
Sensitivity Analysis on Eco-geological Environment of Huangshan Scenic Spot Based on “3S” Technology

ZHAO Ping¹, YANG Cizhong, HUANG Jia-zheng

*School of Resources and Environmental Engineering, Hefei University of Technology, Anhui Hefei
230009*

Abstract: With the vigorous development of heritage tourism and the accelerated process of urbanization, China's world heritage sites are generally facing the prominent contradictions between protection and utilization. Eco-geological environment is the important foundation for the development and utilization of tourism resources in scenic spots. Eco-geological environment sensitivity analysis is to evaluate the possibility of eco-geological environment problems occurrence under the influence of natural and human activities, which has an important guiding significance for the conservation and sustainable development of heritage sites. Huangshan Mountain is one of the top ten scenic spots in China with three crowns of "World Natural and Cultural double Heritage" and "Geological Park". This paper took the core of Huangshan Scenic Spot as the study area, 30m × 30m grid for the evaluation unit, based on the analysis of the main eco-geological environment problems in study area, a two-layered evaluation index system was constructed including geological environment factors ecological environment factors hydrological factor, the impact of human activities, landscape value and natural hazard factor of six major categories impact factors composed of twelve secondary indicators. After the weights of all indicators were determined by AHP method, under the support of the "3S" techniques, these indicators were extracted, and the weighted overlay comprehensive analysis were applied to evaluate eco-geological environment sensitivity of Huangshan Scenic Spot. The whole study area was divided into extremely sensitive, highly sensitive, moderately sensitive, lowly sensitive and insensitive five levels. The final results showed that the sensitivity of eco-geological environment in Huangshan Scenic Spot is mainly affected by human activities. The insensitive areas were account for 75.71% of the study area where there are relatively few tourists, tourist facilities and popular attractions, such as Fugu and Yangshu management zone. Extremely and highly sensitive areas are account for less than 1% of the total area, and mainly distributed in the popular attractions focused areas such as Yuping, Yungu and Beihai management zone where the human activities are very frequent. The

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First author biography: ZHAO Ping (1975—), female, Associate Professor, PH.D graduated from Nanjing University, interested in resources and environment remote sensing, has published more than 20 papers..

E-mail: njuzhp@sina.com

moderately sensitive areas were account for about 2%, mainly concentrated within the 100m-200m buffer zones of the roads, residential facilities and tourist attractions, around the extremely and highly sensitive area and affected by human activities relatively obvious. The research also indicates that effective protection of attractions focused areas and appropriate development of decentralized district in Huangshan Scenic Spot are important for its sustainable development.

KEY WORDS: "3S" Technology, eco-geological environment, sensitivity analysis, Huangshan Scenic Spot

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1 INTRODUCTION

The World Heritage Site is the valuable wealth of mankind. However, with the rapid development of tourism in the world, excessive urbanization construction and commercial development, the eco-geological environment of many World Heritage Sites and their surrounding area has been severely damaged, generally facing the prominent contradictions between protection and utilization. Eco-geological environment is the basic conditions for scenic spot's existence, and its sensitivity(also known as vulnerability) refers to the sensitive degree of eco-geological system in response to all kinds of environmental variations and human activities, which is used to measure the possibility and impact of ecological imbalance and eco-geological environment problems(Fan & Yang, 2009). Fast, accurate, and objective analysis of the eco-geological environment of heritage sites, is an important prerequisite for scientific planning and management of heritage sites to achieve sustainable development. With the rise of computer science, "3S" technology has gained popularity around the world, and they can effectively extract, store, manage, process and analyze the multi-sources data for eco-geological environmental sensitivity analysis. Sensitivity analysis on eco-geological environment of World Heritage Site based on "3S" technology, has become an important content and advanced means to protect World Heritage sites.

At present, the domestic and international research on eco-geological environment is still in its infancy stage. Study of eco-geological environment started earlier in foreign countries, and its application level and depth is beyond ours. However, these studies mainly focused on the forecast of geological disaster and evaluation of eco-geological environmental quality, and less sensitivity study(Trorimov, 2004; Huang, et al. , 2008; Mondal & Maiti, 2012; Reis, et al. , 2012 ; Clerici, et al. , 2006; Oh H J & Pradhan, 2011; Gillespie, et al. , 2007; Mclchiorre, et al., 2011; Atkinson & Massari, 1998). Domestic research mainly focused on eco-geological environmental survey and quality evaluation, and also less sensitivity analysis on eco-geological environment. Huang Runqiu, et al. (2001, 2002, 2008) discussed principles and methods of eco-geological environmental evaluation in detail, summarized the application of "3S" techniques in the survey and evaluation of eco-geological environmental, and evaluated the eco-geological environment quality in Anning River basin of the upper Yangze River; Fan Tao and Yang Shiyu(2009) summarized the theoretical research on eco-geological environment of tourism destination , and they studied the eco-geological environmental sensitivity in Lijiang scenic spot. In addition , many relevant studies on eco-geological environment have been carried out in the Qinghai-Tibet and QingZang plateau(Fang, et al., 2007;Li Y H, et al., 2008),the Yangtze River and the Yellow River basin (Zheng, et al., 2010; Yuan, et al., 2008; Xu X N, et al. , 2003;), Sichuan and Liaoning province(Zhao, et al., 2010; Li L & Zhang Z W, 2008), Jiuzhaigou scenic spot(Zhang, 2007) and other regions. Mt. Huangshan, national 5A class tourist scenic spot in China, is the only world famous mountain chosen as World Cultural

