Original Research

Study on Sustainable Development Evaluation of Mountain Scenic Spots Based on Ecological Footprint Composition – Take Chinese Mount Heng as an Example

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Abstract

The evaluation of sustainable development in mountain scenic spots can provide reference for the tourism development of in mountain scenic spots. This study takes mountain Heng as a case, collects relevant data through field investigation, and explores the ecological status by combining the tourism ecological footprint model, tourism ecological carrying model and tourism ecological footprint index model. The results show that the tourism ecological footprint of transportation and catering is relatively high. The overall ecological pressure value is -140813.2423 hm^2, the tourism ecological footprint index is -6.2477 hm^2, the TEFI value is $\leq$-1, and the sustainable level of tourism development is negative. The ecological footprint of Nanyue tourism area is severely depleted, and the sustainable level of tourism development obviously deviates from the normal track. Based on the loss ratio of ecological footprint account, the paper aims to strengthen the rectifying level of tourism ecology from the aspects of tourist capacity, practitioners, ecological development concept and business model, so as to promote its sustainable development.

Keywords: tourist spending, mountain-type scenic spots, tourism ecological footprint, footprint index

Introduction

The ecological footprint method aims to judge the sustainability level of current tourism development by analyzing the gap between the ecological consumption (ecological footprint) of regional natural resources and the ecological supply (ecological carrying capacity). Rees [1] (1992) proposed the calculation method of ecological footprint, believing that ecological footprint is the consumption state of maintaining material and energy flow in the economy. Then Hunter [2] (2007), based on multiple dimensions, expounded tourism ecological footprint. Combining the theory of tourism

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life cycle system, he explained tourism ecological footprint calculation model and its measuring value in the sustainable development of tourism, and New Zealand as a case he built index system of ecological footprint, revealed the influence of tourism on the ecological environment in detail. Stefan G. [3] (2002) investigated the tourism industry of Seychelles Islands in Africa, and the results showed that the ecological footprint was not sustainable. Peter Allan Johnson [4] (2003) empirically studied and compared the utilization of tourism ecological resources in Ontario, Canada. Valentina C. [5] (2008) studied the sustainability of tourism activities in Italy through the combination of ecological footprint model and LCA.

The concept of ecological footprint was introduced in China in 1999, and finally was widely accepted after a variety of explanations such as ecological trace, ecological occupation, ecological space occupation and ecological stomping occupation. Dai [6] (2022) and Xu [7] (2022) reviewed the ecological footprint from the aspects of theory, method and calculation model. Subsequently, the ecological footprint model was introduced into the tourism industry. Li [8] (2022) evaluated the contribution rate of ecological footprint in sustainable tourism development. Fu [9] (2022) eliminated the impact of trade factors on regional tourism sustainability assessment; Liu Xintian [10] (2013) applied ecological footprint to dynamically monitor the sustainability of regional tourism; Zhao Jian-qiang [11] (2016) and Li Peng-hui [12] (2018) improved the evaluation model by energy evaluation and three-dimensional ecological footprint respectively. Based on the perspective of sustainable development, Zhu Wan-chun [13] (2018) introduced the footprint model into the tourism poverty alleviation and accurate identification system, which extended the functional value of the model. Huang He-ping [14] (2019) studied the carbon footprint and eco-efficiency of rural tourism destinations. In terms of typical mountain scenic spots, Xia [15] (2022), Wang Peng [16] (2014) and Yang Yi-min [17] (2016) have a certain representative significance in evaluating ecological security by ecological footprint in Lushan mountain in Jiangxi province, Hengshan mountain in Hunan province and Zhangjiajie in Hunan province.

Based on the above research, it can be found that, firstly, the empirical research on tourism ecological footprint pays less attention to the special regions with higher ecological sensitivity, and the regional selection is mainly based on the urban tourist destination. Only a few sources have studied the rural tourism destinations, but the ecological loss of mountain scenic spots is ignored. In general, the threshold of ecological carrying capacity in ecological fragile zones is low, and the ecological footprints of tourism service providers are all in the core areas of scenic spots. They are more continuous in time than tourists, therefore, this part of the ecological footprint can not be ignored. Based on this, this paper selects the typical mountain scenic spot – Nanyue Mount Heng China (Nanyue) as the research target area. This paper made a comprehensive

calculation of its tourists' consumption and the ecological footprint account of tourism practitioners. Based on the ecological footprint index model, this paper evaluated the sustainable development level of tourism, and provided suggestions and references for the sustainable development of mountain scenic spots.

The method of ecological footprint analysis is a specific method to measure the balance state between ecological consumption and ecological supply in an area, which is not only suitable for mountain scenic spots, general scenic spots, and even modern urban living areas. The method can be used to measure the local ecological consumption and ecological supply balance state, and the fluctuation of both.

