Research Article

Evaluation of Rural Tourism Carrying Capacity Based on Ecological Footprint Model

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The evaluation of the environmental carrying capacity of tourism resources has important guiding significance for the sustainable development of tourism. This study uses the ecological footprint index to construct the evaluation model of rural tourism environmental carrying capacity and quantitatively analyzes the impact of rural tourism ecological footprint on the environment, ecological pressure, and the maximum carrying capacity of tourists in Nanyang City (China) from 2011 to 2020, so as to provide a reference basis for local rural tourism planning and ecological environment management. The empirical analysis results show that (1) during the decade 2011–2020, the overall ecological footprint increased by 31.47%; however, the per capita ecological footprint showed a downward trend year by year; (2) in the ten years from 2011 to 2020, although the environmental carrying capacity was in surplus, it showed a downward trend year by year, and the ecological pressure index initially appeared; (3) taking the number of tourists in 2020 as the reference value, the prediction of the ecological pressure of rural tourism environment and the carrying capacity of tourists shows that although the ecological pressure is in a relatively safe state, it will show an unsafe state with the increase of the number of tourists. Based on the above results, it is suggested that local governments and tourism planning and management departments should pay full attention to the adverse impact of tourism development on the environment, strengthen the construction of green transportation, balance the development of tourism resources, scientifically control the number of tourists, improve tourists' awareness of environmental protection, protect the ecological environment of Nanyang City, and realize the sustainable development of rural tourism.

1. Introduction

Tourism is the main way of relaxation and entertainment for modern people. Because of its beautiful natural scenery, strong local flavor, and rich folk culture, rural tourism is sought after by tourists all over the world. With the vigorous development of rural tourism, some scenic spots or tourist destinations operate in the pursuit of short-term interests, saturated or super environment carrying capacity, and it leads to the destruction of ecological environment, the decline in the humanistic environment, the waste of social resources, and the decline of tourists' satisfaction, which seriously affects the long-term and stable development of rural tourism. With the popularization of the concept of sustainable development, in order to realize the sustainable development of the tourism environment, the carrying

capacity of tourism resources and environment has become one of the criteria to judge the sustainable development of tourism [1] and the focus of rural tourism research. Therefore, it is of great significance to evaluate the environmental carrying capacity of the rural tourism accurately and ensure its operation within the carrying capacity range to ensure the healthy and long-term development of the rural tourism.

Henan Province is a major agricultural province in China. It carries about 8% of the population (994 million people) with 1.7% of the land (167000 square kilometers). It is rich in tourism resources, but more than 70% of the tourism resources are located in rural areas. Therefore, the effective utilization and economical development of tourism resources have become the key factors for the sustainable development of rural tourism. The size of resource carrying

capacity can evaluate the current situation of rural tourism development and put forward theoretical suggestions for rural tourism development [2]. In recent years, Nanyang City, Henan Province, has vigorously developed rural tourism projects and has formed more than 30 special tourism villages and rural tourism demonstration sites [3], and more than 15,300 rural tourism business units, which have strongly contributed to local economic growth [4]. At present, the operation and management mode of the tourism industry gradually presents the development trend of information. In order to adapt to the development of the contemporary information society, the rural tourism industry should gradually implement the information construction of its own industry. However, with the rapid development of tourism, the impact on the environment has become increasingly severe, which is not conducive to the sustainable development of rural tourism in Nanyang City. The evaluation of tourism environmental carrying capacity is an important tool to ensure the rational planning and effective management of scenic spots [5]. Therefore, this study applies the ecological footprint index to construct an evaluation model of the environmental carrying capacity of rural tourism in Nanyang City and quantifies and analyzes the impact of the ecological footprint of rural tourism on the environment, ecological pressure, and the maximum carrying capacity of the number of tourists during the ten years from 2011 to 2020, in order to provide a reference for its next rural tourism planning and ecological and environmental management (Figure 1).

2. Literature Review

In recent years, with the deterioration of the ecological environment caused by tourism in China becoming more and more prominent, the harmonious development of tourism and ecological environment has become one of the hot spots of academic research, and measuring the specific impact of tourism activities on ecological environment has undoubtedly become an important reference for formulating relevant countermeasures. In this regard, the ecological footprint theory proposed by Wackernagel and Rees is currently recognized as an effective means to measure the environmental carrying capacity at home and abroad [6]. This theory believes that the development and expansion of economies are limited by the environmental carrying capacity, so human consumption must consider the limits of ecological capacity [7]. Wackernagel further points out that the ecological footprint is proportional to the size of the environmental impact, the larger the ecological footprint, the greater the impact on the environment, and in addition, it is also inversely proportional to the area of biologically productive land available per person [8].

