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ECOLOGICAL FOOTPRINT-BASED ENVIRONMENTAL IMPACT ASSESSMENT OF STRUCTURAL ADJUSTMENT OBJECTIVES FOR OVERALL LAND UTILIZATION PLANNING-AN EMPIRICAL STUDY BASED ON LINXIANG CITY

Y. Z. Liu[§], X. Zhou, Y. Chen, Z. Zhang[*] and L. L. Zhou

School of Resources and Environment Engineering, Wuhan University of Science and Technology,Wuhan, China
[*]School of Business, Hubei University, Wuhan, China
[§] Present address: School of Resources and Environment Engineering, Wuhan University of Science and Technology, Qingshan District, Wuhan430081, China
[§] Corresponding author:Liuyanzhong@wust.edu.cn;Lyz0118@126.com

ABSTRACT

The ecological footprint model is modified pursuant to the characteristics of the overall land utilization planning of Linxiang City to conduct the ecological footprint accounting of the structural adjustment objectives of the planned land. The results show that compared to 2005, the total ecological capacity will rise to some extent in Linxiang City by the end of the planning period, the total ecological profit/loss of consumption will change from an ecological profit to an ecological loss, the total ecological profit/loss of output will present a growing ecological deficit. The sustainable ecological loss will decline to some extent, but the degree of ecological sustainable development will be still maintained at a higher level. The research proves thatthe structural adjustment objective of the planning land determined in the overall land utilization planning of the city will alleviate the pressure on the ecosystem created by the implementation of the planning, and help increase the sustainable utilization level of the land ecosystem. The research concludes that the major way to further promote ecological sustainability of Linxiang City is to increase the resource yield rate, resource utilization rate and intensive land utilization, and control excessive population growth.

Keywords: Overall land utilization planning, structural adjustment objectives of land utilization, improvement of ecological footprint model and environmental impact assessment.

INTRODUCTION

The implementation of the strategic objectives of the structural adjustment of the overall land utilization planning delivers a very small impact on the environment, but a far-reaching, complex, macro, abstract and irreversible impact on the environment with the conduct of land utilization. Yet, the environmental impact assessment of the implementation relates to the significant issues of regional ecological security, sustainable economic development and sustainable social development. In China, the general planning system for land utilization includes five levels: national, provincial, municipal, county and township. The environmental impact assessment of the county-level planning is very limited due to the policy that the planning at the level of a city supervising districts and above must receive the environmental impact assessment. Compared to the planning at the city level and above, the county-level planning is closer to the actual conditions and delivers a more direct impact on the environment. For this reason, it is imperative to research the environmental impact assessment of the structural adjustment objectives for the county-level planning to explore the environmental impact assessment and implement a sustainable development strategy. Linxiang City, a county-level city in the central region of China, has a superior geographic location and rich water resources, and faces diverse, complex land utilization. Therefore, the results of the research on the environmental impact assessment of the strategic objectives of structural adjustment of its overall land utilization planning are representative to some extent.

The ecological footprint model designed by the Canadian researchers Rees (1992, 1994) and Wackernagel (1994) connects consumption and different types of lands supporting the consumption demand. It converts the consumption of materials into the areas of six types of ecological production land (land and waters having the ecological production capacity), including farmland, woodland, grassland, finished land, fossil energy land and water areas to measure human consumption's occupation of ecological resources and impact on the ecological environment. It is based on the basic precondition that different types of ecological production lands are mutually exclusive in space, and one land can't be a forest, arable land or grassland simultaneously. This precondition makes it possible to add up different types of ecological production lands. The model has the uniform unit, broad scope of comprehensive application of the simplified calculation account and other advantages (Wang et al., 2002). So far, the model has been widely used to study the sustainable development assessment of different regions, dimensions (Wu et al., 2006) and industries (Erb 2004; Xi et al., 2004; Li et al., 2005; Fan et al., 2005). In the past years, the Chinese researchers have preliminarily explored the application of the ecological footprint model to the strategic environmental impact assessment of the overall land utilization planning (Chen and Mao, 2007; Cai et al., 2010; Shao et al., 2011; Bai 2012) , but currently, they are still exploring the applicability of the model.