Material and Methods

Study Area Overview and Data Sources

Hengshan General Situation of the Southern Mountain

Mount Heng refers to the scenic area of Mount Heng, which belongs to the typical mountain tourism area of China. The geographical coordinates are located between 27°4'N and 27°20'N, 112° 34'E and 112°44'E, with a northeast-to-southwest trend. Nanyue is a key scenic area and 5A tourist area, with unique tourism resources with natural and cultural landscapes. According to the national standard "Classification, Investigation and Evaluation of Tourism resources" (GB/T18972-2003), Nanyue tourism resources have 8 main categories, 17 subcategories and 29 basic types. From the total tourism income, ticket income, total tourist reception and group tourist reception of Nanyue from 2013 to 2019, it can be seen that the current development of tourism economy is in good condition (Table 1). However, the development and overuse of tourism resources lead to obvious changes in the ecological environment, and the influx of tourists and the increase in employees. All of them have a great impact on the local soil, atmosphere, water, vegetation, wildlife and landscape architecture.

Data Sources and Processing

The sustainable development level of Nanyue tourism is evaluated based on the ecological footprint account. The research time is 2019. The data range includes basic data, survey data, standard data and estimated data, which are explained in detail as follows:

(1) Basic data. Nanyue tourism income, tourist reception of visitors, hotel, number of beds and the room occupancy, residents food consumption type and quantity, scenic sightseeing area, entertainment area, the scenic personnel, all data come from Hengyang city government's official website, such as Hengyang city bureau of statistics released by the Hengyang city statistics bulletin, and "Hengshan Tourism Development

Table 1. Nanyue tourism revenue and number of tourists, 2013-2019.

Year	Number of visitors (Ten thousand)	Tourism revenue (Billion RMB)
2013	648.59	49.77
2014	706.05	57.33
2015	794.98	63.45
2016	875.67	69.84
2017	1003.08	80.32
2018	1164.17	100.42
2019	1316.37	113.52

Master Detailed Plan", "Ticket briefing" and other official data.

(2) Survey data. Scenic traffic, catering, accommodation, sightseeing, shopping and entertainment facilities, average residence time, and its utilization, destination traffic tool selection, group composition and the average trip distance of tourism, tourist shopping preferences and their average consumption levels, price and market conditions and other all belong to the survey data. We get data mainly through the Nanyue tourists and various tourism enterprises and institutions.

(3) Standard data. Specifically, it includes the energy resource loss generated in the process of tourism behavior, yield factor, average calorific value and conversion coefficient used in this type of land consumption. There is the annual ecological productivity of food, the per unit built-up area of accommodation beds and the amount of energy used. The data were obtained from relevant international standards and authoritative literature.

(4) Estimated data. Due to the large and complex data required for ecological footprint calculation, estimation errors existed in statistical data, it is necessary to estimate and interpolate the missing data when obtaining actual data.

After data collection and sorting, excel software is mainly used to give variable meaning to the corresponding original data according to the calculation model, and the sustainable level of tourism development is determined according to the tourism ecological Footprint index (TEFI) value.

Construction and Calculation of Nanyue Tourism Ecological Footprint Model

Overall Model of Tourism Ecological Footprint

Tourism Ecological Footprint (TEF) is developed on the basis of the concept of ecological footprint. It is generally considered that tourism ecological footprint is productive land area needed by a certain region to support a certain number of tourist activities (Zhao [18], 2022).

Tourism is mainly based on various stakeholders in the tourism system as the main body, tourist attractions and behavior as the object, through the subject and object in a certain area, the interaction among the flow of tourist activities, production, management and consumption in the act of tourism. The six elements of tourism activities form a closed-loop structure of the tourism industry chain, which is transformed into the output value of land area through the resource consumption of specific links. After the balance, the specific value of tourism ecological footprint can be measured. A large number of practitioners should participate in the operation of tourism services, it needs calculating the six ecological footprint accounts of tourists, and the ecological footprint accounts of tourism practitioners are also added. The model is as follows:

$$TEF = TEF_{food} + TEF_{accomodation} + TEF_{transport}$$
$$+ TEF_{purchase} + TEF_{visitting} + TEF_{entertainment} + TEF_{employee} \quad (1)$$

The variables in the equation represent the partial ecological footprint accounts of tourism catering, accommodation, transportation, shopping, sightseeing, entertainment and tourism practitioners in turn.

Measurement and Analysis of Ecological Footprint Account of Nanyue Tourism Consumers

Nanyue Tourism Traffic Ecological Footprint

The specific calculation model of tourism traffic ecological footprint is as follows:

$$TEF_{transport} = \left[\sum (S_i \times R_i) + \sum (N_j \times D_j \times C_j) \right] \times F_v \quad (2)$$

S_i is the built-up area of the first type of transport; R_i Is the tourist utilization rate of the i mode of transport; N_j The number of tourists of the j mode of transport; D_j Is the flat travel distance of tourists who choose the j type of transport; C_j Represents the ecological footprint per capita of the j type of transportation. F_v (v = 1, 2, …6) is the corresponding land type equilibrium factor in six types of ecologically productive land.

