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A Vertical and Horizontal Comparison of Sustainable Development Status in Western China from the Perspective of Ecological Footprint

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Abstract On the basis of ecological footprint theory, the ecological footprint and ecological carrying capacity of western China and 12 provinces and cities in 2009 are calculated. From the perspective of ecological footprint, the sustainable development status of west China and 12 provinces and cities in 2009 and 1999 are compared vertically and horizontally. Results assume that no matter weighting by using local or national ecological carrying capacity, the west area laid in the unsustainable development state in 2009; in 1999, the west area was on the unsustainable development stage taking the local and national level as the reference and it was at the sustainable stage at the global level. In 2009, most provinces in western China laid on the unsustainable stage at the local, national and global level. Compared with that in 2009, few provinces in western China were on the unsustainable stage at different levels. In general, the sustainable developmental momentum of western China in 2009 was weaker than that in ten years ago and many provinces and cities decreased to unsustainable state.

Key words Ecological footprint, Ecological carrying capacity, Sustainable development, Western China

There are 12 provinces (cities and regions) in western China, with a total area of 6.88 million km^2, accounting for 71.67% of that in the whole nation. By the end of 2009, the total population in western China was 0.367 29 billion, accounting for 27.51% of Chinese total population. Western China is confronting with the problems of fragile ecology, backward economy and rapidly increased population. In recent years, parts of western resources have been transported to eastern China and the natural resources in western China have been decreased. Besides, both the great development aiming at exploiting resources and environment and developing western and national economy; and the acceleration of people's consumption level have all deepened the conflict between Western population and ecological resources and threatened the sustainable development of western China. In the paper, ecological footprint analysis is adopted to compare vertically and horizontally the sustainable development status of western China and its 12 provinces, cities or regions from the perspective of ecological footprint. The sustainable development level of western China is evaluated under the national and worldwide standard. The suggestions on improving ecological environment are put forward. The suggestions are beneficial to both the sustainable development of western China and the ecological safety of middle and eastern China and the whole nation.

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1 Data source and research method

1.1 Data source The research statistics mainly come from the 2010 statistical yearbook of 12 provinces (cities, regions) in western China[1-12], *China Statistical Yearbook* 2010[13], *China Energy Statistical Yearbook* 2010[14].

1.2 Ecological footprint and analysis model

1.2.1 Theory of ecological footprint. The theory of ecological footprint is based on people's production and living consumption on resource environment. The theory is composed by ecological footprint and ecological carrying capacity. Ecological footprint index is used to calculate the biological production area needed for maintaining ecological resource consumption and assimilating wastes under certain population and economic scale[15]. Ecological footprint weights the necessary production area demanded by human beings to maintain a certain consumption level; reflects human demands on resource environment and the intensity and pressure of human exploitation on ecological environment. The standard unit of ecological footprint is global hectare (ghm^2). A global hectare is tantamount to a hectare of biological production area with global average productivity. Ecological carrying capacity means the biological production area provided by the ecological environment system. Its standard unit is also global hectare (ghm^2). Through comparison and analysis on the gap between ecological carrying capacity and ecological footprint in target area, whether the production and consumption intensity of the target area is in the scope of local ecological carrying capacity can be judged[16]. When the ecological carrying capacity in the target area is larger than ecological footprint, it is called ecological surplus and it is regarded that human production and consumption activities have not surpassed the carrying capacity of ecological system.

The ecological, economic and social system in the target areas is still in the sustainable developmental status. When the ecological carrying capacity in target area is smaller than ecological footprint, it is called ecological deficit and it can be regarded that the current production and living consumption intensify of the target area has surpassed the regeneration capability of resource environment. The development of ecological economic system has become unsustainable.