and Natural Heritage, and World Geological park simultaneously. In this paper, based on the previous studies, a set of indicator system was established from both natural and human perspectives to analyze the eco-geological environmental sensitivity of Huangshan Scenic Spot. With the support of "3S" technology, weighted overlay analysis function of GIS and AHP method were used for the eco-geological environmental sensitivity analysis, and some effective measures were put forward to deal with the eco-geological environmental problems possibly appearing in Huangshan Scenic Spot according to the analysis results. These results can also provide basis for decision making on the planning management of Huangshan Scenic Spot to ensure the sustainable development of tourism resources.

2 STUDY AREA

Huangshan Mountain is located in south of Anhui province, Huangshan City territory, across Huizhou District, Huangshan District, Xiuning and Yixian County. It extends from northeast to southwest with 40 kilometers long from north to south and 30 kilometers wide from west to east. It is the watershed of Yangtze and Qiantang River in southern Anhui and occupies a total area of 1,200 square kilometers. The core region covers an area of 160.6 square kilometers, located at $118^{\circ}05'E \sim 118^{\circ}15'E$ and $30^{\circ}04'N \sim 30^{\circ}13'N$. The whole scenic area is divided into Beihai, Yuping, Wenquan, Songgu, Diaqiao, Fugu, Fuxi and Yanghu nine management zones. The study area in this paper is a rectangular area including Huangshan core scenic spot and its surrounding (as shown in Fig.1).