The equilibrium factor is an important parameter in the calculation of ecological footprint, which converts the area of six biological productive land types into the area with the same biological productivity, thus, the sum of six types of land area is realized. Therefore, the accuracy of the equilibrium factor directly affects the reliability and comparability of the calculated results. Refer to Wackernagel [19] (1999).

The research group selected 100 tourists in Nanyue to conduct an interview survey, and found that tourists mainly arrive at the tourist destination by plane, train, coach and self-drive, accounting for 4.17%, 30.42%, 39.83% and 25.58% respectively. Since Nanyue has

not counted the number of tourists corresponding to various modes of transportation in the total number of tourists received by tourism, this part of data is estimated and analyzed by the method of scaling and shrinking. The calculation of tourist travel distance includes three segments: long range, medium range and short range. According to the distance attenuation law of tourism market and the economic effect principle of distance and cost, it is assumed that long range tourists use plane, medium range tourists use train and coach, and short range tourists use self-drive. Through the query of Hengyang Nanyue airport flight information, combined with Nanyue market data can determine the remote provinces including Shanghai, Hainan, Fujian and Shandong four provinces. Medium-haul tourists mainly come from neighboring provinces, with mature markets including Guangdong Province, Pingxiang in Jiangxi province, Guilin in Guangxi Province and Hubei province. The near distance tourist source is mainly distributed in Hengyang City and its neighboring areas in Hunan Province, including Hengyang, Zhuzhou, Shaoyang, Changsha, Yueyang, Chenzhou and other places. For the convenience of calculation, all provinces and regions are summarized according to the linear distance between the provincial capital city and Nanyue to take the average distance.

According to the above data, the calculation results of Nanyue tourism traffic ecological footprint account are shown in Table 2. The ecological footprint per capita corresponding to the four transportation tools was summarized, and the ecological footprint per capita of tourism transportation in Nanyue in 2019 was 0.060724082 hm².

Nanyue Tourism Accommodation Ecological Footprint

The specific calculation model is as follows:

$$TEF_{accomodation} = \left[\sum (N_i \times S_i) + \sum \left(365 \times K_i \times N_i' \times \frac{C_i}{r}\right) \right] \times F_v \quad (3)$$

S_i is the built-up area of total beds of type i accommodation facilities; N_i Number of beds for type i

accommodation facilities; K_i is the average annual room occupancy rate of type i accommodation facilities; N_i' Number of beds actually used for type i accommodation facilities ($N_i' = N_i \times \frac{1+e_i}{2}$, e_i is the double opening rate of the i accommodation facility): C_i Is the energy consumption per bed of type i accommodation facility, r is the average calorific value per unit of fossil fuel-producing land in the world.

There are significant differences in the energy consumption of different levels of hotels, which are calculated according to the differences in hotel levels in this paper. At present, there is only one four-star hotel in Nanyue, with one and two star hotels occupying the main body. In addition, there are many private hotels, inns and other small accommodation facilities near the scenic spot, which account for 16.45%. This study only takes the estimated value of hotel income level and tourist person-times provided by relevant departments. For the convenience of calculation, the actual room double opening rate is 50%, and the actual number of guests in each star hotel is calculated by double standard room. Based on this, the results of Nanyue tourism accommodation ecological footprint account are shown in Table 3. According to the data summary, the total ecological footprint of tourism accommodation after equilibrium is 3564.861025 hm², and the per capita ecological footprint is 0.001640868 hm².

Nanyue Tourism Catering Ecological Footprint

The calculation model is as follows:

$$TEF_{food} = \left[\sum S_i + \sum \left(N \times D \times \frac{C_i}{P_i}\right) + \sum \left(N \times D \times \frac{E_j}{r_j}\right) \right] \times F_v \quad (4)$$

S_i I s the built-up area of type i catering facilities; N is the total number of people received by the scenic spot; D is the average travel days of tourists. C_i is the per capita daily consumption of food group i; P_i is the annual average productivity of ecologically productive land corresponding to food type i; E_j is the per capita daily energy consumption of tourists; r_j is the average calorific value of land area produced per unit of fossil fuel for the world's i energy source.

Table 2. Nanyue Tourism transportation ecological footprint energy account in 2019.

	Fuel type	Tourists (person)	Average travel distance (km)	Unit ecological footprint (hm²/km)	Equilibrium factor	Ecological footprint after equilibrium	Ecological footprint per capita (hm²/person)
Plane	Aviation kerosene	485459	1096.025	0.0000293	1.1	17148.7837	0.035324886
Train	Diesel	3541405	469.575	0.0000174	1.1	31828.9635	0.008987666
Coach	Gasoline	4636889	469.575	0.000017	1.1	40716.7657	0.008781053
Car	Gasoline	2977947	152.4571	0.0000455	1.1	22723.1586	0.007630478

Table 3. Nanyue tourism accommodation ecological footprint energy account in 2019.

