Beijing. These areas have already carried on several ecological conservation region projects to protect and renovate ecological resources, which in turns play a very important role in improving ecological environment of Beijing that securing realization of Green Olympics idea. Three types of leading industries, special forest fruits, green farm, ecological tourism, have been developed very well, satisfying citizen's growing needs for being health, going back to nature, as well as enjoying the agriculture for resting and so on. Therefore, it is meaningful for new counties construction in mountainous areas.

Quantitative measurement for calculating regional resources carrying capacity has already become very important in recent years. Carrying capacity conception origins from ecology, meaning 'The organism numbers a community could carry based on the existing resources.' We can analyze the regional resources environment capacity according to two rules, 'the speed of social production can not exceed the speed of earth's decomposition and reproduction.' and 'materials basis of productivity and biological diversity can not be damaged', from the view of sustainability. As for quantitative evaluation for resources and environment carrying capacity, there have been many researches in the world and a serious of index and methods are available. Among them, ecological footprint is developed comparatively fast. It is created by Canadian professor William Rees in 1992(William ER, 1992), soon later he and his student Mathis Wackernagel introduced how to use it for calculating in details(Wackenagel M, William ER. 1996) and gained ecological footprint in 52 countries and areas. Internal scholars have tracked the ecological footprint method. These researches include static analysis in a certain point of time, like calculation and conclusion of ecological footprint in Zhangye district, 1995, Gansu province, 1999(Zhongmin Xu, Zhiqiang Zhang, Guodong Chen. 1996) and dynamic analysis in certain regions at certain time, taking China ecological footprint during 1978-2003 (Min Chen, Lijun Zhang, Rusong Wang, 2005), and supply and demand of ecological footprint since 'Reform and Opening' (Xiaoqing Zhong, Yongliang Zhao, Shan Zhong, 2006). These researches covered several levels of county, region, and city, hoping to find the effects of human beings on the local biosphere. However, there have not many researches referring to counties by far. This issue is planning to apply ecological footprint method to the research of countryside ecological carrying capacity calculation, measuring the supply and demand for ecological footprint based on the consumption and production, and then judge whether counties are in ecological surplus or deficit. Moreover, from this judgment, we will find rural population's effects on the biosphere, and try to offer a new research method for analyzing the resources carrying capacity for new county construction.

2. CONCEPTION, CONNOTATION, MODEL AND CALCULATING STEPS OF ECOLOGICAL FOOTPRINT

2.1 Concept Connotation of Ecological Footprint

Biosphere that human depend on not only offers various materials for human living, such as biological and energy resources, but decomposing place for all the waste coming from human consumption. Whether biosphere could play its role and being used forever depend on whether effects of human activities are within biosphere's hold value. Ecological footprint means how many biological productive land areas are needed for maintaining resources consumption along with waste absorption under a certain population, consumption level, and economical condition. It is used to evaluate effects of human activities on biosphere, whose essence is to change the compare between supply and demand of regional resources into compare between supply and demand of land, which could be gained through calculation of ecological footprint and ecological carrying capacity of target region. The hold value of biosphere is called ecological carrying capacity. The result of compare between ecological footprint and ecological carrying capacity (ecological surplus or ecological deficit) indicates whether human use biosphere excessively.

Calculation of ecological footprint is based on following assumptions: (1) the consumption data of regional biological and energy resources, namely detailed statistics of residents' consumption in target region is available; (2) the majority biological resources production consumed by people in target region and waste from biological and energy resources consumption can be converted into certain areas of land; (3) giving weight to each type of land (equivalence factor and yield factor), transfer it into a standardized global unit with world average production ability so that world compare is possible; (4) each type of land use is exclusive, therefore the total demand can be gained by plus the areas of resources use and waste absorption; (5) the total land supply is the current land use condition in target region in a certain time; (6) through comparing the total supply and demand, we can find the human effects on biosphere. Ecological surplus implies that effects are within hold value, and ecological deficit implies human effects exceed hold value, which is unsustainable.

2.2 Model of Ecological Footprint calculation

Human's producing and living consumption is made of ecological resources consumption and energy consumption. Ecological resources can be divided into produce, animal product, fruit, and wood. Energy consumption includes: coal, electric power and so on. In the rural areas, residents get their food main from local place, but their energy consumption depends on outside production, of course to some extent depends on local biological productivity, like stalks and firewood. This issue assumes that rural biological resources consumption is satisfied by local production and there is no interregional exchange, while the demand for energy consumption is totally covered by outside import. In the ecological footprint model, the main effects of energy consumption on region are exhausting gas' assimilation produced by human consumption. There is no influence by using ecological footprint method.

