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Evaluation on Sustainable Development Ability of Anhui Province, China

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Using improved EF Model, this paper calculated the Sustainable Development level of Anhui province between 2004 and 2013.The results show that (1) the total Per capita EF was constantly increasing in Anhui province from 1.2413 hm^2 in 2004 to 1.6157 hm^2 per person in 2013, (2) the total Per capita EC is increasing from 0.2471 hm^2 to 0.2640 hm^2 per person, which is much smaller than the total Per capita EF. And the ecological deficit shows Anhui province is under huge ecological pressure and the economic and social development is unsustainable; (3) the EF diversity index rose from 1.2876 hm^2 to 1.3902 hm^2 per person, which shows that the EF distribution is increasingly imbalanced and the ecological system is in steady; (4) the sustainable development index increased from 1.5524 hm^2 to 2.2460 hm^2 per person, which shows that Anhui ecological capacity is gradually improving despite its ecological deficit.

1. Introduction

The ecological footprint (EF) Model, proposed by Rees the etc. in the 1990S, is a method to evaluate quantitatively regional sustainable development. A region's resources, energy consumption and its ecological capacity will be contrasted by EF model to evaluate whether the development of the region is sustainable (Rees (1992); Wackernagel and Rees (1996)). Since the EF Model was proposed, it has been popularized and applied internationally, becoming an important tool to measure a region's sustainable development, for the model's objectivity and manageability. Currently, scholars abroad made a wide research on EF Model, some of whom had a thorough research on theories of EF Model (Ayres (2000); Dietz et al, (2007); Stuart et al, (2010)), while others from micro perspectives, had specific researches on petrochemical energy, tourism and agriculture, and so on and so forth (Holden and Hoyer (2005); Cuandra and Bjorklund (2006); Hunter and Shaw (2007)). .The concept of EF Model was introduced to China in 1999 and scholars at home also had researches from theoretic and practical perspectives and have achieved some fruits. On the whole, these fruits can be divided into the following three aspects: the first one is researches on theories of EF Model (Zhang et al, (2000); Ma and Chen, (2015)); the second one is researches on EF Model application to evaluation on different regions sustainable development (Mu et al, (2014); Yang and Jia (2015)); and the third one is the analysis of industry development and resources application using EF theory (Wang and Su, (2013); Wang and Yang, (2014)).

Now Anhui province has achieved rapid development in economy and great changes have taken place. However, with the processing of urbanization, environment and resources have become the bottle neck to restrict further development of Anhui province. Therefore, in this case, researches on supply and demand of Anhui ecological capacity (EC) and scientific evaluation on the capacity of sustainable development of Anhui province has become an important issue of the current society. However, few researches have been found on sustainable development of Anhui province using EF model, in addition, these researches only covered Anhui province EF, EC, ecological deficit, etc., without covering the degree and level of the province ecological coordination. In the view of this, this paper based on the improved EF model, EC and EF are calculated and a systematic analysis is made. Meanwhile, ecological coordination index and EF diversity and sustainable development index are constructed and applied to have a deep research on sustainable development capacity of Anhui province, reveal the relationship between the demand of Anhui economic and social development and its ecological supply and measure the level of its sustainable development. The author hopes that

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scientific basis can be provided through this paper to help to handle the relationship between the economic and social development and the population, resources and environment to realize sustainable development.

2. Study area

Anhui province is located between east longitude from 114°54′ to 119°37′ and north latitude from 29°41′ to 34°38′, with the population of 60.30 million, and GDP RMB 1922.934 billion yuan that is 32001 RMB yuan per person. The ratio of the first industry, the second industry and the tertiary industry is 12.3:54.6:33.1. The area of Anhui province is 139.6 thousand square kilometers, and the cultivated land per person is 0.07 hm^2. Therefore the resources of land to be cultivated are insufficient, the development and utilization of this land is difficult, and exploitable land resources are limited. There are bountiful water resources with the total amount of 68 billion cubic meters, but the distribution is unbalanced.

