Desalination and Water Treatment
www.deswater.com

doi: 10.5004/dwt.2021.27789

241 (2021) 243–248
November

Study on landscape evaluation and soil and water conservation of geological relics based on GIS

Yang Wang, Langma Liang*

Hainan College of Vocation and Technique, Haikou 570100, China, email: lianglangmavtc6@126.com (L. Liang)

Received 20 August 2021; Accepted 23 September 2021

ABSTRACT

Aiming at soil and water conservation and geological relic landscape based on GIS, it can effectively enhance the real-time and sharing of soil and water conservation data, and present the content of soil and water conservation data in a more intuitive and reasonable way. An open source geospatial database based on the combination of PostgreSQL and PostGIS from the perspective of visualization of soil and water conservation big data. With the support of D3 for geographic operation and visualization, a complex composite map is realized, which fully reflects the spatial characteristics of soil and water conservation data and the accuracy of comprehensive results. It has been proved that the application of spatial operation methods provided by PostGIS in visualization of soil and water conservation transfers a large number of complex operations such as calculation and transformation to the database layer, which reduces the complexity of the system, reduces the dependence of the system on various commercial or open source geographic service tools, and ensures the lightweight of the system itself.

Keywords: Geographic information system; Geoheritage; Evaluation factor; Soil and water conservation

1. Introduction

Geoheritages are formed and preserved with the various geological processes of the earth in a long period of time. They have typical geological and geomorphologic characteristics as well as good ornamental value and scientific research value. Important geoheritages are extremely valuable and non-renewable natural resources. Thus, they are not only the rare wealth of mankind, but also an integral part of the natural ecological environment [1]. In recent decades, the rapid development of China's social economy has seriously affected the ecological environment in which Chinese people live. As a part of the ecological environment, geoheritages have also been damaged to varying degrees, so it is urgent to protect the environment and geoheritage. Since the 1980s, people's awareness of protecting geoheritages has been increasing [2]. Due to the needs of various work, evaluation work has been put on the agenda. How to evaluate geoheritage landscapes objectively and reasonably, fairly and systematically has become an urgent problem to be solved. As an important indicator of national environmental protection, soil and water conservation is an important part of national sustainable development strategy. Under the background of the rapid development of mobile Internet technology, the research of soil and water conservation is constantly exploring in the direction of information. Soil and water conservation data itself is stored in the form of documents, which is not fundamentally different from other data in this regard.

Geoheritages have high scientific research value in geology and geomorphology. Besides, the rare, beautiful, unique and novel geological landscapes in geoheritages are highly sought after by people, which have noticeable exploitable ornamental value. Geoparks can effectively protect and reasonably develop geoheritage landscape resources [3].

* Corresponding author.

The establishment of geoparks requires numerous studies on geoheritages, including the basic theoretical research on the construction of geoparks, the investigation and evaluation of geoheritage resources, the protection of important geoheritages, and the operation and management of geoheritage parks. The investigation and evaluation of geoheritage resources are the primary link among all research, which provide a data basis for the establishment of subsequent geoparks [4].

Based on GIS, landscape resources of geoheritages are evaluated to provide high-quality data basis for the establishment of geoparks and the protection of geoheritages. Starting from the landscape evaluation of geoheritages, the quantitative evaluation of geoheritages is discussed, and a landscape evaluation system for geoheritages is established to provide decision and support. By analyzing the similarities and differences between the above evaluation results and the evaluation results of the commonly used AHP (Analytic Hierarchy Process), the evaluation method is feasible with more effective and objective results.