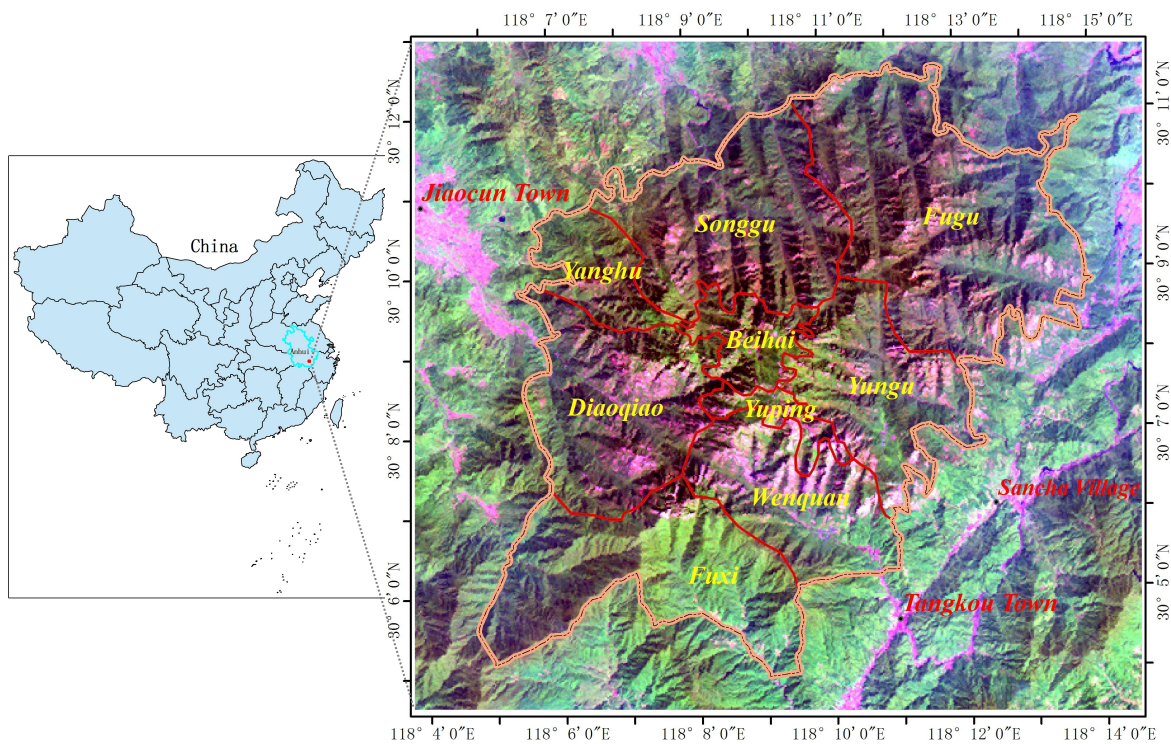


Fig. 1 Location of the study area

The tectonics in Huangshan Mountain is situated in the south side of Southern Anhui platform subsidence of the Lower Yangtze syncline, linking the anteklise along the Yangtze River in the north and Jiangnan platform uprise in the south. The main tectonic line here is in the direction of NE-SW, similar to the strike of mountains. Huangshan Mountain is mainly composed of Yanshanian granite. There are many granite caves and tunnels because of vertical joint development, strong erosion and incision, fault and fracture crisscross, and long-term corrosion by water(Wang, 1989) . Besides , a lot of Quaternary glacial remains are found in Huangshan Mountain, mainly distributed in southeast of the front range of the mountain, such as "U"-shaped valleys, aretes, horns, hanging valleys and moraine stones(Lee, 1936) .

Huangshan Scenic Spot is in the subtropical climate zone, damp-warm and rainy all year round, with four distinct

seasons. The annual average temperature is 7.8 °C, annual average rainfall is 2394.5mm, and annual average sunshine hours are 1810.2h. Huangshan plants show obvious vertical zonation with one alpine meadow and one alpine swamp preserved. The forest coverage rate is 56% and the vegetation coverage is 83%. There are 1452 species of wild plants and more than 300 species of animals in Huangshan Scenic Spot.

3 DATA AND METHOD

3.1 Data sources

The data used in this paper are as follows: 1:50,000 topographic map, 1:200,000 geological map, scenic tourist traffic map, 30m spatial resolution DEM, 2.5m spatial resolution SPOT5 fused image acquired on February 9th in 2004, 30m spatial resolution landsat5 TM image acquired on October 3rd in 2009, 1:100,000 land use map in 2006, and 1:25,000 vegetation survey map, also with reference to Google Earth and other network resources. Take the corrected topographic map as a reference, all maps and images are unified into Beijing 54 Albers projection.

3.2 Method

Sensitivity analysis on eco-geological environment of Huangshan Scenic Spot is a multivariate analysis involving large amount of data. It is difficult to make scientific decisions by experience and artificial means. Firstly, the index system of eco-geological environmental sensitivity evaluation was established by field investigation and experts' analysis in this paper. And then AHP method was used to determine their weights. Finally, with the support of "3S" technology, these indicators were extracted, and weighted overlay analysis function of GIS was used to carry out the eco-geological environmental sensitivity analysis on Huangshan Scenic Spot. The analysis process is shown in Fig. 2.

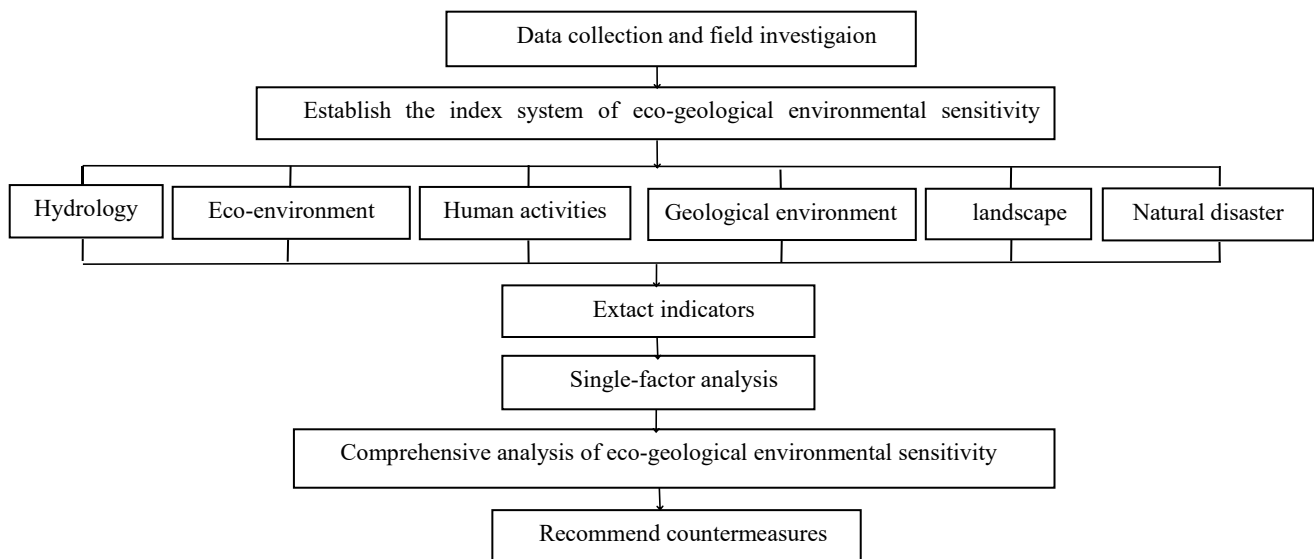


Fig. 2 Flowchart of eco-geological environmental sensitivity analysis of Huangshan Scenic Spot