II. Profile and Improvement of Ecological Footprint Model

A. Calculation method of ecological footprint

The ecological footprint model consists of three calculation indicators: ecological footprint, ecological capacity and ecological profit/loss.

(1) The ecological footprint (*EF*), meaning the ecological demand, is the true ecological production area required by the resource consumption and waste absorption of the population or economy in a country or region. It is calculated with the following formula:

$$EF = N \; r_j \sum_{i=1}^{n} (c_i / p_i) \quad (1)$$

In the formula(1), *N*is the total population, p_i is the average production capacity of consumption item *i*, c_i is the per capita consumption of commodity *i*,*n*is the number of consumption items, and r_j is the balance factor corresponding to ecological production land type *j*. The last variable r_j is the average ecological productivity, which is the ecological production land *j* divided by the average ecological productivity of all types of ecological production lands in the world.

(2) Ecological capacity (*EC*), meaning the ecological supply, is the practical ecological production area owned by the population of a country or region. Calculation formula:

$$EC = N \sum_{i=1}^{n} (a_j r_j y_j) \quad (2)$$

In the formula(2): a_j is the per capita area of ecological production land type *j*, and y_j is the yield factor of ecological production land type *j*, which is the ratio of the average productivity of ecological production land *j* to the average productivity of the land of the same type in the world.

During the calculation of the ecological capacity, a 12% biodiversity production area shall be deducted to protect the biodiversity.

(3) Ecological profit/loss. An ecological profit (*ER*) will appear when the ecological capacity of a region is bigger than the ecological footprint, and an ecological deficit (*ED*) will appear when the ecological capacity is smaller than the ecological footprint. Calculation formula:

$$ED\,(ER) = EF - EC \quad (3)$$

A. Improvement of the Model

1. Classification of ecological production lands

Nature reserves (including unused grassland, alkaline land, marshland, sandy land, bare land and other unused lands) have important ecological values and should be included in the ecological capacity calculation. However, these reserves don’t directly provide human consumption products, so they can be excluded from the ecological footprint accounting. For this reason, this paper divides the ecological production lands in the planning region into seven types: farmland, grassland, woodland (including garden land), waters, fossil energy land (including mining land), construction land (excluding mining land) and nature reserve.

2. Classification of footprint accounting type

The traditional ecological footprint model is a method used to measure the extent of sustainability of a region. The research on the ecological footprint assessment often finds that the less developed a region is and the lower living standard people have, the stronger the sustainability will be. This, however, conflicts with the concept of sustainability. The overall land utilization planning mainly provides the function of ecological capacity. When the ecological footprint model is used for the environmental impact assessment of the overall land utilization planning, it will be necessary to perform classified accounting of the ecological footprint defined as “consumption – yield” to be more suitable for the purpose. According to the characteristics of the overall land utilization planning, this paper accounts the ecological footprint of consumption based on the consumption and the ecological footprint of yield based on the yield in the research region. The ecological footprint of consumption measures the extent to which the population in a region require from the ecological production lands from the perspective of resource consumption, and the difference with the ecological capacity will be the ecological profit/loss of consumption. At the same time, the ecological footprint of yield measures the extent to which people inside and outside the region require from the ecological production lands from the yield corresponding to the resource consumption account. Its difference with the ecological capacity will be the ecological profit/loss yield. The yield deficit represents the boundary of the ecological deficit that can be borne by the land in the region. The “difference” between the ecological profit/loss of consumption and that of yield, or the sustainable ecological loss index, measures the extent of sustainable ecological land utilization in the region.

II. Ecological Footprint Assessment of Strategic Objectives of Structural Adjustment for overall land utilization planning of Linxiang City

A. Analysis of structural adjustment objectives for overall land utilization planning of Linxiang City

This paper has compared the objectives of the overall land utilization planning of the city to the current structure and the major control indicators for land utilization (Table 1). The results show that the areas of construction land and waters will grow a bit, while the areas of the other major lands will present a declining trend. However, the areas of forest land, grassland and construction land will not meet the control indicators of the planning issued by the higher level. The areas of forest land and grass land are a bit lower than the control indicators, while the total area of construction land is roughly equal to the controlindicator.

