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Study on ecological evaluation of water resources in Mountain Park Model based on GIS

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ABSTRACT

In order to realize the sustainable development of water resources in Mountain Parks, the ecology of Mountain Parks is understood. Through GIS (geographic information system) technology and analytic hierarchy process, ecological assessment in Mountain Park was carried out. The Mountain Park is divided into three fields, the construction of Mountain Park Water Resources Ecological Evaluation Index System. Two aspects of water resources and the Primitiveness of water sensitivity were chosen as the standard layer. Four evaluation indexes are selected to construct the water resources ecological evaluation system of Mountain Park. The three areas of the Mountain Park are different. Reasonable protection and development should be carried out according to local conditions in order to realize the long-term sustainable development of water resources in Mountain Parks.

Keywords: GIS technology; Mountain Park; Ecological evaluation; Water resources

1. Introduction

The Mountain Park not only allows people to return to nature and approach nature, but also increased their financial revenue from all over the country. Although the development is relatively fast, China's Mountain Park is still in the initial development phase [1]. The tourism industry in the Mountain Park has the phenomenon of coarse and blind utilization. It often ignores the water resource environment issued by the development and construction process [2]. For a long time, tourism has been respectful from the people. The water resource ecological environment of the Mountain Park is getting worse, worse, and some people can't even recover. People have gradually realized serious damage caused by natural environment entertainment. The water resources ecological environment of the Mountain Park needs to be protected in a timely manner to prevent the water resources ecosystem of the Mountain Parks from being completely destroyed [3].

According to the ecological point of view of sustainable development, based on GIS (geographic information system) technology, select the appropriate assessment factor according to the study. Build a reasonable Mountain Park Water Assessment system, determines the index weight, the ecological evaluation of water resources in Mountain Parks were studied. Science and balance the important relationship between the development of Mountain Parks, utilization and protection. The traditional rough planning and construction methods have changed. Mountain Park master plan is reasonable preparation, which provides an important significance for the long-term and sustainable development of water resources in the Mountain Park.

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2. Methods

2.1. Principle of constructing the water resources ecological evaluation system in the Mountain Park

2.1.1. Principles of Constructing Ecological Evaluation Index System of water resources in Mountain Park

① Scientific

The evaluation index system to be constructed should be based on scientificity and be able to accurately reflect the nature of the evaluation object's characteristics.

② Representative

The indicators in the water resources ecological evaluation system of Mountain Parks must be representative and irreplaceable, and can fully reflect the ecological attributes of the Mountain Park water resources. As a complete set of evaluation standards, the index system must be able to comprehensively evaluate the ecological characteristics and current situation of the water resources [4].

③ Stability

Under the premise of representativeness, the selection of indicators must be comprehensive and non-repetitive. After selection, indicators should not be changed to ensure the stability.

④ Practicality

The data of the selected indicators should be easily obtained in the evaluation work. The selected indicators should have guiding significance for actual work, and make full use of the characteristics of the evaluation object to determine.

2.1.2. Principles for constructing ecological evaluation system of Mountain Parks

The establishment of the Mountain Park ecological evaluation system is to comprehensively evaluate the ecological attributes of the Mountain Park water resources. The ecological characteristics are fully understood, and the research is analyzed objectively and scientifically. The ecological evaluation system of Mountain Parks is a comprehensive evaluation process.

① Systematic

The first thing to consider when constructing an evaluation system is that the evaluation conclusions are systematic and comprehensive. However, in the process of evaluation, the water resources ecology of Mountain Parks needs to be comprehensively analyzed from multiple angles and layers. Each evaluation index reflects the ecological characteristics of Mountain Park water resources from one angle. The evaluation work needs a systematic and overall concept, not only the systematicness of each evaluation process. Evaluation is required before the planning and design of Mountain Parks and after the development and utilization to ensure the success of the planning and design [5]. The construction of Mountain Park water resources ecological evaluation not only provides feasibility development suggestions before planning and design, but also provides suggestions for water resources quality improvement after completion, which run through the management of Mountain Parks.

② Scientific

The research work of water resources ecological evaluation of Mountain Parks aims to reflect the ecological current situation of water resources resources and provide scientific basis for development and construction. The evaluation process and evaluation results must be scientific and reasonable, with correct theories and clear steps.