4 SENSITIVITY ANALYSIS OF ECO-GEOLOGICAL ENVIRONMENT

4.1 Establishment of index system

Establishing a scientific, perfect and feasible evaluation index system and choosing appropriate evaluation criteria is

the key to carry out the eco-geological environmental sensitivity analysis successfully, so reasonable and appropriate selection of indicators is the primary task of the eco-geological environment sensitivity analysis. Establishment of indicators should follow the principles of synthesis, differences, regional particularity, measurable and sustainable use (Li X H, 2001; Huang, et al., 2008; Zhang R Y, 2007). Based on the investigation and analysis of eco-geological environment in study area, and following the principle of indicator selection, geological environment, ecological environment, hydrology, human activity, landscape value and natural disaster, six categories influencing factors had been chosen in this study. These factors involve 12 secondary indicators described below.

Geological environment indicators include geologic structure, elevation, slope and aspect. The impact of geological structure can be represented by the distance to the faults and fault zones. Faults and fault zones are active zones in the crust, and apt to cause earthquake or other disasters in these places. So the nearer distance to the faults and fault zones, the sensitivity of eco-geological environment is higher. Elevation, slope and aspect are common description factors of the terrain. The higher the altitude, the lower the temperature, the less the vegetation and the simpler the ecosystem, and is easier to cause eco-geological environmental problems. Slope is the inclination of the ground. The greater the slope, surface erosion is more serious, so the possibility of eco-geological environment problems occurrence is greater. Aspect has strong impact on debris flow, landslide and other geological disasters. Because Huangshan is in direction of NE-SW, the northwest and southeast direction is vulnerable to cause debris flow and landslide, and disaster possibility is relatively smaller in the other directions. Because of adequate lighting, vegetation is very lush in the east and south of Huangshan Mountain and flat place where the probability of landslide and other geological disasters taking place is the smallest.

Ecological environment indicators include biodiversity, vegetation fraction and land use/cover. The higher the level of biodiversity, the more complex the ecosystem, and the possibility of eco-geological environmental problems occurrence is smaller (Zhang R Y, 2007). Since the biology in Huangshan Mountain depends largely on vegetation cover, vegetation fraction, land use / cover and elevation were chosen to carry out the assessment on biodiversity level of the Scenic Area, and thus biodiversity level map was generated. Vegetation fraction directly affects ecological environment. The structure of ecological system is usually complex and diverse in these regions with high vegetation fraction. That is to say, the higher vegetation fraction, the ecological environmental problems are less likely to occur. In all types of land use/cover, the forest system is difficult to cause environmental problems due to its strong adjusting ability, while a single and simple ecological structure is vulnerable to human impacts and easy to cause environmental problems.

Hydrology impact is represented by the distance to water system. Water resources are the essential resources in the scenic spot. Most human activities are around the water system, so the nearer to the water, the more strongly affected by human, and the sensitivity are higher.

Human activities impact is represented by the distance to road, settlements and tourist facilities. Roads and settlements and tourist facilities are the most active areas of human activity. Away from the greater distance to these regions, the degree of human activities is reduced accordingly, and is more prone to eco-geological environmental problems.

Landscape value impact is also represented by the distance to the attractions. In this study, attractions are divided into key attractions and general attractions according to their conservation value and the annual number of tourists. The impact range of key attractions is greater than that of general attractions. The nearer from attractions, human activities are more frequent, and the eco-geological environmental problems are more likely to occur.

The natural disaster mainly refers to geological disaster in this paper, and is indicated by geologic hazard risk level.

The place with higher level of geological disasters risk is more prone to geological disasters, so the eco-geological environmental sensitivity is higher (Li W, 2009).

With reference to the relevant researches and according to the actual situations of the study area, the grading standard of each secondary indicator is established as shown in Table 1.

Table 1 Influencing indicator grading standards of eco-geological environmental sensitivity analysis