2. Methods

2.1. Characteristics of soil and water conservation data

Soil and water conservation data mainly include vector data and raster data. The vector data mainly preserves the boundary information of administrative area or basin, and the raster data preserves the detailed data of each major factor in the calculation process of soil and water conservation. The vector data has only spatial characteristics, while the raster data has both spatial and temporal characteristics because of the result data of soil and water conservation calculation. The characteristics of soil and water conservation data are as follows:

- *Data is associated with space*: There is a strong correlation between soil and water conservation data and its geographical location, and the data itself has no significance, only its spatial coordinates. Only then can they present their value.
- *Data is correlated with time*: There is also a strong relationship between soil and water conservation data and time, both in different places at the same time and in the same place at different times.
- *Large amount of data*: Soil and water conservation data have a variety of formats, a variety of precision, a number of regions and ranges and a number of impact factors, which determine the huge amount of data.
- *The data correlate with each other*: The boundary information of soil and water conservation data is stored in vector format and the soil and water loss factor data is stored in raster format.

2.2. Basic concepts of GIS

GIS is the abbreviation of Geographic Information System. It is a comprehensive technology of computer science, geography, surveying and cartography. It is difficult to give an accurate definition of GIS which involves an extensive scope, so definitions are different from each other from different angles [5]. GIS can usually be defined in four different ways.

- *Function-oriented definition*: GIS is a system for collecting, storing, examining, manipulating, analyzing and displaying geographic data.
- *Application-oriented definition*: According to the different application fields of GIS, GIS is divided into various application systems, such as land information system, urban information system, planning information system, spatial decision support system.
- *Toolbox definition*: GIS is a set of tools for collecting, storing, querying, transforming and displaying spatial data. This definition emphasizes tools provided by GIS for processing geographic data.
- *Definition based on database*: GIS is a kind of database system with data in spatial order providing an operation set for data operation, which is used to answer the query of spatial entities in the database.

2.3. Selection of evaluation factors

The Regulations for Geoheritage Survey (temporary) lists the evaluation factors of geoheritage evaluation, including scientific research value, ornamental value, rarity, integrity, preservation, accessibility, and protectability. These factors basically involve all aspects of the value of geoheritage, and can play an effective role in qualitative evaluation [6]. However, in quantitative evaluation, many factors cannot be quantitatively assigned, or the meaning represented by quantitative assignment cannot accurately express its original meaning, such as protectability, ornamental value and scientific research value. Therefore, more scientific, reasonable and easy-to-operate geoheritage evaluation factors are expected to be found by further exploration [7]. Through the summary of previous research results, the different evaluation factors selected by different regions, different geoparks and different scholars are shown in Table 1.

Since previous evaluations of geoheritage landscape are carried out in geoparks, many humanistic factors are included in the evaluation factors, such as historic culture, folk customs, and protection measures. The addition of these factors will partly make the evaluation results deviate from the intrinsic value of the geoheritage [8–10]. Therefore, the evaluation factors are eliminated in the following experiments, as shown in Table 2.

2.4. GIS technology scoring method GIS

GIS is a specific and vital spatial information system, which collects, stores, manages, calculates, analyzes and describes geographically distributed data related to the entire space with the support of computer hardware and software systems [11,12]. GIS technology is adopted in the evaluation to score the evaluation factors including regional economy, distance to central city, and accessibility.

The economy is the most direct factor to measure the strength of a region or country, while tourism income has been one of the main sources of economy. Most geoheritages are distributed in the suburbs around the city, and the tourism income of the suburbs is the pillar industry of

Table 1
Evaluation factors of geoheritage landscape

Evaluation factor	Resource attribute	Natural attribute	Scale
			Ornamental value
			Integrity
			Rarity
			Popularity
		Humanistic attribute	Historic culture
			Folk customs
		Scientific attribute	Scientific research value
			Popular science education value
	Tourism attribute	Tourism environment	Seasonal variation of environment
			Environmental capacity
			Environmental carrying capacity
			Surrounding ecological environment
		Locational condition	Regional economy of the scenic spot
			Distance to central city
			Accessibility
		Facility and service	Perfect structural establishment
			Device safety
			Reasonable distribution of facilities
			Management quality
			Service quality
	Social attribute	Resource safety	
		Resource protectability	Conservation statues
			Appropriate protected area
			Effective protective measures
			Stable geological protection condition

