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Research on Ecological Environmental Carrying Capacity in Yellow River Delta

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Abstract

The Yellow River Delta was selected as study area in this paper. Based on a comprehensive analysis of environmental capacity theory, environmental carrying capacity was studied using ecological footprint model, combining with the economic and social data of the Yellow River Delta from 2001-2008. The results showed that the ecological footprint per capita had increased two times from 2001-2008, which was from 0.1885 hm^2 in 2001 to 0.4639 hm^2 in 2008. The diversity of ecological footprint had changed slightly, and the ratio of biotic resources requirement was largest among all the other types. The development ability of ecosystem had a little improved. Environmental carrying capacity of the Yellow River Delta had increased. But compared to the increasing of ecological footprint, the increasing degree was not notable, and the ecological deficit increased obviously. The unsustainable development has already appeared from the analysis of ecological footprint index. Finally, some countermeasures were advanced in order to improve the environment situation of the Yellow River Delta, such as adjusting industrial structure through developing circulate economy vigorously, saving mine resources and protecting pasture environment through strengthening management, controlling the population and advocating sustainable life style.

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Keywords: Sustainable development; the Yellow River Delta; Ecological environmental carrying capacity; Ecological footprint

1. Introduction

Since the reform and opening, development of economy in China has made great achievement. In the

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meantime, the environment has deteriorated, going with resource consumption and the pollution. In 1921, Parker and Burgis proposed the concept of carrying capacity explicitly, namely "maximum quantity of individual existed under some specific environmental condition (refers to combination of ecological factor including space, nutrients, sunlight et al.)"[1]. Later this term was applied in the environmental science. In 1990s, the environmental carrying capacity research was started in China [2].

The Yellow River delta, where environment is very fragile, has not been exploited deeply until now. With the developing rapidly, ecological environmental carrying capacity confronts of huge pressure in Yellow River delta. Therefore, researching ecological environmental carrying capacity of Yellow River delta would have significant on realizing regional economic sustainable development.

2. Ecological footprint model

Ecological Footprint is a set of quantitative indexes based on land use, which was calculated based on 5 fundamental assumptions [3-5]: 1. The humanity can estimate most consumption quantity of resources and energy and the amount of waste generated; 2. The amount of these resources and waste can be converted into productive land use area which can generated or absorbed them; 3. Six land use types which are farmland, grassland, forests, fossil energy land, construction land and waters, can be expressed by the same unit through converting according to their productivity. 4. Each land use type is not intersection in the same region, namely the land use type is the unique. 5. The total areas human demanded may compare with the ecosystem service (ecological carrying capacity), and the result can be expressed land use area under the standard productivity [6].

Calculation formulas of *EF* were:

$$EF = N \times ef \tag{1}$$

$$ef = \sum aa_i = \sum (c_i / p_i) \tag{2}$$

In formula *(1)* and *(2)*, *i* is the type of commodity and investment; p_i is the average production ability of commodity of the *i* type; c_i is consumption per capita of the *i* type commodity; aa_i is productive land area of the *i* type of commodity per capita; *N* is the population of the area; *ef* is the ecological footprint per capita; *EF* is the total ecological footprint.

Areas of the farmland, the grassland, the forest, building land and the sea multiplied by corresponding balanced factor and the local output factor, then ecology carrying capacity (*EC*) were obtained:

$$EC = \sum c_j \cdot N = (\sum a_j \times r_j \times y_j) \cdot N \tag{3}$$

In formula *(3)*, *j* is the land use type; *EC* is the total ecology carrying capacity of the region; *N* is population; a_j is productive land area per capita; r_j is the balanced factor; y_j is the output factor.

The ecological deficit size may be expressed as: $ED = EF - EC$. The positive or negative and size of *ED* indicates ecological deficit or ecological surplus, which can reflect the degree of sustainable development in a certain region.

3. Ecological footprint analysis in Yellow River delta

3.1. Change of Ecological Footprint

As shown in table1, the ecological footprint per capita in Yellow River delta has been from 0.1885 hm^2 in 2001 to 0.4639 hm^2 in 2008. It meant that natural resources consumption increased by 2 times in 8 years. According to "Report of Ecological Footprint in China" in 2003, Chinese average ecological

footprint per capita was 1.6hm^2, from the table, average value of Yellow River delta was smaller than that of nation at the same period, which reflected that resources requirement of Yellow River delta had increased dramatically, and the ecological pressure was increasing continuously.