③ Operability

Evaluation indicators can reflect the ecological characteristics quantitatively, and some need qualitative analysis. The indicators of qualitative analysis can be quantified and transformed into quantitative analysis, so that the research can be operated and the evaluation results are correct and standardized.

2.2. Method of determining the weights of ecological evaluation indexes in Mountain Parks

The determination of the index weight is the most critical step in the multi-index comprehensive evaluation work. The weight indicates the relative importance of the evaluation index. The greater the weight value, the more important the indicator in the entire evaluation system and the greater its influence. Whether the weight is accurate or not directly determines the scientificity and correctness of the final evaluation result. Therefore, to construct the evaluation system, the weight of the index selected first needs to be determined [6]. The analytic hierarchy process (AHP) is a method that combines quantitative and qualitative methods to express and process people's subjective judgments in a quantitative form [7–9]. AHP minimizes the abuses caused by personal subjective factors, and makes the evaluation results more credible [10]. AHP can simplify complex issues while ensuring the rationality of the content. AHP is highly systematic, logical and practical, so it is widely used in planning, evaluation and decision-making [11]. Therefore, the determination of the weight of the water resources ecological evaluation index of Mountain Parks also adopts AHP. Fig. 1 shows the application steps of AHP.

2.2.1. Establishment of the index system of the hierarchical structure

On the premise of fully studying the ecological connotation of the Mountain Park water resources, according to the evaluation content, evaluation indicators are selected. According to the grading of the impact of the specific research content, a hierarchical index system is established as shown in Fig. 2.

The evaluation index system establishes three layers according to the association and affiliation: the target layer, the criterion layer, and the index layer. The target layer is the ecological sensitivity evaluation of Mountain Parks, which includes 5 criterion layers, which are topographic features, natural conditions, vegetation conditions,

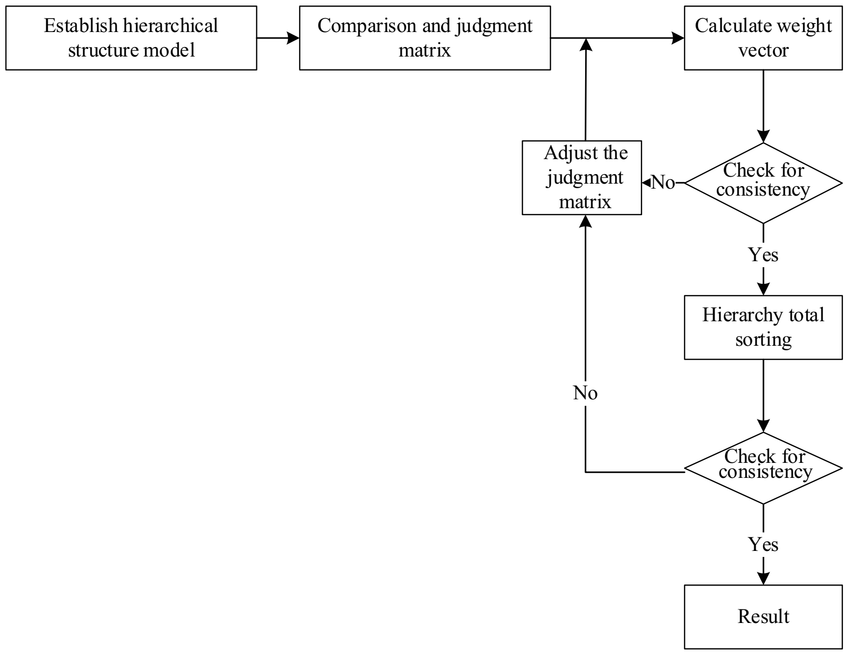

Fig. 1. Steps of AHP.

