The dynamic research of ecological footprint in Hunan province based on "national hectares"

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Abstract: Based on the concept of national hectares, the traditional model of equilibrium factor and yield factor have been amended, and the deep analysis has been conducted about the per capita ecological footprint and ecological bearing and its changing trends of Hunan province from 2000 to 2011; And based on the supply of various types of land situation, using the improved method, we calculate the total ecological deficit. The different calculation method of ecological footprint analysis shows that the national ha ecological footprint model and improved method of the ecological deficit calculation are more in accord with the actual situation of Hunan province. According to the influence factors of ecological profit and loss, and combining the characteristics of the economic development and resource distribution in Hunan province, we put forward the measures to reduce regional ecological deficit.

Introduction

Ecological footprint means the land area of a certain region that is required for sustaining human life. From ecology, it studies the condition of human's resource consumption and its influence on ecosystem. By doing research on natural resource supply and biological bearing, it describes the relationship between human society and the nature. After professor William Rees the Canada ecological economist, came up with this method, it has attracted immense attention for its originality, abundant connotation, clarity and operability.

As for the two problems above, this thesis takes Hunan Province for example,and follows the concept of National Hectare.It adopts dynamic equivalence factor and yield factor, and conducts time series analysis on ecological footprint and bearing to solve the singleness invariable equivalence factor and yield factor problem. At the same time, we use the improved method to calculate ecological deficit to get the total ecological deficit of different land types in Hunan Province, overcoming of inaccurate calculation results. Eventually, according to the result, we have put forward some suggestions about the proper use of resources and economic development in Hunan Province.

Methodology

"National Hectare" ecological footprint model

The difference between the National Hectare model and global hectare model is that the National Hectare uses the national average productivity instead of global productivity to calculate the equivalence factor, at the same time it calculates the yield factor taking the local data into account, and makes comparative analysis on ecological footprint and bearing as standard square national hectare. In this way, the result could better reflect the real situation of every province .

Conversion Factors

Equivalence Factor. Different kinds of land have different biological productivity. By multiplying their own equivalence factor, they could be transformed to comparable standard area. All kinds of land average biological productivity divided by total land average biological productivity is the equivalence factors of the National Hectare. The calculation formula is below.

$$q_i=\frac{\overline{p_i}}{p}=\frac{Q_i}{S_i}/\frac{\sum Q_i}{\sum S_i}=\frac{\sum_k p_k^i r_k^i/S_i}{\sum_i\sum_k p_k^i r_k^i/\sum S_i} \quad (1)$$

Qi represents equivalence factor of the type iland；

$\overline{p}_i$ represents the average productivity of the type iland （109J/hm^2）,

P represents the average productivity of all types of land in China

Qi represents the total biological output of the type i land(109J)

Si represents the biological productivity area of the type i land（hm^2）；

p_k^i represents the k kind of biological output of the type i land(kg);

r_k^i represents the average calorific value of the k kind biological productivity of the type i land(103 J/kg)。

Yield Factor. Because of the difference in environment, technology and economy between different regions, it needs to multiply converted yield factor for comparison, as even on the same type of land, the biological productivity varies. So, all kinds of land average productivity in one province divided by the same kind of land average productivity in the whole country equals to yield factor. Then provincial biological productivity land is converted to the standard square of the National Hectare. The calculation of yield factor is below.

$$y_i^z=\frac{\overline{p_i^z}}{p_i}=\frac{Q_i^z}{S_i^z}/\frac{Q_i}{S_i}=\frac{\sum_k (p_k^i)^z r_k^i}{S_i^z}/\frac{\sum_k p_k^i r_k^i}{S_i} \quad (2)$$

y_i^z represents yield factor of the type i landin z province （109J/hm^2）,

$\overline{p_i^z}$ represents the average productivity of the type i land in z province（109J/hm^2）,

$\overline{p}_i$ represents the average productivity ofthe type i land in China（109J/hm2）,

Q_i^z represents the total output of the type i land in z province(109J)

S_i^z represents the total area of the type i land in z province

Qi represents the total biological output of the type i land in China（109J）,

Si represents the total area of the type i land in China（hm^2）,

$(p_k^i)^z$ represents the k kind of product yearly output of the type i landin z province(kg);

Other coefficients refer to the meaning of equation（2）above.