After the theory was proposed, it has been widely used by domestic and foreign scholars in the evaluation of various ecotourism cases. For example, the Lausanne School of Management in Switzerland uses it as an indicator for evaluating the competitiveness of environmental infrastructure. Meanwhile, the Global Environmental Sustainability Indicators published by the European Union

Research Centre also use it as a basis for assessing waste and consumption pressure. In addition, Wackernagel evaluates the state of the ecological footprint of tourism globally based on the ecological footprint theory [9].

Ecological footprint theory has also been further developed and expanded in China [10]. For example, Zhang Bo used the ARIMA model to carry out the prediction of the carrying capacity of ecological footprint indicators in Gansu Province [11]. Zhu Xinling used a neural network model to calculate the total ecological footprint of Wuhan city [12]. Yang Yimin used the ecological footprint model to study the sustainable development level [13] of the tourism industry in Zhangjiajie. Zhang Zhihong calculated the ecological footprint index of tourism in three cities of Guangxi [14].

In summary, it can be seen that domestic and foreign scholars' research on ecological footprint mostly focuses on the composition, influencing factors, and measurement models of tourism environmental carrying capacity, but the research results on the current trend of tourism ecological footprint, ecological safety, and tourist carrying capacity still need further improvement. In view of this, this paper constructs a rural tourism environmental carrying capacity evaluation model by quantitatively analyzing the impact of rural tourism ecological footprint on the environment, ecological pressure, and the maximum carrying capacity of the number of tourists during the decade of 2011–2020 in Nanyang City, with a view to providing concrete supporting evidence for the research innovation and practical application of ecological footprint theory.

3. Carrying Capacity Evaluation of Rural Tourism Based on Ecological Footprint Model

3.1. Model Construction. This study incorporated transportation, accommodation, tourism activities, and food and fiber consumption into the analysis framework, constructed an environmental carrying capacity evaluation model for rural tourism, and quantified and analyzed the impact of the ecological footprint of rural tourism on the environment, ecological pressure, and the maximum number of tourists during the decade 2011–2020 in Nanyang City with reference to the tourism ecological footprint calculation method proposed by Martin and Sanchez. The ecological footprint of rural tourism in Nanyang City from 2011 to 2020 was quantified and analyzed. The evaluation model is shown in Figure 2.

The model includes three parts as follows: ecological footprint, ecological carrying capacity, and ecological security. The calculation part of the model refers to the ecological footprint calculation method proposed [15] by Martin and Sanchez. By calculating the ecological footprint of rural tourism in Nanyang City from 2011 to 2020, the ecological footprint of transportation, accommodation, tourism activities, food, and fiber consumption and the corresponding ecological footprint of agricultural land, forest, grassland, water, and built-up land are calculated. The

(a) The position of Henan Province in China

(b) Location of Nanyang City in Henan Province

FIGURE 1: Geographical location map of Nanyang City.

FIGURE 2: Evaluation model framework of rural tourism carrying capacity based on ecological footprint.

ecological footprint of rural tourism in Nanyang City is calculated by calculating the ecological footprint of transportation, accommodation, tourism activities, food, and

fiber consumption and the corresponding ecological footprint of agricultural land, forest, grassland, water, and built-up land from 2011 to 2020.

3.2. Data Sources. Research data from Nanyang (China) statistical yearbooks 2010–2020, Nanyang municipal people's government public website of the economic and social statistics (<https://www.henan.gov.cn/2018/05-22/390850.html>), and Nanyang land, rural tourism statistics released tourism management department. Because some data are incomplete or not available, the calculation is carried out in a hypothetical way. Statistics show that Nanyang covers a total area of 26,600 square kilometers and has a population of 11.94 million. In recent ten years, Nanyang City attaches great importance to the development of tourism, based on the rich ecological resources, cultural tourism resources, to build an internationally renowned ecological and cultural tourism destination as the goal, the development of rural tourism as an important part of the implementation of the development of all-for-one tourism. There are 40 national A-level scenic spots, including 2 5A-levels scenic spots and 18 4A-level scenic spots. There are 83 star-rated hotels, including 1 five-star hotel and 10 four-star hotels. There are 105 travel agencies, more than 60 demonstration sites for characteristic tourism and rural tourism, and more than 1,300 operating units for rural tourism. There are 3 national model villages for rural tourism, 3 national model families for rural tourism, and 30 national rural tourism farmhouses.