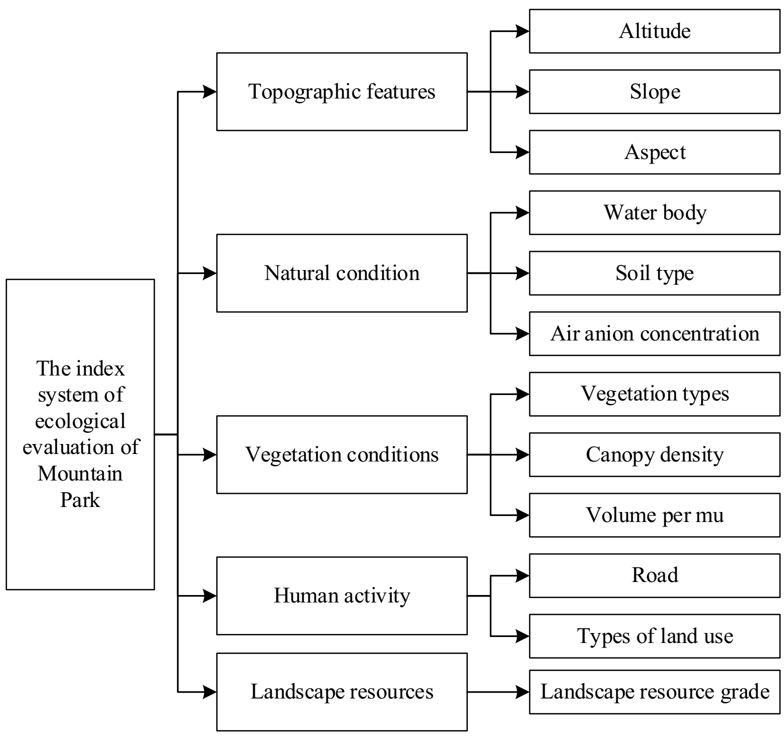

Fig. 2. Ecological evaluation index system of Mountain Park.

human activities, and water resources resources. There are totally 12 indicators under each criterion layer (Fig. 3).

According to the hierarchical structure of the evaluation index system, the judgment matrix is established. A certain index of the above layer is the basis for judgment, and the sub-elements of the next layer are compared in pairs. Filling in the matrix generally requires repeated inquiries from experts to strive for accuracy. The sub-elements are compared and assigned after the importance degree is compared. Each index in the evaluation index system is scored separately to

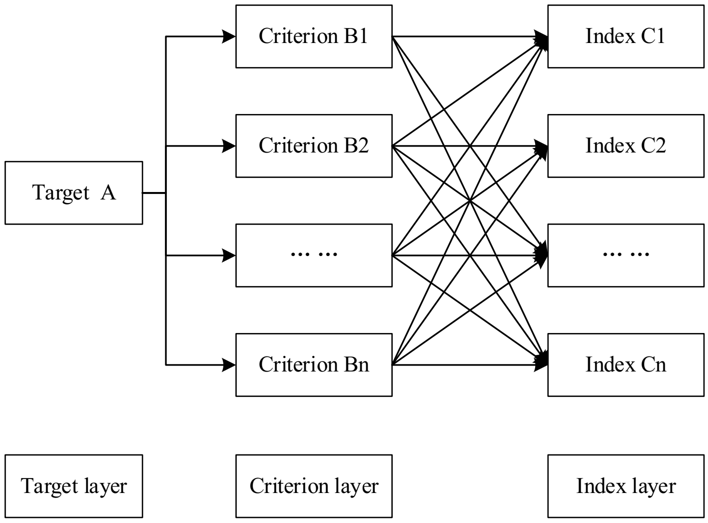

Fig. 3. Hierarchical model.

calculate the weighted average, and the relative weight of each index is obtained. Table 1 shows the scale and meaning of judgment.

All elements in the judgment matrix are greater than 0, and the values of the elements on the diagonal are all 1. The importance of the factor A_i and A_j is compared, and the value is A_{ij}, then the ratio of the importance of the factor A_i to A_j is $A_{ij} = 1/A_{ji}$.

2.2.2. Calculation of indicator weight

The AHP is used to calculate the judgment matrix and obtain the weight value of each evaluation index.

The elements in the judgment matrix are multiplied by rows.

$$M_i = \prod_{j=1}^{n} a_{ij} \left(i, j = 1, 2, 3..., n\right) \tag{1}$$

where M represents the product of each element in the matrix, a_{ij} represents each element in the matrix.

The geometric mean of the product of the elements in each row is calculated.

$$\overrightarrow{V_i} = \sqrt[n]{M_i} = \sqrt[n]{\prod_{j=1}^{n} a_{ij}} \left(i, j = 1, 2, 3, ..., n\right) \tag{2}$$

where $\overrightarrow{V_i}$ represents the geometric mean of the product of elements in each row, M represents the product of each element in the matrix, a_{ij} represents each element in the matrix.

The geometric mean of the product of elements in each row is normalized, and the weight of each element is determined.

$$W_i = \frac{V_i}{\prod_{j=1}^{n} V_i} \left(i, j = 1, 2, 3, ..., n\right) \tag{3}$$

where W represents the weight of each element, V_i represents the geometric mean of the product of the elements in each row, M represents the product of each element in the matrix, a_{ij} represents each element in the matrix.

