RESEARCH ARTICLE

Environmental analysis of forest scenic spots based on ecological carrying capacity

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The analysis of ecological carrying capacity (EC) is important for understanding environmental changes and formulating relevant development policies. Based on EC, this study calculated and analyzed the changes of ecological footprint (EF) and EC of the forest scenic spots in Hunan Province, China from 2014 to 2018 using the ecological footprint (EF) method. The calculation results showed that the tourism industry in Hunan Province developed rapidly with the number of tourists and tourism income increased rapidly too. The EF and EC also increased year by year, but ecological footprint per capita (ef) and ecological carrying capacity per capita (ec) decreased at the same time. In addition, EF had a rapid growth rate, and it was always higher than EC, which made the scenic spots always in a state of ecological deficit, and the situation deteriorated year by year. According to the analysis results, it was found that the forest scenic spots in Hunan Province were in the state of unsustainable development, which required the rational development and management.

Keywords: ecological carrying capacity; forest scenic sport; Hunan Province; ecological footprint.

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Introduction

With the development of society and economy and the continuous improvement of productivity, more and more problems such as environmental damage and resource exhaustion have appeared in the natural ecosystem. To avoid the deterioration of the environment, the scientific and reasonable use of the environment and the sustainable development of environment can be realized only when the use of the environment has been controlled within its bearing capacity. The analysis of ecological carrying capacity (EC) relationship is of great significance for understanding the regional environment and formulating future development strategies, which has been widely concerned by researchers. Peng, *et al*. took Dali Bai Autonomous Prefecture of Yunnan Province, China as the research subject and studied the construction of its mountainous cities [1]. Through the analysis of EC, it was found that Yunlong County had rich water and soil resources, and the ecological environment was well protected with the highest EC value. According to different EC values, regions were divided to achieve the sustainable development of the mountainous areas. Wang, *et al*. analyzed the EC values of the Yangtze River urban agglomeration and found that Nanjing, Yangzhou, Taizhou, and Changzhou cities were in the high load stage, while Suzhou, Wuxi, Nantong, and Zhenjiang cities were in the low load stage [2]. It was necessary to coordinate the social, economic, and ecological development of cities according to the actual situation. Kusumoarto, *et al*. calculated the ECs of several tourist areas in the Halimun Salak National Park, West Java, Indonesia and found that all areas had great development potential and the current number of tourists in these areas had not exceeded their carrying capacity [3]. Li *et al*. calculated the water EC of Heilongjiang Province, China, analyzed the changes of EC in different cities from 2000 to 2011, and found that there was a serious ecological deficit in Nenjiang River Basin and Suifen River Basin [4]. Forest has functions of wind prevention, sand fixation, water and soil conservation, *etc*. As a scenic spot constructed with forest as the main body, forest tourism scenic spot can provide people with superior ecological environment and leisure space, which is widely loved by people. Forest scenic spots have high requirements for forest ecological environment, but with the rapid development of tourism industry, many scenic spots are facing some problems, such as the superior ecological environment has not been converted into a competitive advantage, or the fragile ecological environment has been damaged by human activities. The main research subject of this study is the forest scenic spots in Hunan Province, China located in latitude 24° 38′ ~ 30° 08′ north, longitude 108° 47′ ~ 114° 15′ east. Hunan Province is in the transition zone from the Yunnan-Guizhou Plateau to the hills of Jiangnan and the Nanling Mountains to the Jianghan Plain. The topography of Hunan Province is a horseshoe-shaped landscape surrounded by mountains on three sides and opening towards the north, straddling the Yangtze and Pearl River systems with a subtropical monsoon climate. Hunan Province is rich in forest resources with a forest coverage rate of 59.96%, and its ecological service function value is ¥1.01 trillion (Chinese Yuan). The subtropical evergreen broad-leaved forest eco-region of the Wuling Xuefeng Mountains and the Nanling Luoxiao Mountains spans five latitudes from 20 to 30 degrees north latitude and is known as the most valuable eco-region in the world in the same latitude zone. Tourism resources are also very rich in Hunan Province with two World Natural Heritage sites, Zhangjiajie and Lang Mountain. There are many scenic spots built on forests, such as Dongtai Mountain National Forest Park, Huayanxi National Forest Park, Zhangjiajie National Forest Park, and Tianmen Mountain National Forest Park. In 2018, the total tourism revenue of the province was ¥835.57 billion showing an increase of 16.5%, while the domestic tourism revenue was ¥825.51 billion showing an increase of 16.5%, and the international tourism revenue was $1.52 billion (USD) showing an increase of 17.4%. This study analyzed the relationship between the current EC and scenic development with ecological footprint (EF) approach to provide theoretical support for the subsequent development strategy and scenic spot management.

