RESEARCH ARTICLE

Ecotourism development based on environmental monitoring technology

Yi Zhou*

Zhengzhou Tourism College, Zhengzhou, Henan, China

Received: September 11, 2023; **accepted:** November 8, 2023.

Ecotourism as a form of tourism that focuses on the protection of the environment and sustainable advancement has just been put forward and received widespread attention. Tourism activities will cause some damage to the ecological advancement of the ecotourism area. In order to carry out sustainable development of ecotourism, this study combined environmental monitoring technology and ecological footprint to conduct environmental monitoring of Sanqingshan scenic spot through 3S technology that is a combination of remote sensing, geographic information systems, and global positioning systems. The data were collected from 2010-2019 in the developable area. The ecological footprint was calculated according to the monitoring data to predict the development direction of the tourism area. By using remote sensing technology to obtain surface data, combining with geographic information systems for data analysis and processing, and then using global positioning systems for location positioning, environmental monitoring and evaluation were achieved. The results showed that, in the comfort calculation, the average comprehensive comfort of the test area was about 0.60. The fluctuation with year was small, while the tourism value was high. In the calculation of the number of tourists and comprehensive income from tourism, the number of tourists increased by about 7 times and the comprehensive income from tourism increased by about 9 times, indicating that the popularity of the test area was high. In the calculation of tourism ecological surplus, the per capita ecological surplus gradually tended to 0, indicating that environmental protection awareness should be raised to reduce the negative impacts of tourism activities. The results of this study provided a theoretical basis for the sustainable advancement of ecotourism.

Keywords: ecotourism development; environmental monitoring techniques; ecological footprint; 3S techniques; sustainable development.

***Corresponding author:** Yi Zhou, Zhengzhou Tourism College, Zhengzhou 451464, Henan, China. Email: 13703925766@163.com.

Introduction

Recently, the development of ecotourism is getting faster and faster, however, the environmental problems faced in the process of ecotourism development are also becoming more and more prominent. For realizing the sustainable development (SDE) of ecotourism, the use of environmental monitoring technology for ecotourism development has become the focus of related research [1, 2]. Environmental monitoring technology is a method of collecting, analyzing, and interpreting environmental data, which can assess environmental conditions and monitoring environmental changes. Environmental monitoring technology can provide comprehensive and accurate data to get the environmental condition of the tourism area, and it can also monitor and analyze the indicators of water quality, air quality, soil quality, *etc*., to understand whether the water source of the tourism area is polluted, whether there are harmful gases in the air, and whether the soil is suitable for the growth of vegetation, *etc*. These data can be used for tourism planning and management and can provide a scientific basis for tourism planning and management departments to formulate corresponding protection measures to ensure that tourism activities minimize the impact on the ecological environment (EEN). At the same time, by monitoring indicators such as the number of tourists, tourist behavior, and tourist satisfaction, it is possible to assess the degree of pressure and influence of tourism activities on the EEN. The use of environmental monitoring technology can also monitor indicators such as biodiversity and vegetation coverage to understand the impact of tourism activities on local ecosystems and to identify and solve potential ecological problems [3].

Ecotourism has emerged and ecotourism development has become a hot issue for the professionals concerned. Rahman *et al*. proposed an ecotourism development assessment for investigating the influence of community participation on the SDE of the marine protected areas by using a structured questionnaire to collect data and analyze it by partial least squares method. The results showed that community participation could explain the differences in ecotourism development [4]. Heshmati *et al*, proposed a strengths-weaknesses-opportunities-threats approach to calculate the errata of the likelihood factors and analyze the factors affecting ecotourism development and sustainable use of natural resources. The results showed that the approach could balance ecotourism development and sustainability of local resources [5]. Omarzadeh *et al*. designed a method based on geographic information system (GIS) multi-criteria decision analysis, which used spatial coordinates to identify areas with the potential to attract tourists and evaluated the effective factors of increasing and decreasing tourism advancement activities through geographic information analysis for analyzing and planning the potential of sustainable ecotourism development. The results demonstrated that the method possessed a high accuracy [6]. In addition, Xu *et al*. designed a scientometric method using visualization implementation, which was able to review the research and development in the field of ecotourism to determine the direction of development in the field of ecotourism. The results showed that the method was more intuitive to determine the progress of ecotourism [7]. To analyze the development of ecotourism in the mangrove forests of the Gulapyeong, Singgalen developed a method based on spatial data and hierarchical analysis, which used the normalization method to analyze the development of mangrove ecotourism. The results indicated that this method could better calculate the priority of ecotourism development projects [8]. Prasandya *et al*. also designed a decision support system and hierarchical analysis-based ecotourism development criteria system for identifying priority villages for ecotourism development. The outcomes indicated that the system could identify the priority villages in a better way [9]. In order to explore the potential of ecotourism development using GIS, Jokar *et al.* designed a methodology for adjusting the effective parameters in ecotourism evaluation, which was assessed by using geometric mean, Boolean, and multi-criteria evaluation methods. The results showed that the methodology outperformed the other methods of evaluation [10]. To test the suitability for SDE of ecotourism, Wibowo *et al*. proposed a sustainable livelihoods method, which used qualitative methods to analyze the data and the outcomes showed that the method could reveal the degree of SDE of ecotourism in many ways [11]. Asadi *et al*. proposed an ordered weighted average algorithm based on GIS and dual-connected nodes for identifying and evaluating ecotourism sites, which selected, weighted, and prioritized the criteria based on the intensity of their impacts. The results demonstrated that the algorithm was more effective in evaluating the ecotourism sites with better results [12]. Khyevari *et al*. designed an identification method based on fuzzy logic and network analysis to identify potential areas for ecotourism development, which used network analysis to determine the weights of the indicators and identified the areas through weighted linear combinations with more reasonable results [13].