The maximum eigenvalue of the judgment matrix is calculated.

$$\lambda_{\max} = \sum_{i=1}^{n} \frac{\left(AW\right)_i}{nW_i} \left(i, j = 1, 2, 3, ..., n\right) \tag{4}$$

where W represents the weight of each element, $\lambda_{\max}$ represents the maximum eigenvalue of the judgment matrix.

The assignment of the matrix is determined by experts, and there may be errors with the actual situation. In the conclusion of the comparison of the importance of the factors, there is a logically unreasonable phenomenon. Therefore, the judgment matrix needs to be checked for consistency, and the logical relationship needs to be checked for correctness.

2.3. GIS spatial analysis method

The spatial analysis of GIS technology is to describe and count the information of geospatial data to obtain its potential information. Spatial analysis the data analysis technique based on the spatial information and attribute information of the research object. The relationship between the spatial data is analyzed and the corresponding spatial model is constructed. Research objects have spatial characteristics such as distribution, location, form, distance, and orientation. In the process of research, space research objects need to be classified and described in the form of points, lines, areas, and volumes. GIS technology performs a series of geostatistical calculations on spatial data, analyzes the spatial position relationship of the data, combines the data analysis results with spatial information, and reveals its general development law [12].

From a technical point of view, the spatial analysis of GIS can be divided into spatial analysis based on raster

Table 1
Scale and meaning of judgment

Scale	Meaning
1	The importance of the two indicators *i* and *j* are compared, and the importance is the same
3	The importance of the two indicators *i* and *j* is compared, the former is slightly more important than the latter
5	The importance of the two indicators *i* and *j* is compared, the former is more important than the latter
7	The importance of the two indicators *i* and *j* is compared, the former is obviously more important than the latter
9	The importance of the two indicators *i* and *j* is compared, the former is intensely more important than the latter
2,4,6,8	The middle value of the importance of the two scales before and after

data and spatial analysis based on vector data. In addition, there are spatial data measurement and spatial interpolation, three-dimensional spatial analysis, and spatial statistical analysis.

3. Results and discussion

3.1. Analysis and processing of data and images

According to the required research data, including the ecological environment, vegetation conditions, land use status, and infrastructure status of Mountain Parks, data from various aspects are collected. Firstly, Mountain Parks are inspected and monitored on site. Secondly, the data are collected and summarized by consulting city chronicles, yearbooks, government websites, documents, development plans and other data. Through communication with relevant departments, some accurate data and information of Mountain Parks are obtained. Finally, the data are summarized in a unified way for later analysis and use [13].

The current topographic map of the Mountain Park is scanned electronically and depicted in CAD software. The elevation value of the contour line is assigned, and the topographic map of the contour line of the Mountain Park is obtained [14]. In the ArcGIS 10.2 software, the topographic map in DWG format after sorting is vectorized. The 3DAnalyst tool in GIS software is used to generate TN files of Mountain Parks. Then the TN file is converted to generate a digital elevation model (DEM) of the Mountain Park.

The selected Landsat-8 satellite image data are downloaded from the global data sharing platform of the geospatial data cloud. Data files with a spatial resolution of 30m and collected visible light and near-infrared light data are obtained. The downloaded raster data are loaded into ArcMap, and the coordinate system is converted to be consistent with the vector range of the Mountain Park. According to the range of the Mountain Park, the grid calculator function is used for calculation. The normalized vegetation index grid data of Mountain Parks are obtained, which is convenient for later analysis and use [15].

3.2. Ecological evaluation process of Mountain Park

3.2.1. Evaluation of the originality of water resources in Mountain Parks

The originality of water resources in Mountain Parks is generally divided into three layers: original water resources, semi-native water resources, and artificial water resources [16]. The original water resources refers to the basic original ecology or original ecology water resources that is slightly or not affected by human activities, including original forest land and natural reserve. Semi-native water resources refers to the obvious impact of human activities, but still maintains part of the original water resources, including sparse woodland. Artificial water resources refers to a water resources that has undergone significant changes in the original water resources, or is a water resources formed by people's development and construction for a long time under the influence of human activities for a long time. The original water resources includes cultivated land, garden land, transportation land, water area, urban and village-layer industrial and mining land [17].

