Geological environment quality assessment based on artificial neural network: A case study of Shengwan-Shigu area

Jinxin Chong, Bei Wang, Yukun Wang, Yixiao Gu, Xueping Li*
Faculty of Engineering, China University of Geosciences, Wuhan 430074, China

ABSTRACT

This paper takes Shengwan-Shigu area, which is located at the junction of Southwest Henan Province and Hubei Province, as the research area. 11 evaluation factors are selected, and the multiple regression analysis function of SPSS software is used to analyze the sensitivity of each index. The sensitivity analysis results of the evaluation index show that the geological environment quality in the study area is the most sensitive to the changes of soil and water loss and desertification. Then establish the geological environment quality evaluation index system. In this paper, the Tensorflow deep learning library based on Python language is used to construct the neural network model to evaluate the geological environment quality of the study area; By using Tensorboard visualization tool, the complex neural network training process is visualized, and the neural network model is debugged and optimized. Finally, the evaluation results are visualized by the map editing function of MAPGIS software. In this paper, the geological environment quality is divided into three levels: good area, middle area and poor area. The evaluation results show that the overall conditions of the study area are good. The results of geological environment zoning and geological hazard survey points superposition in the study area show that the evaluation process and results are reasonable and feasible. The research conclusion of this paper can provide scientific basis for regional geological environment management in areas with serious soil and water loss and rocky desertification, and has important practical significance.

Keywords: Artificial neural network, geological environment, quality evaluation, sensitivity analysis, visualization

1. INTRODUCTION

Geological environment is the necessary material basis for economic and social development and human survival. However, with the rapid development of human society, the intensity of human activities is more than the geological environment can bear. This accompanies corresponding geological environment problems, resulting in frequent geological disasters, and it is difficult to guarantee the life and property safety of the surrounding residents. Therefore, it is more and more important to carry out the research of geological environment quality evaluation.

With the maturity of traditional methods, some unavoidable disadvantages begin to appear. Researchers began to focus on the improvement of evaluation accuracy in the evaluation process, and the popularity of machine learning algorithm has always been high. Hu et al.[1] Used correlation coefficient and support vector machine theory to establish support vector machine model to study landslide stability. The results show that the research results of support vector machine model are in good agreement with the actual situation. Based on the analysis of the geological environmental conditions and landslide development characteristics in the study area, Wang et al.[2] Analyzed the correlation between the evaluation factors, and used the support vector machine model to evaluate the geological disaster risk in Chang'an District. Guo et al.[3] Normalized the qualitative or quantitative factors by using the landslide density value, and completed the landslide sensitivity evaluation of Yanchang County by using the support vector machine algorithm. Among machine learning algorithms, artificial neural network is widely used in prediction and evaluation because of its unique associative memory ability, strong fault tolerance and high reliability. Bi et al.[4] used the artificial neural network evaluation method, established the evaluation index system on the basis of analyzing the distribution and causes of landslides, and evaluated the susceptibility of landslides in Western Hunan basin; In order to better simulate the nonlinear relationship between landslide and geological and geomorphic parameters, Paraskevas[5] and others used artificial neural network model to evaluate the susceptibility in two stages; Joaquín and Andreas[6] used neural network model to evaluate the conditions for the susceptibility of kapitaniho landslide in Colombia; Andang et al.[7] evaluated the landslide susceptibility by using the evaluation method of logical regression and artificial neural network, and the prediction accuracy reached more than

*1073669101@qq.com

International Conference on Computer Application and Information Security (ICCAIS 2021),
edited by Yingfa Lu, Changbo Cheng, Proc. of SPIE Vol. 12260, 122600R · doi: 10.1117/12.2637470

90%; Moayedi et al.[8] applied the artificial neural network optimized by particle swarm optimization algorithm to the prediction of landslide sensitivity map; Bragagnolo et al.[9] selected seven factors such as landform and formation lithology and used the artificial neural network model to evaluate the landslide susceptibility in Porto Alegre and Rio de Janeiro areas in Brazil; Lucchese[10] trained four groups of models using neural network to evaluate the landslide susceptibility in the study area respectively; Dong et al.[11] studied the development and verification of deep learning neural network model for predicting landslide susceptibility. The insights provided by this study are of significant value for further developing landslide prediction model and spatial evaluation of landslide prone areas all over the world.