In addition, Mansour *et al*. proposed a spatial assessment of the suitability of ecotourism land and a method based on GIS and dual-connected nodes, and a multi-criteria analysis method based on geospatial space for spatial assessment of ecotourism land suitability, which determined multiple criteria and evaluated them through multilevel analysis [14]. Kianisadr *et al*. reported a fusion assessment method on the ground of the Delphi method, the hierarchical analysis method, and the weighted overlapping method for ecotourism land standards and appropriate land management. The method utilized the Delphi method for questionnaire survey, and the hierarchical analysis method to obtain and rank the weights [15].

Many previous studies have proposed various development assessment methods and priority area determination methods about ecotourism development and achieved better results. However, only a few methods combined environmental monitoring technology with ecological footprint (EFO). Therefore, this study applied 3S technology that was a combination of remote sensing, geographic information systems, and global positioning systems for environmental monitoring and EFO calculation to predict the direction of SDE of ecotourism development. The objective of this study focused on the environmental issues faced in the development of ecotourism and the achievement of sustainable development of ecotourism. An environmental monitoring system based on 3S technology, which could obtain exploitable areas and calculate ecological footprints based on monitoring data, were studied, and constructed. In addition, a function of tourism ecological footprint was designed to predict the development direction of tourist areas, provide practical guidance for the sustainable development of ecotourism, and help achieve harmonious development between ecology and tourism.

Materials and Methods

The area of research

The study site involved in this research is Sanqingshan Ecological Scenic Spot in northeast of Jiangxi Province, China (118° 03' E and 28° 54' N) with bordering to Anhui Province to the east and Zhejiang Province to the north. The scenic area consists of ten smaller scenic areas with a total area of 756.57 km^2 and the center area of 229.5 km^2. The geographical location is very advantageous with well-developed traffic, completed transportation infrastructure, and multiple air routes of many provinces and cities. The shape of the mountains in the scenic area can be roughly seen as a triangle with the apex in the north of the center, while the height of the mountains gradually decreases from the center to the surroundings, presenting the form of a mountain range with a complicated topography. The main part of the mountain is composed of granite and magma rock peaks. The variety of rock peaks and the long period of crustal movement create its unique landscape, which is rich in plant species and has a high vegetation cover, even above 95% in the central area. Survey data showed that the study area contained more than 2,300 different types of higher plants such as quince and ferns, among which there were many rare plants. Meanwhile, there were 49 species of endangered plants in the study area. In addition, the study area has a variety of rare and protected animals such as short-tailed monkeys, silver pheasants, white headed swallows, and red billed lovebirds. Together, these rare plants and animals form a complete and stable ecosystem in the ecological scenic area. The eco-scenic area has long been famous in China for its long history of Taoist culture, especially for its unique granite peaks and forests landscape, which has become a scenic calling card to attract domestic and foreign tourists. Recently, with the continuous expansion of the scale of the scenic area and the continuous improvement of infrastructure construction, the tourism business in the area has ushered in new development opportunities. According to official statistics, the number of tourists received in the area was more than 100,000 people in 2003, However, with the development in recent years, the number had grown to 9.85 million by 2019. At the same time, the trend of diversified synergistic development was becoming more and more obvious, driven by the expansion of the park. Under the current conditions, the total number of A-level scenic spots around the site is 6, divided into 2 "national 4A-level scenic spots" and 4 “3A-level rural tourist spots”. Therefore, even though it covers the smallest area, it has the widest range of A-class attractions and has become one of the most competitive attractions in the area.