Based on the distribution of land use types in Mountain Parks, GIS spatial analysis and reclassification tools are used for analysis. The area and proportions of the three grades of water resources are calculated as shown in Figs. 4 and 5.

The original water resources area of the Mountain Park is 3,252.46 hm^2, accounting for 95.45% of the total area. The originality of water resources is relatively high, the woodland water resources area is large, and the plant species are rich. The semi-primary water resources area is 142.442 hm^2, accounting for 4.18% of the total area. The semi-native water resources is mainly concentrated in Area 1 and is affected by certain human activities. The artificial water resources area is 12.68 hm^2, accounting for 0.37% of the total area, which reduces the impact on the originality of Mountain Parks and maintains a good ecosystem.

The AHP is used to construct a comparison matrix of the originality of water resources weights. Yaahp software is used to determine the weights of the three grade indicators of original water resources, semi-native water resources, and artificial water resources. The importance of the three levels and the impact on the originality of the water resources are analyzed. Table 2 shows the originality weight of Mountain Parks.

According to the above equation, the maximum eigenvalue λ_{max} = 3.0387 is calculated. The consistency ratio of the judgment matrix is CR = 0.0372 < 0.1. The judgment matrix satisfies the consistency test, and the weight value can be adopted. Therefore, the weight value of the original water resources is 0.6333, the weight value of the semi-native water resources is 0.2605, and the weight value of the artificial water resources is 0.1062.

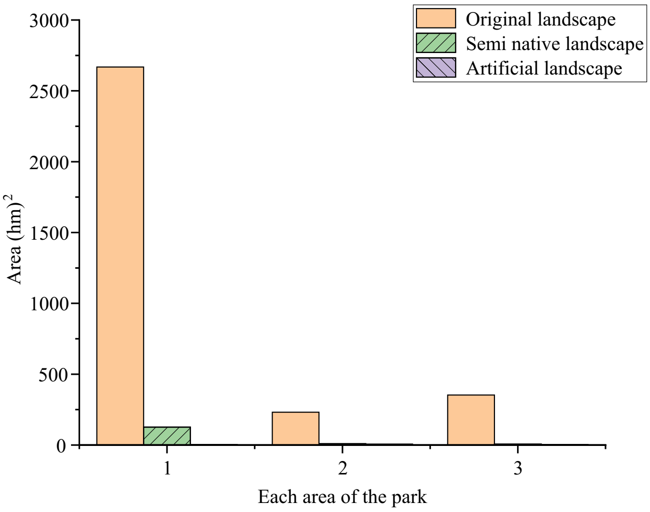

Fig. 4. The area occupied by the originality of water resources in each area of the park.

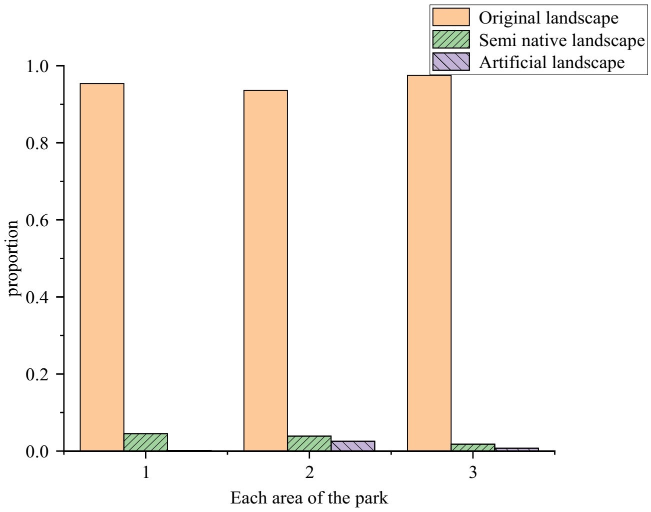

Fig. 5. The proportion of the area occupied by the originality of water resources in each area of the park.

Table 2
Originality weight of Mountain Parks

The originality of water resources	Original water resources	Semi-native water resources	Artificial water resources
Original water resources	1	2	4
Semi-native water resources	1/2	1	3
Artificial water resources	1/4	1/3	1
Weight value	0.6333	0.2605	0.1062

According to the ratio and weight value in the originality classification table of Mountain Parks, the overall original degree of Mountain Park $N = 0.94 \times 0.6333 + 0.05 \times 0.2605 + 0.0037 \times 0.1062 = 0.6120$ is calculated. The original degree of water resources in Area 1 is 0.6159. The original degree of water resources in Area 2 is 0.6054. The original degree of water resources in Area 3 is 0.5879. The original degree of water resources in Area 1 is higher, and the water resources is less affected by human activities.