Table1. Ecological Footprint in Dongying City

Type	2001	2002	2003	2004	2005	2006	2007	2008
Farmland(hm^2/cap)	0.1144	0.1231	0.2667	0.1362	0.1533	0.1777	0.1453	0.164
Grassland(hm^2/cap)	0.0129	0.0276	0.0338	0.04	0.046	0.0496	0.0459	0.0479
Forest (hm^2/cap)	0.0003	0.0003	0.0003	0.0003	0.0009	0.0004	0.0004	0.0004
Water (hm^2/cap)	0.0199	0.0202	0.2275	0.2502	0.2808	0.2974	0.2625	0.2035
Fossil fuel(hm^2/cap)	0.0406	0.0478	0.0316	0.0386	0.0479	0.0491	0.0474	0.0471
Construction land (hm^2/cap)	0.0003	0.0004	0.0005	0.0005	0.0006	0.0007	0.0007	0.0008
Ecological footprint per capita(hm^2/cap)	0.1885	0.2195	0.5603	0.4657	0.5296	0.5749	0.5024	0.4638
Total ecological footprint(10^4hm^2)	327097	384810	990617	832752	955938	1E+06	919774	852901

3.2. Diversity Analysis of Ecological Footprint

The diversity index of ecological footprint in Yellow River delta was calculated using Shannon-Weaver index which can be expressed as follows:

$$H = -\sum (Pi * \ln P_i) \quad (4)$$

There, H is the diversity index, p_i is the proportion of i land use type to the total ecological footprint. The diversity index is higher, the proportion of various land use type is close to equality. The diversity index in Yellow River Delta was relative high and changed slightly (fig.1), which indicated that the distribution of ecological footprint types in eco-economic system was much balance.

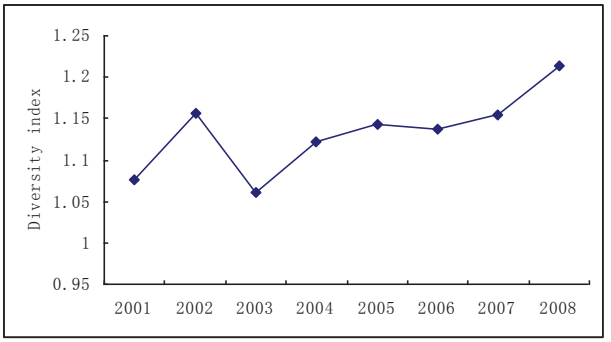

Fig. 1 The diversity index of ecological footprint

3.3. Analysis on Development Ability of Economic System

The development ability is a good indicator to reflect the sustainable development of economic system. It can be described as the following:

$$C = EF \times [-\sum (P_i \ln P_i)] \quad (5)$$

In *(5)*, *C* is the development ability; *EF* is the ecological footprint of the country or region. The development index increased notably from 2001-2006, and reached peak, later decreased. The development index can be decomposed two parts: one is regional ecological footprint, and the other one is ecological footprint diversity. Due to low ecological footprint in Yellow River delta, development capacity can increase through increasing the ecological footprint.

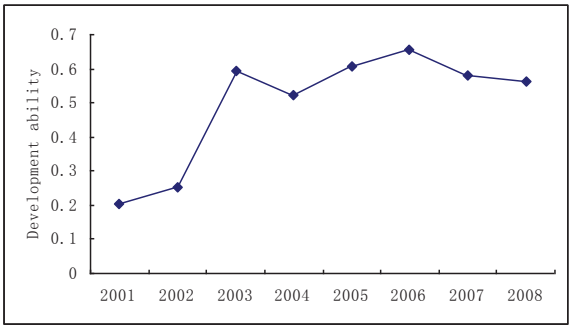

Fig. 2 Change of Development index

4. Analysis of environmental carrying capacity in Yellow River Delta

4.1. Change of Environmental Carrying Capacity

The result of ecological carrying capacity per capita of Yellow River Delta during 2001-2008 is as table 2. Through the table, we found it remained relatively stable. In 2003, the ecological carrying capacity per capita was only 0.1095hm^2, only accounted for 13.6% of that in China (0.8047hm^2), and accounted for 6.1% of that in the world (1.8hm^2). Further analysis showed that the farmland decreased year by year, water and grassland kept stable, forest and construction land increased slightly, which reflected the change of resources demanded.