Data collection

The remote sensing (RS) data used in the study were Landsat data from 2010 to 2019 and vegetation normalized data obtained by Moderate Resolution Imaging Spectroradiometer instrument. The Landsat data was Landsat TM/ETM+/OLI, obtained through the United States Geological Survey (USGS) website (https://www.usgs.gov/search?keywords=Landsat+data) with a spatial resolution of 30 m. The landscape was at a higher elevation, and in summer it is mostly cloudy, which obscured the RS data resulting in inaccuracy. There was a very small amount of data that could be utilized in each month. During the winter season, there was less cloudiness. The data was more accurate, and more data could be used. Therefore, the data from January, November, and December of each year were used for the study. In this study, only the vegetation cover was calculated without considering the spatial resolution, and the Landsat data were non-real-time and volatile. Therefore, vegetation normalized data derived from the Moderate Resolution Imaging Spectroradiometer (MRIS), which had been publicized through normalization and was commonly used in various experiments, was used as the source data. Meteorological data were obtained from the nearest meteorological observatory to the study area to calculate the comfort level. The relevant statistical data were downloaded from the Statistics Bureau of Shangrao City (Shangrao, Jiangxi, China) and the Tourism Bureau of Mount Sanqing Management Committee (Shangrao, Jiangxi, China).

Environmental monitoring system based on 3S technology

RS is a modern observation technology developed in the 1960s, which can receive electromagnetic wave information radiated or reflected from a remote target through multiple sensors, process the collected information and image it, so as to complete the detection and identification of the ground scenery [16, 17]. Remote sensing image processing included inputting original image, combining the output single-band image through the band selection module to generate the synthetic image, enhancing the synthetic image through the image stretching and sharpening process, correcting the image after projection, and outputting the image by mosaicking and cropping the corrected image. The vegetation cover of the study area was calculated by the vegetation normalization index using the following equation.

$$NDVI = \frac{NIR - RED}{NIR + RED} \tag{1}$$

where $NDVI$ was the normalized difference vegetation index. NIR was the reflectance of Landsat data in the near-infrared band. RED was the reflectance of Landsat data in the red light band. The vegetation cover was calculated as:

$$FVC = \frac{NDVI - NDVI_{soil}}{NDVI_{veg} - NDVI_{soil}} \tag{2}$$

where FVC was the fractional vegetation cover. $NDVI_{soil}$ was the vegetation NDVI for the ideal case of areas without vegetation cover. $NDVI_{veg}$ was the vegetation NDVI for the ideal case of areas with full vegetation cover.

GPS was capable of all-weather, global navigation, positioning, and speed measurement through radio signals emitted by satellites and consisted of ground monitoring system, receiving system, and space satellite system. By using the space satellite system and ground monitoring system for tracking and positioning, the users could obtain the information through GPS receiver. GIS is a kind of computer technology system that can analyze and process spatial information and can process the images provided by RS and GPS accurately. The image calibration started with data preparation followed by inputting the original image obtained from RS and GPS, establishing a correction function to determine the range of the output image, and then geometrically transforming the image element by element while resampling the grayscale, and finally outputting the image for effect evaluation after completion of the calibration. The three systems including RS, GPS, and GIS could be connected to form a monitoring system with the 3S technology. Among them, RS could supervise the classification and validation of the information provided by GPS. GIS could provide and update the regional information for RS, while RS could assist the classification of GIS and perform geometric alignment. GPS could also query the information of RS and the thematic information of GIS to provide updated spatial positioning.

Sustainability assessment based on ecological footprint

For measuring the impact of tourism activities on the ecosystem of the pilot area, the study introduced an EFO model to determine the advancement trend of ecotourism in the study area. The EFO is a method for evaluating the consumption of natural resources and the impact of human activities on the environment. The EFO is calculated by utilizing the bioproductive area, and the result can show the gap between the demand for human economic system and natural ecosystem services and the carrying capacity (CCA) of the natural ecosystem, which reflects the SDE status of the test area in a more concise way [18, 19]. The EFO model was shown in Figure 1 and was calculated from the amount of bioproducts, and energy products consumed for human survival and advancement, and the ecological CCA of each type of bioproductive land was also calculated. Biologically productive land included five types of productive territories as forests, grasslands, waters, arable land, and buildings. The EFO was compared with the ecological CCA. If the EFO was smaller than the ecological CCA, the ecosystem was in a state of ecological surplus, at which time the ecosystem was able to maintain its health and stability [20]. However, if the EFO was larger than the ecological CCA, the ecosystem was in ecological deficit and its SDE was threatened. The specific formula for calculating the EFO was as follows.

$$\begin{cases} E_f = N \times e_f \\ e_f = r_i \times \sum_{i=1}^{n} \frac{P_i + I_i - E_i}{Y_i N} \end{cases} \quad (3)$$

where E_f was the total EFO of the test area. e_f was the per capita EFO of the test area. N was the population of the test area. r_i was the equalization factor of the i^{th} type of land. n was the total number of land types. P_i was the amount of production of resources. I_i was the amount of resource imports. E_i was the amount of resource exports. Y_i was the global average production of the goods that were consumed by the species. In biologically productive land, different types of territories have different productive capacities. So, it is essential for introducing equalization factors for equalization and normalization. The ecological CCA could represent the upper limit of the test area that could carry the EFO, which was calculated as:

$$\begin{cases} E_c = N \times e_c \\ e_c = \sum_{i=1}^{n} (a_i \times r_i \times y_i) \end{cases} \quad (4)$$

where E_c was the ecological CCA of the total population in the test area. e_c was the ecological CCA per capita. r_i was the per capita bioproductive area of the land of category i . y_j was the yield factor. When the EFO was smaller or larger than the ecological CCA, the ecological surplus and ecological deficit could be obtained and were expressed as follows.