Analysis and forecast of resource "consumption-yield" account: The resource accounts for the ecological footprint accounting in this paper mainly include the ecological "consumption-yield" account and energy "consumption-yield" account, and the resources in both accounts support most of the production and consumption activities of the population in the research region. The ecological "consumption-yield" account mainly includes food crops (grains, beans and potatoes), oil crops, cotton, hemp, sugar canes, vegetables, fruits, tea, tung tree seeds, tea oil crops, palm sheets, dry bamboo shoots, woods, meats, poultry eggs and aquatic products, while the energy "consumption-yield"account mainly includes electric power, coal, liquefied petroleum gas and gasoline. The data come from the 2010 statistical yearbook of Linxiang City and the forecast of the consumption and yield of relevant resources in 2020. (Table2).

C. Values of balance factor and yield factor: This paper adopts the values of the balance factor and the yield factor in the Wackernagel traditional accounting model for the ecological production lands. However, this paper modifies the model by setting the balance factor of nature reserves to the value defined by Lai Li in the balance factor algorithm for unused lands, the yield factor of the nature reserves to the value of 1, and the yield factor of farmland to the ratio of the unit food yield of Linxiang City to the world's unit food yield. (Table 3).

Structural adjustment of land utilization: Ecological footprint accounting and analysis: With the improved model, this paper accounts Linxiang City's ecological footprint of consumption, ecological capacity for consumption, ecological profit/loss of consumption, ecological footprint of yield, ecological capacity for yield and ecological profit/loss of yield in 2005 and 2020 respectively (Table 4, 5 and 6). The actual land areas used to account the ecological capacity come from the current land utilization data of the cityin 2005 and the land planning objective of the city in 2020 determined in the overall land utilization planning. Meanwhile, the population data come from the statistical yearbook of the city in 2010 and the forecasted population at the end of 2020 in the overall land utilization planning.

Table 4 shows that the total ecological capacities of different ecological production lands, excluding waters and construction lands, will decline to vary degrees during the planning periods, and the proportion of the ecological capacity of construction lands in the total ecological capacity will rise to some extent. The total consumption footprint will rise to varying degrees for different ecological production lands during the planning period, and the proportion of the consumption footprint of grassland and waters in the total consumption footprint will fall down. The yield footprints of all ecological production lands, excluding construction land, will rise to different degrees, but only the proportion of the yield footprint of waters in the total yield footprint will rise.

Table 1. Comparison of Objectives of Overall Land UtilizationPlanning of Linxiang City to Current Status and Major Control

Unit:*hm*²

Types	Current status in 2005	Planning by 2020	Net change in planning period	Planning control indicator	Comparison to major planningcontrol indicator
Farmland	38129.67	37410.14	-719.53	34346.90	3063.24
Woodland (including garden land)	96514.33	96103.4	-410.93	97571.82	-1468.42
Grassland	60.95	59.6	-1.35	212.71	-153.11
Consumption land (excluding mining)	11230.77	13116.37	1885.6	13115.21	1.16
Mining land	557.18	322.33	-234.85	322.33	0
Water area	12447.61	12459.31	11.7	——	——
Nature reserve	1492.72	1213.2	-279.52	——	——

table 2. Values of biological and energy "consumption-yield" accounts of linxiang city in 2005 and 2020