Ecological Footprint Calculation

According to ecologically productivity, ecological account can be divided into biomass account, fossil energy account, construction land account to calculate.

Biomass Account. Biomass Account contains four types of land:plowland, grassland, woodland and water area. Total biomass consumption in some particular region equals to its productivity together with import minus export. The import biomass which are producedinother regionsoccupies ecological productive land of thatregions, so it couldn't impact the local environment. Although the export biomass are consumed in other regions, it occupies ourregion, so it could impact the local environment. So, as for biomass account, it uses the ecological footprint based on the production.

$$ef_i = \frac{q_i}{N} \times \sum_k^n \frac{p_k^i}{y_k^i} \quad (i=1,2,3,4) \qquad (3)$$

efi represents the average of per capital ecological footprint of the type ibiomass land（hm^2/人);

Qi represents equivalence factor of the type i land；

Nrepresents the total population of Hunan Province,

y_k^i represents theaverage of national productivity of k kind of biological product of the type i land （kg/hm^2）;

p_k^i represents the yearly output of k kind biological product of the type i land in Hunan Province(kg).

Fossil Energy Account. Fossil energy account is used to calculate land area needed by absorbing greenhouse gases released by human activities. Whether import or export, the greenhouse gases released by consumption of fossil energy needs local forest to absorb. So the ecological footprint calculation of fossil energy account is based on consumption, and our research uses consumption data about fossil energy instead of producing data. The ecological footprint calculation formula is below.

$$ef_e = \frac{q_e}{N} \times \sum_k \frac{c_k}{y_k} \qquad (4)$$

efe represents the average of per capita ecological footprint of the fossil energyland（hm2/人);

Qe represents equivalence factor of the fossil energy land；

Ck represents the consumption ofthe type k fossil energy;

Yk representsthe consumption of the type k fossil energy corresponding the greenhouse gases every national forest area absorbed（GJ/hm^2）。

Construction Land Account. Construction land includes residential land, water conservation land, traffic land, as well as industrial and mining land. As most construction land occupies cultivated land, the yield factor and equivalence factor of construction land are similar with that of cultivated land. The ecological footprint calculation formula is below.

$$ef_b = q_b \times A_b \qquad (5)$$

efb represents the average of per capita ecological footprint of the construction land（hm^2/人);

qb represents equivalence factor of the construction land；

Ab represents the area of construction land（nhm^2）。

Biological Bearing

Biological bearing means the aggregation of biological productive land area that could provide to people ,also called ecological footprint supply capacity.

$$BC = \frac{\sum_{i}^{6} A_i \times q_i \times y_i}{N} \quad (6)$$

BC represents total land per capita biological bearing in one location（ hm^2/人）;

Ai represents the area of the type i land in Hunan Province（ hm^2 ）;

Qi represents equivalence factor of the type i land；

Yi represents yield factor.

Biological Surplus/ Deficit

Traditional ecological footprint method takes the difference between ecological footprint and ecological bearing force of the six major categories of land as the number of ecological deficit, so that the land ecological deficit will be offset by other land ecological surplus, the total ecological deficit is lower.In fact, ecological surplus has physical properties, and is real land, while the ecological deficit is virtual, or just a number, and does not exist, so they do not have linear additivity [13-14]. This paper uses Fang Kai (2012) method [15], calculates the total ecological deficit according to the various types of land with the deficit data and is not cumulative data. The calculation formula is as follows:

$$EO = \sum_i EO_i = \sum_i \max(ef_i - BC_i, 0) \quad (7)$$

EO represents total land ecological depict，

EOi represents the ecological depict of the type i land，

efi represents the ecological footprint of the type i land，

BCi represents of the biological bearing capacity the type i land

Million GDP

Million GDP ecological footprint, the production of the required resources and energy of the GDP of the ecological land area, can measure the use efficiency of regional resources by calculating the ecological footprint of the unit GDP:

Million GDP ecological footprint=EF/GDP.

GDP refers to the year's gross domestic product,
EF represents the ecological footprint of all land.

Result

Based on the national hectare, the equivalence factors of our country during 2000 to 2011 are showed below. Hunan Province yield factors are showed in Tab.2during2000 to 2011.According to the calculation formula of ecological footprint and biological bearing capacity, using the equivalence factor in Tab.1 and yield factor in Tab.2, we get the data of ecological footprint and biological bearing capacity in Hunan Province during 2000 to 2011.The result are showed as Tab.3and Tab.4.

