The ecological environment capacity of different functional zones in Lushan Scenic Area

Li Wen¹, Dongming Xie¹³, Guohong Zhou¹, Haiyan Qian² and Ziwei Guo¹

¹College of Tourism, Jiangxi Science and Technology Normal University, Nanchang 330038;
²Department of Earth Sciences, East China University of Technology, Nanchang, 330013, China
³Email: xdm0791@126.com

Abstract. Eco-environment capacity assessment is to appraise the status of the eco-environment. Lushan Scenic Area is one of the global famous cultural landscapes in China. A multi-factor comprehensive analysis method and indicator weighting method are used to appraise the status of the eco-environment of different eco-function zones by building the eco-environmental capacity indicator system in Lushan Scenic Area. The results explain the different eco-function zones were various in the status of the eco-environment. The eco-protect zone was good status of eco-environment in middle and low hot tourism season, but it was bad status of eco-environment in high hot tourism season. However, the control developing zone, the natural landscape protect zone and eco-restoration zone were bad status of eco-environment in total tourism season. Many elements lead to the bad status of eco-environment, such as heavy tourist activity, high density buildings, water contaminating, and noise destroyed the eco-environment together.

1. Introduction

The impact of scenic tourism activities on the ecological environment and its evaluation have gradually received widespread attention[1]. Scholars at home and abroad have carried out certain research, mainly through the analysis of environmental factors in soil, water environment, animals and plants, air temperature, air quality, etc.[2] The research of foreign scholars began in the 1920s, and the research in the 1960s gradually deepened[3]. Chinese scholars began to study the environmental impact of tourism activities in the 1980s[4], Liu Xiaobing and Bao Jigang[5], Gong Jie and Lu Lin[6], Lu Zhenglan et al[7] Xie Dongming et al.[8] conducted relevant research reviews. The methods used by domestic scholars to study the impact of tourism on the ecological environment include ecological footprint[9], environmental health[10], and environmental factor method[11]. The methods used by foreign scholars to study the impact of tourism on the ecological environment include environmental audit method[12], Solow's economic growth model method[13], and ordinary least square regression model simulation method[14]. From the perspective of domestic and foreign research status, research methods have gradually changed from qualitative research to quantitative research, and the research object has the characteristics of broadness and diversity.

Lushan is a world cultural heritage site with very high historical and cultural value, scientific investigation value and aesthetic appreciation value. From ancient times to the present, Lushan has attracted a large number of literary scholars due to its own advantages. The large number of tourists,
the excessive construction of tourist facilities such as roads, ropeways, parking lots, cable cars, and hotels in the Lushan tourist area, the oversaturation of long-term tourists and uncivilized tourism behavior, and the unreasonable management methods of tour operators and local residents, caused losses to the ecological environment of the scenic area, which cause a certain impact on the ecological environment of the tourist area, and seriously restricted the healthy development of Lushan tourism. The ecological environment load of scenic spots is the basis and prerequisite for the socio-economic development of scenic spots and sustainable development of tourism. Therefore, carrying out research on the assessment of the ecological environment load of Lushan Scenic Area will not only guide the tourism management department of Lushan or the local government in the management or policy formulation of Lushan tourism, but also be useful for other scenic spots.

2. Materials and methods

2.1. Overview of the study area

Lushan Scenic Area is located in Jiujiang City, Jiangxi Province, facing the Yangtze River in the north and looking at Poyang Lake in the east. It is an independent mountain with geographic coordinates of 29° 30′ ~ 29° 41′ north latitude and 115° 51′ ~ 116° 07′ east longitude. The mountain is 29 km long from north to south, 16 km wide from east to west, and the mountain area exceeds 300 km²[15]. Lushan belongs to the subtropical monsoon climate zone with mild and humid climate. The annual average temperature is 11 °C, the annual average relative humidity is 78%, the annual average foggy day is 191 days, the forest coverage rate is 76.6%, and the mountainous microclimate features are significant[16]. Luling Town, Lushan has a permanent population of about 15,000 people. Tourism activities and other human activities have a long history, frequent and profound, and the environmental impact is relatively severe[17].