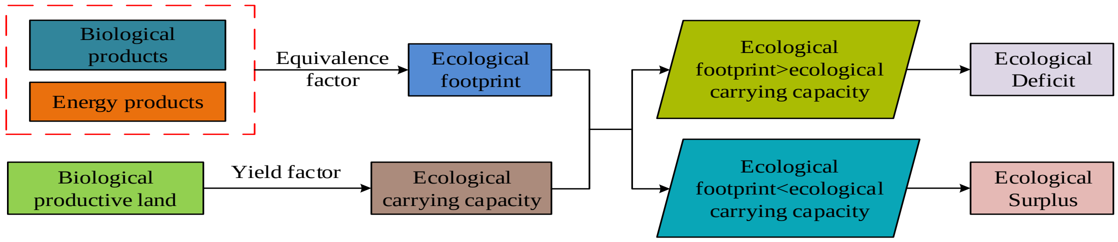


Figure 1. The ecological footprint (EFO) model.

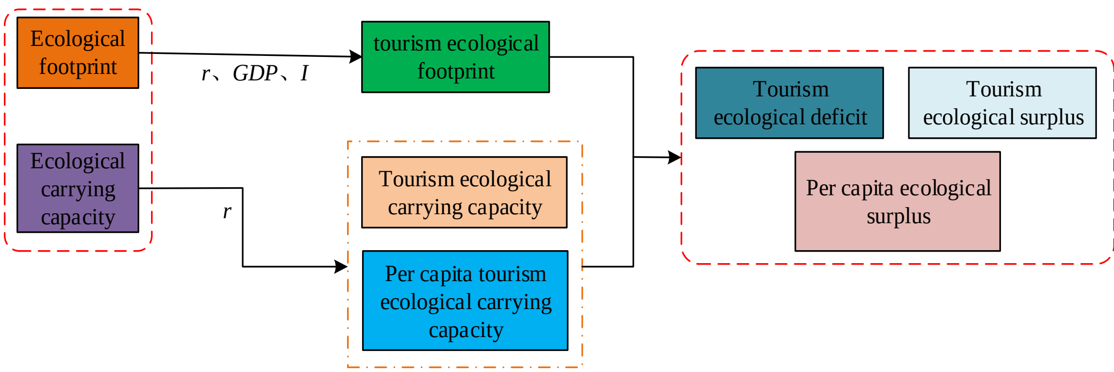


Figure 2. The specific calculation process of tourism EFO.

$$\begin{cases} E_{D1} = N(e_f - e_c) \\ E_{D2} = N(e_c - e_f) \end{cases} \quad (5)$$

where E_{D1} was ecological surplus and E_{D2} was ecological deficit. The EFO could be obtained from the EFO of tourism in the test area and its specific calculation process was shown in Figure 2. The contribution of tourism industry, gross domestic product (GDP), and current year tourism value added in the test area were used to calculate the EFO of tourism by using Equation (6).

$$\begin{cases} E_f(T) = E_f \times r \\ e_f(T) = \dfrac{E_f(T)}{N_T} \\ r = \dfrac{I}{GDP} \end{cases} \quad (6)$$

where $E_f(T)$ was the EFO of tourism in the test area. r was the contribution rate of tourism in the test area. N_T was the total of tourists in the test area in the current year. I was the value added of tourism in the test area in the current year. GDP was the GDP in the test area in the current year. Then the tourism ecological CCA was calculated as:

$$\begin{cases} E_c(T) = E_c \times r \\ e_c(T) = \dfrac{E_c(T)}{N_T} \end{cases} \quad (7)$$

where $E_c(T)$ denoted the current year's tourism ecological CCA of the test area and $e_c(T)$ denoted the per capita tourism ecological CCA of the test area. The tourism ecological surplus or tourism ecological deficit was then calculated as follows.

$$\begin{cases} E_D(T) = N_T[e_f(T) - e_c(T)] \\ e_d(T) = \dfrac{E_D(T)}{N_T} \end{cases} \quad (8)$$