This paper selects Shengwan-Shigu area in the junction of Southwest Henan Province and Hubei Province for research. Based on the geological conditions, climatic and hydrological conditions, environmental geological problems and human engineering activities in the study area, the evaluation index system of geological environment quality is established; Using Python language and Tensorflow deep learning library, the neural network model of the study area is constructed to evaluate the geological environment quality. Multiple regression analysis is used to analyze the sensitivity of evaluation index in the study area. The conclusions of this paper can provide scientific basis for regional geological environment management in areas with serious soil erosion and rocky desertification, which holds important practical significance.

2. MATERIALS

2.1 Location of study area

The study area is located at the junction of Southwest Henan Province and Hubei Province, northwest of Danjiangkou reservoir; Shengwan area in the north and Shigu area in the south; The administrative divisions are Xichuan County, Neixiang County in Henan Province and Yun County in Hubei Province,at 111°15’00’’-111°30’00’’E and 32°40’00’’-33°00’00’’ N. The area has a subtropical semi humid monsoon climate with an average annual temperature of 15℃, rainfall of 700-900 mm and annual evaporation of about 2000 mm.

2.2 Data sources and processing

All the original data of this paper come from field geological survey data and geographic information system. After later processing in ArcGIS software, the data of 11 evaluation indexes of engineering rock formation, slope, geomorphic type, fault zone density, annual rainfall, water system density, groundwater abundance, mountain disaster point density, water and soil loss and rocky desertification, surface water pollution and mining activities are obtained.

3. METHODOLOGY

In this paper, artificial neural network modeling is used to realize the geological environment quality evaluation. The technical route is as follows: the first step is to establish the geological environment database by using GIS technology based on collecting the geological environment conditions of the studied area. In the second step, based on the study of the influencing factors of geological environment quality, the evaluation index system is preliminarily established by using pairwise comparison method. The sensitivity of the evaluation index is tested, and the evaluation index system is finally determined. The third step is to establish the evaluation database, divide the evaluation cell network and extract the evaluation information. The fourth step is to select typical areas to establish artificial neural network model, train the model, and evaluate the effect of the model. Finally, the trained model is used to evaluate the whole region.

3.1 Evaluation method of artificial neural network

In this paper, the deep learning algorithm theory of artificial neural network is used to evaluate the quality of geological environment. Taking various factors affecting the quality of geological environment as input variables, a highly nonlinear mapping neural network model between these factors and the classification of geological environment quality is established; Then the artificial neural network model is used to evaluate the geological environment quality.

3.2 Constructing sample set and data set

By consulting the relevant literature and the convenience of practical operation, the size of the evaluation grid is determined as 500m × 500m. The studied area is divided into 3478 evaluation grid cells, which are numbered from left to right and from top to bottom to form a data set. Relying on the environmental geological survey of the Yangtze River Economic Belt “Danjiangkou Reservoir Nanyang Shiyan City water source area 1:50000 environmental geological survey” project, 888 representative areas are selected from the data set as the source of sample data to form the sample set.

4. RESULT

4.1 Evaluation index system

Combined with the geological environment conditions of the study area, following the principles of science, systematisms, pertinence and availability, this paper establishes a three-layer evaluation index system, which includes the target layer, the criterion layer and the index layer. The target layer is the evaluation of geological environment quality in the study area, and the criterion layer is geological conditions, meteorological and hydrological conditions, environmental geological problems and human engineering activities; The index layer includes 11 evaluation indexes: engineering rock group, landform type, slope, linear density of fault, annual rainfall, linear density of water system, water abundance of underground water, density of mountainous disaster points, soil erosion and rocky desertification, surface water pollution and mining activities. The division of evaluation index system is shown in Figure 1.