Infuencing factors	indicators	Sensitivity indicator classification and score				
		Very low	Low	Moderate	High	Extreme
Geological environment	Distance to tectonic lines	>200m	150m~200m	100m~150m	50m~100m	<50m
	Slope	<8°	8°~15°	15°~25°	25°~45°	>45°
	aspect	Flat, east	North	South, west	South east, north west	North east, south west
Ecological environment	Elevation	<400m	400m~700m	700m~1000m	1000m~1500m	>1500m
	Biodiversity level	Rating 5	Rating 4	Rating 3	Rating 2	Rating 1
	Vegetation fraction	>75%	60%~75%	45%~60%	30%~45%	<30%
Hydrological information	Land use / cover	Forestland	Grassland	Unused land	Settlement	Farmland
	Distance to water system	>200m	150m~200m	100m~150m	50m~100m	<50m
	Distance to roads	>200m	150m~200m	100m~150m	50m~100m	<50m
Human activities	Distance to settlements	>200m	150m~200m	100m~150m	50m~100m	<50m
	Distance to key attractions	>320m	240m~320m	160m~240m	80m~160m	<80m
	Distance to general attractions	>200m	150m~200m	100m~150m	50m~100m	<50m
Natural disaster	Geological hazard risk	Rating 1	Rating 2	Rating 3	Rating 4	Rating 5
Assign a value to all levels		1	3	5	7	9
Grading standards		<2	2~4	4~6	6~8	>8

4.2 Extraction of eco-geological environmental sensitivity indicators

Geological environment: The distances to tectonic lines were acquired by buffer analysis of tectonic line in geological map. The elevation, slope and aspect three indicators are extracted directly using GIS digital terrain analysis from DEM data. And then these result layers were reclassified and assigned new values based on grading criteria in Table 1. The results are as shown in Fig.3 to Fig.6.

Ecological environment: Biodiversity indicator and land use/ cover indicator were obtained by reclassifying the biodiversity rating map and land use map respectively (shown as Fig.7 and Fig.8). Vegetation fraction was got from remote sensing estimation using dimidiate pixel model based on NDVI layer from the TM image (Li M M, et al, 2004;

Xu H Q, 2008). And then the result layer was reclassified and assigned a new value according to the grading criteria in Table1. The result is as shown in Fig.9.

Hydrology: The distance to water system was obtained by buffer analysis of point and line shape water system elements. Then the buffer layer was reclassified according to the grading criteria in Table 1. The result is shown in Fig.10 .

Human activities: The distance to road and settlements were also obtained by buffer analysis of roads and settlements layer and the reclassification of the buffer layers. The results are shown in Fig.11 to Fig.12.

Landscape value: Firstly, key attractions and general attractions were carried out buffer analysis and reclassification respectively, and then the above two result layers were overlaid to integrate as one layer, choosing the greater value as the new layer's property value. After performing all the process, landscape value map was acquired (as shown in Fig. 13).

Natural disaster: There are many control factors of geological disaster. After thorough study of the Huangshan Scenic Spot, six geological disaster influencing factors such as slope, aspect, formation lithology, road engineering, geologic structure and vegetation fraction were taken into account to evaluate the geological hazard risk (Li W, 2009). And then the geological hazard risk level layer was reclassified according to the grading criteria in Table 1. The final result is shown as Fig.14 .

