Ecotourism risk assessment in Yaoluoping Nature Reserve, Anhui, China based on GIS

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Abstract

With the continuous increase of tourism development and human disturbance, the functional structure distribution, sustainable utilization of resources and ecological benefits of nature reserves have been affected, and its ecological risk has increased significantly. This study proposes ecotourism development patterns for risk areas at each level, to provide a basis for stabilizing and promoting the ecological sustainable development of nature reserves. Yaoluoping National Nature Reserve in China is used as a study example. Based on GF-2 satellite data within the reserve area in 2017, ENVI, Fragstats and ArcGIS 10.2 are used for land use classification as well as evaluation indicators selection and analysis. The ecotourism risk assessment model of the reserve is constructed, which is combined with the analytic hierarchy process and the fuzzy comprehensive evaluation method. The model consists of landscape ecology, topographic hydrology, land use and human activities factors, and it can produce the distribution map at the ecotourism risk level of the reserve. Results show that the high ecotourism risk areas in the reserve are mainly located around rivers and roads, and they are distributed in strips. Overall, the ecotourism risk level in the northern part of the reserve is higher than that in the southern part. Nearly 90% of the regional ecotourism risk is at the middle or low level, implying the reserve in a healthy level overall. However, except for low risk areas, the proportion of risk areas at all levels in the core zone is higher than that in the buffer zone.

Key words: ecotourism risk assessments, nature reserve, tourism development, GIS, Yaoluoping

Introduction

Ecological risk refers to the risk that the ecosystem suffers from the disturbance of nature or human activities, that is, the adverse effects of accidents or disasters in a certain region on the structure or function of the ecosystem, thereby endangering the safety and health of the ecosystem (Mao and Ni 2005; Cao et al. 2018; Tang and Ma 2018; Guo et al. 2017). Ecological Risk Assessment is to organize and analyze existing data, evaluate the possible negative Ecological effects, and predict the probability and consequences of the occurrence of risks (Meng and Zhao 2009; Rohr et al. 2016). The research on ecological risk assessment began in the 1930s. It mainly went through embryonic
stage, human health assessment stage, ecological risk assessment stage and the multiscale comprehensive ecological risk assessment stage from the 1990s to the present (Thomsen et al. 2012; Long et al. 2015; Kang et al. 2016; Kapustka 2005; Hua et al. 2017). In recent years, scholars have extended and improved the study of ecological risk assessment to landscape, region, watershed and other levels (Xu et al. 2013; Peng et al. 2015; Liu et al. 2015; Li et al. 2018; Bayliss et al. 2012; Detenbeck et al. 2000). For example, Zhang and Xie (2015) extracted the ecological receptor information of Nansihu lake by artificial neural network, and used Kriging interpolation to simulate the intensity and spatial distribution of risk source, as well as the vulnerability of risk receptors, to calculate the ecological risk value of the study area based on the comprehensive risk probability and ecological loss. Piet et al. (2017) discussed the optimal method for ecological risk assessment under different circumstances in terms of risk source determination and risk calculation method.

In addition to the functions of protecting precious species and maintaining ecological balance, nature reserves have gradually become the main places for ecotourism activities due to their original and unique regional landscapes (Zhang et al. 2016; Sheng et al. 2015; Xue et al. 2019). The existing research on ecotourism in nature reserves mainly focuses on the evaluation of development potential, status and planning (Lian et al. 2010; Zong et al. 2016; Zhong and Yang 2018; Pastorok et al. 2003). However, with the continuous increase of tourism development and human disturbance, nature reserves are facing with severe ecological problems such as resource reduction, ecological function degradation and ecological benefit reduction, and the ecological risk is significantly increased (Liu et al. 2018; Wei et al. 2018; Van Strien et al. 2016; Peng et al. 2015; Wang et al. 2016). Yaoluoping National Nature Reserve plays an important role in protecting the representative forest ecosystem in Dabie Mountains, the national rare and endangered wildlife, and the water security of Mozitan and Foziling reservoirs in Huaihe River Basin. Therefore, carrying out ecotourism risk assessment, determining the spatial distribution of ecotourism risk levels in the reserve and discussing and proposing ecotourism development countermeasures tailored to local conditions in Yaoluoping Nature Reserve, which can provide decision-making basis for risk management of the reserve and the sustainable development of resources and environment (Wang et al. 2018; Zhang et al. 2018; Li and Gao 2019).