All the consumption items researched by ecological footprint method are classified into six types of biological productive areas, cultivated land, forest land, grass land, building site, fossil energy land and waters. The conception of biological productive area is a standard for measuring various natural resources. Because of different ecological productivity of these six types lands, in order to shift them into lands with the same biological productive area so that we can calculate the sum of them to find the ecological footprint and ecological carrying capacity, each type of biological productivity should multiply an equivalent factor, which is used to describe a certain land's potential biological productivity with given input (such as water and fertilizer), but not considering current management. Equivalent factor of a certain type of biological productive area is equal to the ration between average ecological productivity of this type all over the world and average ecological productivity of all the biological productive areas in the world. Current using equivalent factor is 2.8 for cultivated land and building site, 1.1 for forest and fossil energy land, 0.5 for grassland and 0.2 for ocean. 2.8 implies ecological productivity of cultivated land and building site's biological productive area is two times the global ecosystem's average productivity, which values 1. The area after this equivalent process is global average biological productive area with the global average ecological productivity that can be summed. Ecological footprint can be expressed as:

$$EF = N \times r_i \times \sum_{i=1}^{6} aa_i \qquad (1)$$

EF is the total ecological footprint, N is region's population, r_i is equivalent factor, and aa_i is biological productive area per capita after equivalent process. What the ecological footprint finds is the demand for the biological productive area used for production of all the resources consumed by people and absorption for all the wastes produced by people in a certain time and certain region.

Regional resources carrying capacity evaluates the supply of ecological footprint in target region which is the sum of all the biological productive lands, representing the supply ability of ecosystem's natural resources in this region. The great differences in productivity per unit area not only exist in different types of biological productive areas, but in the same type for different resource endowment all over the world when we calculate ecological carrying capacity. Such discrepancy can be expressed by yield factor which is the ratio between productivity of a certain type of land in a country or region and the global average productivity of the same kind of land, mainly reflecting the differences in land managing, technology and so on. The formula of ecological carrying capacity is:

$$EC = N \times ec = N \times \sum_{i=1}^{6} a_i \times r_i \times y_i \qquad (2)$$

EC represents the regional total ecological carrying capacity; N represents population, a_i implies biological area per capita, r_i is equivalent factor, and y_i is yield factor.

2.3 Ecological footprint's calculating steps

Calculating steps are: (1) shift the consumption of biological and energy resources into global average biological productive area with the global average ecological productivity that can be summed according to the subsidiary ledger of residents' consumption statistics; (2) analyze target region's land use status and area in the investigation period; (3) the demand part of ecological footprint multiplies equivalent factor, the supply part, namely region resource carrying capacity, multiplies equivalent and yield factor to shift into the per unit biological productive area that can be compared, and deduct 12% for biology diverse protection; (4) compare ecological footprint's demand and supply to gain the result, ecological surplus or ecological deficit.

3. CASE STUDY: ECOLOGICAL FOOTPRINT IN BEIJING'S 7 MOUNTAINOUS REGIONS.

The area of Beijing's mountainous regions amounts to 10072km^3, or 62% of that of the whole city, mainly covering in western, northern, and eastern part. 7 of all 18 counties, Fang Shan, Men Tougou, Chang Ping, Yan Qing, Huai Rou, Mi Yun, and Ping Gu, have more than 50% mountainous area up to 66.6%, 98.5%, 59.2%, 72%, 81.9%, 56.2%, and 57.2%, respectively. Beijing is one of the largest cities lacking water seriously in the world. Per capita water resource a year is less than 300m^3, only a eighth of global average and a thirtieth of nationwide average. It is regarded as water resources shortage. Surface water systems and the main reservoir are locating in the mountainous areas of Beijing. It is recon that more than 80% of water supply comes from these areas. By the end of 2005, Beijing's permanent residents are 15.38million, 3.384million of which (about 22%) are in 7 mountainous counties, whose total rural population is 1.89million.

These counties are not only the first screen for ecological environment protection, but the water conservation and supply places. Meanwhile, for their profound cultural details, and outstanding tourism advantage, they are also the important tourist resorts, and manufacture and processing base for green food. Sustainable development there is favorable to windbreak and sand fixation, water conservation, and air purification in Beijing.