3.3. Calculation Method

3.3.1. Methodology for Calculating the Ecological Footprint

(1) Calculation of the Ecological Footprint of Transport. The transport ecological footprint (TEF) is the sum of the transport built-up footprint (TEFBU) and the transport carbon footprint (TEFCU). The transport ecological footprint calculation method in this study refers to Martin-Cejas and Sanchez's (2010) method for calculating the ecological footprint of tourism traffic. Traffic volume, type of transport, the fuel efficiency of transport, and road network are included in the calculation. The calculation formula is shown in equation as follows:

$$\sum \text{TEF}_{\text{CU}} \times P_i \times 2Di \times \frac{\sum (V_{ij} \times EI_j)}{51} \times EQF_{\text{FL}}, \quad (1)$$

where P_i : i is the number of regional visitors, Di : i is the average mileage of Nanyang City, V_{ij} : i is the number of visitors in Nanyang City, and j is the percentage of using transportation to the scenic spot. EI_j : i is the intensity of transportation. The calculation results are shown in Table 1.

(2) Calculation of the Ecological Footprint of Accommodation. Accommodation facilities are one of the necessary conditions for tourism activities. The ecological footprint of accommodation includes the following four categories: hotels, guest houses, inns, and B&Bs. They are equipped with internal facilities such as parking spaces, plazas, restaurants, and recreational areas. The Ecological Footprint of Accommodation (ACCEF) is made up of two main productivity land categories: the Ecological Footprint of Built-up Accommodation (ACCEFCU) and the Carbon Footprint of

Accommodation (ACCEFCU). The calculation of the accommodation carbon footprint (ACCEFCU) is most directly evaluated in terms of the electricity consumption generated by each type of accommodation. Since specific electricity usage data are not easily available, this study calculates the carbon footprint of accommodation based on the average number of kWh of electricity consumed per night by accommodation beds, converted to carbon emissions from energy consumption.

$$\begin{aligned} \text{ACCEF}_{\text{CU}} \times \text{Room} \times \text{Room}_{\text{EN}} \div 3.6 \times 0.625 \\ \div 1000 \div 3.6666 \times EQF_{\text{EN}}. \end{aligned} \quad (2)$$

In this equation, Room is the number of bed occupancy in the dwelling for that year. Room_{EN} is the energy consumption per bed night for that dwelling class.

(3) Calculation of the Ecological Footprint of Tourism. The ecological footprint of tourism activities (ACTEF) refers to the area of public facilities required by tourists to carry out various tourism activities in tourist destinations, which belongs to the category of built-up land in productive land, and therefore, ACTEF is the footprint of built-up land for tourism activities (ACTEFBU). In this paper, the land and areas within Nanyang City are defined into five categories: four types of recreation areas, historical preservation areas, special landscape areas, and ecological protection areas. After summing up the four types of areas and obtaining the weighted land area according to formula (3), the ecological footprint of tourism (ACTEF) from 2011 to 2020 can be measured, as shown in Table 2.

$$\text{ACTEF} = \text{Area}_{\text{ACTBU}} \times YF_{\text{CL}} \times EQF_{\text{CL}}. \quad (3)$$

(4) Ecological Footprint of Food and Fiber Consumption. The assessment of the ecological footprint of food and fiber consumption (FEF) is divided into two main components: food consumption and fiber consumption. The former of which the productive land corresponding to the resource consumption of tourists visitors in terms of food is agricultural land, grazing land, and fishing grounds; the latter of which is the demand of tourists for fiber products. Since information on food consumption in Nanyang City is not easily available, this study refers to the method of Gossling et al. to calculate the ecological footprint [16]. Assuming that the food and fiber consumption of tourists in Nanyang City is consistent with that of the average domestic household, the average annual productivity (average yield, AY_i) of the food item can be obtained by dividing the calendar year domestic food production (P_i) by the productive land area (A_i) (equation (4)) and then multiplying the i -th food consumption by the equilibrium of the productivity land category corresponding to the i -th food item, respectively. The EQF_i and YF_i factors were then divided by the average productivity of the productive land for food item i (AY_i) and converted to the ecological footprint of food and fiber consumption (FEF) (equation (5)). The forest production in a calendar year was then divided by the population and 365 days a year to obtain the daily per capita forest product

TABLE 1: Ecological footprint of transportation in Nanyang City, 2011–2020 (unit: gha).