According to the frequency of Lushan tourists' activities, August, March and December each year are selected to represent Lushan's peak tourist season, normal season and low season. According to the "Master Plan of Jiangxi Lushan Scenic Area", Lushan is mainly divided into four major functional blocks, namely ecological protection zone, natural landscape protection zone, ecological restoration
zone and controlled development zone, with an area of 37.773 km², 96.013 km², 135.193 km², and 52.122 km² (Figure 1).

2.2. Research methods

2.2.1. Evaluation method. (1) Evaluation index
With reference to the relevant literature[18,19], the following indicators are selected as the influencing factors of the ecological environment load of Lushan Scenic Spot.

1) Visitor volume and local population (P); 2) Acoustic environment (N); 3) Solid waste (D); 4) Building density (B); 5) Air environment (A); 6) Water environment (W); 7) Green area and water area (E); 8) Negative oxygen ion concentration (O); 9) Tourism environmental capacity (C).

According to the above nine indicators, determine the level 2 evaluation indicator values of different ecological function blocks, including $Y_1$, $Y_2$, $Y_3$, $Y_4$, $Y_5$, and $Y_6$ indicators. They are the tourism environment capacity utilization intensity $P / C$; acoustic environment quality, $N / \text{noise standard}$; ground cleanliness, which is divided into 1 to 5 grades according to the amount of garbage heaps per unit area, 1 is the cleanest, 5 is the dirtiest, and so on; building load intensity, $B / E$; air quality, $A / O$; water environment quality, using the average multi-factor environmental quality index. Process each index value, determine the contribution weight of each index, and finally calculate the ecological load comprehensive grading index of each ecological function block in different time domains (divided into three seasons: prosperous, pale, and flat), formula (1).

$$I_i = \sum_{j=1}^{6} A_j Y_j$$  \hspace{1cm} (1)

In Equation 1, $A_j$-weight, $Y_j$-normalized variable values.

2.2.2. Evaluation criteria. According to relevant national standards and related planning of Lushan Scenic Area, the standard values of the four functional areas are as follows (Table 1):

| Index/Ecological function area | Ecological protection area | Natural landscape protection area | Ecological restoration area | Control development area |
|-------------------------------|---------------------------|-----------------|---------------------------|-------------------------|
| Acoustic environment standard / N\(^\circ\) | 50 | 50 | 50 | 50 |
| Solid waste / D | 1 | 1 | 2 | 3 |
| Building density/refer to the ratio of the area occupied by ground structures to the visited area / B \(^2\) | 0.05 | 0.1 | 0.2 | 0.5 |
| Air pollution / pm2.5 / A\(^\circ\) | 15 | 15 | 15 | 15 |
| Water environment quality / W\(^\circ\) | 4 | 4 | 4 | 4 |
| Green area and water area ratio / E\(^\circ\) | 0.95 | 0.9 | 0.8 | 0.5 |
| Negative oxygen ion concentration / O\(^\circ\) | 3,000 | 3,000 | 2,000 | 1,000 |
| Tourism environmental capacity / C\(^\circ\) | 1,000 | 30,000 | 50,000 | 100,000 |
| Comprehensive evaluation index | 0.68 | 0.68 | 0.78 | 0.91 |

| standard of scenic spots (GBT 51294-2018) and comprehensive relevant literature; \(^\circ\)refer to ambient air quality standard (GB 3095-2012), PM2.5 Standards; \(^\circ\)Comprehensive measurement results based on surface water environmental quality monitoring data; \(^\circ\)Same as \(^\circ\);\(^\circ\) Comprehensive references; \(^\circ\)Tourism environmental capacity of natural landscape protection areas According to Jiangxi Lushan National Geopark Planning (2013-2030) Environmental capacity The carrying capacity and other daily averages are comprehensively calculated by the survey. |
2.2.3. Index weighting method. The weights are obtained according to the Delphi method (expert consultation method, 15 experts were invited there) and the AHP method (analytic hierarchy process), and the calculation formulas of the weight consistency test are shown in formula (2) and formula (3):

\[ CI=(\lambda_{\text{max}}-n)/(n-1) \] (2)

\[ CR=CI/RI \] (3)

Among them, CR is the random consistency ratio of the judgment matrix, CI is the deviation consistency index RI is the average random consistency index value, in the 1-9 order judgment matrix, the details of the RI value are shown in Table 2.