3.2.2. Sensitivity evaluation of Mountain Park water resources

Based on the related research results of water resources sensitivity and the types of water resources resources of Mountain Parks, four indicators of relative slope, relative distance, visual probability, and eye-catching degree are selected to evaluate the water resources sensitivity of Mountain Parks [18]. Through the spatial analysis method of GIS software, each index is analyzed, and then the Mountain Park is evaluated for comprehensive water resources sensitivity. The research only focuses on the relative slope.

Relative slope refers to the angle between the viewing surface and the viewing line of sight. The greater the angle of the included angle ($0 \le \alpha \le 90°$), the more likely the water resources will be seen. The larger the area where the water resources is noticed, the greater the sensitivity of the water resources. Development and construction or human activities in places with high water resources sensitivity are more likely to be noticed. The areas with greater impact on the original water resources are also key areas for water resources development and protection. In general, the angle α is actually the slope of the terrain. The following formula shows the relative slope value of water resources sensitivity.

$$S\alpha = \sin\alpha\left(0 \le \alpha \le 90°\right) \quad (5)$$

In the equation $S\alpha$ represents the relative slope value of water resources sensitivity. When α is 0, the relative slope value $S\alpha = 0$, and the water resources sensitivity is the lowest. When α is 90, the relative slope value $S\alpha = 1$, and the water resources sensitivity is the highest. It can be seen that the greater the α, the greater the relative slope, and the higher the water resources sensitivity. Under normal circumstances, head-up or upside-down view is regarded as the dominant, and the relative slope value is between 0–1.

The expressions of relative slope in water resources sensitivity by scholars in China and other countries are referred to, and the actual situation of Mountain Parks is combined. Professor Qiu Yishu's classification method on relative slope is adopted. The relative slope is divided into four grades, namely $S\alpha < 1/4$, $1/4 \le S\alpha < 1/2$, $1/2 \le S\alpha < 3/4$, $3/4 \le S\alpha < 1$. The area and proportion of the four grades of water resources are calculated by GIS spatial analysis tool. Table 3 shows the relative slope water resources

Table 3
Water resources sensitivity classification of relative slope in mountain parks

Grades	Slope value	Relative slope value
Primary sensitivity zone	$45° \leq \alpha < 90°$	$3/4 \leq S\alpha < 1$
Secondary sensitivity zone	$30° \leq \alpha < 45°$	$1/2 \leq S\alpha < 3/4$
Third sensitivity zone	$14.5° \leq \alpha < 30°$	$1/4 \leq S\alpha < 1/2$
Fourth sensitivity zone	$\alpha < 14.5°$	$S\alpha < 1/4$

sensitivity classification of each area of the Mountain Park. Fig. 6 shows the water resources sensitivity area of relative slope in each area, and Fig. 7 suggests the proportion of the area occupied by the water resources sensitivity of the relative slope of each area.

The secondary sensitive area of the Mountain Park relative slope water resources is 1,388 hm^2, accounting for 40.32% of the total area of the Mountain Park. The secondary sensitive area in Area 1 is 1,277.51 hm^2, accounting for 45.40% of the total area. The fourth sensitive area in the Area 2 is 130.11 hm^2, accounting for 53.75% of the total area. The third sensitive area in Area 3 has a larger area of 201.17 hm^2, accounting for 52.06% of the total area. Among the three areas, the overall slope of Area 1 is steeper, and the overall slope of Area 2 is relatively gentle.

3.3. Comprehensive evaluation of the ecological nature of Mountain Parks

water resources suitability, water resources sensitivity, water resources originality, and water resources health are selected as evaluation indicators for the evaluation of water resources ecology of Mountain Parks. In the process of comprehensive evaluation of water resources ecology, it is also necessary to determine the weights of indicators. According to the impact of each index on the water resources ecology, the expert scoring method is used to determine the index weight, and the index weight comparison matrix is established (Table 4).