Unit:*t*、*kw•h*

Classification of ecological production lands	Accounting item	Consumption in 2005	Yield in 2005	Consumption forecast in 2020	Yield forecast in 2020
Farmland	Food crops	154780	277834	385181	368319
Farmland	Oil crops	1965	12980	2999	25438
Farmland	Cotton	2651	2651	3690	4256
Farmland	Hemp	2322	2322	1231	1070
Farmland	Sugar canes	525	1625	497	6970
Farmland	Vegetables and fruits	73904	275268	90868	254681
Woodland	Tea	44	4700	56	6065
Woodland	Tung tree seeds and tea oil crops	224	224	1687	1557
Woodland	Palm sheets and dry bamboo shoots	85	85	523	210
Woodland	Woods (cubic meters)	30017	30017	23517	24162
Grassland	Meats	14094	53533	18491	53534
Grassland	Poultry eggs	1479	2446	1820	10387
Water area	Aquatic products	4709	24170	5980	34758
Construction land	Electricity	14595	27362	65048	26436
Fossil energy land	Coal	68110	0	345	0
Fossil energy land	Liquefied petroleum gas	2300	0	68490	0
Fossil energy land	Gasoline	10720	0	80575	0

Table 3. Values of Balance Factors and Yield Factors of Seven Types of Ecological Production Lands

Classification of ecological production lands	Farm-land	Grass-land	Wood-land	Water area	Construction Land	Fossil energy land	Nature reserve
Balance factor	2.8	0.5	1.1	0.2	2.8	1.1	0.12
Yield factor	1.73	0.19	0.91	1.00	2.19	0.91	1.00

Table 4. Total Ecological Footprint, Capacity and Profit/Loss of "Consumption-Yield" of Ecological Production Lands of Linxiang CityUnit: *hm*²

Year	Classificationof ecological production lands	Farm-land	Grass-land	Wood-land	Water area	Constru-ction land	Fossil energy land	Nature reserve	Biodiversity protection area of 12%
2005	Total ecological capacity	184700	5.79	96611	2490	68867	558	179	42409
	Percentage	46.66%	0.002%	24.41%	0.63%	17.4%	0.14%	0.05%	10.71%
	Total ecological footprint of consumption	101855	60328	270	32478	1471	35613	0	——
	Percentage	43.9%	26%	0.12%	14%	0.63%	15.35%	0	——
	Total ecological footprint of yield	210035	207716	25912	166690	2758	0	0	——
	Percentage	34.26%	33.88%	4.23%	27.19%	0.45%	0	0	
2020	Total ecological capacity	181215	5.66	96200	2492	80430	323	146	43297
	Percentage	44.84%	0.001%	23.81%	0.62%	19.9%	0.08%	0.04%	10.71%
	Total ecological footprint of consumption	219391	78332	1462	41240	6557	93314	0	——
	Percentage	49.83%	17.79%	0.33%	9.37%	1.49%	21.19%	0	——
	Total ecological footprint of yield	272785	261373	26291	239712	2665	0	0	——
	Percentage	33.98%	32.56%	3.27%	29.86%	0.33%	0	0	——

Judging from the calculation results (Table 5 and 6) and the trend charts (Figures 1、2、3 and 4) of different indicators, by the end of the planning period, the total available ecological capacity, the total ecological footprint of consumption and the total ecological footprint of yield will all present a growing trend and grow by 2.09%, 89.77% and 30.94% respectively, but all fall short of the population growth rate of 18.5%. As a result, the per capita available ecological capacity will decline by 19.85%, and the per capita ecological footprint of consumption and per capita ecological footprint of yield will grow by 60.14% and 10.5% respectively. The total ecological profit/loss of consumption and the per capita ecological profit/loss of consumption will change from an ecological profit in 2005 to an ecological deficit in 2020, and the total ecological deficit of consumption and the per capita ecological loss of consumption be 201767hm^2 and 0.3753 hm^2/person respectively. The total ecological profit/loss and per capita ecological profit/loss of yield will both suffer a growing ecological deficit. That is, the ecological deficit boundary will enlarge by 60.64% and 35.56% respectively, and the total ecological loss of yield and per capital ecological loss of yield will reach 183205hm^2 and 0.2208 hm^2/ person respectively.

