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Prediction and Verification of Groundwater Potential in Qingyang Area Based on Reliability Test, Validity Test and ROC Curve Method

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ABSTRACT: The combination of remote sensing and GIS has become a common method to locate groundwater potential. Selecting reasonable and effective evaluation factors has become the most important thing in groundwater potential prediction. In this paper, reliability test and validity test are used to evaluate the rationality and validity of evaluation factors. The weight is determined by comprehensive weight method, and the groundwater potential map is obtained by visualization processing based on GIS.

KEYWORDS: Groundwater potential (GWPA); ArcGIS; Reliability; Validity; ROC curve.

I. INTRODUCTION

The analysis and prediction of groundwater potential based on GIS and remote sensing images is a common method for scholars at home and abroad to study groundwater potential. Abid Farooq Rather et al. not only obtained seven parameter maps affecting groundwater potential by combining RS, GIS and other technologies, but also weighted the parameters by AHP, so as to delineate the groundwater potential area. According to the mapped groundwater potential area, the location and water depth of the groundwater well in the study area were analyzed, and the results were verified by the ROC operating characteristic curve and the area under the AUC curve, showing a high accuracy. The effective management of groundwater resources provides a basis for decision-making. Santosh Kumar Singh et al. attempted to delineate GWPA by combining the application of remote sensing (RS), geographic information system (GIS) and analytic hierarchy Process (AHP). Different thematic maps are produced using a variety of influencing variables, including geology, geomorphology, soil, linear structure and river network density, rainfall, land use and land cover, slope, elevation and water depth. Moreover, statistical analysis is carried out based on AHP method to determine the weights and ratings of various topics. Thus, GWPA groundwater recharge potential area is divided. Finally, static groundwater table records, kappa coefficient (0.81) and total accuracy (88.57%) were used to obtain the accuracy and reliability of discovering groundwater recharge potential areas. Researchers often divide groundwater potential areas by weighted assessment factors and then by superposition

analysis. However, it rarely mentions how to select evaluation factors and whether they can be accurately selected. Through consulting the data, the author found that the reliability and validity test is an effective means to determine the reliability of evaluation factors. Xiang Chengge et al. verified the reliability and validity of the FBSD self-rating table through reliability and validity, and the results showed that the FBSD scale had good reliability and validity in the application of HIV infected persons/patients, and could be considered for clinical and scientific research to study the family burden of disease of HIV infected persons/patients. Xie Jinli et al. verified that FFQ has good reliability and validity through reliability and validity evaluation, and it can be used for the study on the correlation between dietary intake and health of young male exercise population. Zhang Qinglan et al. proved by using reliability and validity tests that Parent-Child Interaction Scales (PCI) could be used as an assessment tool for the quality of parent-child interaction among children aged 0 to 3 in China. Therefore, this paper decides to determine the reliability and validity of the quantitative data of the evaluation factor based on the reliability test and validity test.

II. OVERVIEW OF THE STUDY AREA

The research area is located in the southwest of Zhengning County, Qingyang City, Gansu Province. The administrative divisions are under the jurisdiction of Gonghe, Zhengning County and Zhongcun Township in Zhongning County. It is about 15 kilometers long from east to west, 12 kilometers wide from north to south, and covers an area of 183.19 square kilometers. The specific overview of the study area is shown in Figure 1.

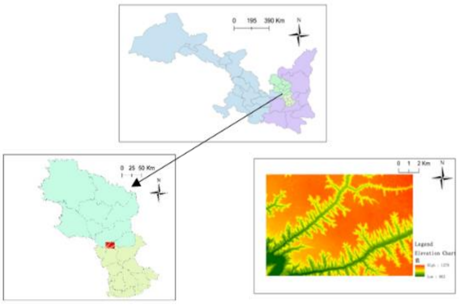

Figure 1. Study area map

III. METHOD AND PRINCIPLE

A. *Reliability test*

The principle of reliability testing is mainly concerned with the consistency and stability of measuring tools. It is based on the assumption that when the same measurement tool is used to measure the same object several times, if the measurement results are basically consistent, then the measurement tool can be considered to have high reliability. In other words, reliability testing evaluates the reliability of a measurement tool by comparing the consistency of measurement results over time or in different contexts.

In the reliability test, the reliability coefficient is usually used to quantify the reliability level of the measurement tool. Common reliability coefficients include Cronbach's alpha coefficient, retest reliability coefficient, etc. These coefficients can help researchers judge the consistency and stability of the measurement tool and thus assess its level of reliability.