3. Research methods and data sources

3.1 Research methods

3.1.1 The method of EF and its improvement

Based on the differences of land productivity, biologically productive land can be divided into cultivated land, grassland, woodland, waters, construction land and fossil fuel land.
The formula of EF model is:

$$EF = N \times ef = N \times \sum_{i=1}^{n} (aa_i \times r_i) = N \times \sum_{i=1}^{n} (c_i / p_i \times r_i) \quad (i = 1, \ 2 \ldots 6) \tag{1}$$

In this formula, EF is the total regional ecological footprint. ef is the per capita ecological footprint in regional scale. N stands for the total number of people in the region. aa_i represents the per capita biologically productive area converted by goods of type i. c_i is the per capita consumption of goods of type i. p_i stands for the world's average production capacity of type i goods. r_i is the equivalence factor.
Equivalence factor is the ratio of ecologically productive area of one kind in a region to the average productivity of all the ecologically productive land. Equivalence factor can transform per unit productive capacity of biologically productive land of different kind to unified, comparable value. In the existing relevant literature, most studies would choose constant equivalence factor, as is shown in Table 1:

Table 1: Different equivalence factors of biologically productive land

cultivated land	grassland	woodland	waters	construction land	fossil fuel land
2.8	0.5	1.1	0.2	2.8	1.1

However, there are differences in each country's and region's geographic location, resources endowment and technical level, which gives rise to large differences in production level of biologically productive land in these countries and regions. Consequently, the results would more or less have some inevitable errors, if the studies use the same equivalence factor to do the research on different objects. To avoid such problems, based on some relevant research achievements of Living Planet Report (2000, 2004) and the World Wide Fund, this study, referring to the existing research (Wackernagel and Rees (1996); Yang and Jia (2015)), aggregates equivalence factors of biologically productive land in different years and takes their mean. Therefore, equivalence factors can be improved to make an objective evaluation on the sustainable development level in Anhui Province. The details are exhibited in Table 2.

Table 2: Improved equivalence factors of biologically productive land

	Cultivated land	Grassland	Woodland	Waters	Construction land	Fossil fuel land
Mean	2.34	0.48	1.64	0.32	2.34	1.64

3.1.2 EC capacity

EC refers to the sum of biologically productive area that regions can provide human with. The formula of EC is:

$$EC = N \times ec = N \times \sum_{i=1}^{n} (a_i \times r_i \times y_i) \quad (i = 1, \ 2 \ldots 6) \tag{2}$$

In this formula, EC stands for the total ecological capacity in a region. ec is EC per capita. N means the total number of people in the region. a_i represents type i ecologically productive area per capita. r_i denotes the equivalence factor of type i biologically productive area. y_i is the yield factor of type i ecologically productive land. The yield factors of cultivated land, grassland, woodland, waters, construction land and fossil fuel land in this study are 1.66, 0.19, 0.91, 1.0, 1.66 and 1.1 respectively.

3.1.3 Ecological deficit or ecological surplus

Ecological deficit (surplus) can be calculated, based on EF and ecological deficit, that is,

$$ED = EF - EC \tag{3}$$

ED represents ecological deficit (surplus), from which we can estimate the state of regional ecology. When EC is greater than EF, ecological surplus appears and it has positive increment with sustainable development. On the contrary, when EF is greater than EC, ecological deficit appears and it has negative increment with sustainable development, which demonstrates the overload of ecological environment in this region. When EC equals EF, the region is in a state of ecological equilibrium and sustainable development.

3.1.4 EF diversity index

EF diversity index describes the degree of equilibrium between biological productive areas that all kinds of consumption in this region nee]. The calculating method based on entropy principle is:

$$H = -\sum (p_i \times \ln p_i) \tag{4}$$

In this formula, H denotes ecological footprint diversity index. p_i is the percentage of type i biologically productive land in ecological footprint. $\ln p_i$ stands for the distribution of type i biologically productive land in ecological footprint. Hence, the greater the value of H is, the more balanced the ecological footprint distribution in the region is. And the reverse is indicative of the single type or imbalance of biologically productive land type in the region, which demonstrates that the ecosystem is in the unstable state.