Table 5. Total Ecological Footprint, Capacity and Profit/Loss of "Consumption-Yield" of Linxiang City

Unit: hm^2

Year	Total available ecological capacity	Total ecological footprint of consumption	Total ecological footprint of yield	Total ecological profit/loss of consumption	Total ecological profit/loss of yield	Population (person)
2005	311001	232017	613110	78984	-302109	486500
2020	317512	440296	802827	-122783	-485315	576500
Growth rate	2.09%	89.77%	30.94%	-255.45%	60.64%	18.5%
Loss	——	——	——	201767	183205	——

Table 6. Per Capita Ecological Footprint, Capacity and Profit/Loss of "Consumption-Yield" of Linxiang City

Unit: hm^2/ *person*

Year	Per capita available ecological capacity	Per capita ecological footprint of consumption	Per capita ecological footprint of yield	Per capita ecological profit/loss of consumption	Per capita ecological profit/loss of yield
2005	0.6393	0.4769	1.2602	0.1624	-0.6210
2020	0.5508	0.7637	1.3926	-0.2130	-0.8418
Growth rate	-13.84%	60.14%	10.50%	-231.18%	35.56%
Loss	——	——	——	0.3753	0.2208

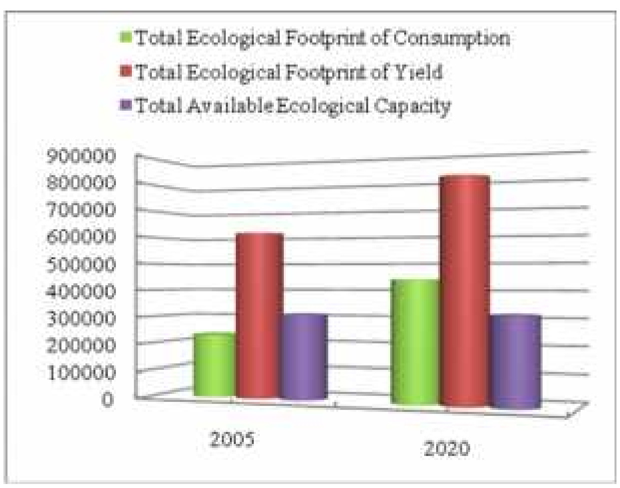

Figure 1. Trends of Total Ecological Footprint and Capacity of Consumption and Yield

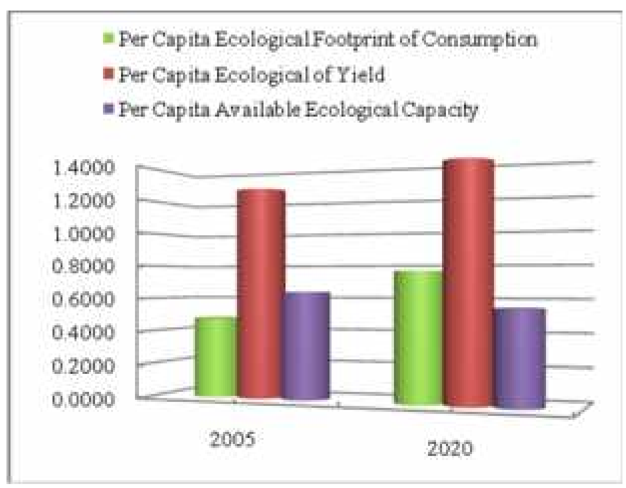

Figure 2. Trends of Per Capita Ecological Footprint and Capacity of Consumption and Yield