The principle of Cronbach's alpha coefficient is based on the internal consistency theory of statistics and is used to assess the consistency and correlation between a set of measurement items (such as questionnaires, scales, etc.). Its mathematical formula is as follows:

$$\alpha = (k/(k-1)) * (1-\sigma (S_i^{\wedge 2})/S_T^{\wedge 2}) \qquad (1)$$

Among them,

alpha is Cronbach's alpha coefficient, which indicates the internal consistency of the measurement tool. k is the number f items in the measurement tool.$S_i^{\wedge 2}$ represents the variance of the i th item.$S_T^{\wedge 2}$ represents the variance of the total score for all items.

The calculation process of Cronbach's alpha coefficient can be understood in the following steps: First calculate the variance ($S_i^{\wedge 2}$) for each item, which reflects the degree of dispersion of each item's score.The variance ($S_T^{\wedge 2}$) of the total scores for all items is then calculated, which reflects the degree o dispersion of the scores for all items as a whole.The ratio of each item's variance to the total variance ($\Sigma(S_i^{\wedge 2})/S_T^{\wedge 2}$) is then calculated, which reflects the correlation between each item' score and the total score.Finally, the correlation was adjused by the weight coefficient (k/(k-1)) in the formula, and Cronbach's alpha coefficient was obtained. Cronbach's alpha coefficient has a value between 0 and 1. When the coefficient is 1, it means that all items are perfectly correlated, that is, all items measure the same underlying concept or trait, and the measurement tools have the highest internal consistency. When the coefficient is 0, it means that the items are completely uncorrelated, that is, each item measures a different concept or trait independently, and the internal consistency of the measurement tool is lowest.

B. *Validity test*

Validity testing is the process of evaluating whether the measurement tool can effectively and accurately measure the concept or feature to be measured. Among them, structural validity is an important aspect to evaluate whether the measurement tool can reflect the theoretical structure or concept to be measured. The KMO value is a common index in the test of structural validity.

The KMO value is used to judge the adaptability of the data to factor analysis. When the KMO value is high, it indicates that the correlation between variables is strong, and the data is suitable for factor analysis, so that effective common factors can be extracted to support the structural validity of the measurement tool. Conversely, if the KMO value is low, the correlation between the variables is weak, and the data may t be suitable for factor analysis, which may negatively affect the structural validity of the measurement tool.

The formula for calculating KMO value is as follows:

$$KMO = \Sigma\Sigma a_{ij}^{\wedge 2} / (\Sigma\Sigma a_{ij}^{\wedge 2} + \Sigma\Sigma b_{ij}^{\wedge 2}) \qquad (2)$$

Among them:

a_{ij} represents a simple correlation coefficient for the i - and jth-th variables.

b_{ij} represents the partial correlation coefficient of the i - and JTH variables.

$\Sigma\Sigma a_{ij}^{\wedge 2}$ represents the sum of squares of the simple correlation coefficients between all the variables.

Sigma sigma $b_{ij}^{\wedge 2}$ represents the sum of squares of the partial correlation coefficients between all the variables.

The KMO value ranges from 0 to 1. A KMO value higher than 0.8 indicates that the data is very suitable for factor analysis and indirectly indicates good validity. A range between 0.7 and 0.8 indicates suitable, 0.6 to 0.7 indicates moderately suitable, and below 0.6 indicates unsuitable. If there are only two items in the sample, the KMO value is always 0.5.

C. *Roc curve principle*

The principle of ROC Curve (Receiver Operating Characteristic Curve) is to set several different critical values through continuous variables, and calculate the corresponding sensitivity and specificity at each critical value, and then draw a curve with the sensitivity as the vertical coordinate and the 1-specificity as the horizontal coordinate.

ROC curve calculation formula:

The ROC curve is drawn with FPR as the horizontal coordinate and TPR as the vertical coordinate. TPR and FPR are calculated as follows:

True case rate (TPR) :

$$TPR = TP/(TP + FN) \qquad (3)$$

TP indicates a true example and FN indicates a false negative example. TPR, also known as the recall rate, represents the proportion of positive cases in which the model successfully predicts a positive case.

False positive rate (FPR) :

$$FPR = FP/(FP + TN) \tag{4}$$

Where FP represents a false positive example and TN represents a true negative example. FPR represents the proportion of negative cases in which the model incorrectly predicts positive cases.

By adjusting the threshold of the classifier, a series of different TPR and FPR values can be obtained to plot the ROC curve.