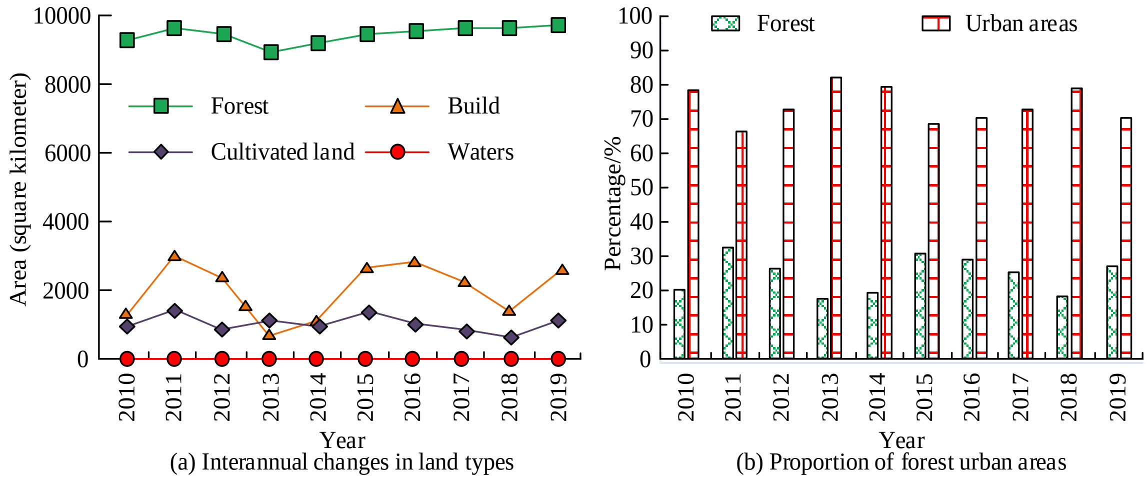


Figure 3. Remote sensing (RS) image processing results.

where $E_D(T)$ was the tourism ecological surplus or ecological deficit of the test area in a certain year and $e_d(T)$ was the per capita tourism ecological surplus of the experimental area.

Results and discussion

The land use coverage of the test area

Due to the impact of force majeure factors in recent years, the number of tourists around the world has declined significantly, which may lead to inaccurate prediction results. This study used the monitoring data from 2010 to 2019 to conduct a simulation investigation. The satellite images and map data obtained by RS were used to calculate the land use coverage of the test area (Figure 3). The results showed that the forest in the test area fluctuated between 8,000 – 9,000 km^2 through the years, while the cultivated area fluctuated between 500 – 1,000 km^2. The variation of the built-up area ranged from 500 – 3,000 km^2, and the area of the water was basically 0 with little change (Figure 3a). The proportion of forests in the test area ranged from 12 to 32%, while the proportion of town areas ranged from 68 to 82% (Figure 3b). The analysis demonstrated that the proportion of town area in the test area was larger, but the forest area was the largest, which indicated that the test area protected the environment better and the distribution of land resources was more reasonable.

The vegetation coverage in the test area

The vegetation cover of the test area was then calculated (Figure 4). The results showed that vegetation cover in the test area varied cyclically over the time in the range of 0.55 to 0.84. The vegetation cover in the test area gradually increased from 2010 to 2016, and slightly decreased from 2016 to 2019, with a general upward trend (Figure 4b). The results led to the conclusion that the vegetation richness of the test area was high and proved that its ecological condition was good.

The comfort level of the test area

The comfort level of the test area was also calculated to judge its ecotourism value (Figure 5). Between 2010 and 2019, the index value of the integrated comfort level of the test area varied up and down in the range of 0.3 to 1.0 in chronological change with an average integrated comfort level of about 0.6. The index value of the comfort level of the test area varied in the range of 0.60 to 0.65 in chronological change with a relatively small change in magnitude. The results indicated that the comfort level changes in the test area were more stable, and the ecotourism value was higher.

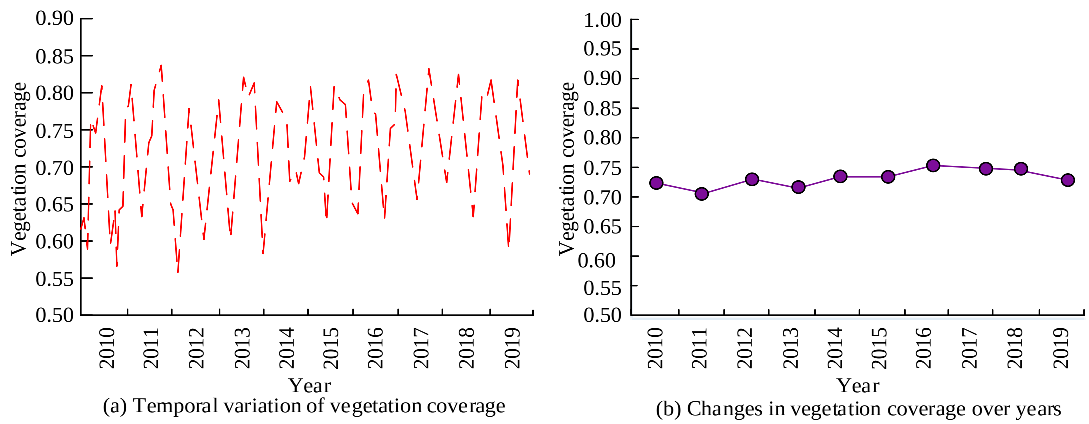


Figure 4. Vegetation coverage in the experimental area.