Tab.1 equivalence factors of biological productive land in China 2000-2011

(hm^2/person)

Year	plowland, equivalence factors	grassland, equivalence factors	Woodland equivalence factors	water area equivalence factors
2000	4.6474	0.0283	0.1518	0.3085
2001	4.5231	0.0319	0.1428	0.3111
2002	5.3116	0.0294	0.1621	0.3781
2003	5.3578	0.0344	0.1709	0.4040
2004	5.4272	0.0360	0.1718	0.3993
2005	5.6837	0.0369	0.1836	0.4295
2006	5.7236	0.0337	0.2097	0.4515
2007	5.3805	0.0378	0.2069	0.4463
2008	5.3472	0.0360	0.2197	0.4370
2009	5.3829	0.0361	0.1993	0.4599
2010	5.3536	0.0357	0.2165	0.4696
2011	5.3587	0.0345	0.2157	0.4744

Tab.2 yield factors of biological productive land in Hunan Province 2000-2011

(hm^2/person)

Year	Plowlandyield factors	grassland, yield factors	Woodlandyield factors	water areayield factors
2000	2.1105	1.0988	2.1439	1.1705
2001	2.0508	0.8782	2.3475	1.1951
2002	1.9459	1.2677	2.1879	1.2007
2003	1.9793	1.2233	2.0477	1.1933
2004	2.0495	1.1971	2.1252	1.1998
2005	2.0331	1.2832	2.2436	1.2202
2006	2.0745	1.5461	1.6527	1.1722
2007	1.9712	1.2629	2.4270	1.0231
2008	1.9679	1.0088	2.2291	1.0318
2009	1.8681	0.9600	1.8086	1.0291
2010	1.8321	0.9432	1.5648	1.0274
2011	1.8051	0.9334	1.6992	0.9919

Tab.3Per capita ecological footprint in Hunan Province 2000-2011

(hm^2/person)

Year	plowland	grassland	woodland	water area	fossil energy	constructi on land	sum
2000	1.0139	0.0014	0.0360	0.0073	0.0335	0.0104	1.1024
2001	0.9866	0.0016	0.0357	0.0074	0.0321	0.0109	1.0743
2002	1.1388	0.0022	0.0330	0.0090	0.0381	0.0138	1.2349
2003	1.1706	0.0026	0.0410	0.0095	0.0465	0.0158	1.2860
2004	1.2109	0.0028	0.0424	0.0094	0.0578	0.0180	1.3413
2005	1.3121	0.0031	0.0451	0.0102	0.0730	0.0205	1.4640
2006	1.3428	0.0035	0.0389	0.0104	0.0902	0.0176	1.5034
2007	1.2732	0.0032	0.0554	0.0089	0.1014	0.0191	1.4612
2008	1.1681	0.0025	0.0631	0.0087	0.1555	0.0250	1.4229
2009	1.0608	0.0023	0.0463	0.0090	0.1402	0.0346	1.2933
2010	1.0520	0.0022	0.0436	0.0089	0.1610	0.0368	1.3045
2011	1.0441	0.0021	0.0464	0.0086	0.1782	0.0418	1.3212

Tab.4Per capita ecological bearing capacity in Hunan Province 2000-2011

(hm^2/person)

Year	Plowland	grassland	woodland	Water area	fossil energy	constructio n land	sum
2000	0.5158	0.0024	0.0513	0.0066	0.0103	0.1908	0.7771
2001	0.4842	0.0026	0.0526	0.0067	0.0105	0.1803	0.7369
2002	0.5339	0.0034	0.0554	0.0082	0.0111	0.1803	0.7923
2003	0.5370	0.0038	0.0548	0.0086	0.0110	0.1852	0.8004
2004	0.5578	0.0039	0.0570	0.0085	0.0114	0.1946	0.8332
2005	0.5764	0.0042	0.0640	0.0093	0.0128	0.2023	0.8690
2006	0.5847	0.0044	0.0536	0.0093	0.0107	0.2103	0.8731
2007	0.5196	0.0039	0.0773	0.0080	0.0155	0.1884	0.8128
2008	0.5126	0.0030	0.0749	0.0078	0.0150	0.1880	0.8014
2009	0.4861	0.0028	0.0547	0.0082	0.0109	0.1783	0.7411
2010	0.4611	0.0027	0.0501	0.0081	0.0100	0.1692	0.7012
2011	0.4518	0.0025	0.0538	0.0079	0.0108	0.1658	0.6926