3.1 Ecological footprint calculation of 7 mountainous counties of Beijing in 2004 and 2005

Wine is added to the general food consumption in statistics and it can be shifted into the need for cultivated land for its self-producing features. By the end of 2004 and 2005, rural population of 7 counties was 1.815million and 1.89million. The results of ecological footprint's supply and demand in 7 counties of 2004 and 2005 are expressed in table 1 and 2 (data resources: National Bureau of Statistics in Beijing rural socio-economic survey team, Beijing Statistics, 2005; Beijing Statistics, 2006)

Table 1. Rural population's supply and need for ecological footprint in 7 counties, 2004

Demand for ecological footprint				Supply for ecological footprint			
Land type	Total area Ha/per capita	Equivalent factor	Equivalent area Ha/per capita	Land type	Total area Ha/per capita	Yield factor	Equivalent area Ha/per capita
Cultivated land	0.2567	2.8	0.71876	Cultivated land	0.0633	1.66	0.2942
Forest land	—	1.1	0	Frost land	0.4033	0.91	0.4037
Gross land	0.1276	0.5	0.0638	Gross land	0.0011	0.19	0.0001
Building site	0.0026	2.8	0.00728	Building site	0.0747	1.66	0.3472
Waters	0.1411	0.2	0.02822	Waters	0.0304	1	0.0061
Fossil and energy	0.1033	1.1	0.14333	Co2 absorption	0	0	0
				Total supply area			1.0513
Total ecological footprint			0.9614	Biological diversity protection (12%)			0.1262
				Ecological protection area (18%)			0.1892
Ecological deficit (Ha/per capita)			0.2259	Total ecological carrying capacity			0.7359

Table 2. Rural population's supply and need for ecological footprint in 7 counties, 2005

Land type	Demand for ecological footprint			Land type	Supply for ecological footprint		
	Total area	Equivalent factor	Equivalent area		Total area	Yield factor	Equivalent area
	Ha/per capita		Ha/per capita		Ha/per capita		Ha/per capita
Cultivated land	0.2874	2.8	0.80472	Cultivated land	0.0604	1.66	0.2807
Forest land	—	1.1	0	Frost land	0.3876	0.91	0.388
Gross land	0.1554	0.5	0.0777	Gross land	0.0011	0.19	0.0001
Building site	0.0028	2.8	0.00784	Building site	0.0719	1.66	0.3422
Waters	0.1724	0.2	0.03448	Waters	0.0292	1	0.0058
Fossil and energy	0.1352	1.1	0.14872	Co2 absorption	0	0	0
				Total supply area			1.0088
Total ecological footprint			1.07346	Biological diversity protection (12%)			0.1211
				Ecological protection area (18%)			0.1816
Ecological deficit (Ha/per capita)			0.3674	Total ecological carrying capacity			0.7061

3.2 Analysis of results

From Table 1, we find in 7 mountainous regions, 2004, per capita ecological footprint, per capita ecological supply area, and per capita ecological deficit by 12% biodiversity deduction according to general method was 0.9614ha, 1.0513ha, 0.0363ha respectively; similarly, from Table 2, we find in 2005, they were 1.0735ha, 1.0088ha, and 0.1858ha. According to 'Beijing Urban Overall Plan', the guiding principle of mountainous sub-region is 'it is the ecology screen for Beijing, rich in historical and cultural heritage and natural resources. Ecosystem maintaining, water protection, moderate tourism, and eco-agriculture exploitation comes priority. Strictly control the exploitation and construction in shallow mountains, as well as strengthen greening construction and ecology recovering'. Ecological service is mountainous area's prime function.

We decide to add 18% of area for ecological environment protection, namely 30% of area deduction, so that its function can better satisfy the urban overall plan's requirement. By adjusting, from Table 1, rural population's per capita ecological deficit is 0.2259ha in 7 counties, 2004, 21.49% of total supply area, 30.70% of total ecological carrying capacity that year. From Table 2, rural population's per capita ecological deficit is 0.3674ha in 7 counties, 2005, 36.42% of total supply area, and 52.03% of total ecological carrying capacity that year. To compare them, we find the larger ecological footprint, reduced total supply area, and growing rather than decreasing total rural population lead expanding ecological deficit.

Via calculating, we also find that the optimum population in 7 counties' rural areas was about 1.389million, 0.426million smaller than the real one in 2004. In 2005, the optimum population was 1.243million, 0.647million less than real population. In a word, 7 counties' population has greatly exceeded regional ecological carrying capacity that we have to conduct ecological migration to satisfy its function orientation and ecological screen role. Moreover, great promotion of rural living level and increase of rural population lead to different optimum population in two years.