**Table 2.** Average random consistency index.

| n  | 1   | 2   | 3   | 4   | 5   | 6   | 7   | 8   | 9   |
|----|-----|-----|-----|-----|-----|-----|-----|-----|-----|
| RI | 0.00| 0.00| 0.58| 0.90| 1.12| 1.24| 1.32| 1.41| 1.45|

When CR ≤ 0.10, it is considered that the judgment matrix A has satisfactory consistency. When CR > 0.10, it is considered judgment matrix A does not meet the random consistency index, and it needs to be adjusted to achieve satisfactory consistency.

2.2.4. Data source and description. 1) The number of tourists and the population of local residents (P), from Lushan Scenic Spot Administration; 2) Acoustic environment (N), measured data; 3) Solid waste (D), from Lushan Scenic Spot Administration; 4) Building density (B) Remote sensing image interpretation data; 5) Air environment (A), from Jiangxi Provincial Department of Ecology and Environment and Jiangxi Meteorological Bureau; 6) Water environment (W), measured data, comprehensive evaluation; 7) Green space and water area (E), remote sensing interpretation data; 8) Negative oxygen ion concentration (O, from Jiangxi Meteorological Bureau); 9) Tourism environmental capacity (C), from Lushan Scenic Spot Administration.

3. Results and analysis

3.1. Index weighting results

According to the expert assignment results, the weight values of \( Y_1, Y_2, Y_3, Y_4, Y_5, \) and \( Y_6 \) are 0.05, 0.20, 0.08, 0.07, 0.26, and 0.34, and the CI value is 0.09977. According to Table 2, CR = 0.08 ≤ 0.10. The matrix has satisfactory consistency.

3.2. Evaluation results of ecological environment load

**Table 3.** Comprehensive index of ecological environment load.

| Ribbon type /tourist season | Peak season | Normal season | Off season |
|-----------------------------|-------------|---------------|-----------|
| Ecological protection area  | 0.99        | 0.56          | 0.56      |
| Natural landscape reserve  | 2.85        | 2.27          | 1.82      |
| Ecological restoration area | 1.94        | 2.08          | 2.30      |
| Controlled development zone | 3.01        | 3.36          | 3.61      |

The calculation results show that the different tourism seasons: in the peak tourist season, the comprehensive index of ecological environment load in each region is controlled development zone> natural landscape protection zone> ecological restoration zone> ecological protection zone; during the tourist season, the controlled development zone> ecological restoration Area> Natural Landscape Protection Area> Ecological Protection Area; During the low season of tourism, control the development area> Ecological Recovery Area> Natural Landscape Protection Area> Ecological Protection Area. Different ecological function areas: ecological protection area, high season> peak season> low season; natural landscape protection area, high season> peak season> low season; ecological restoration area, low season> peak season> low season; controlled development area, low season> peak season> peak season. In ecological protection areas, the comprehensive evaluation index is higher than the standard value in the peak tourist season, and lower than the standard value in the
normal and low seasons; the comprehensive evaluation index of the natural landscape protection areas is higher than the standard value in the peak, normal and low seasons; ecological restoration areas and control The development zone also has a comprehensive evaluation index higher than the standard value (Table 3).

4. Discussion and conclusion

4.1. Discussion

The ecological protection area is mainly located in the core area of the Lushan National Nature Reserve. Strictly speaking, there can be no tourism activities in this area. However, due to the large number of tourists in the peak tourist season, a small number of tourists will enter these areas to carry out activities, which affects the nature of the ecological function zone to a certain extent. The natural landscape protection area is the area with the most frequent tourism activities in Lushan, and the instantaneous ecological environmental load value during peak tourist periods (especially around May 1st and 11th and summer and July and August) far exceeds the environmental capacity. Most tourist attractions are distributed in this area, and the main tourist service facilities are also distributed in this area, such as Guling Visitor Center is located in this area. There are many factors that affect the high comprehensive evaluation index of the area, such as high building density, serious water pollution, and high air noise. The comprehensive evaluation index of ecological restoration area and controlled development area is higher than the standard value, mainly because the construction density of these areas is relatively high, the activities of local residents are more frequent, especially the controlled development area, which is the stronghold of some villages and towns, and the commercial activities are more frequent. The solid waste, noise, and water pollution are relatively serious. There are many tourists and floating population, the density of vehicles is large, and the greening is small. The controlled development zone is not only a distribution center for tourists, but also a living area for local residents and passing people. This special marginal zone characteristic determines that their ecological environment load value is higher than other ecological function zones.