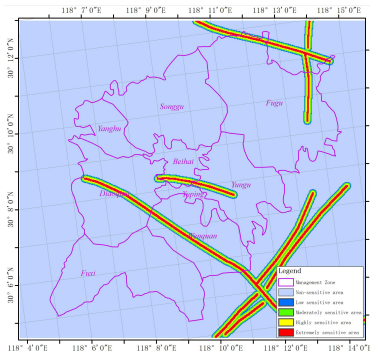


Fig. 3 Distance to tectonic line

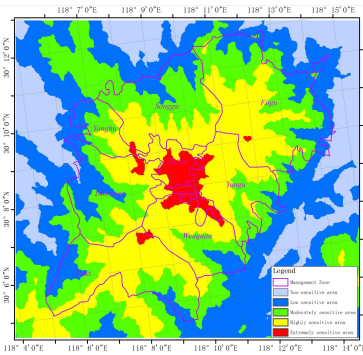


Fig. 4 Elevation

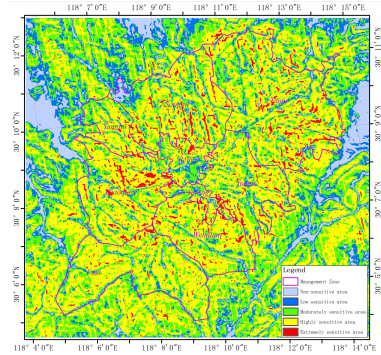


Fig. 5 Slope

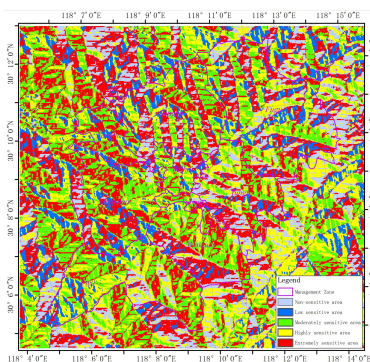


Fig. 6 Aspect

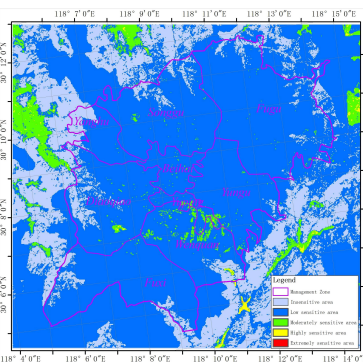


Fig. 7 Biodiversity level

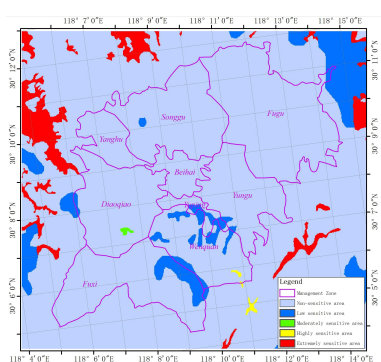


Fig. 8 Land use/cover

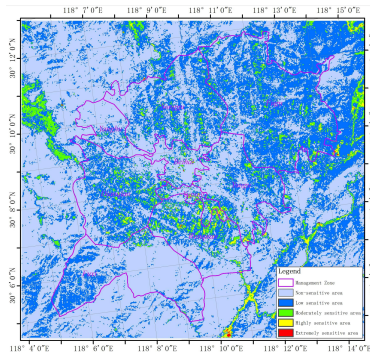


Fig. 9 Vegetation fraction

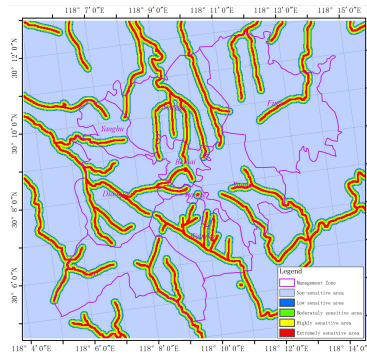


Fig. 10 Distance to water system

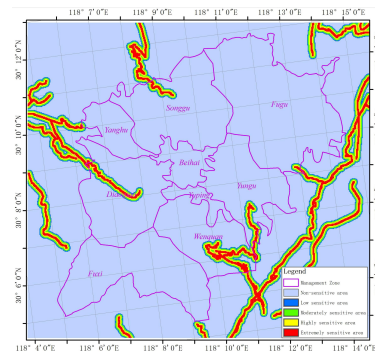


Fig. 11 Distance to roads

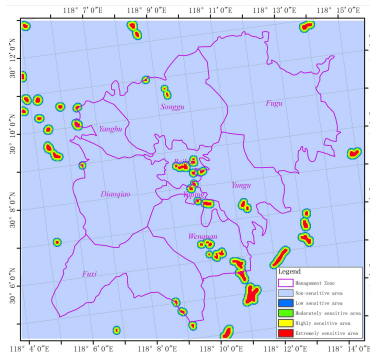


Fig. 12 Distance to settlements

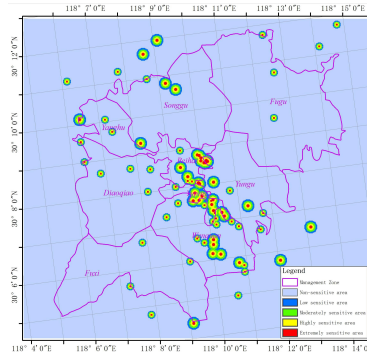


Fig. 13 Distance to attractions

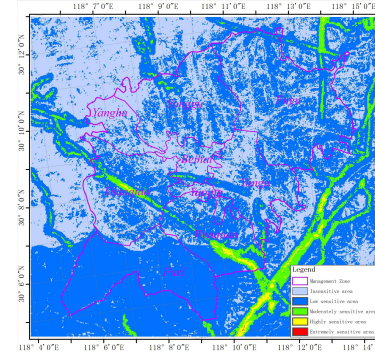


Fig. 14 Geologic hazard risk

4.3 AHP to determine the weight of each factor

The influence of every influencing factor on eco-geological environment is diverse from each other. So they should be given different weights according to the degree of influence. The important factors give greater weights. In this paper, AHP method was applied to determine the factor weights. The sensitivity level and weight of all the influence factors and secondary indicators are shown in Table 3. The analytic hierarchy process (AHP), also known as multi-hierarchy weight analysis, is to break down the related evaluation elements into goal, guideline, and indicator layer (Li X H, et al, 2001; Huang, et al, 2008). On the basis of this, a combination of qualitative and quantitative evaluation is carried out. The judgmental matrix of the six categories factor of eco-geological environmental sensitivity analysis in study area is shown in Table 2.