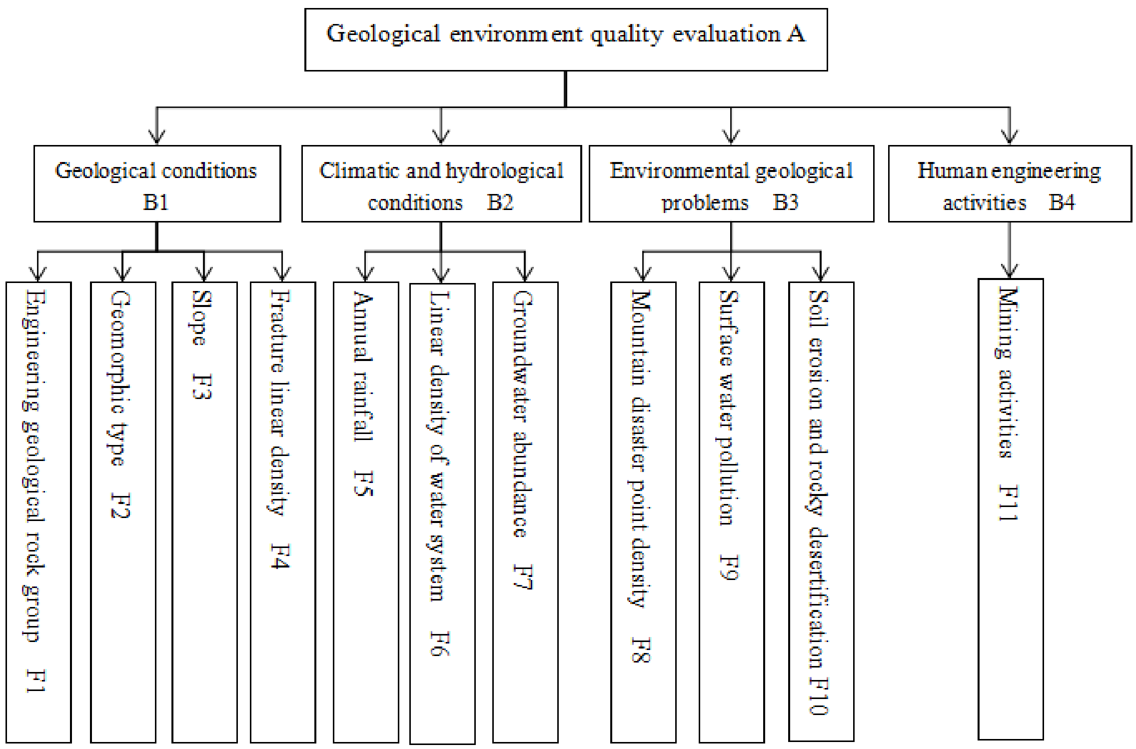

Figure 1. Geological environment quality evaluation index system.

4.2 Sensitivity analysis of evaluation index

The paper extracts 11 index values corresponding to 30 sample points, carries out multiple regression analysis on each index and geological environment quality grade of sample points, and analyzes the sensitivity test results. The data of variance analysis and coefficient analysis are shown in Table 1 respectively.

Table 1. Model sensitivity test variance analysis and coefficient analysis.

Index	Regression coefficient	Standard error	*t*
Engineering geological rock group F1	0.058	0.024	2.484
Geomorphic type F2	0.142	0.013	9.121
Slope F3	0.213	0.012	16.602
Fracture linear density F4	0.009	0.002	2.745
Annual rainfall F5	0.056	0.022	4.133
Linear density of water system F6	0.249	0.072	19.649
Groundwater abundance F7	0.145	0.021	6.661
Mountain disaster point density F8	0.272	0.061	21.985
Surface water pollution F9	0.471	0.037	37.94
Soil erosion and rocky desertification F10	0.113	0.013	9.133
Mining activities F11	0.171	0.078	13.777