1.2.2 Analysis model of ecological footprint. From the ecological footprint theory, the analysis model of ecological footprint in general form can be concluded:

$$EF = N \times ef = N \times r_j \times \sum A_i = N \times r_j \times \sum (C_t / P_i) \quad (i = 1, 2, 3, \cdots, n) \quad (1)$$

In the equation, EF is the global ecological footprint (ghm^2) in target area; N is the number of population; ef is per capita global ecological footprint (ghm^2); C_i is the per capita consumption of the i resource; P_i is the average productivity of the i resources; A_i is the biological productive land area converted by the per capita consumption on the i resource (hm^2); i is the kinds of resources consumed; j represents the land type of biological production; r_j is equivalence factor. It is worth noticing that different types of biological productive land of the same quantity have different resource production capability, so the biological production area of each land type should multiply by relevant equivalence factor to transfer them into unified and comparative standard area. The research adopts the global land equivalence factor universally used in international[17]. The global equivalence factor of a certain land is the ratio of global average productivity of biological production land to the average productivity of all global biological productive land.

1.2.3 Ecological carrying capacity model. The general form of ecological carrying capacity concluded from the theory of ecological footprint is as follows:

$$EC = N \times ec = N \times \sum S_j \times r_j \times y_j \quad (j = 1, 2, 3, \cdots, 6) \quad (2)$$

In the equation, EC represents global ecological carrying capacity of target area (ghm^2); ec is global ecological carrying capacity per capita (ghm^2); S_i is per capita owned biological productive area (hm^2); y_j is yield factor; it is the ratio of the average productivity of the j type of land to the average productivity of the same kind of land in the world[18]; the connotations of other symbols are similar to the model (1). Different countries and regions have different resource endowments, so different land types of the same unit area have different biological production capabilities, and the productivities of same type of land in different area have gaps. Therefore, the actual area of the same type of biological productive land in different countries and regions can not be compared directly; the yield factor should be adopted to adjust.

In the calculation of the index system of ecological carrying capacity, the following six types of biological productivity land, including fossil fuel, farmland, woodland, grassland, construction land use and waters, are considered[19]. The research adopts the global equivalence factor and yield factor of biological productive land, which can be seen on Table 1.

2 Results and analysis

Western ecological footprint is composed by biological resource consumption and energy consumption. The consumption on biological resource includes 15 types, such as, vegetable oil, woodland products, *et al.* energy consumption includes four types, such as coal, petroleum and its products, natural gas and electric power. According to the sources, various kinds of resources consumed by western China are included into six types, such as farmland, grassland, woodland, waters, construction land, and fossil energy land. Besides, the global average yield is taken as the standard[20], the global equivalence factor is taken as adjust coefficient; the units are transformed into global hectare (ghm^2) as standard area; in the end, through summing, the western ecological footprint can be obtained. In the process of calculating, the consumption account directly adopts the actual consumption statistics of western production and living on natural resources, so the impacts of import and export trade are excluded. By adopting the relevant statistics in statistical yearbook and by using the model (1) and (2), the western ecological footprint and ecological carrying capacity in 2009 can be calculated (Table 1). In Table 1, waters include rivers, lakes, man-made wetland, alongshore and seacoast; the statistics of woodland come from the 7th national woodland resource; the construction land includes residential places, factory and mineral land use, transportation land use and water conservancy land use.

Table 1 Calculation of *EF* and *EC* of western China in 2009

Land types	Ecological footprint			Ecological carrying capacity			
	Land per capita converted from eco-resources consumption // hm^2/per capita	Equivalence factors ghm^2/hm^2	EF per capita ghm^2/per capita	Land hm^2/per capita	Equivalence factors ghm^2/hm^2	Yield factors	*EC* per capita ghm^2/per capita
Farmland	0.366 3	2.80	1.025 8	0.122 4	2.80	1.66	0.568 9
Grassland	0.130 6	0.50	0.065 4	0.698 3	0.50	0.19	0.066 3
Woodland	0.032 3	1.10	0.035 5	0.482 1	1.10	0.91	0.482 6
Waters	0.151 0	0.20	0.030 2	0.024 6	0.20	1.00	0.004 9
Construction area	0.025 3	2.80	0.070 9	0.026 3	2.80	1.66	0.122 2
Fossil fuel land	0.687 4	1.10	0.765 2		1.10	0.00	0
Total			1.993 0				1.244 9

In Table 1, 12% of the total ecological carrying capacity per capita (1.244 9 ghm^2) is left to other lives (0.149 3 ghm^2), the rest ecological carrying capacity per capita is 1.095 6 ghm^2. according to this, the total ecological carrying capacity is

402 402 924 ghm^2. By the same way, the ecological footprint and ecological carrying capacity of 12 provinces, cities or regions in 1999 was calculated by citing the literature[21]. The statistics of national and global ecological indexes in 1999 came form the literature[22]. The ecological footprint and ecological carrying capacity of 12 provinces, cities and regions of western China in the year of 2009 and 1999 can be seen on Table 2.