Year	Transportation built-up footprint (TEF _{BU})	Transport carbon footprint (TEF _{CU})	Transport ecological footprint (TEF)	Transportation ecology per capita footprints (PTEF)
2011	5482.54	11070.85	16553.39	0.018372
2012	5482.54	10286.17	15768.71	0.018372
2013	5482.54	12076.60	17559.14	0.016011
2014	5482.54	17479.73	22962.27	0.013187
2015	5482.54	20125.69	25608.23	0.012709
2016	5482.77	17587.89	23070.65	0.013031
2017	5482.77	17390.58	22873.35	0.012995
2018	5482.77	22063.01	27545.78	0.012268
2019	5482.77	27896.90	33379.67	0.011693
2020	5482.77	27936.72	33419.49	0.011624

TABLE 2: Ecological footprint of tourism activities in Nanyang City, 2011–2020.

Year	Recreation centre area (ha)	Ecological footprint of tourism (gha)	Ecological footprint of tourism per capita (gha per capita)
2011	7520	18819.980	0.0208
2012	9520	18819.980	0.0219
2013	12120	11892.380	0.0108
2014	13120	11892.380	0.0068
2015	14120	11892.380	0.0059
2016	14120	11892.380	0.0067
2017	14120	11892.380	0.0067
2018	14120	11892.380	0.0052
2019	19390	11892.380	0.0041
2020	19390	11892.380	0.0041

consumption and then multiplied by the number of visitors, and finally, the consumption was converted into an ecological footprint using the equilibrium factor of forest land (EQFFL). The calculation is shown in equations (4)–(6).

$$AY_i = P_i \div A_i, \quad i = 1, 2, \dots, 8, \quad (4)$$

$$FEF = \sum C_{\text{food}} \times EQF_i \times YF_i \div AY_i, \quad i = 1, 2, \dots, 8, \quad (5)$$

$$FEF_{\text{FL}} = \text{Pop}_{\text{total}} \div 365 \times \text{Pop}_{\text{tourist}} \div \text{Global TimberYield} \times EQF_{\text{FL}}. \quad (6)$$

3.3.2. *Analysis of the Carrying Capacity of the Tourism Environment.* Natural resources of rural tourism can be broadly classified into productive and unproductive categories: productive resources can be used as agricultural land, building land, etc. and unproductive resources are mostly special landscape, ecological, environmentally sensitive, and unsuitable for development and use. This study refers to the environmental carrying capacity calculation method of Monfreda et al. and calculates the environmental carrying capacity of tourism in the formula area according to the land category [17]. The calculation formula is shown in equation as follows:

Tourism carrying capacity

$$\begin{aligned}
 & \left\{ \begin{array}{l} \text{Agricultural land area} \times \text{agricultural land yield factor} \times \text{agricultural land equilibrium factor} \\ \quad = \text{biological carrying capacity of agricultural land} \\ \text{Grassland area} \times \text{Grassland yield factor} \times \text{Grassland equilibrium factor} = \text{Grassland biological carrying capacity} \\ \text{Forest area} \times \text{forest yield factor} \times \text{forest equilibrium factor} = \text{forest biological carrying capacity} \\ \text{Watershed area} \times \text{watershed yield factor} \times \text{watershed equilibrium factor} = \text{watershed biological carrying capacity} \\ \text{Built-up area} \times \text{built-up yield factor} \times \text{built-up equilibrium factor} = \text{built-up biological carrying capacity} \\ \text{Carbon sequestration area} \times \text{carbon sequestration yield factor} \times \text{carbon sequestration equilibrium factor} \\ \quad = \text{carbon sequestration biocarrying capacity.} \end{array} \right. \quad (7)
 \end{aligned}$$

In this case, the conversion factors for carbon-sequestering land in the environmental carrying capacity calculation are the

equilibrium factor for forests (EQFFL) and the yield factor (YFFL) for its multiplication. According to the assumptions of

Monfreda et al. for anthropogenic structures and public facilities, the land is usually originally available for agricultural use. Therefore, the calculation is multiplied by the equilibrium (EQFCL) and yield factors (YFCL) of the agricultural land.