Table 2 Judgment matrix of six categories influence factor of eco-geological environmental sensitivity

Factors	Geological environment	Ecological environment	Hydrological information	Human activity	Landscape value	Natural disaster
Geological environment	1	1	1	1/2	1/3	1
Ecological environment	1	1	1	1/2	1/3	1
Hydrology	1	1	1	1/2	1/3	1
Human activities	2	2	2	1	1/2	2
Landscape value	3	3	3	2	1	3
Natural disaster	1	1	1	1/2	1/3	1

The weight of each factor and other relevant parameters determined by AHP approach are as shown in Table 3. It can be seen from the Table 3 that the weight of landscape value is the maximum in six categories factors, followed by

human activities, while the weights of geological environment, ecological environment, hydrology and natural disaster are all equal to 0.11. In all the secondary indicators, the weight of the distance to attractions is the maxium, and the followed is the distance to water system and geologic hazard risk. The weights of the distance to road and settlements and tourist facilities are in the third, and the weights of elevation and slope aspect are all equal to 0.016, the smallest in all the secondary indicators .

Table 3 Weights of eco-geological environmental sensitivity analysis indicators and relevant parameters

Influence factors	Restraint layer		Indicators	Indicators layer		Total weights
	Weights	$\lambda_{\max}$,CI,RI,CR		Weights	$\lambda_{\max}$,CI,RI,CR	
Geological environment	0.110	$\lambda_{\max}=6.01$, CI=0.002, RI=1.24, CR=0.001	Geologic structure	0.455	$\lambda_{\max}=4.01$	0.050
			Slope	0.263	CI=0.003	0.029
			Elevation	0.141	RI=0.90, CR=0.004	0.016
			Aspect	0.141		0.016
Ecological environment	0.110		Biodiversity level	0.26	$\lambda_{\max}=3.039$	0.029
			Vegetation fraction	0.633	CI=0.019	0.070
			Land use / cover	0.106	RI=0.58, CR=0.033	0.012
Hydrology	0.110		Distance to water system	0.110		0.110
Human activities	0.211		Distance to road	0.5	$\lambda_{\max}=2$	0.106
			Distance to Settlements and tourist facilities	0.5	CI=0	0.106
					RI=0, CR=0	
Landscape value	0.348		Distance to attractions distribution	0.348		0.348
Natural disaster	0.110		Geologic hazard risk	0.110		0.110

4.4 Comprehensive analysis of eco-geological environmental sensitivity

The comprehensive analysis of eco-geological environmental sensitivity is executed by using multi-factor comprehensive evaluation mode. This model is relatively simple and highlights the synthesis, hierarchy, objectivity and comparability of eco-geological environmental sensitivity analysis, and it is one of the most popular evaluation method at present. Supported by GIS technique, firstly all indicator layers were resampled to 30m spatial resolution raster layers; then these raster layers were summed up by using the weighted overlay analysis; finally, the comprehensive analysis result was reclassified into five levels according to the grading standards in Table 1. The final evaluation result is shown as Fig. 15, and the area and proportion of each level are shown in Table 4 .

Table 4 Area and proportion of each class of eco-geological environmental sensitivity

Classes	Area/km ²	% of total area
Insensitive area	205.41	75.71
Lowly sensitive area	60.59	22.33
Moderately sensitive area	4.65	1.71
Highly sensitive area	0.64	0.23
Extremely sensitive area	0.03	0.01

It can be drawn from the final result that of all the Huangshan Scenic Areas, less than 1% is extremely sensitive and highly sensitive areas, approximately 22% lowly sensitive areas, about 2% moderately sensitive areas and about 76% insensitive areas. This shows that the eco-geological environment of Huangshan Scenic Spots generally remain at low sensitive and insensitive levels against natural environmental changes and human activities, which implies that the

eco-geological environment of most study area is little affected by environmental changes and human activities. In these areas there are relatively less of scenic spots, only with general attractions such as in Fugu and Yanghu Management Zones. So these areas can be appropriately developed while at the same time some precautionary measures should be taken. Although a very small proportion, extremely sensitive and highly sensitive areas are concentrated in the places with popular attractions such as Wenquan, Yuping, Yungu and Beihai Management Zones where there are many tourists every year, so they are largely affected by human activities and highly likely to suffer from eco-geological environmental problems. In view of the fact that tourism resources in these places have been fully developed, efforts should focus on protecting instead of further developing them. They should be given high priority to eco-geological environment construction and protection. Popular attractions in Huangshan Scenic Spot regularly respite is a viable protection measures. This may prove to be critical to sustainable development of these attractions. Though moderately sensitive areas can be seen in all management zones, they concentrate in the buffer areas within a 100m~200m radius of roads, popular attractions and residential facilities. Though only accounting for 2% of the total area, moderately sensitive areas are obviously affected by human activities due to near to extremely or highly sensitive areas, so new development should be also strictly controlled in these areas.