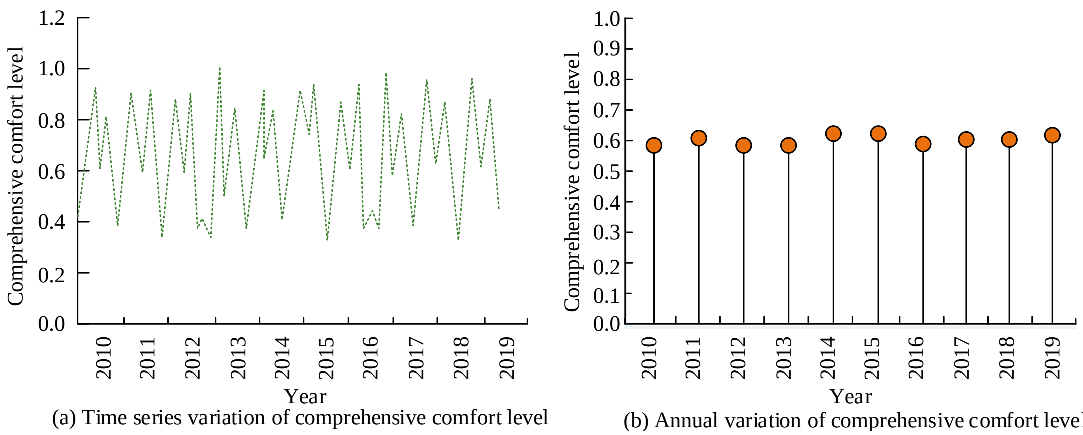


Figure 5. Comfort level of the experimental area.

Analysis of the development trend of EEN sustainability

For studying the influence of tourism development on the EEN, the EFO, ecological CCA, and ecological surplus of the experimental area were analyzed through the 10 year period. The comparison of the EFO and ecological CCA as well as the results of the ecological surplus over the time were shown in Figure 6. The EFO of the test area varied between 16.0 - 21.3 khm^2 with an average EFO of about 18.0 khm^2, while the ecological CCA ranged between 20.5 - 32.0 khm^2 with an average of about 25.2 khm^2. Both the EFO and the ecological CCA showed a general trend of increasing, and the ecological CCA change curve was above the EFO change curve (Figure 6a). The ecological surplus of the test area was in the range of 4.0 - 11.0 khm^2 with the average of about 7 khm^2 (Figure 6b). The results suggested that the test area consumed more resources, but the ecological protection of the environment was good. So that, the ecological surplus was greater than 0, and the overall SDE was maintained.

The results of calculated annual changes of tourism EFO, tourism ecological CCA, tourism ecological surplus, and per capita tourism ecological surplus were shown in Table 1. From 2010 to 2019, the tourism EFO first increased from 2010 to 2011, then slightly decreased from 2011 to 2012 followed by gradually increased from 2012 to 2017, and then decreased again from 2017 to 2018, and eventually increased from 2018 to 2019 with a general increasing