3.3.3. Calculation of Ecological Deficit/Surplus Status. Using the ecological footprint method, the environmental carrying capacity (BC) on the supply side of environmental resources in Nanyang City is subtracted from the ecological footprint (EF) on the demand side of environmental resources, and if the value is greater than zero, it is called an ecological surplus; conversely, it is an ecological deficit. The calculation formula is shown in equation as follows:

$$BC - EF. \quad (8)$$

3.3.4. Ecological Stress Index (EFI) and Visitor Number Carrying Capacity Projections. Ecological stress index (EFI) refers to the ecological footprint per unit ecological carrying area of a region. In order to find the ecological footprint on the unit carrying area can better reflect the pressure on the ecological environment, this study uses the ecological pressure index (EFI) to evaluate the regional ecological security, using the number of tourists in 2020 as a control standard to predict the trend of ecological pressure changes due to the increase in the number of tourists in the future, the critical value of the carrying capacity of the number of tourists. The calculation formula is shown in equation as follows:

$$EFI = \frac{EF}{BC}, \quad (9)$$

where EFI is the ecological pressure index; EF is the ecological footprint; BC is the environmental carrying capacity. Because $EF > 0$ and $BC > 0$, when $0 < EFI < 1$, $EF < BC$, the supply and demand of ecological resources reach a balance, and the region is in a critical state of ecological security. when $EFI = 1$, $EF = BC$, ecological resources supply and demand reach balance, the region is in a critical state of ecological security; when $EFI > 1$, $EF > BC$, the unit ecological bearing. When $EFI > 1$, $EF > BC$, the pressure per unit of ecological carrying area is greater than the supporting capacity it can provide, the supply and demand are unbalanced, and ecological security is threatened, and the greater the difference between EFI and 1, the greater the degree of ecological insecurity.

3.4. Results and Analysis

3.4.1. Results of Ecological Footprint Calculation in Nanyang City

(1) *Transport Footprint of Nanyang City 2011–2020.* Reference to Martin-Cejas and Sanchez's method for calculating the ecological footprint of tourism traffic, traffic volume, type of transport, fuel efficiency of transport, and road network are included in the calculation. The transportation footprint of Nanyang City from 2011 to 2020 was obtained as shown in Table 1.

As shown in the calculation results of Table 1, the transportation built-up land footprint (TEF_{BU}), transportation carbon footprint per capita (TEF_{CU}), and transportation ecological footprint per capita (TEF) all show an increasing trend year by year. The increase in the number of tourists has an important impact on the ecology of Nanyang City.

(2) *Ecological Footprint of Accommodation in Nanyang City 2011–2020.* The ecological footprint of accommodation in Nanyang City was calculated based on the average number of electricity consumption degrees per night of accommodation beds and converted into carbon emissions of energy consumption, as shown in Table 3.

As seen in Table 3, the trend in the carbon footprint of accommodation ($ACCEFCU$) is broadly in line with the built-up land. Visitor use of built-up land resources ($ACCEFBU$) for accommodation is low, increasing only from 5.535 gha to 13.369 gha from 2011 to 2020, and there is a low peak in the accommodation built-up land footprint in 2020.

(3) *Ecological Footprint of Tourism Activities in Nanyang City, 2011–2020.* The ecological footprint of tourism activities in Nanyang City between 2011 and 2020 ($ACTEF$) was measured by calculating the area of tourism area according to equation (3), and the ecological footprint of tourism activities between 2011 and 2020 was obtained, as shown in Table 2.

Table 2 shows the change trend of tourism ecological footprint and per capita footprint of Nanyang city. The per capita tourism footprint decreases due to the increase in tourist arrivals, from 0.0208 gha in 2011 to 0.0041 gha in 2020, a decrease of 80.20%. This result reflects the dilution of the ecological footprint by the increase of tourists on the one hand and the improvement of the ecological environment in recent years on the other.

4. Ecological footprint of food and fiber consumption (FEF).

Calculated by equations (4)–(6), the ecological footprints of food and fiber consumption responses in the four land categories of agricultural land ($FEFCL$), grazing land ($FEFGL$), fishing land ($FEFFG$), and forest land ($FEFFL$) were obtained, respectively, for the calendar year, and the ecological footprints of food and fiber consumption (FEF) for each land category were summed to obtain the ecological footprint (FEF) for each land category, as shown in Table 4.