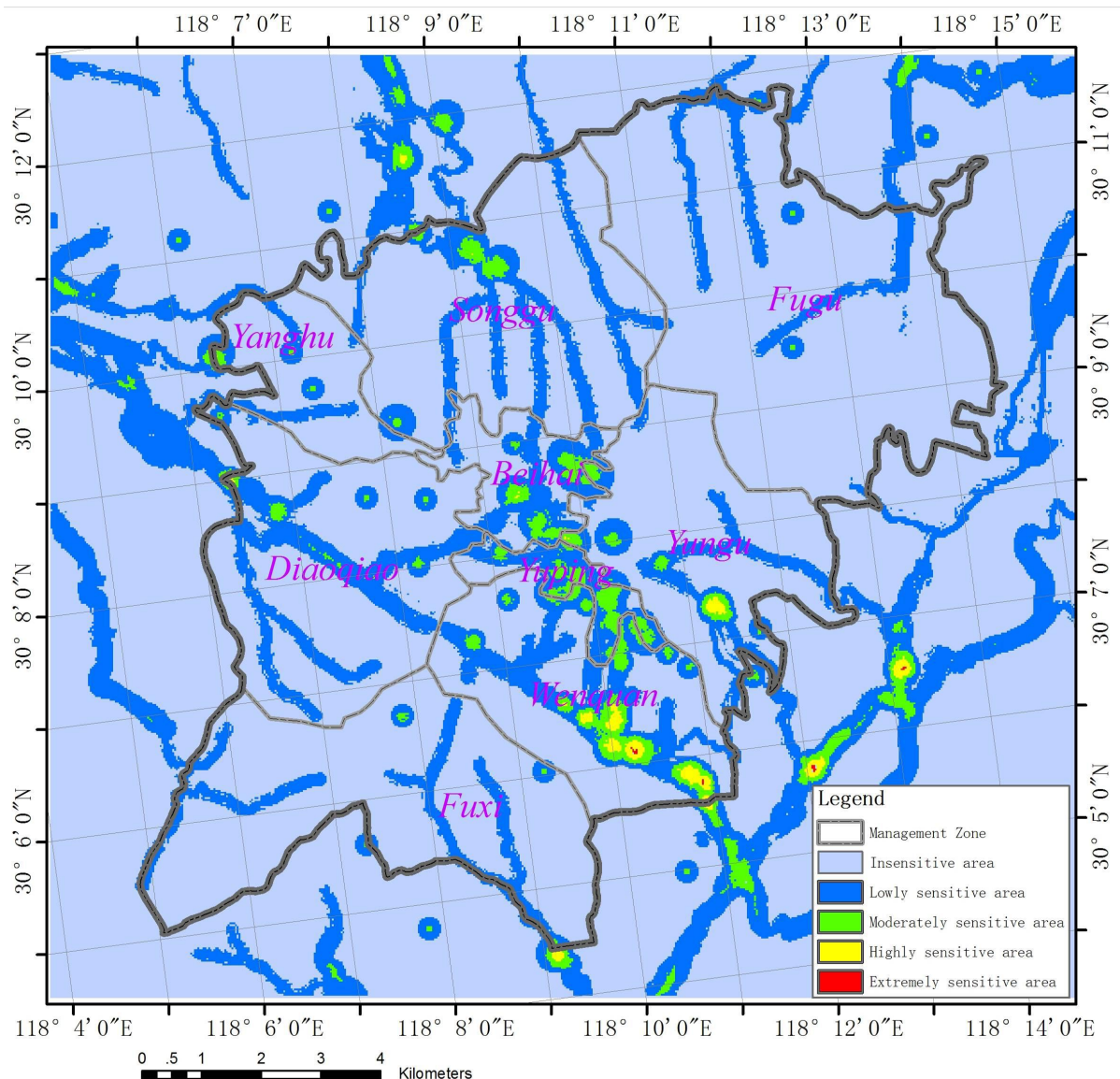


Fig. 15 Eco-geological environment sensitivity classification map

5 CONCLUSIONS

Comprehensive analysis of eco-geological environmental sensitivity can help to decrease the eco-geological environmental risk, guide the rational development and utilization of tourism resources and ensure sustainable development of the world heritage site. In this study, an index system of eco-geological environment sensitivity in Huangshan Scenic Spot was established which involved six categories factors composed of twelve secondary indicators. On this basis, eco-geological environmental sensitivity in Huangshan Scenic Spot was evaluated. The results show that eco-geological environment in Huangshan Scenic Spot is basically stable and less susceptible to outside interference. The human activities are the main influence on the eco-geological environment. So in the areas near the popular attractions, influenced by human activities seriously, the eco-geological environment sensitivity is at high level. Therefore, it is necessary to strengthen the protection to sensitive areas and appropriately develop the insensitive areas.

The "3S" technology can provide the effective tools for the eco-geological environmental sensitivity of world heritage sites. However, the evaluation methodology system at present is not enough perfect and has much room for improvement. For example, it is needed to make the evaluation factor selection more comprehensive and representative and to make full use of the advanced RS and GIS technology, such as using high resolution images, building more indicators from remote sensing data.

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