The formula for calculating the AUC value is:

The AUC value is obtained by summing the areas under the ROC curve. A common method is to use the trapezoidal rule for numerical integration. The specific steps are as follows:

The points on the ROC curve are sorted according to the value of FPR from smallest to largest.

Calculate the trapezoidal area between two adjacent points, i.e. (FPR2-FPR1) * (TPR2 + TPR1) / 2.

Add all the trapezoid areas to get the AUC value.

IV. RESULTS AND DISCUSSION

The data was imported into SPSS software, and the quantitative data of evaluation factors such as topography, river network density and vegetation coverage were tested for reliability, and the results were shown in Table I.

Table I. 11 Results of factor reliability analysis

Cronbach reliability analysis			
name	Total Correlation of Adjusted Terms (CITC)□	The α factor for which the item has been removed	Cronbach α□
landform	0.761	0.780	0.822
Density of river network	0.477	0.809	
Vegetation coverage	0.922	0.796	
Ecosystem type	0.696	0.785	
Distance from the river	0.863	0.762	
Type of land use	0.052	0.852	
Groundwater type	0.603	0.796	
slope	0.277	0.832	
Vegetation type	0.640	0.803	
Altitude	0.467	0.811	
Aspect of slope	0.115	0.833	

Table II. 8 Results of factor reliability analysis

name	Correction item Total correlation (CITC)□	The term has been deleted for the α coefficient □	Cronbach α
landform	0.688	0.864	0.883
Density of river network	0.507	0.881	
Vegetation coverage	0.945	0.864	
Ecosystem type	0.779	0.855	
Distance from the river	0.808	0.851	
Groundwater type	0.736	0.860	
Vegetation type	0.633	0.874	
Altitude	0.434	0.886	

From Table II, we can clearly see that the reliability coefficient value is 0.883, higher than 0.8, which fully proves that the reliability quality of the research data is very high. After analyzing the α coefficient of deleted items, we find that even if any item is deleted, the reliability coefficient does not show a significant upward trend. This further validates the stability of all items in the overall reliability assessment, so no items need to be excluded. In addition, for the "CITC value", we found that all analysis items had CITC values greater than 0.4. This indicates that there is a good correlation between the analysis items and the reliability level of the data is excellent. In summary, the reliability coefficient value of the research data is higher than 0.8, which fully proves the high reliability quality of the data and is fully qualified for further in-depth analysis.

The quantitative data of eight evaluation factors, including topography, river network density, vegetation coverage, ecosystem type, distance from river, groundwater type, vegetation type and altitude, were imported into SPSS for validity test

. The validity test results are shown in Table III.

Table III. 8 Results of factor validity analysis

Validity analysis results			
name	Factor load coefficient		Common degree (common factor variance)
	Factor 1	Factor 2	
landform	0.834	0.163	0.722
Density of river network	0.933	-0.266	0.941
Vegetation coverage	0.823	0.508	0.936
Ecosystem type	0.681	0.490	0.704
Distance from the river	0.651	0.612	0.797
Groundwater type	0.739	0.343	0.663
Vegetation type	0.278	0.858	0.813
Altitude	-0.018	0.977	0.955
Characteristic root value (before rotation)	4.856	1.677	-
Variance explanation rate %(before rotation)□	60.694%	46.571%	-
Cumulative variance explanation rate %(before rotation) □	60.694%	107.265%	-
Feature root value □	3.755	2.778	-
Variance interpretation rate %(after rotation)	46.934%	34.725%	-
Cumulative variance explanation rate %(after rotation)□	46.934%	81.659%	-
KMO□	0.704		-
Barth spherical value□	234.609		-
df□	28		-
p	0.000		-

From Table III, we can observe that the common degree value of all studies is higher than 0.4, which indicates that the information of the studies can be effectively extracted. In addition, the KMO value reached 0.704, higher than the critical value of 0.6, which further proves that the data is suitable for factor analysis, that is, the information it contains can be efficiently extracted. The results of factor analysis show that the variance explanation rate of the two factors is 46.934% and 34.725% respectively, and the cumulative variance explanation rate after rotation is 81.659%, far exceeding the threshold of 50%. This indicates that the information in the study item can be effectively interpreted and extracted by these two factors.

After comprehensive analysis, the evaluation factors of groundwater potential were determined as elevation, vegetation type, groundwater type, distance from river, ecosystem type, vegetation coverage rate, river network density, topography and geomorphology.