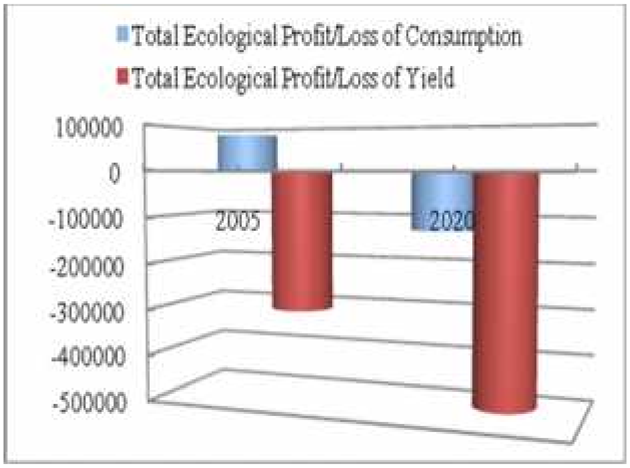

Figure 3. Trends of Total Ecological Profit/Loss of Consumption and Yield

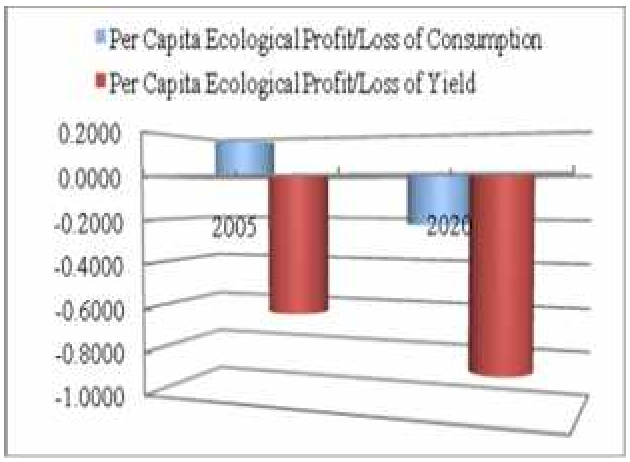

Figure 4. Trends of Per Capita Ecological Profit/Loss of Consumption and Yield

Analysis of sustainable ecological loss index: The accounting method of the ecological footprint model determines the value of the ecological profit/loss of yield is usually a deficit. This paper designs the sustainable ecological loss index (*EL*) based on the relation between the ecological profit/loss of consumption and the ecological deficit of yield to judge the extent of ecological sustainability of the structural adjustment objectives.

$$EL = \left|ED_{yield}\right| + ER_{consumption} \quad (4)$$

$$EL = \left|ED_{yield}\right| - \left|ED_{consumption}\right| \quad (5)$$

When the ecological profit/loss of consumption is a profit, formula (4) will be used, or formula (5) will be used.

The sustainable ecological loss index means the loss area of the ecological production land the region can continue to undertake as of the time point of research. If the ecological profit/loss of consumption is a profit or the ecological deficit of consumption is smaller than the ecological deficit of yield, the region can use its ecological production land area to satisfy its own development demand, and also help mitigate the ecological pressure outside the region through the foreign trade export of resources. When the ecological profit of consumption gradually changes to an ecological deficit of consumption and the ecological deficit of consumption gradually rises to be equal to or bigger than the ecological deficit of yield, the ecological production land area of the region can no longer satisfy its own development demand. Then, the region will have to transfer its ecological pressure to an external region through the foreign trade import of resources, or increase the productivity of its ecological production land. However, such potential of supply will be very limited in the foreseeable future and aggravate the ecological pressure on the region.

Judging from the sustainable ecological loss index of Linxiang City (Table 7, Figures 5 and 6), the total sustainable ecological loss index of the city in 2020 will reach 362531hm^2, representing an increase of -4.87% compared to 381094hm^2 in 2005. At the same time, the per capita sustainable ecological loss index will fall down by 19.72% due to the rapid population growth.

Table 7.Sustainable Ecological Loss Index of Linxiang City

Year	Total sustainable ecological loss (hm^2)	Per capita sustainable ecological loss index (hm^2/person)
2005	381094	0.7833
2020	362531	0.6288
Total increment	-18563	-0.1545
Annual average increment	-1238	-0.0103
Growth rate	-4.87%	-19.72%