Materials and methods

Data source

This study mainly analyzed the EC changes of forest scenic spots in Hunan Province, China from 2014 to 2018. The data needed for calculation were retrieved from Hunan Statistical Yearbook (2014-2018) [5], China Forestry Statistical Yearbook [6], relevant data provided by scenic spots, and some data obtained through consultation with scenic spot management personnel.

Ecological carrying capacity (EC) analysis

The methods for analyzing EC are as follows.

(1) Logistic method:

Through logistic model, the EC can be expressed by the number of populations that can be carried, which can only be used for static and short-term analysis.

(2) Net primary productivity (NPP) of natural vegetation:

The EC is expressed by the production capacity of plant community, i.e., the recovery capacity of ecosystem [7].

(3) Index system method:
The EC is analyzed through the pressure state response (P-S-R) model [8] and its derivative model.

(4) System model method:
It includes system dynamics model (SD) [9] and statistical model.

(5) EF method:
It is simple and practical and can reflect the relationship between bearing capacity and pressure through the comparison of supply and demand [10]. It is the most commonly used method in the analysis of EC. Therefore, this method is also adopted in this study.

Ecological footprint analysis (EFA)
EF refers to ecologically productive areas that can provide resources that the productive populations need and absorb wastes [11]. The relationship between EF and EC is as follows: (1) If EF < EC, it indicates the region is in a state of ecological surplus (ER), and its development is sustainable; (2) if EF > EC, it indicates that the region is in a state of ecological deficit (ED), and its development is unsustainable.

The general calculation formula of EF can be expressed as:

$$EF = N \times ef = N \times \Sigma r_j \times \frac{c_i}{p_i}$$

where N stands for number of people, ef stands for per capita EF, rj stands for equilibrium factor, i stands for type of consumables, j stands for type of ecological productive land, C_i stands for per capita consumption of the i-th commodity, and p_i stands for the world average productivity of the i-th commodity.

The general calculation formula of EC can be expressed as:

$$EC = N \times ec = N \times \Sigma A_j \times r_j \times y_j \,,$$

where N stands for number of people, ec stands for per capita EC, A_j stands for per capita land area, r_j stands for equilibrium factor, and y_j stands for yield factor.

The equilibrium factor adopted the calculation result, and the yield factor referred to the value as shown in Table 1 [12-13].

Table 1. Values of EFA parameters.

Land type	Equilibrium factor	Yield factor
Cultivated land	2.8	1.63
Woodland	1.1	1.4
Grassland	0.5	8.37
Building land	2.8	1.63
Fossil energy land	1.1	1.4
Water area	0.2	1.46

Results

The changes of tourism in Hunan Province from 2014 to 2018 were shown in Table 2. The tourism industry in Hunan Province was in a state of rapid growth from 2014 to 2018. Comparing to 2014, the numbers of domestic and inbound tourists in 2018 increased by 82.93% and 66.33%, respectively, while the total tourism income increased by 173.89%. The rapid growth of tourism population has brought huge economic income to the tourism industry of Hunan Province, but also increased the burden of ecological environment.