Table 2 Eco-footprint (*EF*) and eco-carrying capacity (*EC*) for 12 regions of western China in the year of 2009 and 1999

Regions	Total population $\times 10^4$ people		*EC* per capita ghm^2/per capita		*EF* per capita ghm^2/per capita		Eco-surplus/eco-deficit per capita // ghm^2/per capita	
	2009	1999	2009	1999	2009	1999	2009	1999
Inner Mongolia	2 422	2 362	3.292 0	2.353	3.857 9	2.371	−0.565 9	−0.018
Guangxi	4 856	4 713	0.710 4	0.425	1.649 1	1.022	−0.938 7	−0.597
Chongqing	2 859	3 075	0.528 8	0.305	2.268 7	1.040	−1.739 9	−0.738
Sichuan	8 185	8 358	0.641 5	0.285	2.375 8	0.951	−1.734 3	−0.566
Guizhou	3 798	3 710	0.742 1	0.352	2.048 6	1.228	−1.306 5	−0.876
Yunnan	4 571	4 192	1.095 4	0.622	1.513 6	0.477	−0.418 2	0.145
Xizang	290	256	7.935	7.584	1.275 6*	2.153	6.659 4	5.431
Shanxi	3 772	3 618	0.816 1	0.742	1.326 0	1.086	−0.509 9	−0.344
Gansu	2 635	2 543	1.239 2	0.806	1.556 9	1.337	−0.317 7	−0.531
Qinghai	557	510	2.290 0	1.173	1.884 8	1.573	0.405 7	−0.401
Ningxia	625	543	1.150 0	1.099	2.258 0	1.278	−1.108 0	−0.179
Xinjiang	2 159	1 774	1.657 5	1.150	1.731 4	2.113	−0.073 9	−1.261
Western China	36 729	35 65 3	1.095 6	0.703	1.993 0	1.172	−0.897 4	−0.469
China	133 474	125 909	0.695 6	1.040	1.715 3	1.540	−1.019 7	−0.500
The World	661 026	589 248	1.800 0	1.900	2.700 0	2.280	−0.900 0	−0.380

Note: The original energy data for Tibet are not completed, so, Tibetan EF calculated in 2009 is smaller than actual ones.

2.1 Sustainable development status of ecological footprint in western China It can be seen from Table 1 that in 2009 the ecological footprint in western China (*ef*) has reached 1.993 0 ghm^2, but ecological carrying capacity per capita (*ec*) had only 1.095 6 ghm^2, the former was 1.819 times more the later . that is to say, if western China wants to keep the current production and living consumption level and maintains western ecological balance and the status of sustainable development, it needs at least 1.819 times the area of western China, which owns the average productivity of that in 2009. Obviously, in 2009, western China has stayed in an unsustainable development status. The further observation spotted that in 2009, the starting year of the first round of western development, the ecological footprint per capita and ecological carrying capacity per capita in western China was 1.172 and 0.703 ghm^2 respectively. So in order to maintain the production and living consumption standard like that at that time and ensure the ecological deficit will not happen, the western China only needs 1.667 times the area of western China, with the productivity at that time (Table 2).