According to the F-distribution table, when the significance $\alpha = 0.1$, $F0.1\ (11.17) = 1.978$, $F = 285.458 > F0.1\ (11, 17)$, the regression equation is valid. After testing, the 11 selected indicators pass the correlation test, and there is no obvious collinear relationship. According to the absolute values of the regression coefficients of the 11 indicators shown in Table 1, the geological environment quality is the most sensitive to the changes of soil erosion and desertification. Therefore, the sensitivity of geo environmental quality assessment model to soil erosion and rocky desertification index is higher than other indexes. Soil erosion and rocky desertification are the most sensitive indicators affecting the quality of the geological environment.

4.3 Neural network training

Taking the geological environment quality control factors as the input value and the geological environment quality evaluation level as the output, the neural network is trained until the training error of the sample data meets the required accuracy requirements. The neural network parameters are saved and the test set is predicted. In this paper, 888 samples are divided into two parts, 788 of which are used as training sets to train the neural network, and the remaining 100 are used as verification sets to verify the trained neural network.

Using the tensorboard visual interface, the optimal neural network model is selected under different learning rates, optimizers and initialization. Adam optimizer has the fastest convergence speed, the smallest loss value and meets the requirements most. The exponential decay learning rate is more suitable for the convergence speed block, and the loss value is small. Although all zero initialization converges, its loss value is too large. In comparison, normal distribution initialization is more suitable.

4.4 Evaluation results of geological environment quality

The trained neural network model is applied to the study area to evaluate the geological environment quality. Through the map editing function of ArcGIS software, the evaluation results are visualized, as shown in Figure 2, and the statistical results of each partition are shown in Table 2.

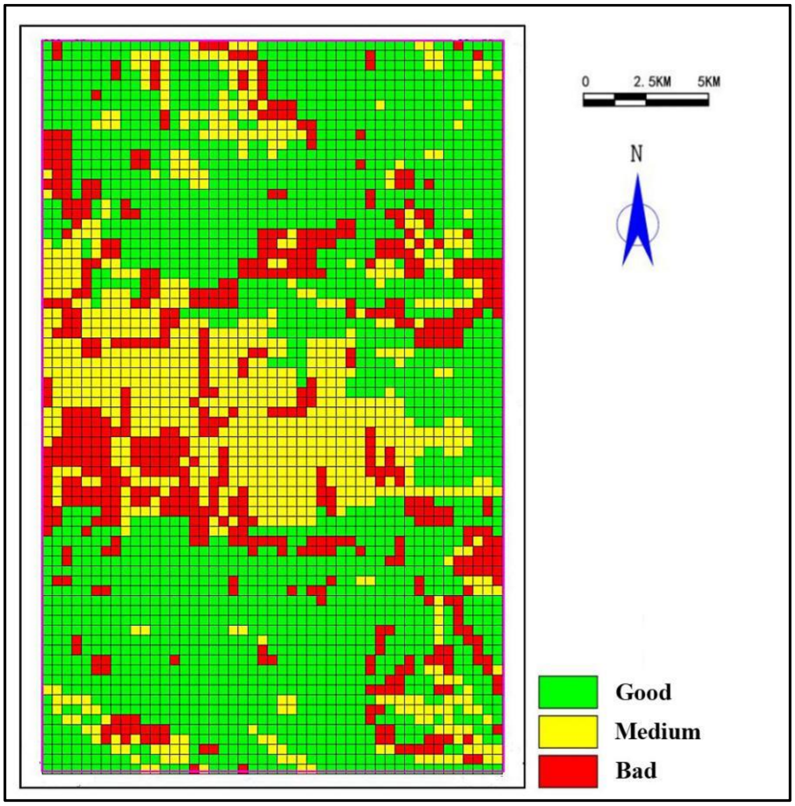

Figure 2. Geological environment quality assessment results.

Table 2. Statistical table of evaluation results.