From the perspective of the whole year, there is a certain conflict between the number of tourists receiving Lushan Scenic Area and its current carrying capacity of the tourist environment, especially in the peak tourist period, there will still be serious overloading, and similar situations exist in other scenic spots throughout the country[20]. The large ecological environment load of the scenic spot will cause insufficient water supply, power supply, catering and accommodation capacity in the scenic spot, will cause pressure on the provision of basic equipment in the scenic spot, and the ecological environmental risk will also increase[21]. The sewage and solid waste in the scenic area increase, and insufficient treatment will reduce the ecological environment quality of the scenic area. The operation of vehicles and people’s activities are more frequent, which also reduces the air quality in the scenic area. Excessive number of tourists will reduce their willingness to watch, which will affect tourists' satisfaction with the scenic area. The problem of overloading or serious overloading of the number of tourists in the scenic spot is not conducive to the sustainable development of the scenic spot. The ecological environment is the foundation of sustainable tourism development, and maintaining a beautiful natural ecological environment is very important. However, as far as Lushan's tourism development trend is concerned, the number of tourists will increase steadily. Therefore, it is necessary to strengthen the construction of the ecological environment, increase the carrying capacity of the tourist environment, and reduce the ecological conflict and load intensity. However, judging from the characteristics of Lushan's tourists' spatial and temporal distribution throughout the year, implementing dynamic tourist regulation is a viable approach, such as peak-shaking regulation, trial preferential policies in the off-season of tourism, and increased tourist marketing measures. In addition, certain infrastructure construction of environmental pollution control must also be invested. For example, constructing an automatic and sustainable monitoring system for the ecological environment to grasp real-time detection of various ec-environment indicators of Lushan, in order to prevent exceeding the standard. What's more, the construction of sewage treatment system is also very
important, domestic sewage and other sewage generated by tourists and residents must be treated in time, otherwise it will cause water pollution in Lushan.

4.2. Conclusion
The comprehensive index of eco-environmental load varies in different tourist seasons and regions with different ecological functions. Generally speaking, there is a certain pressure on the ecological environment load of Lushan Scenic Area. In general, when Lushan is in the peak tourist season, the ecological environment load index of each functional area of Lushan is higher, and the pressure of ecological environment load is greater; the average season is followed by the lowest season. Whether in peak season, normal season or low season, the comprehensive index of ecological environment load of ecological protection area is much lower than that of the other three functional areas, and the comprehensive index of ecological environment load of controlled development area is higher than that of the other three areas. The comprehensive index of the ecological environment load of the ecological restoration zone fluctuates back and forth between these two functional zones. Because the ecological protection area is located in the core area of the Lushan National Nature Reserve, the area is strictly protected by the government, and there cannot be any tourism and other human activities. The other three areas can be in the peak season, the flat season or the low season. Restricted to carry out tourism activities and other activities, Lushan because of its popularity, even in the flat season and low season, many tourists come here to travel, resulting in a higher ecological environment load index of Lushan. The controlled development zone is a tourist distribution center, as well as a living area for local residents and passing people. The high pedestrian flow and high activity intensity determine that the ecological environment load value of this zone is higher than other ecological function zones. The natural landscape protection area is the main area for tourists to carry out tourism activities. During the peak season, the number of tourists increases sharply, and the ecological load value of the natural landscape protection area is higher than that of the ecological restoration area. The value of the ecological environment load generated for Lushan is not as high as the local residents’ activities. Therefore, the value of the ecological restoration area is higher than the value of the natural landscape protection area in the normal season and the low season. Therefore, the tourism scenic spot management department or the government needs to properly manage tourists: in the peak season, appropriate restrictions should be implemented; in the flat season, especially the low season, innovative product types, innovative marketing concepts and methods are needed to attract potential tourists to Lushan Tourist Area. In this way, the social and economic benefits of Lushan Scenic Area can be realized, and the damage to the ecological environment of Lushan Mountain caused by the over-saturation of tourists during the peak tourist season can be avoided, and significant ecological benefits can be produced.

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