Dynamic Comparison and Trend analysis of Southeast Guizhou's Experimental Area of Eco-civilization Construction and the National Eco-efficiency

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Abstract　In order to better understand the development level of eco-efficiency in Southeast Guizhou's experimental area of eco-civilization construction，we conduct dynamic comparison research of its eco-efficiency and the national eco-efficiency，using single ratio method based on the ecological footprint model，to grasp the gap between its eco-efficiency and the national eco-efficiency，so that we can take appropriate countermeasures to improve eco-efficiency. The results show that in the period 1978 − 2010，the eco-efficiency in Southeast Guizhou's experimental area of eco-civilization construction was always lower than the national eco-efficiency；the long-time average annual value of its eco-efficiency was less than one half of that of the national eco-efficiency，with the absolute gap of 1 630. 095 yuan/hm^2，and the gap tended to widen year by year in the period 1978 − 2002（the gap increased from 276. 551 yuan/hm^2 in 1978 to peak of 3 227. 713 yuan/hm^2 in 2002，with an average annual increase of 118. 047 yuan/hm^2，and especially after 1992，the gap was particularly evident，with an average annual increase of 194. 771 yuan/hm^2），but from 2003，the gap between the two tended to decrease. Based on the prediction results of grey system，in the period 2011 − 2025，the gap between the eco-efficiency in Southeast Guizhou's experimental area of eco-civilization construction and the national eco-efficiency will gradually narrow，and from 2019，the eco-efficiency in Southeast Guizhou's experimental area of eco-civilization construction will be higher than the national eco-efficiency.

Key words　The ecological footprint model，Single ratio method，Grey prediction，Southeast Guizhou's experimental area of eco-civilization construction

Since the reform and opening-up, Southeast Guizhou has experienced rapid socio-economic development. But its GDP growth, to a large extent, relies on the pattern of high input, high energy consuming, high emission and low efficiency[1], affecting and even damaging the ecological environment to a certain degree, thereby affecting the sustainable development of the region. Sustainable development has become the future development objective of countries in the world. Eco-efficiency becomes an important breakthrough point for the implementation of this objective at different levels[2]. It gives consideration to the efficiency of economy and ecology（including resources and the environment）, achieving three goals, "reduction of resource consumption, reduction of impact on the environment, and increase in the value of products or services"[3]. Eco-efficiency, as an important means to measure sustainable development and a necessary step to implement sustainable development, has gradually evolved into the preferred policy concept and philosophy of management for the government in many countries to practise *Agenda* 21[4].

In order to better understand the development level of eco-efficiency in Southeast Guizhou's experimental area of eco-civilization construction, we conduct dynamic comparison research of its eco-efficiency and the national eco-efficiency, using single ratio method based on the ecological footprint model, to grasp the gap between its eco-efficiency and the national eco-efficien-

cy, so that we can take appropriate countermeasures to improve eco-efficiency. This is of great practical significance to eco-civilization construction and regional sustainable development in Southeast Guizhou.

1　Research method and data source

1.1　Overview of the study area　Miao and Dong Autonomous Prefecture in Southeast Guizhou is located in the southeast of the Yunnan – Guizhou Plateau（107°17′ – 109°35′ E, 25°19′ – 27°31′ N）, east to the Huaihua area of Hunan Province, south to the Liuzhou and Hechi areas of the Guangxi Zhuang Autonomous Region, west to Buyi and Miao Autonomous Prefecture in South Guizhou, and north to Zunyi and Tongren. The total land area of this prefecture is 3 027 805. 89 hm^2. Miao and Dong Autonomous Prefecture in Southeast Guizhou is in the transitional slope area from the Yunnan – Guizhou Plateau to western Hunan and Guangxi hilly, where the high and steep mountains crisscross, and the rivers are deep. It has a subtropical monsoon humid climate. It has towering mountains covered by verdant trees, with rich forest resources, the forest coverage rate reaching 62. 78%, which is one of important forest areas in China, and also a green ecological protection barrier for the Yangtze River Delta and the Pearl River Delta.

1.2　Research method

1.2.1　Single ratio method based on the ecological footprint model. According to the definition of this single ratio method, the single ratio calculation method based on the ecological foot-

print model is as follows：we can define the regional eco-efficiency as occupying GDP output created by unit ecological footprint. The calculation formula is as follows：

$$EE = GDP/EF \qquad (1)$$

where *EE* is eco-efficiency；*GDP* is the total regional output value；*EF* is the regional ecological footprint.