Environmental quality grade	Number of grid cells	Area (km^2)	Proportion
Good area	2033	508.25	58.5%
Medium area	839	209.75	24.1%
Bad area	606	151.5	17.4%
Total	3478	869.5	100%

Most areas in the study area are areas with good geological environment, accounting for about 58.5% of the study area. The medium geological environment area is mainly distributed in the south of Shenwan area and the north of Shigu area, accounting for about 24.1% of the study area. The area with poor geological environment has prominent geological environmental problems or is a mining area, and the geological background conditions are relatively complex, accounting for about 17.4% of the study area.

5. CONCLUSION

(1) Based on the natural geography and geological environment background of the studied area, the paper selects 11 evaluation indexes to establish the evaluation index system of geological environment quality in the studied area.

(2) In this paper, the linear regression function of SPSS software is used to verify the correlation between 11 evaluation indexes and test the sensitivity of evaluation indexes to the geological environment quality of the study area. The sensitivity conclusion of the evaluation index reveals that soil erosion and desertification are the key factors affecting the quality of geological environment in the studied area.

(3) This paper uses the Google open source Tensor flow deep learning library to build a neural network model, and uses its visualization tool Tensor board to select the optimal network structure model, which makes the results of machine

learning more objective and reasonable.

(4) Compared with the results of geological disaster survey, most of the disaster points are located in the areas with poor and medium geological environment quality. 92.1% of the disaster points are located in the areas with poor geological environment quality, which means that the evaluation results are credible.

REFERENCES

[1] Hu, A. L., Wang, K. W., Li, J. L., Tang, F. Y., Chang, D. L. and Guo, Z., "Landslide stability prediction based on intelligent algorithm optimization support vector machine model," Journal of Natural Disasters, 25(05), 46-54 (2016).

[2] Wang, N. Q., Guo, Y. J., Liu, T. M. and Zhu, Q. H., "Landslide risk assessment based on support vector machine model," Science, Technology and Engineering, 19(35), 70-78 (2019).

[3] Guo, T. S., Zhang, J. Q., Han, Y., Zhong, Y. L., Tan, J. R. and Wei, J. C., "Evaluation of landslide susceptibility in Yanchang County based on particle swarm optimization support vector machine," Geological Science and Technology Information, 38(03), 236-243 (2019).

[4] Bi, N. N., Markus, S., Joachim, R., Dominik, E. and Wei, X., "Landslide susceptibility analysis based on ArcGIS and artificial neural network for a large catchment in three gorges region China," Environmental Earth Sciences, 72(6), (2014).

[5] Paraskevas, T. and Andreas, B., "Estimating landslide susceptibility through a artificial neural network classifier," Natural Hazards, 74(3), (2014).

[6] Joaquín, A. V. O. and Antonio, M. M., "A neural network model applied to landslide susceptibility analysis (Capitanejo, Colombia)," Natural Hazards and Risk, 9(1), 1106-1128 (2018).

[7] Andang, S. S., Tetsuya, K. and Hideaki, M., "Optimization of causative factors using logistic regression and artificial neural network models for landslide susceptibility assessment in Ujung Loe Watershed, South Sulawesi Indonesia," Journal of Mountain Science, 16(2), (2019).

[8] Moayedi, H., Mehrabi, M. and Mosallanezhad, M., "Modification of landslide susceptibility mapping using optimized PSO-ANN technique," Engineering with Computers, 35(3), 967-984 (2019).

[9] Bragagnolo, L., Silva, R. V. and Grzybowski, J. M. V., "Artificial neural network ensembles applied to the mapping of landslide susceptibility," Catena, 184, (2020).

[10] Lucchese, L. V., Oliveira, G. G. and Pedrollo, O. C., "Attribute selection using correlations and principal components for artificial neural networks employment for landslide susceptibility assessment," Environmental Monitoring and Assessment, 192(2), (2020).

[11] Dong, V. D., Abolfazl, J. and Mahmoud, B., "A spatially explicit deep learning neural network model for the prediction of landslide susceptibility," Catena, 188, (2020).