The changes of EF and EC in forest tourist attractions were shown in Figure 1 and 2. Figure 1 showed that the EF value of the scenic spot increased year by year from 0.75 in 2014 to 0.91 in 2018 with an increase of 21.33%, while the ecological footprint per capita (ef) value decreased year by year from 0.051 to 0.027 with a decrease of 47.06%. Figure 2 demonstrated that the EC value of the scenic spot gradually increased from 0.278 in 2014 to 0.289 in 2018 with an increase of 3.96%, while the ecological carrying capacity per capita (ec) value gradually decreased from 0.018 to 0.009 with a decrease of 50%. With the development and utilization of scenic spots, the values of both EF and EC

Table 2. Tourism from 2014 to 2018.

	2014	2015	2016	2017	2018
Number of domestic tourists (100 million person-times)	4.1	4.7	5.6	6.7	7.5
Number of inbound tourists (10,000 person-times)	219.5	226.1	240.8	322.7	365.1
Total tourism income (¥100 million) (Chinese Yuan)	3,050.7	3,172.9	4,707.4	7,172.6	8,355.7
Domestic tourism revenue (¥100 million) (Chinese Yuan)	3,001.5	3,660.0	4,640.7	7,085.2	8,255.1
International tourism revenue ($100 million) (USD)	8.0	8.6	10.1	13.0	15.2

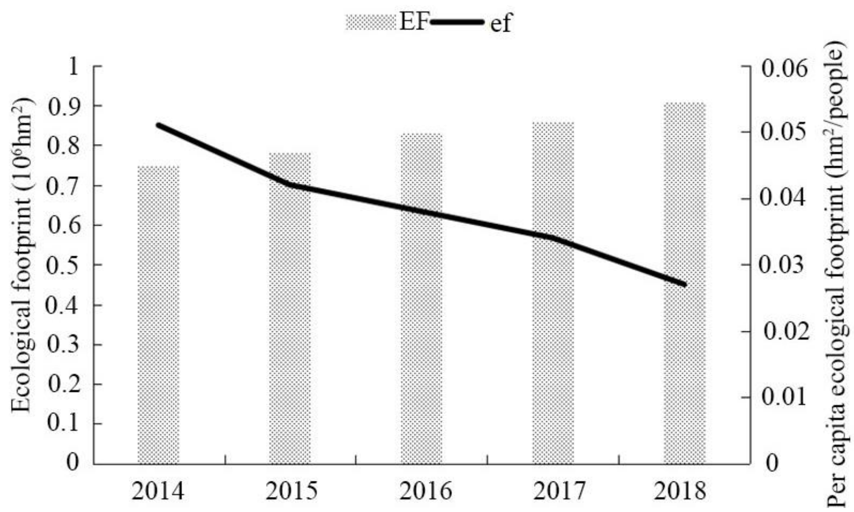

Figure 1. Calculation results of EF.