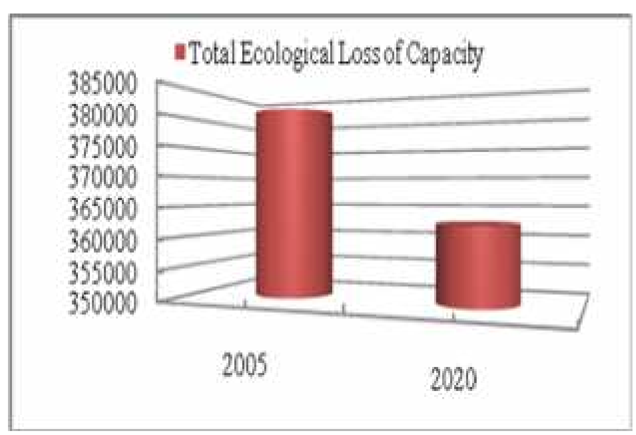

Figure 5. Trends of Total Ecological Loss of Capacity

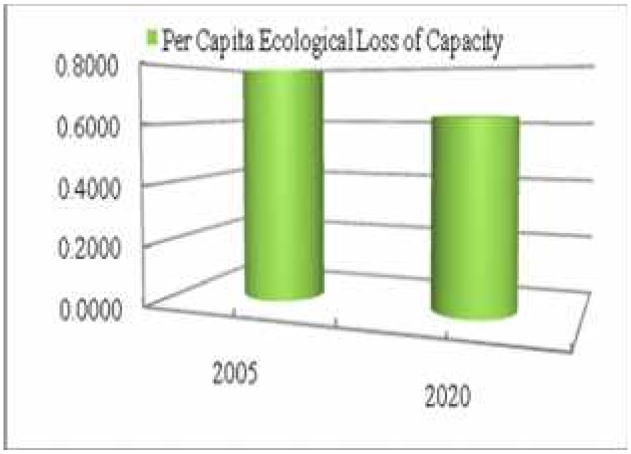

Figure 6. Trends of Per Capita Ecological Loss of Capacity

RESULTS AND DISCUSSIONS

The decrease in the sustainable ecological loss index shows that the ecological sustainability capacity of Linxiang City will decline during the planning period. However, the structural adjustment objectives for the land utilization planning of the city can effectively increase the ecological capacity, enlarge the boundary of the sustainable ecological loss, and slow down the rapid growth of the ecological deficit of consumption. The sustainable ecological loss will decline to some extent， but the ecological deficit of consumption is far from reaching the boundary of the ecological deficit of yield of the city, therefore, the degree of ecological sustainable development will be still maintained at a higher level. The overall land utilization planning will reasonably allocate and optimize the land utilization structure of Linxiang City to some extent, and the adjustment of the land utilization structure will promote the sustainable utilization of the land ecosystem.

The boundary of the total sustainable ecological deficit of the city will enlarge, mainly thanks to the increase in the yield efficiency of resources produced by farmland, forest land, grass land, waters and other ecological production lands. The city does not produce fossil energy, so the ecological production land for fossil energy will not contribute to the enlargement of the total sustainable ecological deficit.

The population growth will be the major negative factor affecting the sustainable utilization of land ecosystem. Judging from the accounting result of the available ecological capacity, the structural adjustment objectives of the land structure can increase the total ecological capacity of Linxiang City, but the population growth rate will be nearly 8.85 times the total available ecological capacity, which will lead to a falling trend of the per capita ecological capacity during the planning period, and judging from the accounting result of the sustainable ecological loss index, the total sustainable ecological loss will be lower than the population growth rate during the planning period. As a result, the per capita sustainable loss rate is 4 times the total sustainable ecological loss.

However, the ecological profit/loss of consumption will change from an ecological profit to an ecological deficit, mainly because the total ecological footprint of consumption will obviously outgrow the available ecological capacity. This indicates the extensive consumption mode, extensive economic development pattern and low level of intensive resource utilization in the city. Therefore, it is not practical to prevent the increase in the ecological deficit of consumption by adjusting the land structure to enhance the ecological capacity, and only by changing the extensive economic development pattern and improving the efficiency of resource utilization, can the city mitigate the increase in the ecological deficit of consumption in essence.

Linxiang City can effectively improve the sustainable land utilization level by formulating the overall land utilization planning, reasonably adjusting the land structure, continuously improve the extent of intensive land utilization, and continuously increasing the yield efficiency of resources.

Controlling the population growth is one of the major ways to mitigate the ecological pressure in the region and promote the sustainable land utilization.

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