In the research program 'Beijing's mountain land-use planning and comprehensive treatment 'the researcher used ecological footprint method as well to conclude that under the production & technology and consumption condition in 2003, the population supporting capacity in mountainous areas is 1.02million. Considering its smaller cultivated land area-60927.8ha (the area here was the area of land adaptive for cultivating based on its land suitability evaluation), the optimum population in this research program was also smaller than what we have calculated. In conclusion, rural optimum population in 7 mountainous counties is about 1.2million.

4. COUNTERMEASURES AND DISCUSSIONS

4.1 Countermeasures

According to the results, per capita ecological footprint in tow years were deficits, along with upward trend. In 2003, per capita ecological footprint of China was 1.547ha, per capita deficit was 0.817ha (Min Chen, Lijun Zhang, Rusong Wang 2005); However, per capita ecological footprint was 1.8016 and per capita deficit was 1.2463ha in 2004 (Xiaoqing Zhong, Yongliang Zhao, Shan Zhong 2006). The existence of ecological deficit will inevitably undermine Beijing's capital functions of better play and 2008 'Green Olympics' perfect realization, though comparing to the whole country, the deficit was small. As a public good, a sound ecological environment can be offered only by government that we propose to seven-county ecological construction on its new building in rural places the primary position since it is not only related to the current livelihoods and long-term interests of rural people in these regions, but also to the major strategic issues such as realization of sustainable development and perfect performance of Beijing's capital function. We should insist on 'Scientific Concept of Development' to guide construction of mountainous countryside, and properly handle the relationship between ecological construction, along with the economic development, and peasants to increase income. Our proposals are as follows:

(1) Strictly control the growth of permanent residents in mountainous areas. Compensate people whose native places are in these regions but no longer live there with money to encourage them to emigrate. Speed up the

eco-emigration project, impose a strict ban on immigration in order to reduce the population growth, and decrease eco-pressure by appropriately restricting periodic immigration.

(2) Implement a serious of key ecological projects. Encouraging residents to purchase from outside to reduce the local production Via external import, changing their lands into forests to increase regional forest coverage and environmental capacity, which call for fiscal transfer payment, as well as a certain eco-compensation for mountainous residents, and establish an effective long-term mechanism.

(3) Strictly control the scales of land use, and establish a real-time monitoring system. Implement the area capping of housing.

(4) Try for resources optimization deployment under the advantageous trend of regional cooperation in Jingjin Ji region. Being a wide hinterland for Beijing and Tianjin, Hebei is the major ecological resources supplier, and they three are inseparable in the areas of ecological protection and water resources utilization. Beijing should try to incorporate closely with Hebei to strengthen the concerted mechanism of resources supply, water resources utilization, and ecological improvement in order to solve the potential problems during development. Hebei should make full use of this trend for welfare enhancing change within region under the premise of overall improvement.

4.2 Discussion

Ecological footprint does not take other human materials demands into account, though it well evaluates human consuming of biological resources and energy. When calculate ecological footprint in target region through ecological footprint method, we consider the consumption statistics account seriously. Despite 12% area deduction for biodiversity protection, we also introduced another 18% area deduction for ecological protection based on the expert evaluation so that the mountainous ecological function can be better practiced. As being a new attempt, there are inevitable many things need to be improved, though to some extent it is subjective.

Through this empirical research, the following factors will affect ecological footprint index calculation and evaluation results:

(1) The basic assumption of the model for ecological footprint analysis is that all the land types are exclusive. Because of this, land can be simplified as it only has a single function, and this simplification process makes land’s diverse functions as well as to some extent functions of alternative ignored completely, which leads to a systematic error of less ecological footprint supply.

(2) As mentioned in this issue, the factors included in calculating model

are not enough. Particularly we should focus on main factors that limit target region's development so a better measurement of local eco-consumption and a more precise conclusion of local eco-consumption can be gained.

(3) With the rise of tourism and the existence of a large floating population, when we calculate the demand for the total ecological footprint, the final theoretic result will be inevitable lower than the actual if the population value used in our model only comes from statistical yearbook.

(4) Statistical data has directly determined the conclusions' accuracy and reliability.

To sum up, ecological footprint is a research method based on data of present situation which is used to evaluate human activities' effects on biosphere and its results have a certain practical guiding significance.

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