The above evaluation factors are weighted based on the comprehensive weight method combined with the improved analytic Hierarchy process (AHP) and the critic method, and the weights of each evaluation factor are calculated, and then the groundwater potential map is drawn by arcGIS, as shown in the figure.

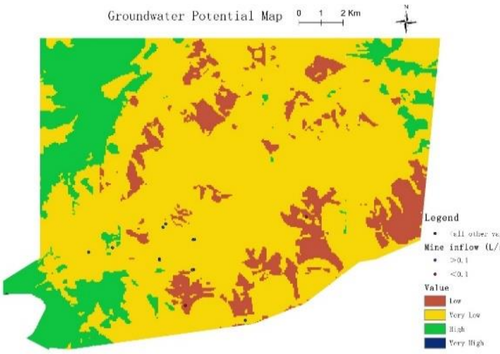

FIG. 2 Groundwater potential map

The distribution of groundwater potential in this area is as follows: groundwater potential is divided into four grades: low, low, high and high. The study area was lower 16.22km2 (8.86%), lower 125.92km2 (68.74%), higher 40.96km2 (22.35%) and higher 0.09km2 (0.05%), respectively. On the whole, the groundwater potential is higher in the surrounding region and lower in the central region. The specific characteristics are as follows: The groundwater potential in the surrounding area is high, mainly because this area is mainly hilly and gully area, the difficulty of groundwater enrichment is small, and the altitude of this area is low, mainly below 1054m. In addition, the river network in the surrounding area is less dense, but the distance to the river is closer. The lower groundwater potential in the central region is mainly due to the fact that this region is mainly loess tableland and the difficulty of groundwater enrichment is relatively large. At the same time, the altitude of this area is higher, mostly above 1194m, and the density of river network is higher. The lower left area has a higher groundwater potential, mainly due to the low density ar ea of 0.45-0.83 river network density in this area. The distribution of groundwater potential is also high in southwest and low in southeast. In summary, the distribution of groundwater potential in the study area is affected by many factors, including topography, elevation, river network density, distance from rivers and vegetation coverage. The combined effect of these factors leads to the uneven distribution of groundwater potential.

The groundwater potential map obtained by borehole inflow data and comprehensive weight method was imported into SPSS2.0 for ROC curve analysis, as shown in FIG. 3. The AUC area is 0.792. It shows that there is a good correlation between the groundwater potential area determined by the comprehensive weight method and the borehole water inflow data.

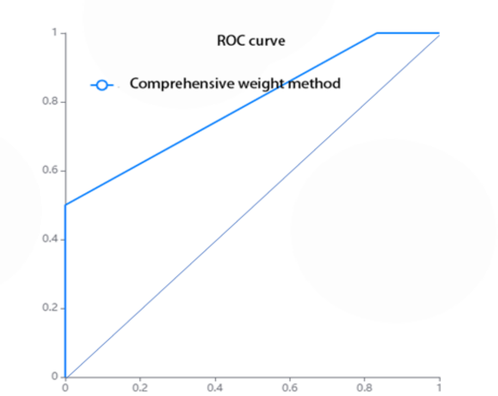

FIG. 3 ROC curve

V. CONCLUSIONS

(1) The comprehensive weight obtained by the improved analytic hierarchy process combined with the comprehensive weight method of CTRITIC method is more accurate and vivid. It has high precision in GWPA and can objectively and accurately reflect the influence weight of each evaluation factor. In this paper, terrain and geomorphology, density of river network, elevation, distance from river, vegetation type, vegetation coverage rate, ecosystem type and groundwater type are selected as factors for groundwater potential analysis and evaluation, and comprehensive weight method and GIS weighted superposition technology are used to analyze and evaluate groundwater potential. Combined with the actual monitoring well data, the AUC area of the ROC curve is 0.792, indicating that there is a good correlation between the groundwater potential area determined by the comprehensive weight method and the borehole water inflow data, which can more accurately evaluate the groundwater potential in the southern Qingyang region.

(2) The groundwater potential of the southern Qingyang area can be divided into four grades: low, low, high and high, according to the comprehensive weight method. The study area was lower by 5.3km2 (2.02%), lower by 171.02km2 (65.13%), higher by 85.84km2 (32.69%) and higher by 0.44km2 (0.17%). The resulting map will help manage groundwater and promote artificial recharge and sustainable development of water resources.

(3) The improved analytic hierarchy process, combined with CTRITIC method, groundwater well database and thematic layer information, can better avoid the subjectivity of weight assignment and generate a more reliable GWPA map, which is simple and easy to operate, with better time and cost effectiveness.

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