The food and fiber footprint responds to the amount of food and fiber consumed by tourists. As shown in Table 4, the overall food and fiber footprint of rural tourism has been increasing year by year in the last decade, from 729.758 gha in 2011 to 2310.246 gha in 2020, with an average annual growth rate of 2.17%. This shows that rural tourism in Nanyang City has shown a rapid development trend.

(5) *Overall Ecological Footprint.* Collating the ecological footprint data for the four tourism categories in Tables 1–4, the overall ecological footprint of rural tourism can be calculated as shown in Table 5.

As shown in Table 5, the overall ecological footprint of rural tourism in Nanyang City increased from

TABLE 3: Ecological footprint of accommodation in Nanyang City, 2011–2020 (unit: hm²).

Year	Accommodation built as eco-foot signs (ACCEFBU)	Accommodation carbon footprint (ACCEFCU)	Ecological footprint of accommodation (ACCEF)	Accommodation ecology per capita footprints (PACCEF)
2011	5.535	514.574	520.109	0.000577
2012	5.535	582.001	587.537	0.000685
2013	5.535	479.087	484.622	0.0004
2014	12.752	541.749	554.500	0.000318
2015	12.752	546.106	558.857	0.000277
2016	12.752	532.761	545.512	0.000308
2017	12.907	488.882	501.790	0.0002
2018	10.495	288.105	298.600	0.0001
2019	13.369	442.619	455.988	0.000160
2020	13.369	511.576	524.945	0.000183

TABLE 4: Ecological footprint of food and fiber consumption in Nanyang City, 2011–2020.

Year	Food and fiber consumption raw state footprint (gha)	Ecology of food and fiber consumption per capita footprints (gha per capita)
2011	729.758	0.0008
2012	731.403	0.0008
2013	1052.440	0.0009
2014	1690.223	0.0009
2015	1670.865	0.0008
2016	1721.833	0.0009
2017	1537.409	0.0008
2018	1942.817	0.0008
2019	2494.538	0.0008
2020	2310.246	0.0008

TABLE 5: Calculation results of the overall ecological footprint of Nanyang City from 2011 to 2020 (unit: gha).

Year	Transport ecology footprinting	Ecological footprint of accommodation	Leisure activities ecological footprint	Food and fiber ecological footprint	Overall life footprint of a state	Overall per capita ecological footprint
2011	16553.390	520.109	18819.980	729.758	36623.671	0.0406
2012	15768.705	587.537	18819.980	731.403	35908.059	0.0418
2013	17559.139	484.622	11892.380	1052.440	30989.015	0.0282
2014	22962.266	554.500	11892.380	1690.223	37099.803	0.0213
2015	25608.227	558.857	11892.380	1670.865	39730.763	0.0197
2016	23070.653	545.512	11892.380	1721.833	37230.813	0.0210
2017	22873.348	501.790	11892.380	1537.409	36805.434	0.0209
2018	27545.781	298.600	11892.380	1942.817	41680.009	0.0185
2019	33379.670	455.988	11892.380	2494.538	48223.056	0.0168
2020	33419.492	524.945	11892.380	2310.246	48147.544	0.0167
Average share	60.84%	1.28%	33.83%	4.05%	100%	0.0406

36,623.671 gha in 2011 to 48,147.544 gha in 2020, with a growth of 31.47% in ten years. Among the four major activity footprints, the transportation ecological footprint (TEF) accounts for the largest share (60.84% on average), followed by the tourism activity footprint (ACTEF) (33.83% on average), and then the food and fiber consumption ecological footprint (FEF) (4.05%) and the accommodation ecological footprint (ACCEF) (1.28%). It can be seen that the main ecological resource consumption during tourism is the energy consumption from transportation between the residence and the destination and the resource consumption of tourists in Nanyang. The overall per capita ecological

footprint (PEF) has been decreasing gradually in the last decade, from 0.0406 gha in 2010 to 0.0167 gha in 2020, a decrease of 58.8%.