This method is built on the basis of the ecological footprint model，which can be used for eco-efficiency comparison of the global and regional industries and products[5]. In order to better grasp the development level of the eco-efficiency in Southeast Guizhou's experimental area of eco-civilization construction，here we conduct dynamic comparison between it and the national eco-efficiency.

1.2.2 Grey prediction method. For the gap between the eco-efficiency in Southeast Guizhou's experimental area of eco-civilization construction and the national eco-efficiency in the future，we use the grey system for prediction. Grey system is the system both containing the known and unknown or uncertain information. There are many types of grey prediction，and this study uses sequence prediction with sequence equally spaced（the prediction of the number and size of time sequence is known as sequence prediction）.

In GM（1，1）model prediction，when the average relative error is too large，greater than 5%，the weakening operator is introduced to process data[6]. Based on the data concerning the eco-efficiency in Southeast Guizhou's experimental area of eco-civilization construction and the national eco-efficiency in the period 1978 – 2010，we predict the future eco-efficiency of Southeast Guizhou and China using grey system theory，and then calculate the gap.

1.3 Data processing and explanation GDP data are from *China Statistical Yearbook* and *Guizhou Statistical Yearbook* from 1978 to 2010；the ecological footprint data concerning Southeast Guizhou's experimental area of eco-civilization construction are from the preliminary findings[7]；the national ecological footprint data are mostly from the research results of Liu Yuhui[8]；other data are obtained through calculation.

2 Results and analysis

2.1 Dynamic comparison of the eco-efficiency in Southeast Guizhou's experimental area of eco-civilization construction and the national eco-efficiency According to the GDP economic statistics in Southeast Guizhou and China during the period 1978 – 2010，we calculate the eco-efficiency value of the two in the study period，using formula（1）. Dynamic comparison of the eco-efficiency in Southeast Guizhou's experimental area of eco-civilization construction and the national eco-efficiency can be shown in Fig. 1. Fig. 1 shows that in the period 1978 – 2010，the eco-efficiency in Southeast Guizhou's experimental area of eco-civilization construction was always below the national eco-efficiency，and the annual average eco-efficiency was 1 486.597 yuan/hm², while the national annual average eco-efficiency was 3 116.692 yuan/hm². It can be seen that the average annual eco-efficiency in Southeast Guizhou's experimental area of eco-civilization construction is less than one half of the national annual average eco-efficiency. The average absolute gap for many years is 1 630.095 yuan/hm²，and in the period 1978 – 2002，the gap between the two tended to increase year by year，from 276.551 yuan/hm² in 1978 to the peak value of 3 227.713 yuan/hm² in 2002，with the average annual increase of 118.047 yuan/hm². Especially after 1992，the gap was particularly evident，with the average annual increase of 194.771 yuan/hm². In 2002，the gap peaked，but from 2003 to 2010，the gap tended to decrease. In 1999，the average eco-efficiency in China's western provinces（autonomous regions and municipalities）was 3 675 yuan/hm²[9]，while the average eco-efficiency in Southeast Guizhou's experimental area of eco-civilization construction was about 1 782 yuan/hm²，less than one half the average eco-efficiency in China's western provinces（autonomous regions and municipalities）.
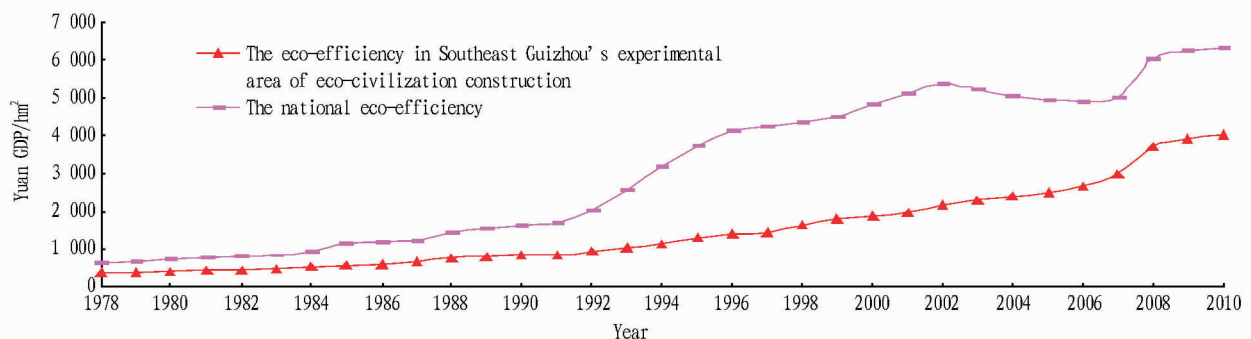

Fig. 1 Dynamic comparison of the eco-efficiency in Southeast Guizhou's experimental area of eco-civilization construction and the national eco-efficiency

These studies have shown that the eco-efficiency in Southeast Guizhou's experimental area of eco-civilization construction is relatively low. On the one hand，it indicates that the social and economic development in Southeast Guizhou's experimental area of eco-civilization construction has consumed a large amount of resources，having a great impact on the environment；on the other hand，it also indicates that the efficient use of resources and the environment in Southeast Guizhou's experimental area of eco-civilization construction still has much room for development.