Table 2
Evaluation factors of geoheritage landscape

Evaluation factor	Resource attribute	Natural attribute	Scale
			Integrity
			Rarity
			Seasonal effect
		Scientific attribute	Scientific research value
			Popular science education value
	Tourism attribute	Ornamental value	
		Locational condition	Regional economy of the scenic spot
			Distance to central city
			Accessibility
	Social attribute	Resource safety	
		Resource protectability	Conservation statues
			Appropriate protected area
			Stable geological protection condition

the suburban economy. Geoparks with higher levels where geoheritages are located attract more tourists, bringing more economic interest. Therefore, the level of the geoparks where geoheritages are located is used to evaluate the regional economy. The evaluation criteria are shown in Table 3.

The distance to the central city is a factor that people need to consider when traveling. Geoheritages close to the central city tend to be the priority choice of people. Nowadays, the traffic extends in all directions, and the straight-line distance between the geoheritage and the central city can determine the actual distance [13,14]. The straight-line distance from the geoheritage to the central city is used for convenient statistics. The evaluation criteria of the distance from the geoheritage to the central city based on GIS are as follows in Table 4.

Accessibility specifically refers to the walking distance to reach the geoheritages. Geoheritages with good accessibility are easily accessible and require less walking distances. That is, the closer the geoheritages are to the road, the better the accessibility is. The evaluation criteria for accessibility is formulated connecting the road classification and walking distances, as shown in Table 5. GIS technology is adopted to score these geoheritages by measurement on the map.

2.5. Selection of evaluation methods

At present, the evaluation methods of geoheritage landscapes include APH, FCE (Fuzzy Comprehensive Evaluation) and comprehensive index method. The evaluation system is designed based on the improvement of traditional evaluation methods to make the evaluation results of geoheritage landscapes more accurate [15,16]. Table 5 is the advantages and disadvantages of each evaluation method summarized by searching for materials.

In view of the advantages and disadvantages of the above various methods, it is first necessary to overcome the information duplication caused by the correlation between the evaluation factors and the subjectivity of artificial weight determination. PCA (Principal Component Analysis) is selected since its advantages shown in Table 5 perfectly solve the above problems [17,18]. However, PCA also has shortcomings of cumbersome calculation and the deviation of the evaluation results due to the nonlinearity among the factors. Back Propagation Neural Network (BP ANN) can simplify the calculation and well simulate the nonlinearity between any factors. Thus, the two methods are integrated together to comprehensively evaluate the geoheritage landscape [19,20].

3. Results and discussion

3.1. Analysis results of transfer function

The Linear function is usually used in BP ANN for analysis, but the linear function often cannot accurately describe the relationship between indicators, which affects the evaluation and analysis results [21]. Through the combination of linear function and Tansig function, linear function and

Table 3
Evaluation criteria for regional economy of geoheritages

Evaluation criteria	Score
Without geopark	1
Located in the municipal geopark	2
Located in the national geopark	3
Located in a world-class geopark	4

Table 4
Evaluation criteria for distance between geoheritages and central cities

Evaluation criteria	Score
More than 50 km away from the central city	1
35–50 km from the central city	2
15–35 km from the central city	3
Within 15 km from the central city	4

Table 5
Comparison of advantages and disadvantages of each evaluation method

Evaluation method	Advantages	Disadvantages
APH	Organic combination of qualitative analysis and quantitative analysis	The unavoidable randomness of evaluation and subjectivity of expert rating
	A systematic view to problems	The tendency of inconsistency of judgment matrixes
FCE	Effective combination of qualitative analysis and quantitative analysis	The remaining information duplication caused by factor correlation
	Elimination of the ambiguity and uncertainty of judgment	Subjective weight determination
	The evaluation result presented as vectors containing rich information	The difficulty in determining the membership function
PCA	Elimination of information duplication caused by factor correlation	Tedious calculation
	Elimination of the subjectivity of the artificial weight determination	The deviation of the evaluation results caused by the nonlinearity among the factors
BP ANN BP	Simple structure and strong operability	Slow learning and convergence speed
	The ability to simulate nonlinear relationships between arbitrary factors	The trend to fall into the local minimal point missing the optimal solution

Logsig function, and Tansig function and Logsig function, it is finally decided to select the combination of nonlinear Tansig function and linear function for the test. The first hidden layer uses the Tansig function, and the second hidden layer uses the linear Purline function.