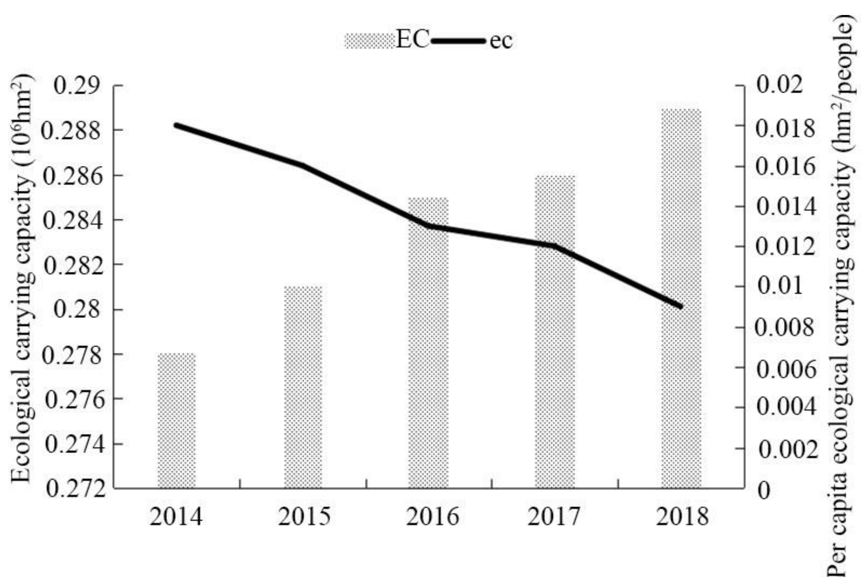

Figure 2. Calculation results of EC.

increased. However, due to the rapid growth of the number of tourists, ef and ec values both declined rapidly. The growth rate of EF value was significantly higher than that of EC value. The increase amplitude of EC value in five years was relatively small, i.e., in an unsustainable state.

By comparing the values of EF and EC during 2014 to 2018 period, it was found that studied areas were in a state of ecological deficit, and the results were shown in Table 3. The EC value of forest tourist attractions in Hunan Province was always smaller than the EF value. The ecological deficit (ED) value increased year by year with the ED value in 2018 was 31.57% higher than that in 2014. Based on the above results, it was found that the development, utilization, and protection of forest tourist attractions gradually improved with the increase of the number of tourists and the increase of tourism income, but generally speaking, it was still in the ED state, indicating that the forest tourist attractions still could not meet the market demand and failed to achieve sustainable development although there was some development.

Table 3. Changes of ecological deficit.

Time	EF	EC	ED
2014	0.75	0.278	0.472
2015	0.78	0.281	0.499
2016	0.83	0.285	0.545
2017	0.86	0.286	0.574
2018	0.91	0.289	0.621

Discussion

Forest tourism scenic spot not only can give full play to the ecological function of forest, but also is an important part of the tourism industry, which has made great contribution to the development of tourism economy. With the growth of the number of tourists, the contradiction between the development of tourism industry and ecology is becoming more and more serious. EC can be used to evaluate the sustainable development capacity of ecology [14, 15]. In this study, the forest tourist attractions in Hunan Province, China were analyzed using EFA method. According to the calculation results, it was found that the tourism industry in Hunan Province developed rapidly from 2014 to 2018. The tourism revenue increased rapidly. However, the EF and EC values increased year by year while ef and ec values decreased at the same time. The EC value was always smaller than the EF value, i.e., in a state of ED, which suggested that forest tourism scenic spots in Hunan Province were in the state of unsustainable development. In order to achieve better development of scenic spots, the following suggestions are put forward.

(1) Scientific and rational development: The development and planning of scenic spots should take the ecosystem as the first, put functions of forest such as air purification and water source with pressure roots in the first place, follow the natural laws, fully understand the characteristics of urban climate, topography, *etc*., reduce the disturbance to the natural environment, carry out the protective development of fragile resources, protect the animal and plant resources in scenic spots, strengthen the monitoring of various resources, master the dynamics of resources, and ensure the balance of ecosystem. Moreover, in order to meet tourists' needs, the planning and construction of trees should be emphasized to create a beautiful tourist space and provide convenient tourist routes.

(2) Control the growth of EF: In the process of traveling, the demands for food, clothing, housing, and transportation are increasing, which lead to the continuous improvement of EF. In order to effectively control the growth of EF, scenic spots can take the way of tourism diversion to appropriately balance tourists in the off-season and the peak season and alleviate the contradiction between the capacity of the scenic spot and the number of tourists by controlling the tour time.

(3) Establish the ecological compensation mechanism: Scenic spots can take part of the tourism revenue as the special fund for the ecological protection of scenic spots to make compensation for the ecological damage caused by the development and construction process. In addition, scenic spots can obtain support from the forestry department to supervise the forest development status and get professional guidance in case of problems.