Accommodation facilities	Land type	Composition of hotels	Beds	Total floor area of beds (hm²)	Average occupancy rate (%)	Ecological footprint after equilibrium (hm²)	Ecological footprint per capita after equilibrium (hm²)
A four-star hotel	Built	1	270	0.03	75	22.68	0.00015342
	Fossil energy land					77.60	0.000525
Two star hotel	Built	129	5000	0.01	80	140	4.79452E-05
	Fossil energy land					876	0.0003
One star hotel	Built	256	11225	0.01	75	314.30	5.11416E-05
	Fossil energy land					1843.70	0.0003
Other Accommodation facilities	Built	76	2519	0.006	60	42.32	3.83562E-05
	Fossil energy land					248.25	0.000225

The ecological footprint of tourism catering consists of two parts: the built-up area of catering facilities and the corresponding productive land area transformed by the consumption of food materials. Considering that most hotels provide catering and restaurants operating catering alone have limited footprint, the ecological footprint of this part of the built area has been included in the calculation of the ecological footprint of tourism accommodation, so the calculation will not be repeated. Considering that the catering industry in tourist destinations often uses local characteristic ingredients and recipes, there is no obvious spatial difference in the consumption of specific ingredients within the province, although there is a great difference in the taste of catering habits. Therefore, it can be assumed that the food consumption of tourists in scenic spots is the same as that of residents in the province. In view of this, this paper selected the per capita major food consumption in Hunan Province in 2019 as the original data, and the calculation results are shown in Table 4. According to the data processing results, the total ecological footprint of tourism and catering after the balance is 44122.40063 hm², and the per capita ecological footprint is 0.003790031 hm².

Nanyue Tourism Tour Ecological Footprint

Tourism activities are the core elements of tourism behavior, and also an important link to reflect the value of scenic spots. The ecological footprint of tourism is an extremely important part of calculation, and its specific model is as follows:

$$TEF_{visitting} = \left[\sum S_{visitting} + \sum E_{visitting} \right] \times F_v \quad (5)$$

$S_{visitting}$ is the built-up area of tourist facilities; $E_{visitting}$ is the energy consumption generated during the tour is converted into bio-ecological land area.

The ecological footprint of tourism is mainly composed of two parts: the scenic space, the scenic walking path, the scenic road and the energy consumption of sightseeing vehicles. Nanyue, as a mountain scenic spot, tourists' motivation is mostly to climb mountains for leisure exercise or pray for god and Buddha. The usage rate of sightseeing cars is relatively small, and the energy consumption of self-driving tour has been calculated in the tourism traffic footprint part, so the energy consumption of sightseeing cars is ignored here.

According to the Hengshan scenic area overall planning, Nanyue temple and center of Hengshan scenic area covers an area of 100.8 km², available for tourists sightseeing accounts for part of the less, in a 5A scenic area, rectification in broadening the free life pond masonry bridge, when in Longkou, drunk sleep lake, lake Jin Longtan to the world a plateau area new recreation area, increase the tourist area. Accordingly, the calculation results of Nanyue tourism ecological footprint account are shown in Table 5. The total ecological footprint after balanced tourism is 18.452 hm², and the ecological footprint per capita is 1.58499E-06 hm².

Nanyue Tourism and Entertainment Ecological Footprint

The calculation of the ecological footprint of tourism and entertainment mainly includes the built-up area and total energy consumption of entertainment facilities such as chess and card rooms, song and dance halls, gyms, network gymnasiums and courts. In order to avoid double counting, the built area is not taken into account for entertainment items attached to the hotel. The calculation model is as follows:

$$TEF_{entertainment} = \left[\sum S_{entertainment} + \sum E_{entertainment} \right] \times F_v \quad (6)$$

Table 4. Energy accounts of tourism and catering ecological footprint in 2019.

Project	Annual per capita consumption (Kg/y)	Per capita daily consumption (Kg/d)	Total visitor consumption (Kg)	Land type	Equilibrium factor	Ecological footprint (hm²)	Ecological footprint after equilibrium (hm²)	Ecological footprint per capita (hm²)
Food	136.07	0.373	1584086119	Arable land	2.8	2372.428	6642.7989	0.0005706
Vegetables	113.78	0.312	1324592626	Arable land	2.8	302.418	846.77154	7.2736E-05
Wine	8.92	0.024	103843964	Arable land	2.8	7759.200	21725.761	0.0018662
Wine dried fresh melon and fruit	34.02	0.093	396050634	Arable land	2.8	90.423	253.18305	2.1748E-05
Oil class	12.27	0.034	142843659	Arable land	2.8	316.287	885.6037	7.6072E-05
Pork	23.44	0.064	272881448	Grass	0.5	15154.468	7577.2338	0.00065087
Beef and mutton	1.41	0.004	16414797	Grass	0.5	2044.184	1022.092	8.7796E-05
Poultry	4.7	0.013	54715990	Grass	0.5	492.036	246.01776	2.1132E-05
Fresh eggs	6.61	0.018	76951637	Grass	0.5	790.599	395.29951	3.3955E-05
Milk and products	4.17	0.011	48545889	Grass	0.5	397.418	198.70882	1.7069E-05
Aquatic products	13.12	0.033	152739104	Water area	0.2	21644.653	4328.9307	0.00037185