2.2 Analysis on the sustainable development status of 12 provinces or areas in western China It can be seen from Table 2 that, in 2009, the national ecological carrying capacity per capita in China was 0.695 6 ghm^2, far smaller than the ecological footprint of western China in the same year (1.993 ghm^2). It can be concluded that in 2009, the western China stayed in the unsustainable state under the national standard. Compared with the 1.8 ghm^2 of global ecological carrying capacity (global ecological standard) issued by *Chinese Ecological Footprint Report* 2010, the developmental status of western China was also in unsustainable state in 2009. Dated back to 1999, at that time, the national ecological carrying capacity per capita was 1.04 ghm^2, while that in western China was 1.172 0 ghm^2, so it can be seen that in 1999, the western China has already stayed in the unsustainable development state under national standard. Compared with the 1.900 0 ghm^2 of global ecological carrying capacity (global ecological standard) in 1999, it can be regarded that in 1999, the western China has been in the sustainable development state under global standard.

The further investigation on Table 2 gets the following results. In 2009, only the Tibet and Qinghai had ecological surplus among 12 provinces or regions in western China (the difference of ecological carrying capacity to ecological footprint is positive), the surplus of them is 6.659 4 and 0.405 7 ghm^2; the ecological carrying capacity per capita of other 10 provinces and regions was all smaller than their ecological footprint and the ecological deficit appeared. The 10 provinces or regions were in unsustainable development state under the provincial or regional standard in 2009. Among the 10 provinces and regions, Sichuan Province and Chongqing Municipal had the largest per capita ecological deficit, which had reached −1.739 9 and −1.734 3 ghm^2. Ten years ago (1999), two provinces and regions out of 12 provinces and regions in western China had appeared the ecological surplus, one of the two was the Tibet, with the surplus of 5.431 ghm^2. the second one was not Qinghai Province but Yunnan Province, with the surplus of 0.145 ghm^2. Other ten provinces and regions in western China have ecological deficits. The province and regions with the most serious ecological deficit was Xinjiang (−1.261 ghm^2), closely followed by Guizhou with the deficit of −0.876 ghm^2.

In 2009, the ecological footprint per capita in 12 provinces and regions in Western China was larger than the ecological carrying capacity per capita in both the western China and the nation, whose eco-carrying capacity was 1.095 6 and 0.695 6 ghm^2 respectively. It can be concluded that, in 2009, 12 provinces and regions in western China stayed in unsustainable

state. In 1999, the ecological carrying capacity per capita in western China was 0.703 ghm^2, and the ecological footprint per capita in 11 provinces and regions was larger than the ecological standard. They were in the unsustainable development state under the western standard. In 1999, the national ecological standard per capita was 1.04 ghm^2, therefore, 8 provinces and regions in western China were in unsustainable state. The ecological footprint in Guangxi, Chongqing, Sichuan and Yunnan was smaller than or equal to the national ecological standard per capita. So the four regions were in sustainable development state.

Table 2 assumes that in 2009, the global ecological standard per capita was 1.800 0 ghm^2, so it can be concluded that in 2009, half of the provinces and regions in western China were in sustainable development state and they were Guangxi, Yunnan, Tibet, Shaanxi, Gansu and Xinjiang. In 1999, the ecological footprint per capita in nine provinces and regions of western China was lower than that in the world(1.900 0 ghm^2), so they were in the sustainable development state under global standard; only the ecological footprint per capita in Inner Mongolia, Tibet and Xinjiang has surpassed the global ecological standard and stayed in the unsustainable development state under global standard.

3 Conclusions and suggestions

3.1 Basic conclusions In 2009, the ecological footprint per capita is far larger than the ecological carrying capacity in western China, at the same time, it is larger than national and global ecological carrying capacity per capita, so no matter from the perspective of local or national standard, in 2009, the development of western China was unsustainable. In 1999, the development of western China was unsustainable under local and national standard, but sustainable under global standard. In general, the sustainable development status of western China in 2009 is weaker than that in 1999.

In 2009, the ecological footprint per capita of 10 provinces and regions in western China was larger than ecological carrying capacity per capita and they were in unsustainable development status under provincial and regional standard. The ecological footprint per capita of the 12 provinces and regions was larger than the western China and national ecological carrying capacity per capita, they were unsustainable in development under western China and national ecological standard. The ecological footprint per capita of six provinces and regions of western China was smaller than global ecological standard and stayed in sustainable development status under global standard. In 1999,10 provinces and regions of western China stayed in unsustainable development state under provincial and regional standard; the developmental status of 11 provinces and regions of western China was unsustainable under western China standard. 8 provinces and regions were in unsustainable development state under national standard; but 9 provinces and regions were in sustainable development under global standard. In conclusion, compared with that in 1999, more provinces and regions declined to the unsustainable development state in 2009.