3.4.2. Analysis of the Carrying Capacity of the Tourism Environment. Referring to the environmental carrying capacity calculation method of Monfreda et al, the overall environmental carrying capacity and the per capita environmental carrying capacity of Nanyang City from 2011 to 2020 were calculated according to the land category. From Table 6 it can be seen that as the number of tourists per year

TABLE 6: Calculation results of the overall environmental carrying capacity and per capita environmental carrying capacity of Nanyang City from 2011 to 2020.

Year	Overall environmental commitment carrying capacity	Environmental carrying capacity per capita	Carrying capacity of agricultural land per capita	Grassland per capita carrying capacity	Forest carrying capacity per capita	Built-up land carrying capacity per capita	Water carrying capacity per capita
2011	128657.862	0.1427	0.0036	0.0072	0.1263	0.0055	—
2012	128657.862	0.1499	0.0038	0.0075	0.1326	0.0058	—
2013	128657.862	0.1173	0.0030	0.0059	0.1037	0.0045	—
2014	128657.862	0.0738	0.0019	0.0037	0.0653	0.0028	—
2015	128657.862	0.0638	0.0016	0.0032	0.0564	0.0024	—
2016	128657.862	0.0726	0.0018	0.0036	0.0642	0.0028	—
2017	128657.862	0.0730	0.0018	0.0036	0.0646	0.0028	—
2018	128657.862	0.0573	0.0014	0.0028	0.0506	0.0022	—
2019	128657.862	0.0450	0.0011	0.0022	0.0398	0.0017	—
2020	128657.862	0.0447	0.0011	0.0022	0.0395	0.0017	—

TABLE 7: Ecological deficit and Surplus Status of Nanyang City, 2011–2020.

Year	Per capita biological carrying capacity (PBC)	Per capita ecological footprint (PEF)	Ecological deficit/surplus
2011	0.1427	0.0406	0.0850
2012	0.1499	0.0418	0.0900
2013	0.1173	0.0282	0.0749
2014	0.0738	0.0213	0.0437
2015	0.0638	0.0197	0.0364
2016	0.0726	0.0210	0.0429
2017	0.0730	0.0209	0.0434
2018	0.0573	0.0185	0.0318
2019	0.0450	0.0168	0.0227
2020	0.0447	0.0167	0.0226

TABLE 8: Ecological stress index and critical value of tourist number carrying capacity in Nanyang City.

	Number of visitors	Ecology per capita footprints (PEF)	Per capita ecological carrying capacity (PBC)	Ecological stress index (EFI)	Safety representation grade status
2020	33380351	0.016747	0.033493	0.50	2 (safer)
EFI = 0.8	52408561	0.016747	0.020933	0.80	3 (critical value)

increases, the average environmental carrying capacity resources (PBC) per person can be allocated gradually decreases. Therefore, it can be seen that controlling the number of tourists is a key factor for sustainable rural tourism development.

3.4.3. Ecological Safety Evaluation of Rural Tourism

(1) *Ecological Deficit/Surplus Status.* Using the ecological footprint method, the environmental carrying capacity (BC) on the supply side of environmental resources is subtracted from the ecological footprint (EF) on the demand side of environmental resources, and if the value is greater than zero, it is called an ecological surplus; if the opposite is true, it is an ecological deficit.

Combining the data from the overall per capita ecological footprint (PEF) and per capita environmental carrying capacity (PBC) calculations for the four major activity categories in Table 7, the ecological deficit and surplus states were obtained, as shown in Table 7.

According to the calculation results, the ecological carrying capacity of rural tourism in Nanyang City has been in surplus in the past ten years, but the surplus tends to decrease, with the per capita ecological surplus decreasing from 0.085010 gha in 2011 to 0.022633 gha in 2020, a significant decrease of 73.38% in ten years. It can be seen that although the environmental carrying capacity of rural tourism is still in surplus, it is still recommended that local governments moderate the development of tourism resources, control the number of tourists, strengthen the publicity of environmental protection, and raise awareness of environmental protection in tourist areas to maintain and improve the current state of ecological surplus.

(2) *Ecological Stress Index Status.* The results of the calculation of the ecological stress index and the critical value of the carrying capacity of the number of tourists in Nanyang City, using the number of 2020 tourists as the control standard, are shown in Table 8.

As seen from Table 8, when the number of visitors is 33380351 in 2020, the ecological stress index (EFI) of

Nanyang City is 0.50 and the ecological safety level is 2 (safer), and when the number of visitors reaches 52408561, the ecological stress index (EFI) of Nanyang City is 0.80 and the ecological safety will reach the critical value.