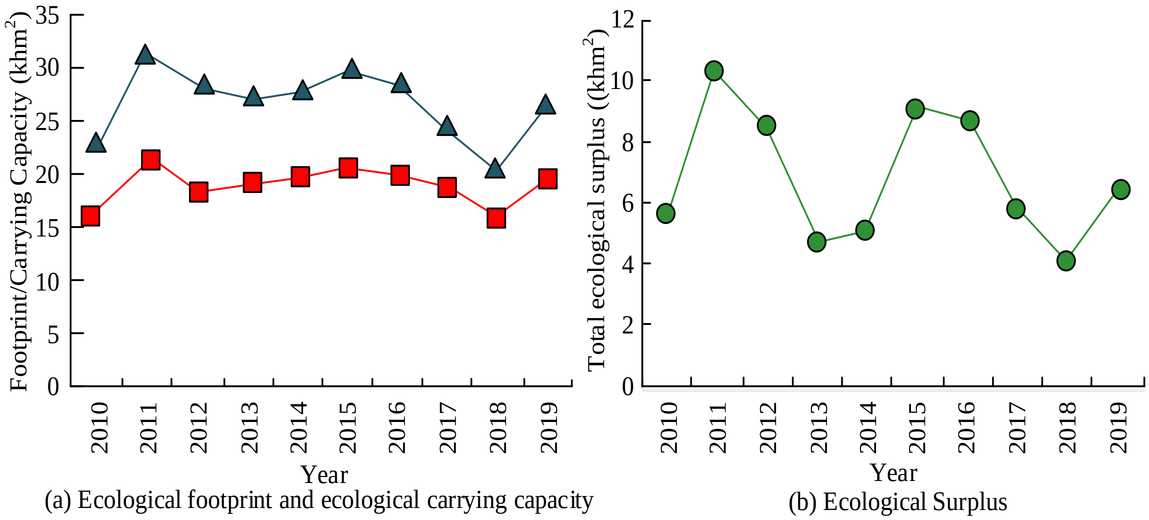


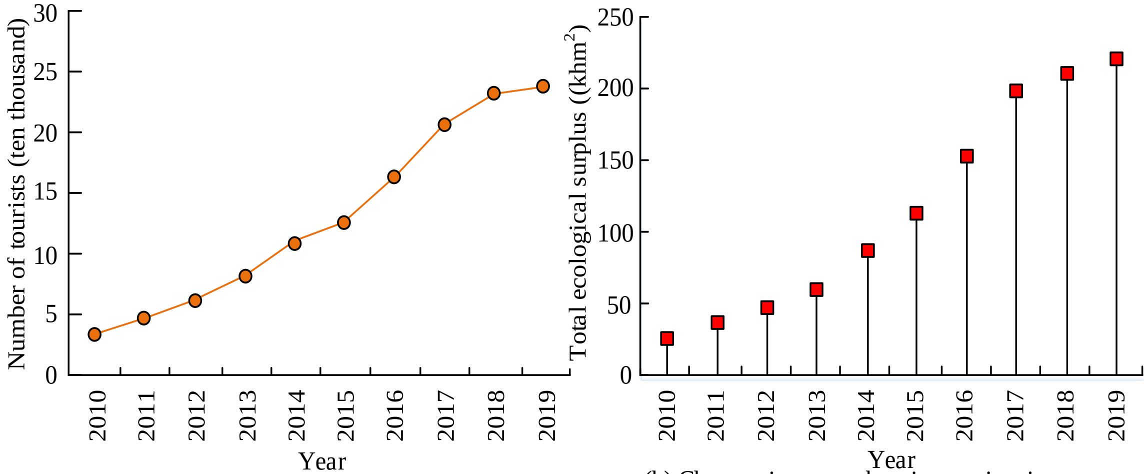
Figure 6. The changes of indicators (EFO, CCA, and Ecological surplus) over the time.

Table 1. Annual average changes in tourism ecological indicators.

Year	Tourism ecological footprint (khm²)	Tourism ecological carrying capacity (khm²)	Tourism ecological surplus (khm²)	Per capita tourism ecological surplus (khm²)
2010	11.33	15.27	3.95	0.012
2011	18.72	27.68	8.96	0.019
2012	14.99	21.76	6.77	0.011
2013	16.06	22.69	6.64	0.008
2014	20.55	28.74	8.19	0.008
2015	25.54	36.96	11.43	0.009
2016	31.02	44.48	13.46	0.008
2017	34.71	45.44	10.73	0.005
2018	30.68	38.38	7.69	0.003
2019	37.63	50.00	12.38	0.005

trend. The trends of tourism ecological CCA and tourism ecological surplus were consistent with the trend of tourism EFO with an overall increasing trend. Per capita tourism ecological surplus increased from 2010 to 2011, then gradually decreased from 2011 to 2014, and slightly rebounded from 2014 to 2015, followed by gradually decreased again from 2015 to 2018, and increased from 2018 to 2019 with an overall decreasing trend. The results suggested that, although the test area was in the stage of SDE, the per capita ecological surplus gradually tended to 0, and might even have an ecological deficit, which in turn affected the development of ecotourism areas.

The number of tourists and tourism income of Sanqingshan were obtained through the tourism statistics released by Sanqingshan Administrative Committee Tourism Bureau and Shangrao City Statistics Bureau, the tourism attractiveness index and comprehensive tourism income of the test area were calculated, and the outcomes were showcased in Figure 7. The results demonstrated that, between 2010 and 2019, the number of tourists and comprehensive income from tourism in the pilot area showed a rising trend year by year, with the number of tourists rising from about 3.5 million to 24 million, which was an increase of about seven times. The comprehensive income from tourism increased



(a) The attractiveness of tourism changes over time (b) Changes in comprehensive tourism income over time

Figure 7. Tourism attractiveness indicators and comprehensive tourism income.

from about 2.5 billion to 22 billion with an increase of about nine times. The results led to the conclusion that the popularity of the pilot area is high.

Conclusion

With the rise of ecotourism, the tourism industry has developed rapidly. However, less attention has been paid to the protection of natural and humanistic landscapes, which makes this development unhealthy. How to carry out SDE has become an urgent problem currently. This study applied 3S technology to monitor the environmental changes and extracted data from the study area. The EFO was then calculated on the ground of the monitoring data to judge the state of SDE in the study area. The results showed that, in the land use coverage, the range of forest area in the test area from 2010 to 2019 was between 8,000 – 9,000 km^2, while the range of arable land area was between 500 – 1,000 km^2. The range of built-up area was between 500 - 3,000 km^2, which indicated a better protection of the EEN. In the vegetation cover, the range of vegetation cover in the test area was between 0.55 and 0.84 with periodic changes, indicating the high vegetation richness. In the comparison of EFO and ecological CCA, the ecological CCA curve was above the EFO curve, indicating that the test area maintained SDE in general. In the annual average changes of tourism EFO, tourism ecological CCA, tourism ecological surplus, and tourism ecological surplus per capita, tourism ecological CCA and tourism ecological surplus both showed an increasing trend, and tourism ecological surplus per capita showed a decreasing trend, demonstrating that, although the test area was in the stage of SDE, eco-tourism had a certain impact on the local environment. The small number of indicators used in the study might lead to inadequate results, which would be improved in future investigations.