$S_{entertainment}$ is the built-up area of tourism and entertainment facilities; $E_{entertainment}$ is the bio-ecological land area converted from the energy consumption generated in tourism and recreation activities.

The ecological footprint of tourism and entertainment only considers the ecological footprint formed by the built-up area of all kinds of entertainment facilities, and the energy consumption is mostly clean energy such as electricity, so the energy consumption footprint is not considered. Regardless of the gyms, chess and card rooms and KTV in star hotels, among the current entertainment facilities in Nanyue, the completed area of Tianzishan Square and Wanshou Square is 0.044 km², the completed area of Genting Gym and Yinma Gym is 0.14 km², and the completed area of song and dance club is 0.0068 km². Network sports club built area of 0.004147 km². According to the calculation model of tourism and entertainment ecological footprint, the total ecological footprint after tourism and entertainment equilibrium is 0.3464417 hm², and the per capita ecological footprint is 2.9759E-08 hm².

Nanyue Tourism Shopping Ecological Footprint

The specific calculation model of ecological footprint of tourism shopping is as follows:

$$TEF_{purchase} = \left[\sum S_i + \sum \left(\frac{R_i/P_i}{g_i} \right) \right] \times F_v \tag{7}$$

S_i Is the built-up area of type i tourist shopping mall; R_i is consumption expenditure for tourists to buy the I tourist goods, P_i is the local average selling price of the i tourist commodity, g_i Is the annual average productivity of the local biologically productive land corresponding to the unit of tourism commodity i.

At present, most of the tourist shopping shops in Nanyue are featured by the demand for incense and sacrificial supplies. Most of the owners are native residents of Nanyue, shops are compact and close to the core scenic area. Therefore, the built-up area of the shop is actually the residential land of the place.

Table 5. Energy account of the ecological footprint of tourism in 2019.

Project	Built-up land area (hm²)	Equilibrium factor	Ecological footprint after equilibrium (hm²)	Ecological footprint per capita (hm²)
The scenic trails	4.56	2.8	12.768	1.0967E-06
Scenic highway	1.35	2.8	3.78	3.2469E-07
Viewing space	0.68	2.8	1.904	1.6355E-07

The specific variables only consider the biological productive land footprint reflected by the goods sold in the Nanyue scenic area, and those non-local produced handicrafts and souvenirs are not considered within the scope. Nanyue popular shopping souvenirs belong to local products are Buddhist beads, cloud tea, Guanyin bamboo shoots, goose fungus, Nanyue longevity wine, longevity cake, Gaoshan longevity rice, yellow essence, kiwi fruit and so on. According to statistics, the total number of tourists received by Nanyue in 2019 was 110 0239 person-times, and the total tourism revenue was 100.42 billion yuan, among which tourism commodities accounted for 17.4%, and the per capita tourism shopping consumption was 1588.12 yuan. Because the statistics related to the number, variety and category of tourist commodities purchased by tourists, consumption expenditure and purchase price at that time have not been completed completely, the data used in the research can only be estimated and assumed. Here, it is assumed that all the products purchased by tourists are local specialties, and the purchase price at that time is 1600 yuan/Kg, the average value of various types and merchants. It can be seen that the total ecological footprint after balanced tourism and shopping is 0.005643055 hm^2, and the ecological footprint per capita is 5.12894E-09 hm^2.

Measurement and Analysis of Ecological Footprint Account of Nanyue Tourism Practitioners

According to the consumption of ecological resources generated by tourism service providers in the core area of scenic spots, the ecological footprint calculation model of tourism human resources is constructed as follows:

$$TEF_{employee} = F_v \times \left[\sum (N \times S) + \sum (365 \times K \times N \times \frac{C}{r}) \right]$$
$$+ F_v \times \left[\sum (N \times D \times \frac{C_i}{P_i}) + \sum (N \times D \times \frac{E_j}{r_j}) \right] \quad (8)$$

F_v is the equilibrium factor of built-up land; N is the number of employees; S is accommodation area for employees; K is staff accommodation rate; C is bed energy consumption; r is the average calorific value of the world's land area per unit of fossil fuel production; D is the annual average working days of employees; C_i is the consumption of the i food per employee per day; P_i Is the annual average productivity of biologically productive land corresponding to food type i; E_j is the j energy consumption per employee per day; r_j is the average calorific value of land area per unit of fossil fuel production for the j energy source.