**Materials and Methods**

*Site description*
Yaoluoping National Nature Reserve is located in the junction of the three counties (Yuexi, Huoshan and Yingshan) in Anhui and Hubei provinces. It is in the hinterland of the Dabie Mountains with a total area of about 123 km². Its landform is middle mountain, and its altitude is normally above 800 m. Its relative altitude difference is 400-1000 m, and its slope is 40-60°. The zonal vegetation of the reserve consists of subtropical evergreen broad-leaved forest and warm temperate deciduous broad-leaved forest. The biodiversity of the reserve is extremely rich, preserving a large number of rare and endangered animals as well as ancient relic plants. There is an important species gene bank in Dabie Mountains. There are more than 2000 species of higher vascular plants and more than 200 kinds of terrestrial vertebrates, including more than 40 species of national key protected rare wild animals and plants, such as *Emmenopterys henryi*, *Euptelea pleiospermum*, *Pinus dabeshanensis*, *Andrias davidianus*, and *Moschus moschiferus*. Meanwhile, Yaoluoping Nature Reserve is also the source area of some important tributaries of Huaihe River and Yangtze River in Anhui Province, such as Qingtian River, Shisheng River, Dongjia River and Caopan River. It has become the main water conservation forest area for protecting the Huaihe River Basin (Wang et al. 2016).

The nature reserve is divided into four core zones: Cuanshi, Qilingou, Diaoguanjing and Duozhijian. Buffer zones are set up around the four zones respectively. Other parts of the nature reserve are experimental zones. The area ratio of the three functional zones is 17%, 24%, and 59%, respectively. The reserve actually receives nearly 40,000 tourists annually, mainly relying on natural resources scenery in buffer zones and experimental zones as well as red tourist attractions such as the old military and political site of the Red 28th Army.

**Research methods**

**Data preprocessing**

GF-2 satellite images in 2017 were used in this study. The resolution of panchromatic band and multispectral data are 1m and 4m, respectively, the cloud amount of image was less than 2%, and imaging quality is good. The DEM data in the study area was ASTGTM2 with a resolution of 30m. Administrative boundaries, regional statistics data and comprehensive planning document of the nature reserve were provided by the Reserve Management Committee.

After data preprocessing such as atmosphere correction, orthographical correction and image fusion for GF-2 images through ENVI5.3, according to the latest national standard (GB/T...
21010-2017) issued in November 2017 for the classification of land use status of the People’s Republic of China, the land types in the study area were divided into six categories by supervised classification, including forest land, cultivated land, construction land, bare land, water area and road (Du et al. 2020; Hua et al. 2018; Zhang et al. 2018; Zhou et al. 2020). Interactive visual interpretations were carried out combined with the field investigation and questionnaire survey in October 2017, and results were with the accuracy of 90.4% and Kappa coefficient of 0.84.

Evaluation index selection
A comprehensive index database affected ecological tourism risk for Yaoluoping Nature Reserve was established according to the characteristics of land use, the effect of tourism development and the availability of data (Duan et al. 2020; Shi et al. 2020; Li and Wei 2020; Liu et al. 2016; Cao et al. 2019). Finally, ArcGIS10.2 was used to analyze and determine the impact factors that can be described and quantified after considering consulted experts’ experience and discussion opinions.

(1) Functional zoning of Yaoluoping Nature Reserve. As the species, quantity and distribution of wild animals and plants, and biodiversity indices date were difficult to quantify in the risk assessment unit, the functional zoning classification of natural reserve was used to characterize the biological resources factors, reflecting the importance of ecological red line and government decision-making. The closer to the core zone of the reserve means both the more various resources that attracted the development of eco-tourism and the higher ecological risk that the area faces.