4. Conclusions

4.1. Research Findings

- (1) The overall transportation ecological footprint of rural tourism has been increasing year by year, from 16,553.39 gha in 2011 to 33,419.49 gha in 2020, with an average annual growth rate of about 10%. This is probably due to the increase in the ecological footprint of transportation caused by tourism transportation energy. To reduce the ecological footprint of tourism transportation, the management of exhaust emissions from cars and other vehicles should be strengthened. It is recommended that local governments develop mass transportation, mainly electric vehicles, to improve traffic pollution.
- (2) The overall ecological footprint of rural tourism increased from 36623.671 gha in 2011 to 48147.544 gha in 2020, an increase of 31.47% in ten years. Among them, the ecological footprint of transportation is 60.84%, the ecological footprint of tourism activities is 33.83%, the ecological footprint of food and fiber consumption is 4.05% and the ecological footprint of accommodation is 1.28%. This shows that the ecological pressure from transport and tourism activities is still increasing year by year. In contrast to the overall ecological footprint, the ecological footprint per capita has shown a decreasing trend in the last decade, from 0.0406 gha in 2010 to 0.0167 gha in 2020, a decrease of 58.8%. The starting reason may be due to the increase in tourism, which dilutes and neutralizes the ecological footprint.
- (3) Analysis of the ecological footprint of tourism by land category shows that the productive land with the highest proportion of the overall ecological footprint is built-up land. This indicates that tourists have the highest demand (52.6%) for services such as public facilities, buildings and dwellings, and activity spaces during their recreation, followed by the carbon footprint emitted from energy consumption (43.82%) and a smaller demand for food and fiber consumption produced by forests, agricultural lands, grasslands, and waters.
- (4) The study uses the annual incremental number of tourists from 2011 to 2020 as the reference value (7.1% per year), and the critical value of environmental pressure on rural tourism using the ecological pressure threshold value shows that when the ecological pressure EFI value is 0.5 (safe), the ecological carrying capacity per capita is 0.3349 gha, and when the EFI is 0.8, the ecological carrying capacity per capita is 0.0209 gha (more safe) shows a decreasing trend.

4.2. *Recommendations.* Based on the results of the above empirical analysis, the paper proposes to make the following recommendations.

- (1) The control of ecological carrying capacity is strengthened, and the formulation of land planning and environmental protection policies is accelerated. On the one hand, the natural environment and the ecological protection system of flora and fauna in Nanyang City should be protected. On the other hand, the control of ecological carrying capacity should be strengthened by enhancing the management of tourists, avoiding their acts of polluting the environment, and promoting energy-saving and environmentally friendly tourism methods and encouraging people to use low-carbon and low-energy-consuming transportation.
- (2) The spatial pattern of tourism should be reasonably designed and the distribution of tourism resources should be reasonably distributed. Since the number of tourists has a positive impact on the total footprint of all kinds of activities, the larger the number of tourists, the larger the ecological footprint, and the greater the impact on the environment. Therefore, the tourism management department of Nanyang City should pay full attention to the environmental problems caused by the uneven spatial and temporal distribution of tourists in the city, further strengthen the balanced planning of tourism resources, and effectively divert the flow of tourists through a combination of measures, so as to achieve a reasonable spatial and temporal pattern of tourism.
- (3) Tourism resources are developed appropriately, and environmental education and publicity are strengthened. In the past ten years, although the environmental carrying capacity of Nanyang City is in surplus, it shows an obvious downward trend, with the per capita ecological surplus reduced from 0.085 gha in 2011 to 0.0226 gha in 2020, a decrease of about 73.38%. This indicates that the pressure on the ecological environment of the city is increasing, so it is suggested that the relevant departments should moderate the development of tourism resources, control the number of tourists, and strengthen the environmental education and publicity training for tourists, so as to cultivate their environmental awareness and reduce the negative impact on the ecological environment of rural tourism.

4.3. *Limitations.* In this paper, the construction of environmental carrying capacity index system is only aimed at rural tourism in Nanyang City (China), which lacks extensive practical verification. The selected indicators are also limited, which cannot achieve comprehensive, and may need further modification and improvement in practical application.

Data Availability

The data that support the findings of this study are available from the corresponding author upon reasonable request.

Conflicts of Interest

The authors declare that they have no conflicts of interest.

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