In the setup of the transfer function:

net.trainparam.epochs = 20, which represents the number of iterations of training;

net.trainparam.goal = 0.00001, and the error value of the training is set to 103;

net.trainparam.Ir = 0.1. Learning rate is usually between 0 and 1, otherwise it will affect the evaluation results.

Fig. 1 is the iterative schema of BP ANN.

In Fig. 1, when the number of training iterations represented by Train is 5, the average error is less than 10^{-10}, which has reached the requirements of 10^{-5}. Train represents the curve of the training sample, while Test represents the curve of the validation sample. The error between the two parts is small and meets the requirements, so the analysis results are feasible.

3.2. Results analysis of the evaluation by the algorithm

BP ANN algorithm has various types such as traingd, trainrp, traincg, traingda, traingdm. The trainlm algorithm is selected in the evaluation. Fig. 2 is the comparison of training samples and evaluation samples.

According to Fig. 2, the error between the training sample and evaluation sample is only within 0.2. This indicates that after using Tansig and Purelin functions as the transfer function and selecting trainlm function as the evaluation algorithm, the results of the training sample and the evaluation sample are close. The comprehensive evaluation value of each geoheritage landscape in Fig. 2 is processed by truncating operation, and finally the grade of each geoheritage is determined by sorting.

3.3. Analysis of evaluation results

Through the above calculation, the evaluation results of the geoheritage landscapes are obtained by the combination of PCA and BP ANN. Nowadays, AHP is widely used to evaluate the geoheritage landscape, so the evaluation process is no longer described here. Among the evaluation results, the evaluation results of three geoheritages are different, and the reason lies in the selection of evaluation methods. In the traditional APH, the judgment matrix is prone to inconsistency, which affects the effective allocation of weights and further affects the accuracy of evaluation results.

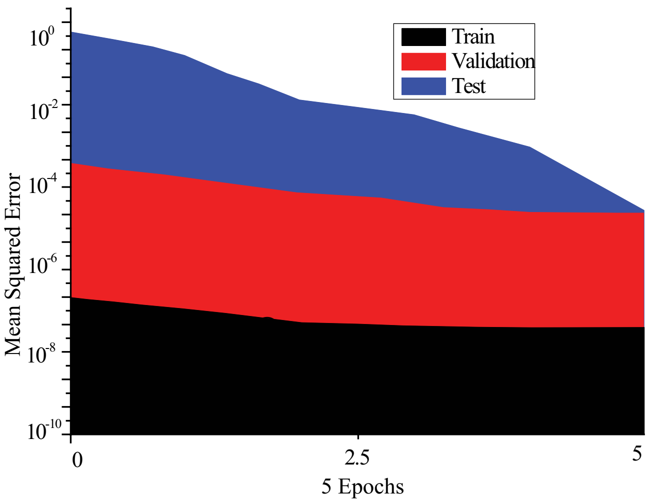

Fig. 1. Iterative schema of BP ANN.

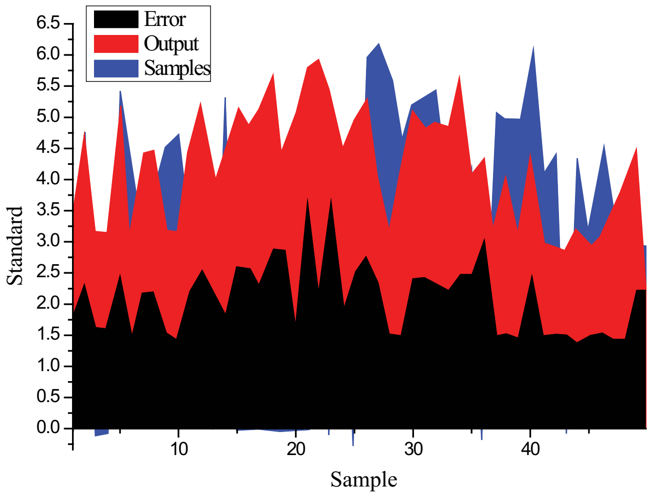

Fig. 2. Comparison between evaluation results of the training sample and evaluation sample.