(2) Vegetation coverage. Vegetation coverage is a key parameter to measure the surface vegetation status and describe the ecosystem, so it is of great significance for conservation water and soil as well as ecological conservation. The higher is the vegetation coverage, the stronger the stability of the ecosystem is, and the ability to resist or self-repair the possible impact of ecological tourism development is stronger. Normalized Difference Vegetation Index (NDVI) was used in this study.

\[ NDVI = \frac{NIR - R}{NIR + R} \quad (1) \]

Where NIR and R are near infrared band and visible red band of GF-2 image respectively. The vegetation coverage \( F_c \) was obtained through statistical range.

\[ F_c = \frac{NDVI - NDVI_{\text{min}}}{NDVI_{\text{max}} - NDVI_{\text{min}}} \quad (2) \]

Where \( NDVI_{\text{min}} \) and \( NDVI_{\text{max}} \) are the minimum NDVI and maximum NDVI within the region.
under the confidence interval of 5%.

(3) Landscape pattern indicators. Landscape index can reflect regional landscape structure change and comprehensively describe the landscape ecological pattern, it can be divided into three levels: individual patch level, patch class level and landscape level (Zeng et al. 2014; Wang et al. 2019; Zhong et al. 2019; Liu et al. 2020; Han et al. 2020). Fragstats4.2 software was used to calculate the three class-level indices as landscape pattern metrics corresponding to the landscape fragmentation, separation and dominance (Table 1) (Jin et al. 2014; Gong et al. 2015; Fu et al. 2019; Qi 2019; Li et al. 2019), and their weight ratio was assigned to 5:3:2 combined with relevant studies and expert scoring method (Li and Li 2008; Lv et al. 2018; Tian et al. 2018; Li et al. 2019).

(4) Basin area. Basin environment is closely related to its ecosystem. The hydrological analysis module of ArcGIS10.2 was used to extract the river network of the nature reserve from DEM data, and then area was generated based on watershed.

(5) Slope. As one of the sensitive elements that may cause geological disasters, slope is of great significance to conserve water and soil, and is also the primary factor in land use planning and control measures (Shi et al. 2015). According to "Technical regulation for inventory for forest management planning and design " (GB/T 26424—2010), slope is divided into four grades: <6°, 6°~15°, 15°~25° and >25°.

(6) Elevation. Since most human disturbance activities are within low-altitude areas, regional ecological risk level is significant negative correlation to elevation (Jing et al. 2008). As elevation rises, temperature drops. Thus, ArcGIS10.2 is used to divide the elevation range from 400 m to 1900 m into five grades with interval of 300m.

(7) Relief of topography. Relief of topography refers to the difference between the maximum and minimum elevations of all grids in a unit area, and it is widely used in regional soil erosion analysis and ecological environment evaluation. The larger is the value, the greater the possibility of geological disasters is. We selected the area of 1 km² as the best statistical unit area and used the neighborhood analysis of ArcGIS10.2 to extract its corresponding grid window (Gao et al. 2015).

(8) Gully density. Gully density refers to the ratio of basin length to basin area per unit area. It is an index to describe the degree of ground broken by water channel, and can reflect the comprehensive influence of climate, topography, lithology, vegetation and other factors. The greater is the density value, the more broken the ground is, the more unstable the surface material is, and
the easier surface runoff and aggravate soil erosion form. Gully density of each functional area was calculated from river network data.

(9) Road network density, construction land proportion and agricultural land proportion. In the aspect of ecological risk assessment tourism-oriented, we carried out the analysis of the basic situation of the natural reserve as well as the status of tourism development and field investigations. The risk indicators of three land use types (i.e., road network density, construction land proportion and agricultural land proportion) were used to characterize corresponding risk situation of convenience of tourism transportation, tourism construction projects and production activities effect of local residents.