Dynamic analysis of ecological footprint

Analysis of ecological footprint

Variation analysis. The change rate of ecological footprint and ecological carrying capacity of Hunan Province in 2000-2011 is shown in Fig. 1. The changes of ecological footprint and ecological carrying capacity werefluctuating, and overall the change rate of ecological footprint was higherthan that of ecological carrying capacity. The change rate of ecological footprint was increasing, and the annual growth rate reachedthe maximum of 1.5034in 2006, and the change rate of ecological carrying capacity was negative in 2000, and the ecological carrying capacity increasedrapidly in 2003. Although the change rate of 2001-2005 is positive, its growth rate was significantly smaller than thatof the ecological footprint, so that the speed of supply increasedfaster than demand, making the ecological deficit increasingly larger.In the years of 2007-2010, the change rate ofecological footprint and ecological carrying capacityremainednegative, and after 2008 the decreasing speed of ecological carrying capacity slowed down, a sign that the protection measures of Hunan Province were taking effect. In 2011, the ecological footprint was far more than the ecological carrying capacity, with heavier ecological pressure.

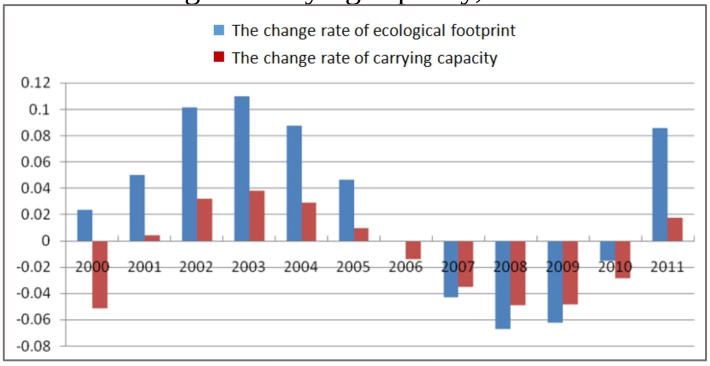

Fig.1Change rate of ecological footprint and ecological carrying capacity of Hunan Province

Price Scissors Analysis. Through the scissors difference analysis of ecological footprint and ecological bearing capacity,as shown in Fig. 2, 2000 - 2004, the reverse trend of change between the ecological footprint and ecological bearing capacityis very clear, and antagonism between the two in 2000 reached themaximum of 0.7499. This ismainly because the ecological carrying capacity greatly reduced, while the ecological footprint substantially increased; During 2005 - 2010, the reverse trend gradually weakened; in 2011, scissors swells to 0.68, indicating that although ecological measures took some effect incontrolling ecological deficit,natural capital stock dramatically reduced, it is still difficult to sustain its development. The contradiction between ecological footprint and ecological carrying capacity is still increasing, so it is necessary to adopt more measures to prevent the further deterioration of ecological environment.

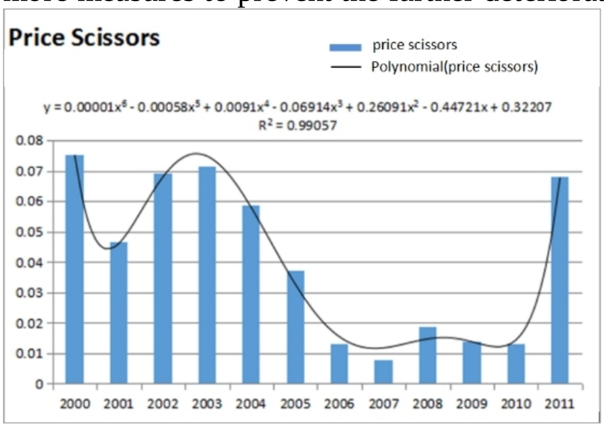

Fig.2 Scissors difference analysis of ecological footprint and ecological bearing capacity in Hunan Province,2000-2011

Ecological Resource EfficiencyAnalysis

From Fig. 3, it can be seen that the million GDP ecological footprint of Hunan province was declining year by year, with the average annual decliningrate of 13.25%.This illustrates that in the economic production process, the technology should be involved,which could improve the efficient utilization of resources, and relievesthe ecological pressure.Thisdownsizesthe stock of natural capital and makes reducing the ecological deficit in Hunan province an essential but daunting task.