3.1.5 Sustainable development capacity index

On the basis of ecological footprint diversity index, we can get sustainable development capability index by using Ulanowicz's formula of development capacity. That is,

$$c = ef \times H = ef \times \left(-\sum (p_i \times \ln p_i)\right) \tag{5}$$

In this formula, c represents sustainable development capability index. According to formula (5), there is a positive correlation between sustainable development capability index and ecological footprint, ecological footprint diversity index. What's more, there is a negative correlation between sustainable development capability index and ecological deficit, ecological footprint of ten thousand yuan GDP.

3.2 Data sources and processing

The data in this study are mainly from *Anhui Statistical Yearbook* (2005-2014). This study calculates biological resources production area by applying the data of FAO about the world's average yield of biological resources in 1993. The research, setting the average calorific value of fossil fuel production area in the world as the criterion, converts consumed calories of this region's energy consumption to a certain fossil fuel production area for ease of comparison between different regions. Meanwhile, it is considered prudent to deduct 12% biodiversity protection area when calculating EC.

4. Results and analysis

4.1 EF analysis

Formula (1) has been used to calculate respectively the per capita EF and total EF of different biological ecological land types of Anhui province between 2004 and 2013. Results are listed on the following table (Table 3).

Table 3: The Per Capita EF of Anhui province between 2004 and 2013 (hm^2/ person)

	Cropland	Grass land	Forest land	Water land	Fossil fuel land	Build-up land	Total per capita EF
2004	0.4907	0.3614	0.0108	0.3036	0.0732	0.0017	1.2413
2005	0.4714	0.3721	0.0108	0.3202	0.1086	0.0504	1.3335
2006	0.4969	0.3132	0.0111	0.2827	0.0860	0.0022	1.1922
2007	0.5059	0.3297	0.0117	0.3002	0.0959	0.0026	1.2460
2008	0.5275	0.3451	0.0109	0.3099	0.1006	0.0029	1.2968
2009	0.5389	0.3652	0.0116	0.3296	0.1047	0.0068	1.3568
2010	0.5547	0.3894	0.0128	0.3581	0.1310	0.0079	1.4539
2011	0.5631	0.3862	0.0135	0.3690	0.1381	0.0089	1.4787
2012	0.5859	0.4085	0.0145	0.3824	0.1501	0.0099	1.5511
2013	0.5808	0.4137	0.0148	0.3944	0.2045	0.0074	1.6157

The above table shows that the total per capita EF of Anhui maintains a trend of rising on the whole, from 1.2413 hm^2/person in 2004 to 1.6157 hm^2/person in 2013 with an average increase of 3.11% per year. 90 percent of the total per capita EF falls into the per capita EF of cropland, grassland and water land, making up the prominent part. The rapid development of Anhui's economy and society guarantees a general increase of the per capita EF of cropland by 19.4 %, from 0.4907 hm^2/person in 2004 to 0.5859 hm^2/person in 2013.
The change of per capita EF of grassland is similar to that of the build-up land, both increasing steadily since 2006. The per capita EF of forestland changes stably, from 0.0108 hm^2/person in 2004 to 0.148 hm^2/person in 2013. There is quite clear growth of per capita EF of grassland especially since 2009. per capita EF of water land changes pace in pace with that of fossil fuel land, and since 2006, featuring a trend of increase-decrease-increase.