2.2 Grey system prediction analysis of the ecological efficiency gap According to the eco-efficiency data in Southeast

Guizhou's experimental area of eco-civilization construction during the period 1978 – 2010, we predict the eco-efficiency in Southeast Guizhou's experimental area of eco-civilization construction in the period 2011 – 2025, using grey system theory. The time response function is as follows:

$x(k+1) = 4\ 199.038\ 822e^{0.07866k} - 3\ 840.503\ 683.$

It has second-class simulation accuracy (the mean relative error is 4.495 806%; $a = 0.078\ 66$). Thus it can be used for direct long-term and medium-term prediction, (data processing: the weakening operator is not introduced).

According to the national eco-efficiency data during the period 1978 – 2010, we predict the national eco-efficiency in the period 2011 – 2025, using grey system theory. The time response function is as follows:

$x(k+1) = 163\ 950.873\ 068e^{-0.020\ 548k} - 160\ 834.180\ 631.$

It has second-class simulation accuracy (the mean relative error is 3.0969 %, a = 0.020548). Thus it can be used for direct long-term and medium-term prediction, (data processing: the weakening operator is introduced).

Prediction results of gap between the eco-efficiency in Southeast Guizhou's experimental area of eco-civilization construction and the national eco-efficiency in the period 2011 – 2025 can be shown in Table 1. Table 1 shows that the eco-efficiency gap between the two will gradually be narrowed in the period 2011 – 2025; from 2019, the eco-efficiency in Southeast Guizhou's experimental area of eco-civilization construction will exceed the national eco-efficiency.

Table 1   Prediction results of gap between the eco-efficiency in Southeast Guizhou's experimental area of eco-civilization construction and the national eco-efficiency in the period 2011 – 2025   yuan/hm²

Year	Ecological efficiency gap	Year	Ecological efficiency gap
2011	2 310.954	2019	−246.859
2012	2 100.839	2020	−739.985
2013	1 861.035	2021	−1 283.284
2014	1 595.227	2022	−1 881.063
2015	1 249.070	2023	−2 537.975
2016	969.776	2024	−3 259.139
2017	604.486	2025	−4 049.952
2018	200.074		

3   Conclusions

In the period 1978 – 2010, the eco-efficiency in Southeast Guizhou's experimental area of eco-civilization construction was always below the national eco-efficiency, and the annual average eco-efficiency in Southeast Guizhou's experimental area of eco-civilization construction was less than one half of the annual average national eco-efficiency. In the period 1978 – 2002, the gap between the eco-efficiency in Southeast Guizhou's experimental area of eco-civilization construction and the national eco-efficiency tended to increase year by year. After 1992, the gap was particularly evident; in 2002, the gap value peaked; after 2003, the gap tended to narrow.

Based on the grey system prediction results, in the period

2011 – 2025, the gap between eco-efficiency in Southeast Guizhou's experimental area of eco-civilization construction and the national eco-efficiency will gradually narrow; in 2019, the eco-efficiency in Southeast Guizhou's experimental area of eco-civilization construction will begin to exceed the national eco-efficiency. If the status quo is maintained, it is expected to take eight years for the eco-efficiency in Southeast Guizhou's experimental area of eco-civilization construction to exceed the national eco-efficiency. However, at present, China is also actively taking measures to develop low-carbon, energy-saving, low-energy-consumption economy, to improve eco-efficiency. At the same time, Southeast Guizhou's experimental area of eco-civilization construction takes on the transfer of eastern industries, and in the process of rapid industrialization, high-energy-consumption industries will enter inevitably, so if we maintain the present rate, it still needs a long time for the eco-efficiency in Southeast Guizhou's experimental area of eco-civilization construction to exceed the national eco-efficiency. From the perspective of eco-efficiency, Southeast Guizhou's experimental area of eco-civilization construction still has a long way to go. For now, low eco-efficiency has seriously impeded experimental area construction and sustainable development of eco-civilization in Southeast Guizhou, therefore, in order to make Southeast Guizhou's experimental area of eco-civilization construction truly become an ecological civilization area, we still need to take positive and effective measures to further improve the eco-efficiency.

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