At present, Nanyue's administrative establishment within the number of 4618 people, more than a year of long-term contract employment for 1232 people,

temporary employment for 57122 people, the total number of employment for 62972 people. The average person works about 235 days a year. According to the actual situation of Nanyuyue, the accommodation environment of employees is managed uniformly according to the bed standard of ordinary hotels, and this standard is used as the bed energy consumption. Nanyue temporary workers accounted for a large number of administrative institutions, long-term contracts hired staff and some temporary staff do not occupy the number of beds, so the comprehensive accommodation rate of 88%. The catering footprint consumption of employees is treated with the same standard as the calculation method of tourists. The results showed that the ecological footprint of the accommodation site was 1798.742 hm^2, the ecological footprint of fossil energy was 1190.43144 hm^2, and the total footprint of the accommodation was 2989.147 hm^2. The catering ecological footprint of employees is 238.6658145 hm^2, and the per capita catering ecological footprint is about 2.05 hm^2. The total ecological footprint of tourism practitioners is 3227.813 hm^2.

Summary and Composition Analysis of Nanyue Tourism Ecological Footprint Account

In order to further understand the specific contribution rate of each account of tourism ecological footprint and summarize the guiding factors and antagonistic mechanism behind the data, the total amount of ecological footprint, per capita ecological footprint and contribution rate of each account are described, as shown in Table 6.

From the above, it is not difficult to see that in recent years, the number of Nanyue tourism soaring, tourism income is increasing, ecological footprint consumption mainly concentrated in tourism traffic, catering, accommodation and practitioners of several aspects, tourism, entertainment, shopping has a great share of space.

Results and Discussions

Calculation and Analysis of Nanyue Tourism Ecological Carrying Capacity

Based on the ecological carrying capacity model, the specific calculation model of tourism ecological carrying capacity is as follows:

$$TEC = N(tec) = N \sum_{j=1}^{6} a_j \times r_j \times y_j \quad (9)$$

$$REC = (1 - 12\%) \times TEC \quad (10)$$

Where j is the type of ecologically productive land; TEC is the total tourism ecological carrying capacity

Table 6. Comprehensive analysis of various accounts of Nanyue tourism ecological footprint.

Specific account	Total ecological footprint (hm²)	Ecological footprint per capita (hm²)	Contribution (%)
Tourist traffic	112417.6716	0.060724082	68.819470%
Tourist accommodation	3564.861025	0.001640868	2.182325%
Tourism catering	44122.40063	0.003790031	27.010702%
Tourist entertainment	0.3464417	2.98e-08	0.000212%
Tourist	18.452	1.58e-06	0.011296%
Tourism shopping	0.005643055	5.13e-09	0.000003%
A tourist practitioner	3227.813	0.051257908	1.975992%
Summary	163351.5503	0.117414509	100.00%

of the region; N is the total number of tourist visits; Tec is per capita tourism ecological carrying capacity; a_j is the per capita ecological productive land area; r_j is the equilibrium factor, y_j is yield factor; REC is the effective ecological carrying capacity after deducting 12% of the protected area of biodiversity. According to the recommendations of the World Commission on Environment and Development, it is more scientific to deduct 12% of the protected area of biological diversity to derive the ecological carrying capacity.

The comprehensive analysis of tourism ecological bearing (TEC) is the second key data to calculate the tourism ecological footprint index. The TEC calculation in this study mainly selects the part of Nanyue used for tourism development planning area and potential resource utilization development zone, including cultivated land, woodland, grassland, water area and built land. According to the particularity of the tourism industry, the carrying capacity is calculated from the land area that can be used for construction in the six accounts of food, housing, transportation, tourism, shopping and entertainment. According to relevant government data such as Nanyue District Tourism Bureau and Land Administration, the total bearing area data of all kinds of land are calculated, and the formula calculation results are shown in Table 7 according to

the corresponding equilibrium factor and yield factor. The results showed that the overall tourism ecological carrying capacity of Nanyue was 25611.71362 hm². After deducting 12% of the biodiversity area, the remaining effective tourism ecological carrying capacity was 22538.30799 hm², and the effective per capita tourism ecological carrying capacity was 0.02048492 hm².

Nanyue Tourism Ecological Footprint Index Calculation and Sustainable Development Level Evaluation

Tourism Ecological Footprint Index (TEFI) is used in this study to measure the degree of sustainable development of a Tourism destination. It is mainly expressed by the difference between the Tourism carrying capacity and the total Tourism Ecological Footprint. The calculation model is as follows:

$$TEFI = \frac{TEC - TEF}{TEC} \quad (11)$$

TEFI is the tourism ecological footprint index, TEF is the tourism ecological footprint, and TEC is the tourism ecological carrying capacity.