4.2 Bio-capacity and ecological pressure analysis

Formula (2)-(3) has been used to calculate the bio-capacity per person and total bio-capacity per person of different biological ecological land types of Anhui province between 2004 and 2013. Details are as follow

Table 4: Bio-capacity Per Person of Anhui province between 2004 and 2013 (hm^2/person)

	2004	2005	2006	2007	2008	2009	2010	2011	2012	2013
cropland	0.2563	0.2602	0.2617	0.2631	0.2624	0.2643	0.2727	0.2723	0.2714	0.2698
grass land	0.0022	0.0022	0.0022	0.0022	0.0022	0.0022	0.0023	0.0023	0.0023	0.0022
forest land	0.0099	0.0101	0.0101	0.0101	0.0101	0.0108	0.0111	0.0111	0.0110	0.0110
water land	0.0054	0.0055	0.0055	0.0055	0.0055	0.0055	0.0057	0.0057	0.0056	0.0056
Fossil fuel land	0	0	0	0	0	0	0	0	0	0
build-up land	0.0070	0.0073	0.0068	0.0078	0.0087	0.0092	0.0100	0.0102	0.0109	0.0114
Deduction of 12% of biodiversity protection area	0.0337	0.0342	0.0344	0.0346	0.0347	0.0350	0.0362	0.0362	0.0362	0.0360
total bio-capacity per person	0.2471	0.2511	0.2520	0.2540	0.2543	0.2569	0.2655	0.2654	0.2651	0.2640
Total ecological deficit per capita	0.9942	1.0814	0.9402	0.9920	1.0425	1.0999	1.1884	1.2133	1.2860	1.3517

The table 4 shows that the total bio-capacity per person of Anhui forms a trend of uprising on the whole, with an average increase of 0.73% per year. The scale of each year does not changed much but is far below the speed of the total bio-capacity per person, which highlights great ecological pressure. Specifically, bio-capacity per person of cropland increases from 0.2563 hm^2/person in 2004 to 0.2727 hm^2/person in 2010, but then, in 2013, drops to 0.2698 hm^2/person. Bio-capacity per person of build-up land shows a tendency of steady increase, from 2004's 0.2471 hm^2/person to 2013's 0.2640 hm^2/person. The bio-capacity per person of other land types-grass land, forest, and water land- generally has few changes. It's clear that between 2004 and 2013, total EF per person is larger than total bio-capacity per person, resulting in ecological deficit. Further study finds a fast growing of the ecological deficit: an average of 3.67% increase per year.

4.3 Comprehensive analysis of sustainable development capacity

Per capita ecological footprint diversity and sustainable development capacity index, shown in Table 6, are worked out through formulas (4) and (5). The study notes that between 2004 and 2013, Per capita ecological footprint diversity index raises from1.2876 hm^2/person to 1.3902 hm^2/person. Distribution of ecological EF is losing balance and the whole eco-system is unstable. Sustainable development ability index goes up from 1.5524 hm^2/person to 2.2460 hm^2/person, evidencing the gradual improvement of Anhui's biological capacity in spite of ecological deficit.

Table 5: Ecological Footprint Diversity and Sustainable Development Capacity Index of Anhui province between 2004 and 2013 (hm^2/person)

	2004	2005	2006	2007	2008	2009	2010	2011	2012	2013
ecological footprint diversity index	1.2876	1.4335	1.3022	1.3148	1.3122	1.3287	1.3524	1.3597	1.3661	1.3902
sustainable development ability index	1.5984	1.9115	1.5524	1.6382	1.7016	1.8028	1.9662	2.0107	2.1191	2.2460

5. Conclusions

Improved EF model is used to analyze empirically the sustainable development capacity of Anhui province between 2004 and 2013.The results reveal that Anhui province's total ecological capacity has deficit and is weak compared with the total EF. Furthermore, the total per capita ecological deficit and total per capita EF diversity index keep growing, which made Anhui province's resources and ecological environment are under huge pressure. The ecological deficit shows Anhui province's economic and social development is unsustainable. However the sustainable development index shows that Anhui ecological capacity is gradually improving despite its ecological deficit. Therefore, a developing Anhui needs to make great efforts to protect its ecological environment, try hard to improve its capacity of ecological environment and forge its sustainable development ability. Only in this way can a solid foundation be laid for the sustainable development of the province's economy and society.

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