(10) Tourist distribution proportion and registered population density. Considering those characteristics that the resident population of the nature reserve is only remaining residents, base education and tourism are developed mainly in the region, the nature of the tourist and preference. On the National Day of China in 2017, 290 questionnaires were provided to tourists in the reserve. 273 of them were valid, so the questionnaire response rate exceeded 94%. Combined the main purpose of tourist in the survey results with the geographical location and tourism planning report of the nature reserve, six main scenic spots, including Shifo Temple, Shili Gallery, Yaoluoping Base Scenic Area, the old military and political site of the Red 28th Army, Xiaqiling and Duozhijian, were selected as the main tourist distribution areas. Their corresponding proportion was determined. Their corresponding registered population densities are obtained through collected statistical questionnaires from the reserve management committee.

In order to eliminate the influence form different dimensions, normalization was used in the above evaluation indices. The grid data diagrams with five levels of different indicators were obtained using the natural break point grading method of ArcGIS10.2. Analytic hierarchy process (AHP) is a decision analysis method decomposing elements related to decision-making into goal level, criteria level and alternative level, which combines both qualitative and quantitative analysis (Liu 2011; Purucker et al. 2007). We summarized all selected indicators as criteria levels such as landscape ecological factors, topography and hydrology factors, land use factors and human activities factors by AHP, used Yaoluoping nature reserve as goal level, and established evaluation system for ecotourism risk assessment.

Construction of evaluation model
AHP method uses the consistency ratio of the judgment matrix which related to the relative importance of each level and judges the quality standard of the level ranking. The judgment matrix is considered to have satisfactory consistency when the consistency ratio (CR) <0.1. Firstly, the importance of various indicators was scored based on the experience of many industry experts. Secondly, the weights of factors affecting ecotourism risks were calculated using Yaahp12.1 software. Finally, an ecotourism risk evaluation index system was built for Yaoluoping Nature Reserve (Table 2). The single-ranking CR value of each factor of the criterion level is less than 0.1, and the total ranking CR at the model level = 0.003 <0.1. Therefore, it implies that the single ranking and total ranking of the evaluation model index level have satisfactory consistency.

Fuzzy comprehensive evaluation can combine qualitative and quantitative, as well as accurate and inexact, with the principle of fuzzy mathematics (Xiong et al. 2020; Su et al. 2020). It has been widely used in ecological risk assessment of landscapes, watersheds and regions. The ecological risk index (ERI) of the nature reserve can be obtained by weighted average combined with a multilevel fuzzy comprehensive evaluation model.

\[
ERI = \sum_{i=1}^{n} (C_i \cdot U_i) = \sum_{i=1}^{n} (P_i \cdot V_i \cdot U_i)
\]  

(3)

where \(C_i\) and \(P_i\) are the value of the i-th evaluation index at the criteria level and the alternative level, respectively; \(U_i\) and \(V_i\) are the weights of their corresponding indices, respectively. Using the reclassification module of ArcGIS10.2, the grid data of weighted criteria level and goal level are divided into five levels by the natural break point grading method. Levels from low to high are defined as low risk area, medium-low risk area, medium risk area, medium-high risk area and high risk area. Finally, the ecological tourism risk evaluation model of Yaoluoping Nature Reserve is established based on AHP and fuzzy comprehensive evaluation method (Eccles et al. 2019; Gaines et al. 2004; Chen et al. 2019; Liu et al. 2019).

**Results**

**Analysis of Single factor evaluation results**

The results of overlaying the four criterion levels that affect the ecotourism risk of the nature reserve with the administrative boundaries and functional zoning data are shown in Fig 1. It can be seen that the high ecotourism risk areas of landscape ecology in the nature reserve are mainly distributed along roads and construction lands. The vegetation coverage in the area is over
90%, the mean patch area of forest land is large, the separation index is small, and the dominance is 
the highest. It shows that the regional vegetation protection is relatively complete and has a good 
ecological function. In addition to woodland, the largest patch area of each landscape type is small, 
the fragmentation and separation level is high, the landscape patches are scattered and greatly 
affected by human interference. Therefore, most of the landscape ecological risk in the nature 
reserve is relatively low except for roads, construction land and arable land. However, the average 
landscape ecological risk in core zones is higher than that in buffer areas and experimental areas 
due to government decision-making as well as abundant animal and plant resources, especially in 
the Diaoguanjing region, where the passage of some main roads makes it one of the peak areas of 
landscape ecological risk.