According to Eq. (4), the maximum eigenvalue of the matrix is calculated as λ_{max} = 4.1201. The consistency ratio of the judgment matrix is 0.0442. The consistency ratio of the judgment matrix is between 0-0.1, which shows that the matrix construction is reasonable and the result is credible, so the above matrix can be used. The weight value is imported into the GIS, the evaluation grading map of each index is weighted and superimposed, and the comprehensive grading map of the Mountain Park water resources ecology is obtained.

The highest value of water resources ecological evaluation data for Mountain Parks is 3.0721, and the lowest value is 1.2103. The overall water resources ecological condition is good. The ecological evaluation results of Mountain Parks are comprehensively considered. The actual conditions of the park are divided into corresponding protection areas. Human activities in each area are controlled to varying degrees, and countermeasures are proposed for the subsequent development and utilization of the park.

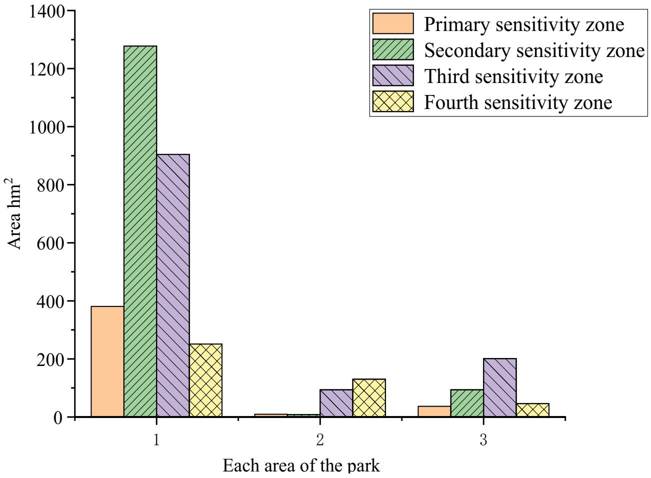

Fig. 6. Water resources sensitivity area of relative slope in each area.

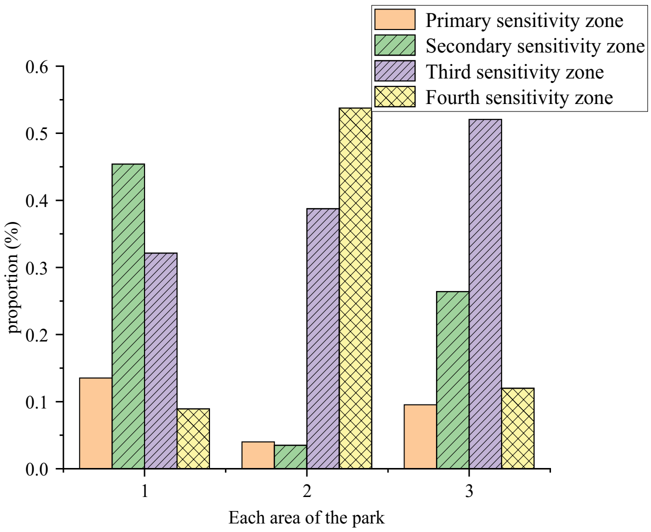

Fig. 7. The proportion of the area occupied by the water resources sensitivity of the relative slope of each area.

4. Conclusions

Through in-depth research on the ecological evaluation of Mountain Parks, two aspects of water resources originality and water resources sensitivity are selected as the criterion layer. Four evaluation indicators are selected to construct a water resources ecological evaluation system for Mountain Parks. Mountain Parks are evaluated and studied by using GIS. The Mountain Park is divided into three areas, each area is different. Therefore, reasonable protection and development should be carried out according to local conditions to realize the long-term sustainable development of Mountain Parks.

The modern evaluation system is used as the basis, and the Mountain Park evaluation system is constituted. However, the AHP of the system has limitations, some data are insufficient, and the selected index factors are not comprehensive enough. The actual conditions of Mountain Parks

Table 4
The weight comparison matrix of the ecological evaluation index of Mountain Park

Factors	Water resources suitability	Water resources sensitivity	Water resources originality	Water resources health	Weights
Water resources suitability	1	1	2	3	0.3969
Water resources sensitivity	1	1	2	2	0.2734
Water resources originality	1/2	1/2	1	1/3	0.1235
Water resources health	1/3	1/2	3	1	0.2076

cannot be fully reflected, and the content of ecological evaluation has limitations and needs to be improved. Therefore, in future planning and design, it is still necessary to judge, correct, and improve the evaluation results of GIS software in combination with scientific theoretical knowledge to ensure the rationality of development and protection.

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