4. Conclusions

Based on the data query and investigation of geoheritage landscape and the evaluation factors, PCA and BP ANN are integrated to comprehensively evaluate the geoheritage landscape.This article from the perspective of soil and water conservation in big data visualization, combined with the characteristics of soil and water conservation data itself, in the data persistence, data distribution scheme and data visualization solutions for research, put forward a can fully embody the multidimensional nature of the data of soil and water conservation and the space-time characteristics of integrated solutions, and verified in the practical project. The evaluation results are compared with the evaluation results of AHP, which has been widely accepted and used. According to the geological background of each region, representative geoheritages are selected to obtain the evaluation criteria by the comparison method and GIS technology. The four grades of the evaluation criteria are distinguished by 1, 2, 3 and 4. By analyzing the specific situation of each geoheritage landscape, the final score of each factor is obtained according to the criteria. Combined with the actual situation of geoheritage landscapes, the multi-factor principal component network method composed of PCA and BP ANN is used to calculate the comprehensive score of each geoheritage. Finally, the grade of each geoheritage involved in the evaluation is obtained after these comprehensive scores are taken into truncating operation.

Through comparing the evaluation results of the evaluation method with that of AHP, there are still shortcomings in this algorithm. With few studies using PCA and BP ANN to evaluate geoheritage, there is insufficient theoretic guidance. Therefore, this immature comprehensive evaluation method of geoheritage landscape needs more scholars to participate in to improve it. Meanwhile, the evaluation method of geoheritage landscape is single which makes the evaluation system not perfect. It is hoped that on the basis of accurate evaluation, more innovation and exploration are carried out on the evaluation method to enrich the evaluation system of geoheritage landscape for more scientific and persuasive evaluation results.

References

[1] L. Gao, C. Ma, Q. Wang, A. Zhou, Sustainable use zoning of land resources considering ecological and geological problems in Pearl River Delta Economic Zone, China, Sci. Rep., 9 (2019) 1–14, doi: 10.1038/s41598-019-52355-7.

[2] J.-s. Yang, Z. Liu, X.-d. Wang, H. Zhao, L. Song, T.-b. Liu, C.-m. Wang, P. Zhang, Features and values of geological heritage resources in Shunping County, Hebei Province, J. Groundwater Sci. Eng., 8 (2020) 349–357.

[3] K.-T. Chang, A. Merghadi, A.P. Yunus, B. Thai Pham, J. Dou, Evaluating scale effects of topographic variables in landslide susceptibility models using GIS-based machine learning techniques, Sci. Rep., 9 (2019) 1–21, doi: 10.1038/s41598-019-48773-2.

[4] J. Gonçalves, K. Mansur, D. Santos, R. Henriques, P. Pereira, A discussion on the quantification and classification of geodiversity indices based on GIS methodological tests, Geoheritage, 12 (2020) 1–20, doi: 10.1007/s12371-020-00458-3.

[5] D. Zhou, X. Li, Q. Wang, R. Wang, T. Wang, Q. Gu, Y. Xin, GIS-based urban underground space resources evaluation toward three-dimensional land planning: a case study in Nantong, China, Tunnelling Underground Space Technol., 84 (2019) 1–10.

[6] Y.-M. Chang Chien, S. Carver, A. Comber, An exploratory analysis of expert and nonexpert-based land-scape aesthetics evaluations: a case study from wales, Land, 10 (2021) 192, doi: 10.3390/land10020192.