The western China should comprehensively adopt the suggestions put forward in the research to improve and enhance the sustainability of its development.

3.2 Suggestions on promoting the sustainable development of western China No matter using which kind of ecological standard to weigh, the development of most parts of provinces and regions in western China in 1999 and 2009 was unsustainable; and the development status in 2009 is worse than that in 1999. The reasons that account for it were the rapid growth of population; the improvement of production and living consumption level and the upgrade of consumption structure; decrease of available resources and low efficiency of resource use. According to this, the following suggestions on resuming and promoting the sustainable development of western China are put forward. In the first place, the rapid growth of population in western China should be controlled to let the growth of consumption by production and living to match the supply capability of natural environment. In the second place, the social wealth distribution model and social system should be optimized. When the resources and wealth are limited, the optimization on distribution way and social system could allow the society to support more population and alleviate the excessive exploitation on ecological resources. In the third place, the unsustainable production and living way (for example low efficient production and luxury consumption for showing off) should be changed to reduce ecological resource consumption. In the fourth place, science and technology progress should be promoted to improve the use efficiency of resources. In the fifth place, the input of external resources should be made use of to transfer ecological pressure. In the sixth place, the energy consumption structure should be adjusted to encourage the use of energies with small demands on ecological footprint (for example electric power) and reduce the use of energies with large demands on ecological footprint (for example coal *et al*.). In the seventh place, the ecological construction on western China should continue and be expanded to promote the increase of ecological carrying capacity. In all, only by comprehensively adopting the above policies, the enhancement on the sustainability of western China's development under the normal production and living can be ensured.

4 Conclusions

Ecological footprint theory explores the sustainable development status in a region by comparison of supply and demand gap of ecological resources in the region. It is scientific, visible and easy to be understood, but it still has disadvantages.

In the first place, ecological footprint is a comprehensive index, so when calculating it, the production and consumption statistics from multiple aspects are needed. Actually, the complete statistics of a certain statistical subject can not be collected, so the accuracy of the analysis and conclusion may be affected.

In the second place, the ecological footprint and ecological carrying capacity calculated by using the global conversion factors are suitable for worldwide comparison, the deviation may happen when used in a small region. If the target region uses its own conversion factors, the results may fit the region more, but may not be globally comparable. So how to handle the problem still needs further study.

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(From page 17)

is safe, orderly and with fair competition, to reduce the circulation links of agricultural products and the intermediaries' price advance, to decrease the cost for circulation and to cut off the channel and chain of the hot money speculation for agricultural products. We should rectify and regulate the market order, severely crack down on speculation such as hoarding, cornering and collusive pricing.

3.2.3 Improve regulation system of agricultural products and stabilize the price of agricultural products. In order to control excessive price hikes of agricultural products, it is necessary to soundly improve the price regulation system of agricultural products. Except for taking temporary price intervention measures for agricultural products in special circumstances, the government should shift the focus of price regulation of agricultural products to maintaining the price order of the market, to severely cracking down on speculation like hoarding, cornering and price gouging. When there is an abnormal fluctuation of market price of agricultural products, it is necessary to stabilize the market price by underselling agricultural products reservation and other measures, and to eventually make the price back to normal.

3.2.4 Strengthen mobility regulation and prevent a flood of speculative cash. As for the rise in agricultural products price caused by excess liquidity, it is suggested to change the current easy monetary policy into a prudent one. The PBC should not only regulate and control the money supply and bank rate, but also regulate the newly increased credit scale, and strengthen the liquidity management by making comprehensive use of various monetary policy tools. In the meanwhile, it should strengthen the private capital management, make more efforts to control and crack down international hot money and maintain a reasonable level of money in circulation. Through all the above monetary policy regulations, we could finally stabilize the agricultural product prices.

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