Comparative Analysis Under Different Calculations

Ecological Footprint Comparison Under Different Standards. As can be seen, the difference between the two methods of calculating the ecological footprint in 2000-2006 was not great, but after 2006, based on National Hectare the ecological footprint showed a downward trend, but it continues to rise rapidly based on global hectares of ecological footprint continues.

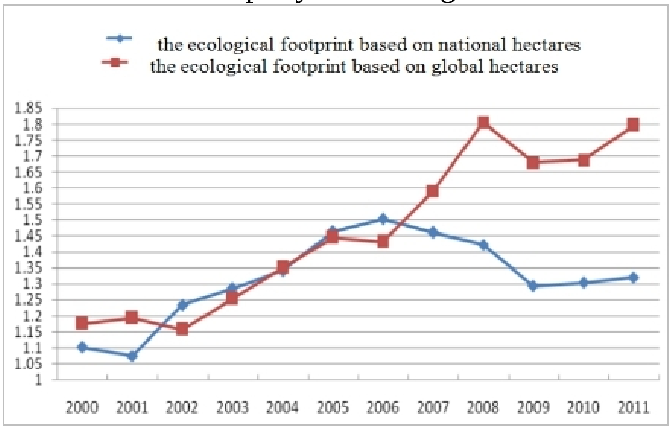

Fig.4Comparison of"National Hectare" and "global hectares ecological footprint

Ecological Deficit Comparison Under Different Calculation. Fig.5 shows the result of ecological deficit before and after improvement. It can be seen that the latter number of ecological deficit was bigger than the former .In 2000-2011, pasture land and construction land were all in surplus, offsetting the ecological deficit of arable land, so that the calculated ecological deficit was not the actual one. The improved method avoids the offset condition so the result will reflect the real situation.

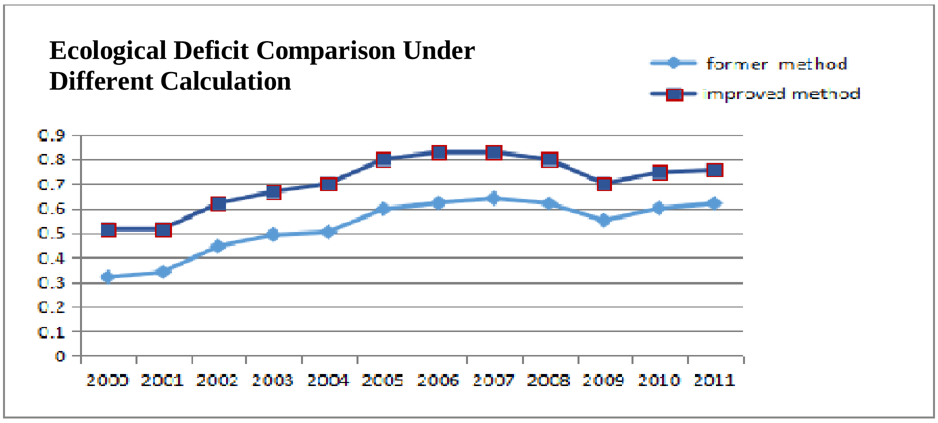

Fig. 5Comparisonof ecological deficit before and after improvement

Policy Suggestion

Based on the "National Hectare" ecological footprint method, the ecological sustainable development of Hunan Province in 2000 to 2011 is evaluated. The results show that the ecological footprint of Hunan province has long been in the ecological deficit. the following countermeasures

are put forward:
(1) land resources rationally used, land regulation should be strengthened, and the level of intensive use of land should be improved. The system of farmland protection should be strictly implemented, the non-agricultural construction land should be controlled, land development and reclamation efforts should be increased, and arable land resources are to be protected.
(2) The natural grassland in Hunan Province should be protected and fully utilized, preventing further deterioration.Management efforts should be done to improve the efficiency of resource utilization,as well as the optimal allocation of water resources.
(3) Urbanization process should be advanced.Based on the capacity of resources and environmental capacity, the rural population transfer should be guided,the utilization efficiency of urban energy system and infrastructure construction should be improved.

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