In general, the topographic and hydrological risk of the nature reserve shows that its spatial 
distribution characteristics is gradually decreasing from north to south, which is consistent with the 
gradual increase of watershed area and the distribution trend of elevation rising from the center of 
upper experimental zone of the Diaoguanjing to outside. The slopes of rivers and roads above the 
Diaoguanjing are relatively slow, and the relief of topography and gully density from the below part 
of the Diaoguanjing buffer zone to Duozhijian buffer zone are lower. Therefore, the topography and 
hydrology risk in these regions are relatively less than their surrounding regions. The topography 
and geomorphology levels of each functional zone are rich, but the entire Chuanshi zone and the 
Diaoguanjing core zone may face a higher ecotourism risk in the aspect of topographic and 
hydrological, and the entire Duozhijian core zone is lower.

Residents' income mainly depends on agriculture, forestry and tourism, and tourists select tour 
activities based on public infrastructure, attractions and service zones. The integration of residents' 
income and tour activities make not only the land use contain only arable land, roads and 
construction land, but also the human activities that aim at population statistics more directly and 
clearly reflect the disturbances from human activities. In the aspect of land use risk area, although 
some land use types are at increased risk, the four core zones are all at a low ecological risk state, 
and the risk value range of buffer zone is medium and below. It indicates that these regions shall 
control land planning management strictly according to the government's decision. The high-risk 
areas of the experimental zone are located between Diaoguanjing and Qilingou, as well as 
Diaoguanjing and Duozhijian. The order of risk values of human activities in the nature reserve is:
core zone <buffer zone <experimental zone. The danger of outdoor sports in the Duozhijian mountainous area is reduced due to high altitude and policy control, the risk values of Shili Gallery and Yaoluoping base scenic area are increased significantly owing to the integration of tourism functions including natural scenery, landscape photography, unique animal and plant ornamental, etc.

**Results analysis of comprehensive ecotourism risk assessment**

The results of ecotourism risk levels in the Yaoluoping Nature Reserve are shown in Fig. 2 and Table 3. It can be seen that the ecotourism risk of Yaoluoping Nature Reserve has obvious spatial difference. The south of the Diaoguanjing core zone is mostly a low-risk area, while the risk level in the north is significantly higher than that in the south. Medium-high and high risk areas are mainly located around rivers, roads, construction land and the northeast of the Chuanshi core zone. In general, nearly 90% of the ecological tourism risks in the nature reserve are at the medium or lower level due to good natural conditions and moderate dispersion of land use, and most of them are at good levels. However, the ecological risk value is high in some areas, the ecosystem is fragile, and the stability and natural recovery ability are poor.

The proportion of medium-high and high ecotourism risk areas in the core zone is 6.77% and 1.74%, respectively. In terms of specific areas, although the risk of landscape, land and humanities in the Chuanshi core zone is at a low or medium-low level, the risk of natural terrain factors is high, and geological disasters are more likely to occur because of the water area of is less and human activities are frequent on low terrain. The Diaoguanjing core zone is located in the center of the nature reserve and has high risks of landscape ecology and topographic hydrology. At the same time, it is adjacent to the Shili Gallery scenic area that is vulnerable to human interference, and its resulting high risk of ecotourism needs to be focused on and measured to prevent. The Duozhijian area in the south is well protected due to its steep terrain, rich biological habitat resources and restricted human activities. It has larger area and relatively complete ecological low-risk district, which is conducive to water conservation and ecosystem function. In the horizontal comparison of functional zones, except for low-risk areas, the proportion of risk areas at all levels in the core zone is greater than that in the buffer zone, and the proportion of medium and medium-high risk areas in the buffer zone is greater than that in the experimental zone. It indicates that the ecotourism risks faced by the core zones and buffer zones in the nature reserve are not optimistic, and the functional
distribution of the nature reserve might be negatively affected.