Table 7. Tourism ecological carrying capacity in 2019.

Type	With a total area (hm²)	Equilibrium factor	Production factor	Tourism ecological carrying capacity (hm²)	Per capita tourism ecological carrying capacity (hm²)
Arable land	1134.09	2.8	1.66	5271.25032	0.004791005
Woodland	14345.83	1.1	0.91	14360.17583	0.013051869
Grass	22.75	1.1	0.19	4.75475	4.32156e-06
Water area	266.65	0.2	1	53.33	4.84713e-05
Built	1274.14	2.8	1.66	5922.20272	0.005382651
Summary				25611.71362	0.023278318
Effective tourism ecological bearing capacity				22538.30799	0.02048492

Table 8. Evaluation criteria of tourism ecological footprint index.

Tefi	≤-1	-1-≤0	0-≤0.2	0.2-≤0.6	0.6-≤1
Sustainable level of tourism development	Intensity of negative	Negative	Weak positive	Positive	Intensity of positive

According to the research results of relevant scholar (Wu Yi [20], 2019), the evaluation criteria of the paper is shown in Table 8.

According to the tourism ecological footprint index model, Nanyue ecological pressure index is obviously super high, the specific data is -140813.2423 hm^2. The result of tourism ecological footprint index is -6.247729085 hm^2. According to the evaluation standard of tourism ecological footprint index, the TEFI value is ≤-1, and the sustainability level of tourism development is intensity negative. The results show that the ecological footprint depletion of Nanyue is serious, and the tourism ecological deficit is 140813.2423 hm^2. The sustainable level of tourism development is obviously deviated from the normal track. It is necessary to start from the loss ratio of the ecological footprint account, strengthen the correction level of tourism ecology, and promote its management and development in the sustainable direction.

Conclusions

Many scholars use the ecological footprint model to study the sustainable development of tourism [21-22] (Gossling 2002; Asmelash 2019), but there are few studies on mountain-type scenic spots from the perspective of ecological footprint assessment. Hu [23] (2007), Shi [24] (2023) and Liu [25] (2023) conducted studies on Jiangxi Mount Lu, Anhui Huang Mount and northern Xinjiang, but there are fewer dimensions. This article uses seven ecological footprint accounts to improve the accuracy of the measurement. This paper evaluates the sustainability level of tourism development in mountain scenic spots. First of all, Nanyue tourism ecological situation is not optimistic, and tourism ecological pressure value is -140813.2423 hm^2. The deficit is more serious. The result of tourism ecological footprint index is -6.247729085 hm^2, and the sustainability level of tourism development is negative, which reveals that local tourism development should focus on reducing the base of ecological footprint and exploring sustainable tourism development mode. From the perspective of the ecological footprint consumption structure of Nanyue, tourism transportation, tourism catering, tourism accommodation and tourism employees play important roles. But the rest of the tourism entertainment, sightseeing, shopping parts are at a low level. Finally, the main factors affecting the ecological capacity on scenic spots are tourism scale, transportation and infrastructure construction, catering consumption. According to the influence degree of

each index in the tourism ecological footprint model, the results of tourism capacity and tourism ecological footprint index, the antagonistic factors of the ecological footprint on scenic spots can be summarized as the scale of tourists, the selection of infrastructure, transportation tools, and the consumption of food and beverage.

In order to achieve sustainable development, the first step is to reduce the base of ecological footprint, especially control the ecological footprint dissipation of tourism traffic. Secondly, the ratio allocation of other accounts should be strengthened. On the premise of decreasing the footprint dissipation base, the accommodation rate of tourists should be increased, sightseeing, entertainment and shopping should be increased, and the ratio of tourism transportation and catering should be reduced. Thirdly, we should strengthen the intelligent management and the tourism transformation facilities, so as to reduce the loss of resources. Strengthening the renovation of accommodation and management facilities reduces the ecological footprint. The accommodation and management facilities should be transferred to the periphery of the scenic area. We should ensure the ecological footprint is in the bearing range through reasonable planning of dormitory area and energy use.

However, because of the difficulty of obtaining local data and evaluating it only on the basis of cross-sectional data, it is difficult to monitor the impact of Nanyue's ecological footprint on the sustainable development. In the future, data collection should be further strengthened so as to accurately measure the ecological footprint and sustainable development level.

Conflict of Interest

The authors declare no conflict of interest.

References

1. REES W.E. Ecological footprint and appropriated carrying capacity: what urban economics leaves out. Environment and Urbanization. **4** (2), 26, **1992**.

2. HUNTER C., SHAW J. The ecological footprint as a key indicator of sustainable tourism. Tourism Mnangement. **28** (1), 46, **2007**.