Table 2. Per Capita Ecological Carrying Capacity of Yellow River Delta during 2001-2008

Type (hm^2)	2001	2002	2003	2004	2005	2006	2007	2008
Farmland	0.0834	0.0942	0.087	0.0834	0.09	0.0808	0.0884	0.0932
Grassland	0.0017	0.0017	0.0017	0.0016	0.0016	0.0016	0.0016	0.0016
Forest	0.0003	0.0003	0.0008	0.0007	0.0002	0.0002	0.0002	0.0004
Water	0.0059	0.0058	0.0058	0.0057	0.0057	0.0057	0.0057	0.0059
Construction land	0.0135	0.0138	0.0143	0.0145	0.0152	0.0153	0.0167	0.0171
Ecological carrying capacity per capita	0.1049	0.1158	0.1095	0.106	0.1127	0.1036	0.1127	0.1182

4.2. Ecosystem Carry Ability Analysis

The difference between the ecological carrying capacity and the ecology footprint is called the ecological deficit (surplus), which can reflect the sustainability of ecosystem carrying capacity of a region. If the surplus value is higher, the supply ability of ecosystem which meets the consumption is stronger. From table 3, despite the ecology carrying capacity showed a rising trend, owing to continuously soaring resource requirement, ecological deficit increased intensely. In 2006, the ecological deficit was up to peak.

Table 3. Ecological Carrying Capacity and Ecological Deficit of Yellow River Delta During 2001-2008

Items	2001	2002	2003	2004	2005	2006	2007	2008
Ecological carrying capacity	55.057	59.747	57.375	56.093	58.965	56.046	59.529	64.63
Ecological footprint	128.46	140.53	203.87	202.04	233.92	248.03	213.45	201.92
Ecological deficit	-73.41	-80.79	-146.5	-145.9	-175	-192	-153.9	-137.3
Overland multiple	1.3	1.4	2.6	2.6	3.0	3.4	2.6	2.1

5. Ecosystem health appraisal of Yellow River delta

5.1. Ecosystem Health Appraisal Method

The ecological footprint index can be used to compare the difference of sustainable development degree among regions [7]. It can be expressed as:

$$EFI = [(EC - EF) / EC] \times 100\% \quad (6)$$

The appraisal criteria of regional ecological sustainable development are shown as table 4.

Table 4. The Relational Table of Ecological Footprint Index and the Degree of Ecological Sustainable Development

Index (%)	Grade	Meaning
EFI=0	Strong Sustainability	Region where human ecological footprint is very small or negligible
50<EFI<100 0<EFI<50	Weak sustainability	There is some residual biological carrying capacity to carry the future ecological footprint, and the region is at the sustainable development condition.
EFI=0	Marginal sustainability	The region is at the critical points of sustainable development and unsustainable development condition, transformation of sustainable development condition can be caused by its slight changes of life style, expense, population, biological carrying capacity, and so on.
-100<EFI<0 EFI<-100	Unsustainable Serious non-sustainability	Biological capacity is insufficient to carry the local ecological footprint, generally pay off the ecology debt by inputting external resources through trade, consuming domestic natural capital stock or waste accumulation.

5.2. Analysis of Ecosystem Health

The ecological footprint index of Yellow River delta during 2001-2008 was shown as table 5. EFI of Yellow River delta was -130 in 2001, which was in a serious unsustainable condition, and this overload condition showed larger trend progressively, and went to the peak in 2006. Although it decreased a lot in the following years, it still was -210, and still in a serious unsustainable state in 2008. To get out of this

state, some methods, such as inputting external resources through trade, consuming domestic natural capital stock should be conducted.

Table 5. Ecological Footprint Index

Item	2001	2002	2003	2004	2005	2006	2007	2008
EFI (%)	-130	-140	-260	-260	-300	-340	-260	-210

6. Conclusion and Suggestion

Through the studying above, we can found that the ecological footprint increased a lot. Although the environmental carry capacity also increased, the ecological deficit was still inevitable, which led to the sustainable development ability decreased. With the rapid development of Yellow River delta, the contradiction of economics, environment and society would be serious. In order to construct sustainable development of economy, environment friendly and resource efficient society, the balance of ecological footprint and environmental carrying capacity should be more concerned.

1. Adjusting industrial structure and developing circular economy. At present, due to lower productivity, unreasonable industrial structure, and excessive consumption of resources, the rapid economic development of the Huanghe Delta was based on over-exploitation of resource and energy, which required strengthening technical innovation, developing the circular economy vigorously, and adjusting industrial structure.

2. Strengthening the strict scientific management, saving the mineral resource and protecting forest land lawn. As an important “oil city” of China, the oil industries is the basic and pillar industries in the Dongying city. So petroleum industry management mechanism and ecological environmental protection methods is the key factors to determine the quality of urban security and sustainable development of economy and ecology.

3. Controlling the population growth strictly. Though population density of the study area was low relatively, due to the large population in Shandong province, and population movement caused by exploitation of Yellow River delta, the speed of population growth would be still high in the future, which must lead to huge pressure on ecosystem.

4. Advocating sustainable life styles. The old life styles which pursued high consumption should be modified, in stead of the sustainable consumption concept should be established. In order to realize the sustainable development of the resource, the economy, the environment and society in Yellow River delta, each kind of resource should be used more scientifically and rationally, and the ecological consciousness of people should be raised.

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