Discussion

Ecotourism development has gradually become one of the hot spots in the nature reserve planning. Existing researches on ecotourism in nature reserve mainly focus on developing potential evaluation, development status and planning, etc. However, there are few researches on ecological risk assessment and protection that is or has been caused by ecotourism development. This study used both biological resources factors expressed by functional zoning of the nature reserve and the comprehensive landscape pattern indices as landscape ecological factors to evaluate the ecotourism risk, which is an innovation of this study. Ecotourism risk level for the Yaoluoping National Nature Reserve was divided, corresponding analysis and evaluation were carried out, and plans of adjusting measures to local conditions and rational development of ecological tourism were proposed. It will provide a theoretical and practical reference for the nature reserve. In 2020, the integration and optimization of national nature protected areas has been gradually carried out, and the functional zoning of nature reserves will be further improved. The original core zones and buffer zones have been transformed into core protection zone, and the original experimental zones have become general control zones. At the same time, the transformation of the core protection zones and the general control zones will be carried out according to the actual situations of those regions. The result of ecotourism risk assessment can also be used as practical reference and guidance for analysis of transformation trend in functional zoning.

Since GF-2 satellite image belongs to four-band hyperspectral remote sensing image with high spatial resolution, this study directly used the maximum likelihood method with human intervention to select training samples in the process of supervised classification of remote sensing images. The selection of classifier includes Neural Network, Support Vector Machine and other image classification methods suitable for high-resolution image, which can be used for specific analogy and verification analysis in order to explore the difference and superiority of classification results.

The key to determine the source of ecological risk is the objective degree how to select qualitative indices and quantitative factor. This study established the ecological tourism risk evaluation index system by four criteria levels and 15 alternative levels, and each factor weight of the evaluation model was determined by reference, software calculation and expert scoring. However, in order to make the evaluation process more rational and scientific, further researches
should consider comprehensively the development of ecotourism project under human disturbance, ecosystem restoration and maintenance mechanism of ecological service for nature reserve. The significance of ecotourism risk evaluation is to provide the guidance of risk mechanism management so as to feedback and act on the further implementation and development of ecotourism. Thus, the future development of ecotourism risk evaluation shall build a risk information database that includes risk source and risk receptor combining with the characteristics of socio-economic development and GIS technology, construct better evaluation index systems and models, establish risk assessment criteria of reasonable dimensions, and discuss the development plans and patterns for sustainable ecotourism in nature reserve.

**Conclusion**

Based on the current situation of tourism development in Yaoluoping National Nature Reserve, this study determined the factors affecting the ecotourism risk of the nature reserve, established the ecotourism risk evaluation index system of the nature reserve, and built the ecotourism risk assessment model of the nature reserve combined with the AHP and the fuzzy comprehensive evaluation methods. Results showed that the overall level of ecotourism risk in the nature reserve is low, the spatial differentiation among risk grade areas was obvious, and regional overall risk was significantly reduced from north to south. In addition, the high risk areas in the nature reserve showed a banded distribution and were located mainly around rivers, roads, construction lands. Under the reasonable control of the management committee policy, the nature reserve was basically in the low risk state of land use, followed by landscape ecological risk. The human disturbance factors under the influence of natural factors and tourism development led to significant differences in the spatial distribution of topographic hydrological risks and human activities risks. Approximately 90% of the functional zones of the nature reserve were at middle and lower levels of ecotourism risks. The proportion of other risk areas basically followed the sequence of core zone > buffer zone > experimental zone except for the highest and the lowest risk areas. Therefore, the key issue to be solved is to eliminate the overall ecotourism risk for the nature reserve.

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