[7] S. Liu, J. Ge, W. Li, M. Bai, Historic environmental vulnerability evaluation of traditional villages under geological hazards and influencing factors of adaptive capacity: a district-level analysis of Lishui, China, Sustainability, 12 (2020) 2223, doi: 10.3390/su12062223.

[8] P. Sanzana, J. Gironás, I. Braud, F. Branger, F. Rodriguez, X. Vargas, N. Hitschfeld, J. Francisco Muñoz, S. Vicuna, A. Mejía, S. Jankowfsky, A GIS-based urban and peri-urban landscape representation toolbox for hydrological distributed modeling, Environ. Modell. Software, 91 (2017) 168–185.

[9] O.B. Oduntan, B.J. Oluwayemi, Optimization of a clay-slate fluidized bed dryer for production of fish feed, J. Sustainable Agric., 5 (2021) 104–110.

[10] A.I. Afangide, I.I. Ekpe, N.H. Okoli, N.T. Egboka, Dynamics of phosphatase enzyme and microbial properties in a degraded ultisol amended with animal manures, J. Clean WAS, 4 (2020) 21–27.

[11] Y. Sismaka BR Purba, I. Nyoman Puja, M. Sri Sumarniasih, Erosion prediction and conservation planning in The Bubuh Sub-Watershed, Bangli Regency, Water Conserv. Manage., 4 (2020) 89–91.

[12] H.T.T. Hoang, Q.H. Truong, A.T. Nguyen, L. Hens, Multicriteria evaluation of tourism potential in the central highlands of Vietnam: combining geographic information system (GIS), analytic hierarchy process (AHP) and principal component analysis (PCA), Sustainability, 10 (2018) 3097, doi: 10.3390/su10093097.

[13] M. Obeidat, M. Awawdeh, A. Lababneh, Assessment of land use/land cover change and its environmental impacts using remote sensing and GIS techniques, Yarmouk River Basin, north Jordan, Arabian J. Geosci., 12 (2019) 1–15.

[14] L. Strokova, Recognition of geological processes in permafrost conditions, Bull. Eng. Geol. Environ., 78 (2019) 5517–5530.

[15] M. Barbarella, A. Cuomo, A. Di Benedetto, M. Fiani, D. Guida, Topographic base maps from remote sensing data for engineering geomorphological modelling: an application on coastal Mediterranean landscape, Geosciences, 9 (2019) 500, doi: 10.3390/geosciences9120500.

[16] J. Chen, Y. Hu, X. Yang, H. Wang, Spatial distribution of cultural heritage in ASEAN countries based on GIS, Des. Eng., 2020 (2020) 249–261.

[17] G. Hil, Better management through measurement: integrating archaeological site features into a GIS-based erosion and sea level rise impact assessment—Blueskin Bay, New Zealand, J. Isl. Coastal Archaeol., 15 (2020) 104–126.

[18] C.J.H. Ames, M. Shaw, C.A. O'Driscoll, A. Mackay, A multi-user mobile GIS solution for documenting large surface scatters: an example from the Doring River, South Africa, J. Field Archaeol., 45 (2020) 394–412.

[19] A. Bonnier, M. Finné, E. Weiberg, Examining land-use through GIS-based kernel density estimation: a re-evaluation of legacy data from the Berbati-Limnes survey, J. Field Archaeol., 44 (2019) 70–83.

[20] V.K. Rana, T.M.V. Suryanarayana, GIS-based multi criteria decision making method to identify potential runoff storage zones within watershed, Annals GIS, 26 (2020) 149–168.

[21] X. Zhang, M. Chen, K. Guo, Y. Liu, Y. Liu, W. Cai, H. Wu, Z. Chen, Y. Chen, J. Zhang, Regional land eco-security evaluation for the Mining City of Daye in China using the GIS-based Grey TOPSIS Method, Land, 10 (2021) 118, doi: 10.3390/land10020118.