Conclusion

Based on the EC, this study analyzed the environment of forest tourist attractions in Hunan Province, China by EFA method. The results demonstrated that (1) from 2014 to 2018, the number of tourists and tourism revenue in Hunan province grew rapidly; (2) from 2014 to 2018, EC and EF values of forest tourist attractions in Hunan Province increased year by year, among which the EC value increased significantly; (3) from 2014 to 2018, the ec and ef values of scenic spots decreased year by year; (4) from 2014 to 2018, scenic spots were in the state of ecological deficit, and the ecological deficit in 2018 was 31.57% higher than that in 2014. The results showed that the forest tourist attractions in Hunan Province were in a state of unsustainable development, which required more attentions in the development and management of scenic spots and the adoption of strategies conducive to ecological balance, so as to achieve a good development of scenic spots.

References

1. Peng J, Du Y, Liu Y, Hu X. 2016. How to assess urban development potential in mountain areas? An approach of ecological carrying capacity in the view of coupled human and natural systems. Ecol Indic. 60:1017-1030.
2. Wang Y, Peng B, Wei G, Elahi E. 2019. Comprehensive evaluation and spatial difference analysis of regional ecological carrying capacity: a case study of the Yangtze River urban agglomeration. Int J Env Res Pub He. 16(18):3499.
3. Kusumoarto A, Ernawati A. 2018. Ecological Carrying Capacity Analysis of Ecotourism Objects in Salak II Resort Area, Halimun Salak National Park. IOP Conf Ser Earth Environ Sci. 145(1):012098.
4. Li J, Lei X, Fu Q, Li T, Qiao Y, Chen L, *et al*. 2018. Multi-scale research of time and space differences about ecological footprint and ecological carrying capacity of the water resources. Appl Water Sci. 8(1):22.
5. Hunan Provincial Bureau of Statistics. Hunan Statistical 2014 Yearbook. China Statistics Press. Beijing, China. 2014. http://222.240.193.190/14tjnj/indexch.htm
6. China Statistical Yearbook for Regional Economy 2015. China Academic Journals Electronic Publishing House. Beijing, China. https://data.cnki.net/trade/Yearbook/Single/N2015100188?z=Z010
7. Wang C, Zhang S, Yan W, Wang R, Liu J, Wang Y. 2016. Evaluating renewable natural resources flow and net primary productivity with a GIS-Emergy approach: A case study of Hokkaido, Japan. Sci Rep. 6:37552.
8. Fan XS, He P, Chen F, Huang LH. 2017. Technical solutions for strategic environmental assessment on ecological carrying capacity-coastal ports master plan. China Environ Sci. 37(5):1971-1978.
9. Sabounchi NS, Hovmand PS, Osgood ND, Dyck RF, Jungheim ES. 2014. A novel system dynamics model of female obesity and fertility. Am J Public Health. 104(7):1240-1246.
10. Du W, Yan HM, Yang YZ, Liu F. 2018. Evaluation Methods and Research Trends for Ecological Carrying Capacity. J Resour Ecol. 9(2):115-124.
11. Mancini MS, Galli A, Niccolucci V, Lin D, Bastianoni S, Wackernagel M, *et al*. 2016. Ecological Footprint: Refining the carbon Footprint calculation. Ecol Indic. 61:390-403.
12. Mathis W, William R. Our Ecological footprint: Reducing Human Impact on the Earth. New Society Publishers. Gabriola Island, British Columbia, Canada. 1996:30-100.
13. Zhang C. 2007. Evaluation of sustainable development in Hunan Province based on local ecological footprint. Central South University. Graduate student thesis.
14. Ma P, Ye G, Peng X, Liu J, Qi J, Jia S. 2017. Development of an index system for evaluation of ecological carrying capacity of marine ecosystems. Ocean Coast Manage. 144:23-30.
15. Xue Q, Song W, Zhang Y, Mou F. 2017. Research progress in ecological carrying capacity: implications, assessment methods and current focus. J Resour Ecol. 8(5):514-525.