3. STEFAN G..Ecological footprint analysis as a tool to assess tourism sustainability.Ecological Economics. **43**, 199, **2002**.

4. PETE A.J. Exploring the ecological footprint of tourism in Ontario. University of Waterloo. **18** (1), 131, **2003**.

5. VALENTINA C.,SERENELLA S. Ecological footprint: A way to assess the impact of tourists' choices at the local scale. WIT Transactions on Ecology and the Environment. **115**, 197, **2008**.

6. DAI Y.T., ZHU D.L., ZHANG H., GUO L.L. Sustainable land natural capital use and decoupling in Shaanxi province based on three-dimensional ecological footprint. Resources and environment of the Yangtze river basin. **31** (09), 1926, **2022**.

7. XU Z.C., WEN L., ZHANG X.F., SONG J., WANG L.X.. Ecological security assessment of ALXA based on ecological footprint.Ecological Science. **41** (05), 90, **2022**.

8. LI Z.Y., DENG X.Y., LONG A.H., CHEN F.L., ZHANG L.L., GAO H.F.. Assessment of water and soil resources and ecological carrying capacity in the Tarim river basin from the perspective of three-dimensional ecological footprint. Environmental Engineering. **40** (06), 286, **2022**.

9. FU X.M., LI X.N., LIN C.Y., XUE C., CHEN R.S., LU S.B. The evolution, framework and frontier of ecological footprint research based on scientific knowledge mapping. Ecology Journal. **42** (13), 5543, **2022**.

10. LIU X.T., GAO Y.Q. Evaluation and demonstration on dynamic change and sustainable development of tourism ecological footprint. Statistics and Decision. **18**, 61, **2013**.

11. ZHAO J.Q. Study on emergy evaluation of sustainable tourism development in ecosystem based on improved tourism ecological footprint model. Journal of ecological economy. **32** (11), 108, **2016**.

12. LI P.H., MI T.T. Application of three-dimensional ecological footprint model in tourism sustainable development evaluation: A case study of Ili Kazakh Autonomous Prefecture. Tourism Review. **5**, 184, **2018**.

13. ZHU W.C.. Research on poverty alleviation and accurate identification of tourism based on ecological footprint method in the context of sustainable development. Ecological economy. **34** (7), 104, **2018**.

14. HUANG H.P., WANG Z.P., SONG Y.Y. Research on Carbon footprint and eco-efficiency of rural tourism destination under the background of rural revitalization: A case study of Wuyuan Huangling Scenic area in Jiangxi Province. Research of agricultural modernization. **40** (4), 683, **2019**.

15. XIA J., DIAO Y. X., SHE D.X., LI M., ZHANG Y.F., DING W.L., YAO C.H., LIU Z. Analysis of ecological security and carrying capacity of water resources in the Poyang lake river basin.Protection of water resources. **38** (03), 1, **2022**.

16. WANG P., KUANG F.M., DENG Y.W., TIAN Y.P., CHEN C.X. Ecological security assessment of tourism destination based on tourism ecological footprint model: A case study of Hengshan Mountain. Journal of hengyang normal university. **35** (3), 54, **2014**.

17. YANG Y.M., XU J. Research on sustainable development of tourism in zhangjiajie based on tourism ecological footprint model. Journal of central south university of forestry and technology. **36** (6), 107, **2016**.

18. ZHAO D.S., ZHANG X.M., DENG S.Q., YU G.R. Discussion on the evaluation theory and method of regional resource carrying capacity. Journal of Applied Ecology. **33** (03), 591, **2022**.

19. WACKERNAGEL M., ONISTO L., BELLO P., et al. National natural capital accounting with the ecological footprint concept. Ecological Economics, **29** (3), 375, **1999**.

20. WU Y. Study on emergy evaluation of sustainable development of ecotourism based on improved tourism ecological footprint model. Journal of chongqing university of technology (natural science). **33** (10), 212, **2019**.

21. GOSSLING S., HANSSON C., HORSTMEIER O., et al. Ecological footprint analysis as a tool to assess tourism sustainability. Ecological Economics, **43** (2), 199, **2002**.

22. ASMELASH A., KUMAR S. Assessing progress of tourism sustainability: Developing and validating sustainability indicators. Tourism Management, **71**, 67, **2019**.

23. HU H.S. Ecological Footprint analysis of mountain scenic spots: A case study of Lushan Mountain [J]. Resources and Environment in the Yangtze Basin, **6**, 814, **2007**.

24. SHI Q.Y., ZHANG J.H., SUN F., etc. Diachronic analysis of the ecological footprint of Huangshan tourism wastes [J]. World Geography study, **32** (01), 150, **2023**.

25. LIU H.B., XIA G.Z., LIN T., etc. Evaluation of sustainable development based on improved ecological footprint model: A case study of northern Xinjiang [J]. Journal of Ecology, **43** (01), 234, **2023**.