References

1. Baloch QB, Shah SN, Iqbal N, Sheeraz M, Asadullah M, Mahar S, *et al*. 2023. Impact of tourism development upon environmental sustainability: a suggested framework for sustainable ecotourism. Environ Sci Pollut R. 30(3):5917-5930.
2. Wu Z, Zhao Y, Zhang N. 2023. A literature survey of green and low-carbon economics using natural experiment approaches in top field journal. GLCE. 1(1):2-14.
3. Tyagi D, Wang H, Huang W, Hu L, Tang Y, Guo Z, *et al*. 2020. Recent advances in two-dimensional-material-based sensing technology toward health and environmental monitoring applications. Nanoscale. 12(6):3535-3559.
4. Rahman MK, Masud MM, Akhtar R, Hossain MM. 2022. Impact of community participation on sustainable development of

marine protected areas: assessment of ecotourism development. Int J Tour Res. 24(1):33-43.
5. Heshmati M, Gheitury M, Shadfar S. 2022. Factors affecting possibility of ecotourism development and sustaining natural resources using SWOT approach in west Iran. IJGP. 10(2):173-183.
6. Omarzadeh D, Pourmoradian S, Feizizadeh B, Khallaghi H, Sharifi A, Kamran KV. 2022. A GIS-based multiple ecotourism sustainability assessment of West Azerbaijan province, Iran. J Environ Plann Man. 65(3):490-513.
7. Xu L, Ao C, Liu B, Cai Z. 2023. Ecotourism and sustainable development: a scientometric review of global research trends. Environ Dev Sustain. 25(4):2977-3003.
8. Singgalen YA. 2022. Priority analysis of mangrove Guraping ecotourism development based on spatial data using process hierarchy analysis. J Inf Syst. 4(1):1-15.
9. Prasandya KDE, Satria MW. 2023. Identification of the hierarchy of ecotourism criteria using the AHP method: reference for determining priority villages for ecotourism development. Journey: Journal of Tourismpreneurship Culinary Hospitality Convention and Event Management, 2023, 6(1):87-96.
10. Jokar P, Masoudi M, Karimi F. 2021. An MCE-based innovative approach to evaluating ecotourism suitability using GIS. Cuadernos de Investigación Geográfica. 47(2):545-556.
11. Wibowo JM, Muljaningsih S, Satria D. 2021. Big data analytics of sustainable ecotourism development in Bromo Tengger Semeru National Park. Sustinere J Envir Sustain. 5(1):35-48.
12. Asadi H, Soffianian A, Hemami MR, Fakheran S, Akbari Feizabadi H, Corcoran F. 2022. A hybrid GIS-OWA and DANP method for the identification and evaluation of ecotourism attractions: the case study of Abbas Abad Wildlife Refuge, Iran. Geol J. 87(6):5179-5196.
13. Khyevari VG, Liaghati H, Mirsanjari MM, Armin M. 2019. Application of analytical network process and fuzzy logic (ANP-FUZZY) in identifying ecotourism development areas in Dena county. Envir Sci. 17(3):29-44.
14. Mansour S, Al-Awhadi T, Al-Hatrushi S. 2020. Geospatial based multi-criteria analysis for ecotourism land suitability using GIS & AHP: a case study of Masirah Island, Oman. J Ecotourism. 19(2):148-167.
15. Kianisadr M, Darani KM, Golkarian H. 2019. Quantitative zoning of ecotourism potential in Oshtorankouh protected area using Delphi method, analytic hierarchy process, and weighted overlay methods. Ecopersia. 7(2):115-123.
16. Xie H, Wen J, Chen Q, Wu Q. 2021. Evaluating the landscape ecological risk based on GIS: a case-study in the poyang lake region of China. Land Degradation & Development. 32(9):2762-2774.
17. Wang ZG, Wang HQ, Feng MC, Qin MX, Zhang XR, Xie YK, *et al*. 2021. Study on the monitoring and classification of winter wheat freezing injury in spring based on 3S technology. J Agr Sci-Cambridge. 159(9-10):623-635.
18. Baloch QB, Shah SN, Iqbal N, Sheeraz M, Asadullah M, Mahar S, *et al*. 2023. Impact of tourism development upon environmental sustainability: A suggested framework for sustainable ecotourism. Environ Sci Pollut R. 30(3):5917-5930.
19. Lee CC, Chen MP, Wu W. 2022. The criticality of tourism development, economic complexity, and country security on ecological footprint. Environ Sci Pollut R. 29(24):37004-37040.
20. Guan C, Rani T, Yueqiang Z, Ajaz T, Haseki MI. 2022. Impact of tourism industry, globalization, and technology innovation on ecological footprints in G-10 countries. Econ Res-Ekon Istraz. 35(1):6688-6704.